WATER BALANCE STUDY AND SUB SURFACE GEOLOGY OF GANGA-SONE DOAB

A DISSERTATION

submitted in partial fulfilment
of the requirements for the award of the Degree
of
MASTER OF ENGINEERING
in
HYDROLOGY

By
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C E R T I F I C A T E

Certified that the dissertation entitled 'Water Balance study and Sub-surface Geology of Ganga-Sone Doab' which is being submitted by Shree Vijay Kumar Verma in partial fulfilment for the award of the degree of Master of Engineering in Hydrology of the University of Roorkee is a record of candidate's own work carried out by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted for award of any other degree or diploma.

This is further to certify that he has worked from 1st of October '75 to 10th of November '76 for preparing this dissertation.

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VKverma

10.11.1976 (Vijay Kumar Verma)

C O N T E N T S

CHAPTER - I

INTRODUCTION

1.1 IMPORTANCE OF WATER RESOURCES ASSESSMENT

All life depends on water. It is one of the most important basic resource available to the civilization. The progress of humanity implies a continuous increase in water consumption due to everlasting demand of water for agricultural, domestic and industrial purposes. In the present age of economic growth coupled with population growth the intensification of water resources exploitation may result in its progressive exhaustion and degradation, thus hindering economic and social development. Concern about the future of water resources has been expressed in an increasing number of articles and books in recent years. Hence a scientific direction of effort is needed for a planned and optimal utilization of water resources. The improvement of knowledge of the hydrological cycles and of the methods of evaluation of water resources, as well as a better assessment of these resources at the regional, national and global levels and of their fluctuations in space and time, are essential for the proper utilization of water resources for the benefit of mankind.

In the present study, water balance approach has been adopted to assess quantitatively the various components of hydrologic cycle in order to evaluate the water resources of the area for the hydrological year 1974-75. The area selected for the study lies in the main alluvial basin of Bihar State. This area is endowed with good ground water reserves in its Recent and sub-Recent alluvial deposits, forming a part of the Ganga basin, which enters the area from Uttar Pradesh and flows towards eastwards into the basin of Northern West Bengal.

1.2 GENERAL INFORMATION

Bihar is the second largest State in India by population which is 56.35 million as against all India figures of 548 millio (10.4%). The ground area of this State is 1,74,000 square kilometres (67,196 square miles) as against all India figures of 3269075 square Kilometres (5.3%). The man-land ratio works out to 324 per square kilometre against all India average of 171.

Bihar lies between latitude N21°58' and N27°32' and longitude E83°20' and E88°. It is bounded on the north by Nepal on the north east by West Bengal, on the west by Uttar Pradesh and Madhya Pradesh and on the south by Orissa.

It consists of two district physical units - the Gangetic plain and the chotanagpur plateau. The Ganga river divides the plain into two parts i.e. North Gangetic plain, known as

North Bihar, and the South Gangetic plain known as South Bihar. Thus Bihar is clearly divided into three natural regions (i) North Bihar, (ii) South Bihar and (iii) Chotanagpur plateau which abounds in hills, mountains and forests.

The economy of Bihar is predominantly rural and agricultural. About 92 percent of the people live in villages and 86 percent of its population is dependent on agriculture. The 60 percent of the income of the State comes from the rural sector.

Out of the total area about 11.55 million hectares is culturable area and the net area sown is 8.54 million hectares. Annual cropped area is about 11.25 million hectares out of which nearly 25% has got irrigation facilities including that by Ahars and pynes which are mostly ineffective during period of drought. The medium and major projects which are comparatively more dependable cover only 0.41 million hectares and 0.82 million hectares respectively i.e. total of 1.23 million hectares till the end of fourth five year plan.

AVAILABLE WATER RESOURCES IN BIHAR

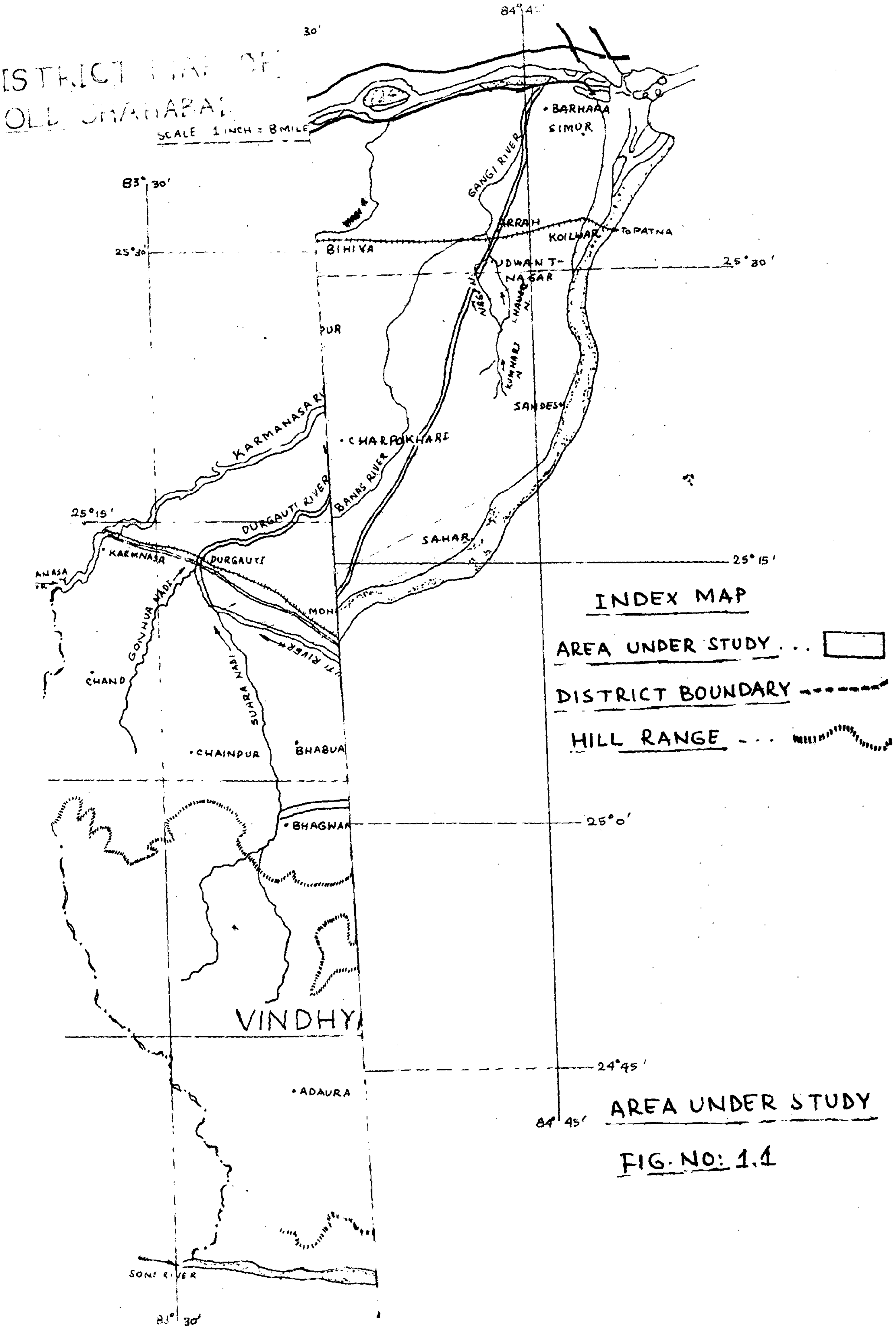
Bihar is one of the few States of the country which has been endowed by nature with abundance of water resources. But an overall development plan of the State is yet to be prepared and implemented. Isolated irrigation schemes have no doubt been taken up and some of them have been completed also but these developments have taken place mostly for meeting the immediate irrigation needs. The Government of Bihar had set up an Irrigation Commission in the year 1967 with a view to prepare comprehensive plan for guidance of the various agencies engaged on irrigation works. The Commission which submitted its report in the year 1971 has roughly assessed the water resources of Bihar on the basis of the data which it could collect and the same is given below in Table 1.1.

TABLE 1.1

INTEGRATED UTILISATION OF WATER RESOURCES
(in million H.M.)

River Zone	Surface water resource within the State	Subsurface water available	Present utilization			
			Irrigation	Domestic use	Power and Industry	Tota
North Bihar	1.63	2.24	1.71	0.0861	0.0037	1.8C
South Bihar	2.20	1.08	0.62	0.0615	0.0086	0.69
Chotanagpur and Santhal Pargana	2.76	-	0.025	0.050	0.0898	0.164
Total	6.59	3.32	2.355	0.1976	0.1021	2.654

Source: Bihar Irrigation Commission Report.

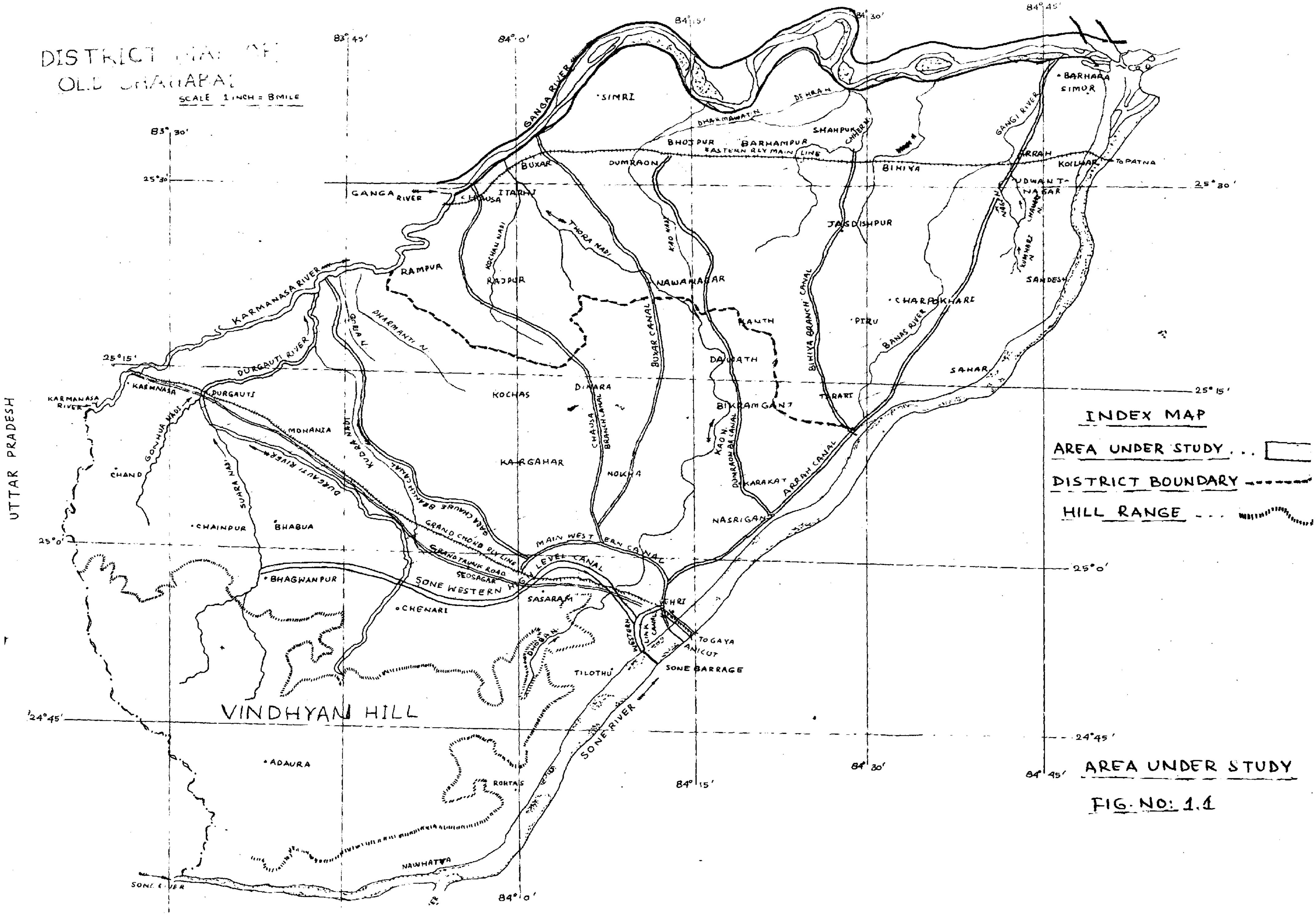


AREA UNDER STUDY

FIG. NO: 1.1

DISTRICT MAP OF
OLD SHAHABAD

SCALE 1 INCH = 8 MILE



AREA UNDER STUDY

FIG. NO: 1.1

So, out of total available water resources of 9.91 million hectare metre only 2.6548 million HM i.e. 26.78% is at present utilized for combined irrigation, domestic and industrial purposes. It has been estimated in the same report that the future water requirement by 1990-91 will increase to 8.27 mil. HM. ~~million HM i.e. 83.45% of the total~~ available water resources ~~in the State~~.

1.3 AREA OF STUDY

The study area occupying 6748.225 square kilometres (2605.5 square miles) i.e. about 3.78% of State area, forms a part of old Shahabad district (whole of newly created Bhojpur district and northern part of Rohtas district) and it lies in the South Bihar plain as shown in figure .

The area lies in between latitude N 24°56' to N25°46' and longitude E83°28' to E84°51' and comprises of nearly whole alluvial plain of old Shahabad district. The entire area falls within the survey of India topographical sheet numbers 630, 63P, 72C and 72D. The distribution of geographical area in between Bhojpur and Rohtas districts is as follows:-

Bhojpur	-	3971.1 square kilometres
Rohtas	-	2777.125 square kilometres
Total	-	6748.225 square kilometres

The area has well defined geohydrological boundaries viz. on the north the boundary is marked by the Ganga and on the east by the Sone, the two rivers uniting in the north-eastern corner thus forming Ganga-Sone doab. The area is bounded in the north west by river Karmanasa. The western and Southern boundary of the study area are respectively river Durgauti and Western High level canal of Sone Barrage Project as shown in fig. . A few kilometres south and south-west of the study area(i.e. outside the doab but forming the southern part of Rohtas district) moderately prominent hills and flat-topped plateaus of rocks of Vindhyan system are present.

1.4 CRITERIA FOR SELECTION OF AREA

The water balance study is generally related to a defined area or region. A river basin, and in case of large river a sub basin, is a natural unit. It has a defined watershed boundary, and within it there is an inter-relationship between the surface and ground water resources. Therefore a river basin is suitable unit for evaluation of quantity, quality and distribution of water resources, 'Doab' is found to be a better defined unit. The word 'Doab' means an area bounded by two rivers of streams. So, river boundary is very well defined in the case of 'Doab' while this is not so in the case of watershed.

Keeping the above view in mind, the Ganga-Sone doab has been selected for the present study.The area is bounded from all sides by well defined water bodies i.e. in three sides perennial rivers are situated while in the western part an irrigation canal,having supply all through the year is present.

1.5 OBJECTIVE OF THE STUDY

The present study is designed to understand and evaluate the various parameters related to water balance of the doab and to quantity each of these for a particular period(1974-75 i.e. in the water year June '74 to May '75) with a view to work out a water budget for the area. An attempt has also been made in this study to analyse the lithologs in order to find out the lateral and vertical distribution of the aquifer horizon and to prepare a subsurface vertical variability pattern map of the area to show the distribution of sand horizon.

1.6 PREVIOUS WORK

As such no detail hydrological or geohydrological study has so far been carried out to find out the total water resources available in this area. However some geological and ground water investigations have been carried out in certain parts of this area by the Geological Survey of India.

The earliest study regarding 'agricultural and geographical features of Shahabad district' is available in Francis Buchanan's journal of 1812-13. Although this work is more of general nature and is important from historical point of view, still it gives a vital information regarding the drainage characteristics and the courses of important rivers as they were existing during that period.

The rocky terrain to the south of the area was geologically mapped and studied by Auden(1939),Oldham(1901) (cited in Pascoe,1950),Dunn(1942) and K.Narain(1949).They mapped the Lower and upper Vindhyans in parts of Shahabad district.

Investigations pertaining to the ground water resources have so far been of rather local character and mainly dealt with local industrial or municipal water-supply problems. In this respect the investigations by Auden (1939) and Chaterji(1952) should be mentioned who have studied water-supply problems in the area between Dehri-on-Sone and Sasaram.More recent studies were done by Roy,Shah,Seth and Goswami(1966) and by Roy and Sinha(1968).

Auden(1939) estimated that about 20 percent of the rainfall would percolate underground. Seth(1950) has assumed that 50 percent of the rainfall is lost through evaporation while 30 percent of it constitutes to the surface runoff.Chaterji (1952) investigated into the problem of water supply to

Sasaram town and based on his recommendations a successful tubewell was later constructed near the town.

Roy, Shah, Seth and Goswami(1966) who have studied the geohydrological features in the western and southern part of the area have indicated the existence of at least four definite and continuous granular zones in the area and they have also found that a minimum thickness of 6 to 21 M of suitable aquifer material would be necessary to support wells yielding one cusec(0.028 Cumec) of water at a drawdown of 6 metres. The water table gradient has been found to be mainly towards north and northwest and almost always towards the principal channels of drainage. It has been concluded that groundwater from both shallow and deeper zones to be generally of good quality and the same has been recommended for irrigational, industrial and municipal uses.

Roy and Sinha(1968) have submitted a report on the groundwater potentialities of Bihar State and in this report they have indicated that this area is composed of unconsolidated alluvium is suitable for high yield prospects i.e. more than 90,000 litres per hour from individual tubewells. They have concluded that there is inter-connection in between the main aquifers encountered in the boreholes drilled in this area. Adequate aquifer zones are encountered within a depth of 70 to 100 metres below land surface. The normal range in variation of water-table depth is from 2 to 10 metres in winter and

5 to 15 metres in summer.

Though these studies and investigations were aimed to get a broad and general picture of the ground water condition and to have a rough estimate of the available subsurface water resources in the area but still they serve a useful purpose by giving basic data for further detailed studies.

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C H A P T E R - 2

HYDROLOGICAL FEATURES OF THE AREA

2.1 GENERAL

The location and boundaries of the area has been dealt in Article 1.3. Parts of the administrative districts, sub-divisions and blocks lying within the study area are as follows:-

DISTRICT	SUB DIVISION	BLOCK
Bhojpur (whole)	Arrah	Arrah, Udwantnagar, Koilwar, Barhara, Sandesh, Piro, Tarari, Charpokhari, Sahar, Shahpur, Bihea, Jagdishpur.
	Buxar	Buxar, Itarhi, Rajpur, Semri, Dumraon, Brahmpur, Nawanagar.
Rohtas (part)	Bhabua (part)	Durgauti, Ramgarh, Mohania, Kudra.
	Sasaram (part)	Karakat, Bikramganj, Dinara, Dawath, Dehri, Nasriganj, Kargahar, Nokha, Sasaram, Seosagar.

2.2 LAND FORMS AND PHYSIOGRAPHY

The whole of old Shahabad district (Bhojpur and Rohtas districts combined) can be divided physiographically into three distinct regions.

The northern most part forms an extensive low lying alluvial plain, fertile and well irrigated. This zone roughly extends upto the North 25 degree latitude line. The southern most part is the hilly country of an undulating table land and forms a part of Kaimur plateau(but it lies outside the study area). Inbetween the two regions,an intermediate region occurs with a cover of erosional scree and detrital material towards south,while clay and coarse sand-covered plains extend northwards gradually merging into the vast alluvial plains of the north.

Pedological characters of these three regions are also quite distinct.The southern region is covered mainly by rubbles of Vindhyan rocks. The intermediate portion,in general,comprises the major part of the area under reference and consists of clay mixed with Kankar.In the eastern part i.e. near the Sone-river the soil is comparatively light and more sandy. Away from the Sone-river the soil gradually becomes poorer and mixed with Kankar.The soil in the northernmost part of the area is sandy to loamy in nature.The silt and sands left by receeding water of Ganga have turned this region into a most fertile one.

2.3 DRAINAGE

From west to east and south to north the area is mainly drained by the rivers Ganga,Sone,Karmanasa,Durgauti and Kudra. Among these rivers Ganga,Durgauti,Karmanasa and Sone are perennial. The Ganga traverses a distance of about 85 miles(135 Km)

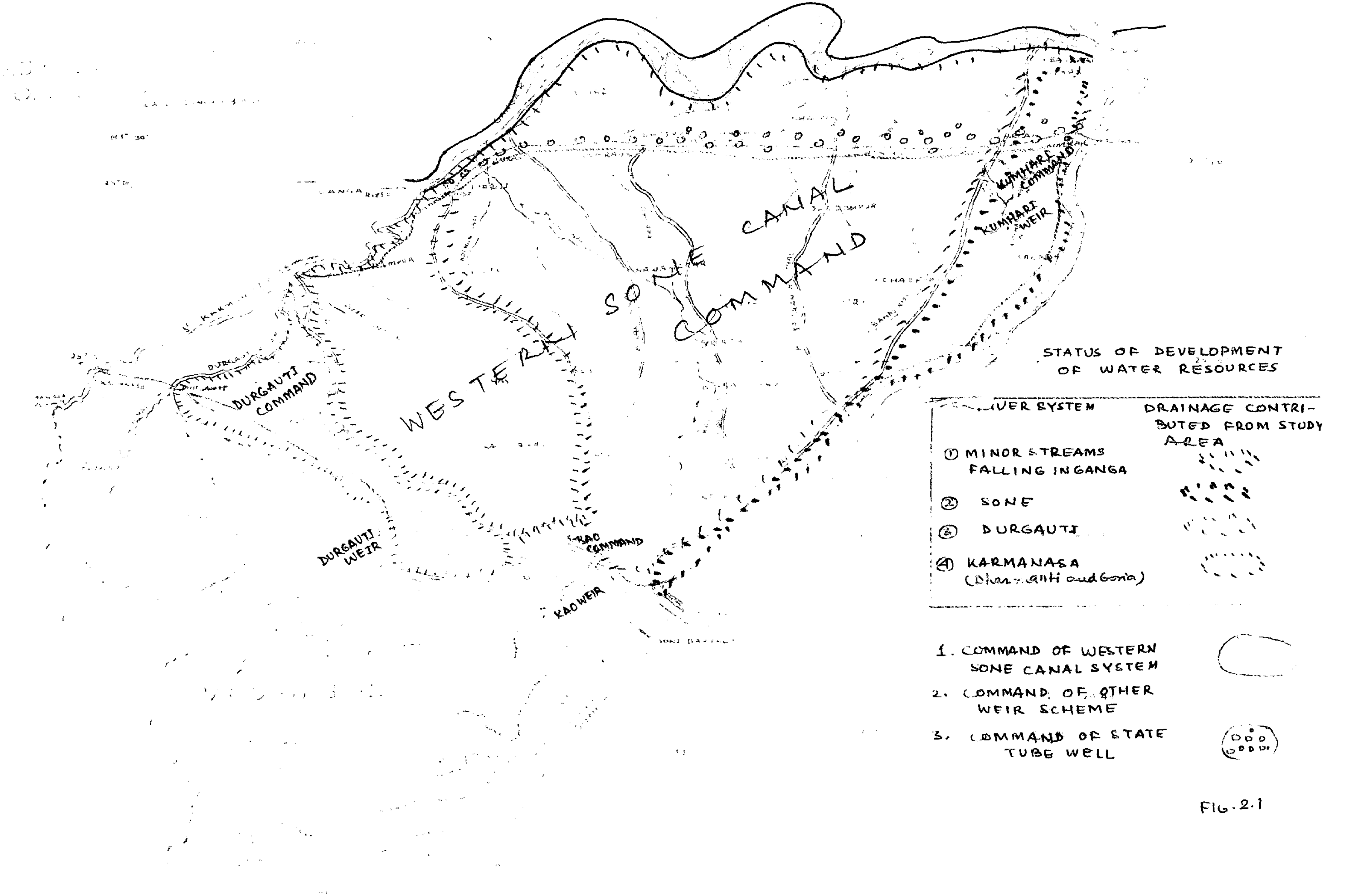

STATUS OF DEVELOPMENT OF WATER RESOURCES
RIVER SYSTEM
DRAINAGE CONTRIBUTED FROM STUDY AREA
① MINOR STREAMS FALLING IN GANGA
② SONE
③ DURGAUTI
④ KARMANASA
1. COMMAND OF WESTERN SONE CANAL SYSTEM
2. COMMAND OF OTHER WEIR SCHEME
3. COMMAND OF STATE TUBE WELL
WESTERN SONE CANAL COMMAND
KUMHARI COMMAND
KUMHARI WEIR
DURGAUTI COMMAND
DURGAUTI WEIR
KAO COMMAND
KAO WEIR

FIG. 2.1

along the northern boundary of the area. The Karamnasa, Kudra and Durgauti rise in the southern slopes of the Kaimur plateau and after traversing in a northeasterly direction fall into the Ganga either directly or after combining with other streams. The minor streams namely Konch,Ganghat,Chher,Banas, Thora,Gangi and Karmanasa fall directly into the Ganga. The supply of minor streams is limited to later part of monsoon period only and they remain dry for rest of the months during the year. During the winding course,the Karmanasa river receives many tributaries e.g.Kulura,Sara,Durgauti,Kudra,Goria,Dharmanti etc. The Sone river separates the districts of Shahabad and Gaya and it traverses along the Southern and eastern boundaries of the Shahabad district. During the years of heavy rainfall the rivers,especially the Karmanasa and Sone, are often in spate.

All these rivers have been shown in ~~the River Basin Map~~ ~~vide~~ fig.2.1.

2.4 MAJOR RIVER SYSTEM

The main rivers draining the study area are described below.

GANGA RIVER

The Ganga enters Bihar, at Chausa in Shahabad district, about 155 kilometres from Varanasi.It forms common boundary of 110 km. length between Uttar Pradesh and Bihar.Its drainage area at Chausa is about 5,30,000 square kilometres. This includes the drainage area of Karmanasa river (72080 km^2) which joins Ganga at Chausa. After its confluence with Karmanasa,Ganga flows past Buxar in north-easterly direction upto Ballia where it bends south eastwards. In this reach of the river there is a constant change of the river bed.

Ganga is joined by river Ghaghara from north at Chapra. The drainage area of Ghaghara of the confluence is about 127950 Km^2.Ganga is joined by river Sone before it leaves Bhojpur district (old Shahabad district). The drainage area of Sone at its confluence with Ganga is about 71259 sq.km.

Small tributaries which join it during its course by Bhojpur district are Konch,Ganghat,Chher,Banas,Jhora and Gangi of which the latter is of some importance as forming the outlet by which the Arrah Canal joins the river.

The description of this part of Bihar by the Chinese pilgrim Hiuen Tsiang,who visited India in the seventh century A.D. shows that the river formerly flowed much further to the south than at present.The town of Masar,which in Hiuen Tsiang's time was close to the Ganga,is now 16 km.away from it,but the high bank of the old bed can still be traced past Buxar, Bhojpur,Belauti,Bihia,Arrah and Koilwar. In the District Gazetteer Shahabad(1924) it is mentioned that in high flood there has been a steady thrust northwards during the last fifty years in the area immediately north of Dumraon, and the site at 25°44'N,where the town of Ballia formerly stood,is now south of the river in Shahabad.

The monthly discharge data for the doab portion under study are classified and restricted and hence they could not be available. However, the difference of monthly average discharge reading for the river Ganga in between Buxar and before the Ghaghara confluence were obtained which are utilized in the present study. The distance between the two discharge observation sites is approximately 120 km. The drainage contributed by the study area to Ganga river is obtained with the help of river basin map and this value is 3561 square kilometre which is about 60 percent of the total drainage contribution from both the banks of the river Ganga for the reach under consideration. The drainage from left bank of the river works out to be 2374 Km^2. The streamflow generated through both the bank of river Ganga inbetween Buxar and just before Ganga-Ghaghar confluence is as follows:

Month	Total stream flow (average-daily)
June 1974	55 cumecs
July 1974	172 "
August 1974	266 "
September 1974	208 "
October 1974	115 "
November 1974	50 "
December 1974	46 "
January 1975	35 "
February 1975	30 "
March 1975	27 "

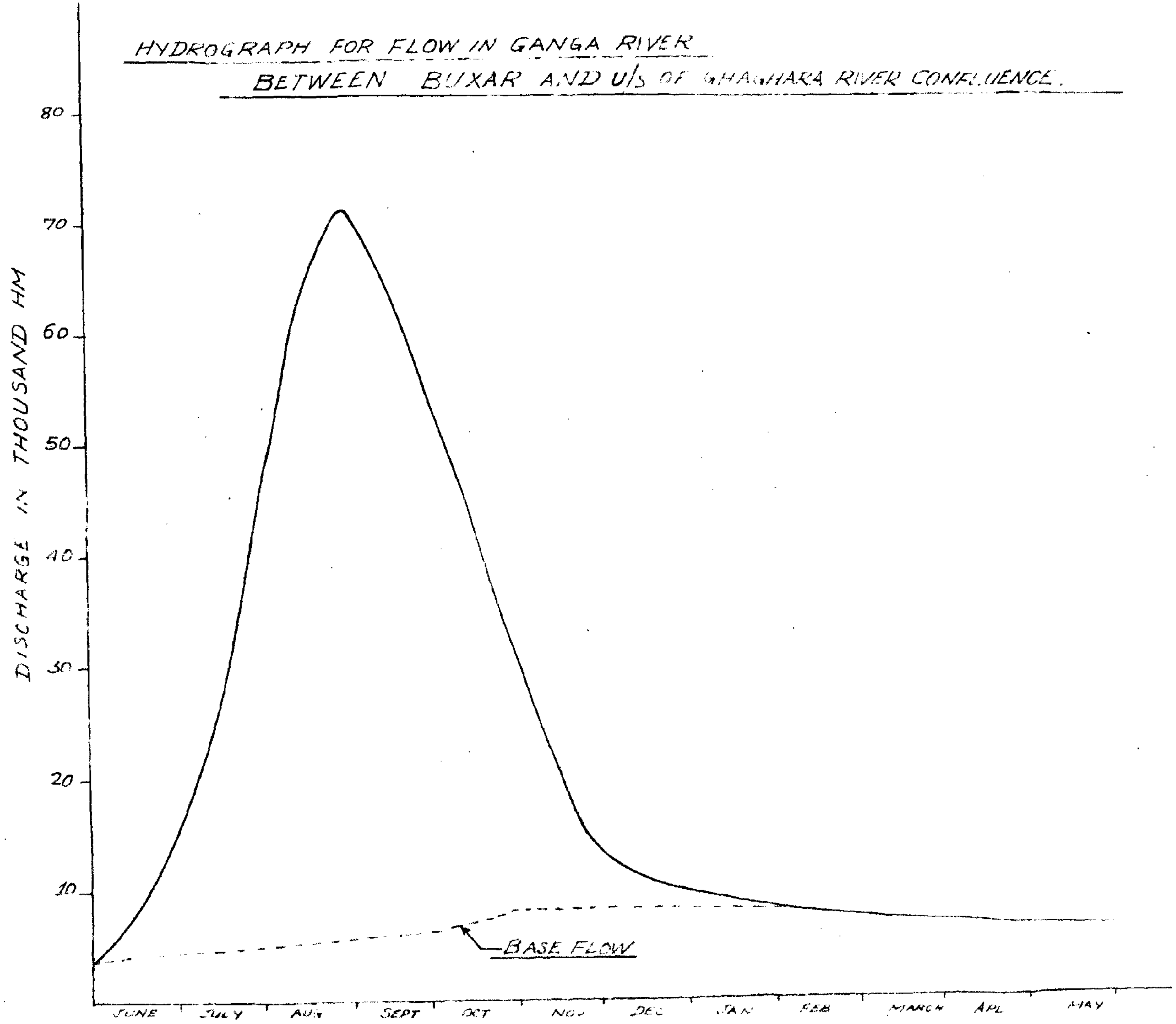

HYDROGRAPH FOR FLOW IN GANGA RIVER
BETWEEN BUXAR AND U/S OF GHAGHARA RIVER CONFLUENCE.
DISCHARGE IN THOUSAND HM
80
70
60
50
40
30
20
10
BASE FLOW
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
JAN
FEB
MARCH
APL
MAY

Fig 2.2.

April 1975	26 cumecs
May 1975	24 "

The above discharge values are to be multiplied by 0.60 to get the streamflow contribution from the study area.

SONE RIVER

River Sone, a principal right bank tributary of the Ganga, rises at Sonbhadra in the Maikalo range of hills in Madhya Pradesh at an elevation of 600 M at latitude N 22°44' and longitude E82°4'. It is an interstate river flowing through Madhya Pradesh for 505 kilometres, in Uttar Pradesh for 96 kilometres and 215 km. in Bihar. The river Sone joins Ganga near Maner, midway between Arrah and Dinapur after traversing a total distance of 816 km. The total catchment area of the river is 70196.77 sq.km.(27,103 sq.miles) at its confluence with the river Ganga. The total catchment area of the river Sone upto Indrapuri barrage near Dehri-on-Sone is 68915 sq.km. From river basin map it is found that the drainage contributed by the study area is equal to 576 sq.km. which is about 45% of the total drainage contribution from both the banks of the river for the reach under consideration.

The Sone river first touches on Shahabad near Kosdera, a place about 45 m. above the mean sea level and after gradually curving round the Kaimur hills on the west, flows by

Akbarpur 13 metres lower. Proceeding to the north it passes Dehri, Hariharganj, Nanaur and Koelwar and finally it falls into the Ganga near Maner. It forms the eastern and north eastern boundary of the area under study.

Sone receives no tributaries of any importance from the point where it enters Sahabad district ~~upon~~ upto Dehri, where most of its water is distributed on the east to Gaya and Patna districts and on the west to Shahabad through the irrigation system of Sone Canals. Old beds are numerous, but they are principally found on the eastern bank in the districts of Gaya and Patna. One such course however, runs in Shahabad district. It is very obscurely marked but apparently rejoins the present channel at the depression near Amiawar, a short distance south of Nasriganj.

The river Sone is of greater economic utility to the district than the other rivers because of Sone canals. The anicut at Dehri with the canal headworks and Sone barrage project at Indrapuri, 8 km.m. upstream of Dehri are the existing organised irrigation system in this area, detail description of the same has been given in art 3.5.

The discharge of the river Sone is daily recorded at Indrapuri. Most of the water is diverted through Sone Western and Eastern main canals for irrigation purpose and watever remains is released downstream of barrage. The data of the releases through the barrage were made available through the authority concerned.

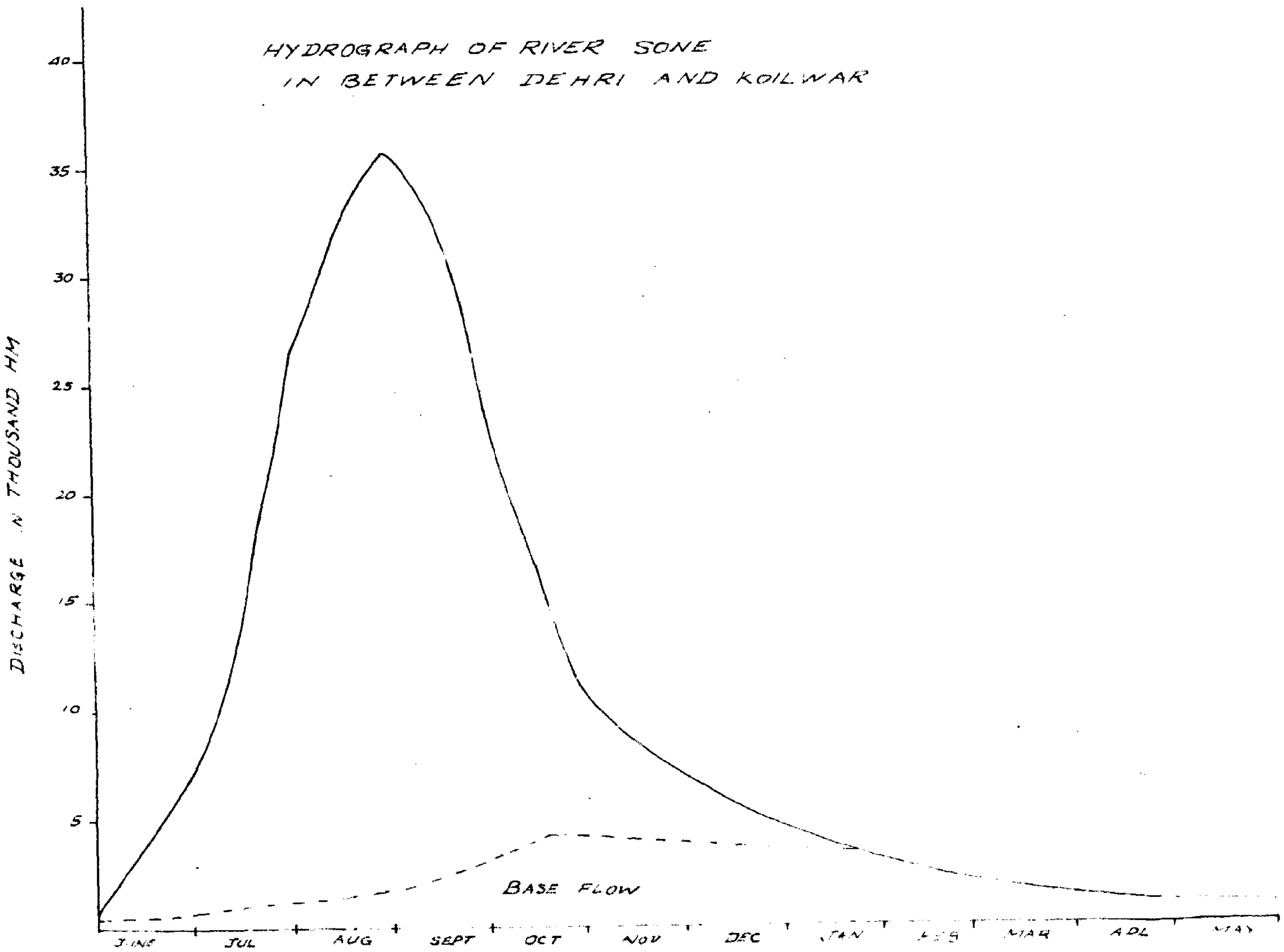

HYDROGRAPH OF RIVER SONE
IN BETWEEN DEHRI AND KOILWAR
DISCHARGE N THOUSAND HM
40
35
30
25
20
15
10
5
BASE FLOW
JUL
AUG
SEPT
OCT
NOV
DEC
MAR

Fig 2.3

The Discharge Division of Bihar Irrigation department maintains a gauge at Koilwar, which is about 109 km. downstream of barrage site, and just before the Ganga-Sone confluence. The discharge data at this site were also obtained from the concerned authority.

The difference of two gauge readings are given below, which gives the amount of streamflow generated inbetween the two discharge measurement site from both the banks of the river. As mentioned earlier the contribution from study area is about 45 percent of the total catchment of the river for the reach under consideration.

Month	Total monthly streamflow
June 1974	7041.6 HM
July 1974	26343.36 HM
August 1974	35821.44 HM
September 1974	16131 HM
October 1974	11085 HM
November 1974	8994.2 HM
December 1974	8856 HM
January 1975	4579 HM
February 1974	3093 HM
March 1975	674 HM
April 1975	527 HM
May 1975	475 HM

The above discharge values are to be multiplied by 0.45 to get the total surface and subsurface runoff contribution from the area under study.

DURGAUTI RIVER

The Durgauti river rises from the Kaimur hill range in the village of Bhakma at an elevation of 457 M. above mean sea level. For about 14 kilometres it pursues a northerly course and on the way it is joined by other minor hilly streams. After passing through the caves of Gupteshwar and the hill fortress of Shergarh, it enters the plains at village Karamchat in the district of Rohtas. It then moves towards Jahanabad, about 13 Km. north on the Grand Trunk Road and then turns to the north-west running parallel to the road for about 36 km. until it crosses it near Sawath, where it bends towards the north-east and joins the Karamnasa river, after receiving the Kudra river from the east. The catchment area of Durgauti at its confluence with the Karamnasa river is about 3056 sq.km. It forms the western boundary of the study area. In the upper part of its course it has a rocky channel with a narrow valley not more than 10 metres wide but after it enters the plain it is wider and at Jahanabad it attains a breadth varying from 30 to 40 metres. The river bed in the plains is of sand mixed with nodular limestones It contains water all the year round. A weir has already been constructed few kms. upstreams of Kudra R.S. and has Gross command of 16180 hactres. For last three years the average area irrigated by this scheme during kharif is about 8900 hactres. The command of the weir scheme falls within the study area.

Recently Durgauti Reservoir Project has been sanctioned which stipulates harnessing of the water resources of the river Durgauti by constructing a dam near Karamchat village and taking off canals on both banks of the river from this dam. This will enable irrigation of 14966 hactre of Kharif and 4450 hactres of Rabi i.e. an annual irrigation of 19416 hactres, besides giving an establishing support to the old Durgauti-weir-situated 37 km. down stream of the dam which will provide assured irrigations of 12135 hactres of Kharif and 4854 hactres of Rabi i.e. additional 16989 hactres of annual irrigation.

Regular discharge measurement of the river is maintained by the Discharge Division of Bihar Irrigation Department. The two gauge sites selected for the present study are as follows:

The upstream gauge site is at Amaon which is about 11 km. downstream of the proposed dam site and about 6 km. upstream of Sone Western high level canal (the southern boundary of the study area). The catchment area at this gauge site is about 684 sq.km.

The downstream gauge site is situated at Ankorhi which is about 9 km. upstream from the confluence of river Karamnasa and the site is just downstream of the confluence of Durgauti with river Kudra.The catchment area of the river at this site is about 3018 sq.km. The distance between the above two gauge sites is about 80 km.(river distance).

The discharge measurements are carried out regularly during monsoon period but during non-monsoon season as the river supply becomes very low so no regular measurements are done. For the present study the non-monsoon discharge has been adopted as 25% of monsoon discharge.This assumption is based on the Bihar Irrigation Commission report in which percentage of monsoon and non-monsoon flows have been worked out for some rivers for which actual discharge observations were regularly done.The percentage of non-monsoon discharge to monsoon discharge for Ganga and Sone rivers during the hydrological year 1974-75 works out to be 30% and 28% respectively.

From the river basin map it is found out that the drainage contributed by the study area is equal to 1196 sq.km. which is about 50% of the total catchment area of the river for the reach under study.

In between the above mentioned two gauge sites 6230 HM of water was diverted through Durgauti weir project during monsoon period of 1974.This amount has to be added to the total monsoon flow,of the river to get net streamflow through the study area. The streamflow generated through both the banks of river Durgauti in between Amaon and Ankorhi is as follows:

Month	Total monthly flow
June 1974	483 HM
July 1974	6508 HM
August 1974	9106 HM
September 1974	5893 HM
October 1974	822 HM
Total:	22812 HM

By adding 6230 HM water, which is diverted through Durgauti weir scheme, Total stream flow = 22812+6230=29045 HM

Non-monsoon flow = 25% of Monsoon flow = 0.25x29045

= 7261.25 HM

Hence total annual stream flow = 29045+7261.25

= 36306 HM

The above discharge values are to be multiplied by 0.5 to get the stream flow contribution from the study area.

KARAMNASA RIVER

The Karamnasa river rises near Saradag on the northern side of the Kaimur range, about 29 km.west of Rohtasgarh in the Mirzapur district of Uttar Pradesh, at an elevation of 350 metres at north latitude 24°37' and East longtitude 83°37'.It flows in a northwesterly direction through the plains of Mirzapur till Lalitpur village.Entering Varanasi district near Govindpur the river flows towards east and joins the Ganga near Chausa in Shahabad district.This forms the common boundary of 76 K.M. length between Uttar Pradesh and Bihar in the lower reach. It is joined by river Durgauti near village Antdih in the Ramgarh block of Shahabad district. The other smaller distributaries are Kudra, Goria, Dharmanti etc. It forms the north-western boundary of the area under study.

The total catchment area of the Karamnasa at its confluence with the Ganga is 7208 sq.km. out of which 2442 sq.km. lies in Uttar Pradesh and 4766 sq.km. lies in Bihar. The catchment area of the river Durgauti at its confluence with the Karamnasa is about 3056 sq.km. Hence 1709 sq.kms. is the catchment of the Karamnasa river in the study area.

This river is tapped at several places in Uttar Pradesh for irrigation purpose. There is an agreement under which Uttar Pradesh is to supply 5092.2 HM(41400 acre ft.) of water from Musakhand reservoir for irrigation in Chand block of Rohtas district.

There is a proposal of Bihar irrigation Department to install pumping stations at Tira and Jaitpura to pump out monsoon discharge of Karmanasa river for irrigation purpose in the tail reach of Sone Canal system.

Regular discharge measurements only for monsoon period (June to October) are taken by Discharge Divisiån of Bihar Irrigation Department.The two gauge sites are located at Tira (just after confluence of Durgauti) and at Sonpa (located 9 km.upstream of Ganga confluence).The river distance between two gauge site is equal to 25 km.

The streamflow generated through both the banks of river Karamnasa inbetween Tira and sonpa is as follows:

Month		Total monthly flow
June 1974		333 HM
July 1974		5321 HM
August 1974		6631 HM
September 1974		5716 HM
October 1974		3942 HM
	Total	21943 HM

Non-monsoon flow = 25% of Monsoon flow

= 0.25x 21943 = 5485.75

say - 5486 HM

Hence total annual streamflow = 21943+5486

= 27429 HM

From the river basin map it is found that the drainage contributed by the study area is about 75% of the total catchment area of the river for the reach under study; therefore, the above discharge values are to be multiplied by 0.75 to get the total surface and subsurface runoff to this river from the area under study.

2.5 MINOR RIVER SYSTEM

Some of the minor rivers within the study are described below:

KAO RIVER

The Kao or Dhoba rises on the plateau 9 km. south west of Tilothu, and, after flowing through a glen in northerly direction, forms a fine waterfall, and enters the plains at the Tarachandi pass, 3 km. south-east of Sasaram. At this place it bifurcates, one branch, the Kudra, turns to the west and ultimately joins the Durgauti, while the other, which preserves the name Kao, flows to the north, and finally falls into the Ganga near Gaighat. There is very little discharge during the winter and hot seasons but in the rains it is subjected to high floods. At Bichchiya it is crossed by the Main western Sone canal through a syphon aquaduct. In the hilly portion of its course and bed is rocky and full of boulders washed down during heavy rains. The banks are generally high and firm but in the plains they are less elevated. This river is one of the drainage channel of the southern and central parts of the district.

A weir has been constructed on this river which irrigates 405 hactres of area during Kharif and has gross command of 1820 hactres. The command of this weir falls within the study area.

KUDRA RIVER

The Kudra, as already explained,is a branch of the Kao, and carry off the overflow of that river when it rises in flood. After leaving the Tarachandi pass near Sasaram,it is met by a number of small streams, and flowing in the north-easterly direction,crosses the Grand Trunk Road at Khurmabad and falls into the Durgauti at Tendwa after a course of 80 kms. In the dry season it contains very little water but during the rains a large flow passes down it.

KUMHARI RIVER

This stream is important from the point of view that a weir has been constructed on it which has command of 3540 acres and it irrigates about 607 hactres during kharif period.The command of the weir lies within the area under study.

The river Kumhari orginates at an altitude of 70m.above MSL in the vicinity of village Bargaon which is about 24 kms. above the weir site.In its first reach of about 8 kms.it acts like acatch drain of the escape water from Koilwar distributary in the east and Arrah canal on its west through a network of existing pynes and Ahars. About 1 km.below the Headworks the river forms a loop of about 6 kms. The two bifurcations are known as Nagi Nadi and Kumhari Nadi.After loop formation the river with its changed name as Nagi nadi runs for another 6 kms.where a right bank tributary known as chawar Nadi joins it. Then the river ultimately falls into the river Banas.The total distance of the river from the Headworks to outfall is about 24 kms.

The river Banas after this confluence is called Gangi Nadi which traversing further for about 13 kms.meets the river Ganga.

2.6 METEOROLOGICAL CHARACTERISTICS

2.6.1 CLIMATE

The climate of the area is generally dry and bracing for the greater part of the year. The cold season starts early in November and extends to late March. The hot season is from April to about the middle of June when the monsoon season commences.The monsoon continues till the end of September, October is a transition month.

2.6.2 METEREOLOGICAL SEASON

The metereological seasons in Bihar can be summarised as follows:

1. South West Monsoon
2. Retreating south-west Monsoon
3. North East Monsoon
4. Hot weather period

The south west Monsoon breaks over the parts of south Bihar in the second week of June and over South-west Bihar in the last week of June.However, by the end of June it is established over the whole of Bihar. The troughis is,however, not stationary but moves north or south of the normal position and affects the rainfall distribution as it moves. The pulsatory character of this action and of the rainfall precipiation is one of the most important features of the monsoon period metereologically, as also economically for agriculture.There are three important variations from the normal in the monsoon rains,firstly, the beginning of rains may be delayed; secondly there may be prolonged break or breaks lasting over the greater part of July or August and thirdly the rain may end considerably earlier than usual.Consequence of the third variation are occasionally very serious and the success of the Kharif crop largely depends on this rain (Hathia rain).

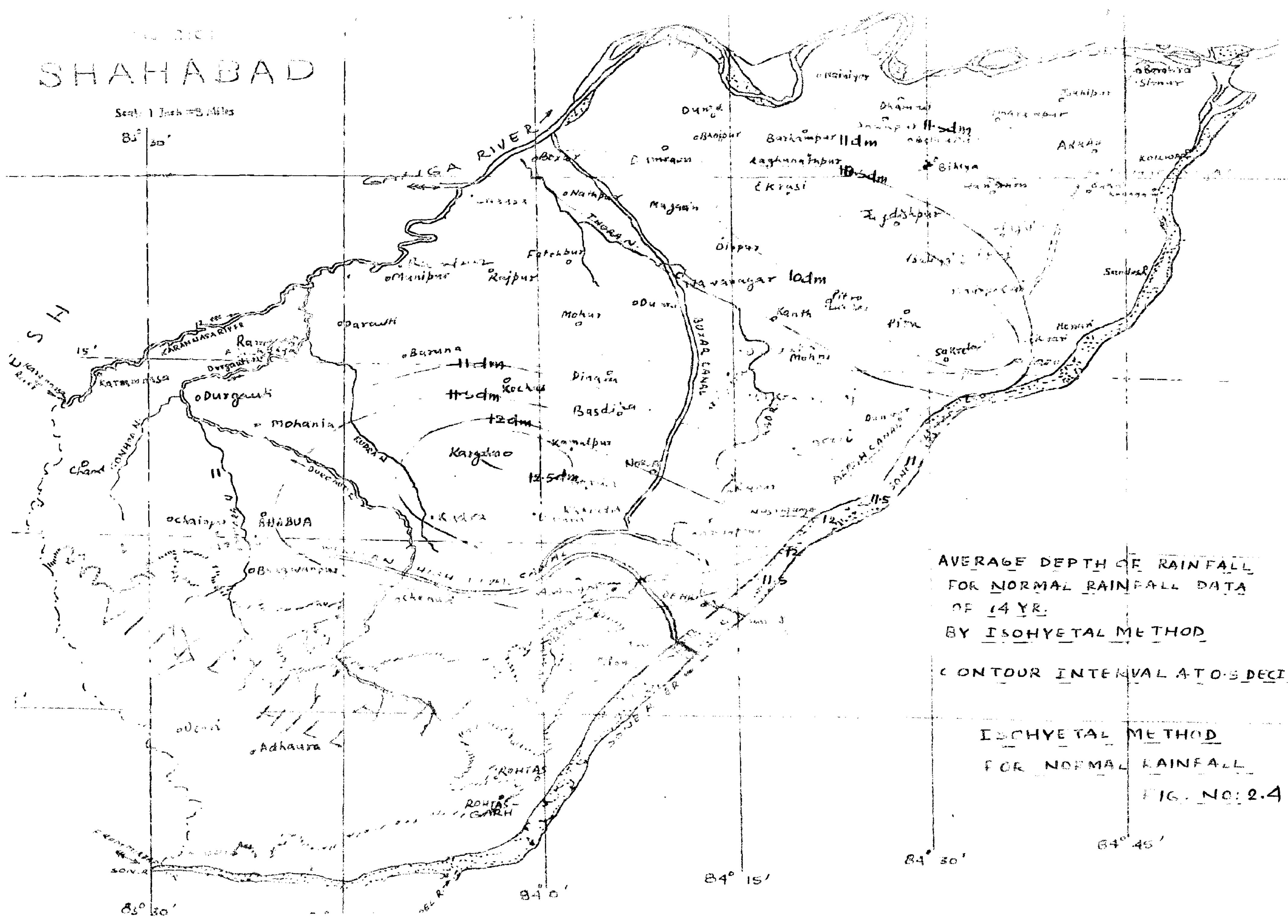
The second half of the west season forms a period of transition leading upto the establishment of the conditions of the dry winter season.This transition begins in the early October and completes in December.The retret is associated with dry weather and sky remains clear.

North East monsoon starts in the beginning of January when the temperature is lowest. Clear skies,low humidity,large diurnal range of temperature and light northerly wind are the usual features interruped only at interval by weather disturbances. Precipitation in winter though in small amount, is very important for the rabi crops.

2.6.3 RAINFALL

The districts of Bhojpur and Rohtas have a net work of 20 rain-gauge stations with records extending in most cases to 60 to 74 years. Tables 2.1, and 2.2 give the details of the rainfall at the 20 stations and for the districts as a whole. There are 15 rain gauge stations within the study area. So, the density of rain gauge stations is of the order of one raingauge in 175 KM^2, which is quite sufficient for the present study. Hence the average depth of rainfall over the area is calculated by both Thiessen Polygon method and Isohyetal method and the values obtained are 1094.83 mm and 1099.64 mm. respectively. The values are identical for all practical purposes. So, either of these two method could be safely adopted for working out the average depth of rainfall over the area. Tables 2.3 and 2.4 show the above two results.

From the given rainfall data and the pattern of Isohytes it is found that in general the southern part of the area receives more rainfall than the northern part. The area around Kargahar, Sasaram, Kudra, Nokha receive little more rainfall then the rest of the district (Fig. 2.4). The area of low rainfall is



AVERAGE DEPTH OF RAINFALL
FOR NORMAL RAINFALL DATA
OF 14 YR.
BY ISOHYETAL METHOD

CONTOUR INTERVAL AT 0.5 DECIME

ISOHYETAL METHOD
FOR NORMAL RAINFALL

FIG. NO: 2.4

around Piru, Ramnagar, Sakreta, Barahi in the northern portion. The local maximum annual rainfall occurs at Kargahar and the local minimum is concentrated at Baruhi. The variation in the annual rainfall value is from 984.5 mm to 1280 mm.

The area receives 92 percent of the annual rainfall during June to October i.e. monsoon period. The maximum rainfall occurs in August. The variation from year to year is not large. In the seventy four years i.e. 1901 to 1974, the highest rainfall amounting to 143 percent of the normal fell in 1936. The year 1966 had the lowest annual rainfall amounting to 52 percent of the normal. During these seventy four years(1901-74) there were sixteen(16) years when the district rainfall was less than 80 percent of the normal. None of these except for 1965, 1966, 1967 were consecutive years. From the data it is observed that 52 years out of 74 years the rainfall in Shahabad was between 900 mm. to 1400 mm. Only during 6 years the rainfall exceeded 1400 mm. mark. The average number of rainy days(days with rainfall of 2.5 mm. or more) per year for the district is 52. Frequency of Annual Rainfall in the district has been given in Table 2.2.

The normal annual rainfall for the whole district is 1122.9 mm.

TABLE 2.2

FREQUENCY OF ANNUAL RAINFALL IN THE DISTRICT (1901-74)

Range in mm.	Number of year
501-600	1
601-700	2
701-800	1
801-900	12
901-1,000	13
1001-1100	14
1101-1200	14
1201-1300	5
1301-1400	6
1401-1500	3
1501-1600	2
1601-1700	1
1701-1800	0
Total	74 years

Source: Deptt of Statistics, Govt of Bihar

TABLE 2.1

(NORMALS OF RAINFALL) ALL FIGURES IN MM.

Stations	Jan.	Feb.	Mar	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual rainfall in mm.
Buxar	19.3	22.1	8.6	5.6	16.5	125	286.8	308.6	194.8	51.3	6.9	5.3	1050.8
Dehri	19.6	24.6	11.7	7.1	12.7	128.5	282.2	360.9	214.9	44.2	11.9	4.3	1122.6
Bhabua	20.3	23.9	11.4	7.9	13.2	128	311.1	350	225.5	51.3	8.6	5.1	1156.3
Sasaram	21.3	25.4	12.2	6.6	14.7	133.9	317.0	387.1	236.5	55.9	11.4	4.6	1226.6
Arrah	17.8	24.6	9.1	7.4	23.1	143	315.5	331	223.0	58.9	9.7	4.3	1167.4
Mohania	15.5	20.8	7.4	5.1	7.9	108.5	309.6	343.1	206.8	45.5	6.6	5.8	1082.6
Ageon	19.1	23.4	7.6	6.3	23.4	141.2	314.5	346.5	225.8	65.3	10.7	5.8	1189.6
Ramnagar	15.5	22.1	9.7	6.3	20.6	117.6	277.6	287.3	170.2	45.7	9.7	6.1	988.4
Koath	17.3	23.6	8.6	7.1	18.3	123.2	280.9	337.1	193.3	54.1	11.7	4.6	1079.8
Sikraul	17.8	23.1	8.6	5.6	11.2	129.8	283.2	321.3	197.4	41.9	8.1	5.1	1053.1
Bassawan	16.5	23.9	9.1	5.8	12.2	125.2	304.5	351.5	213.1	54.4	6.3	5.3	1127.8
Manoharpur	18.3	20.8	8.4	6.3	16.3	116.1	296.9	323.1	213.9	46.5	11.4	7.1	1085.1
Akbarpur	21.3	29	11.2	9.9	14.5	150.4	322.1	351.3	186.6	46.2	9.9	4.6	1169
Chand	16.5	16	11.4	[illegible]	10.9	102.9	282.2	358.1	220.5	43.7	10.9	4.8	1082.2
Chenari	24.4	28.5	10.9	6.3	15.2	141.0	399.8	385.8	252.5	55.9	11.7	5.8	1337.8
Kochas	21.3	20.1	7.6	7.9	9.1	131.1	296.2	330.5	214.4	51.1	12.9	8.1	1110.3
Adaura	22.9	23.9	10.9	5.8	15.5	101.1	326.9	399.3	217.7	55.1	11.2	7.9	1198.2
Baruhi	22.9	29.5	7.1	7.6	14.7	125.2	224.0	282.7	238.3	24.6	3.6	3.3	984.5
Chouri	20.3	38.9	8.4	6.1	8.4	110.5	294.4	331.7	242.3	52.8	2.0	7.1	1122.9
Kargahar	13.7	16.3	3.3	1.8	40.1	156.6	379.2	353.3	250.7	41.4	12.7	1.3	1280.4
District as a whole	19.4	24.4	9.5	6.6	14.7	125.4	301.3	341.9	215.8	49.7	9.2	5.5	1122.9

Source : Statistical Deptt., Govt of Bihar.

TABLE 2.2

FREQUENCY OF ANNUAL RAINFALL IN THE DISTRICT (1901-74)

Range in mm.	Number of year
501-600	1
601-700	2
701-800	1
801-900	12
901-1,000	13
1001-1100	14
1101-1200	14
1201-1300	5
1301-1400	6
1401-1500	3
1501-1600	2
1601-1700	1
1701-1800	0
Total	74 years

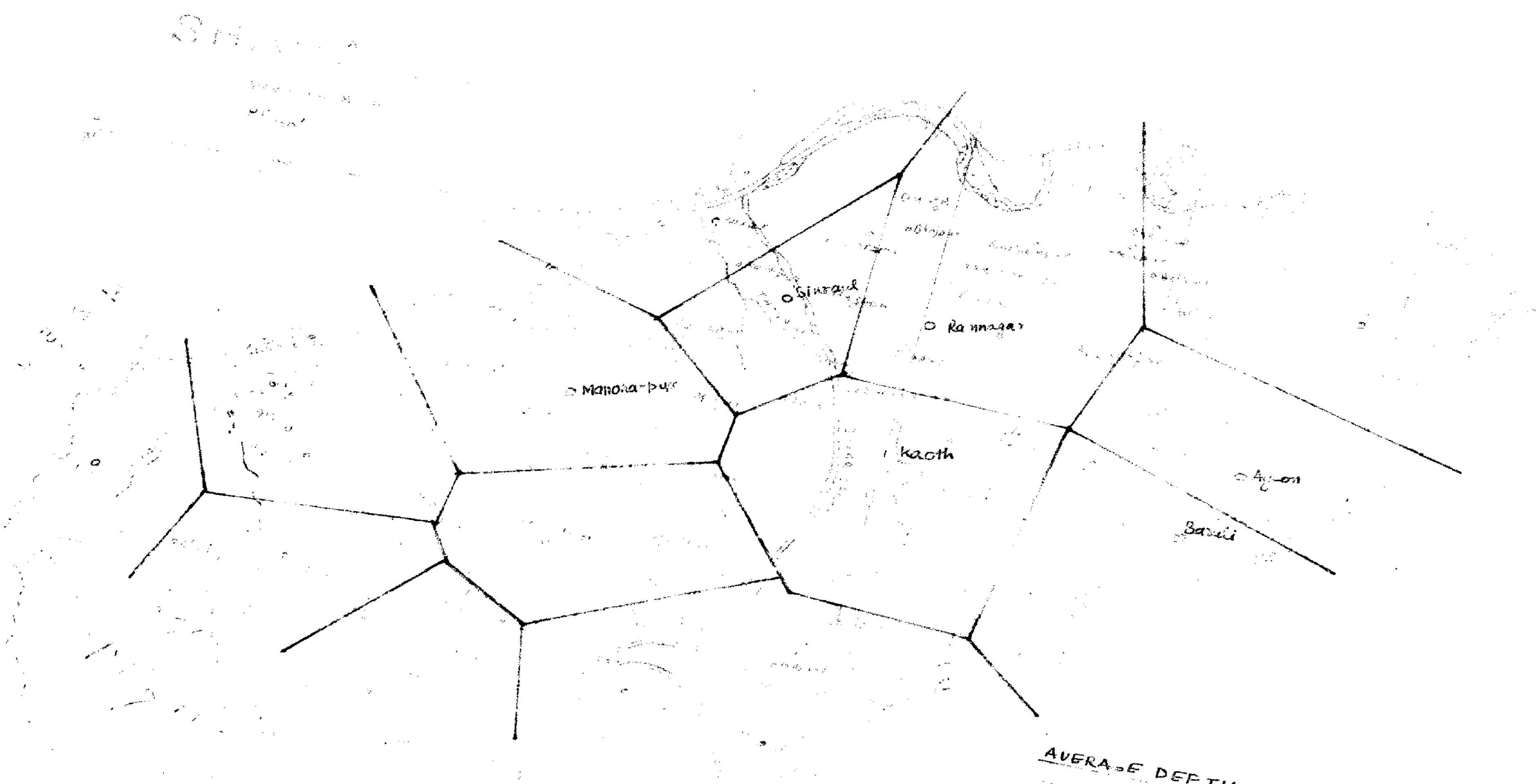
Source: Deptt of Statistics, Govt of Bihar

TABLE 2.3

AVERAGE DEPTH OF NORMAL RAINFALL IN STUDY AREA BY ISOHYETAL METHOD(Fig.2.4)

Isohytes Interval mm. (1)	Average Isyhytes mm (2)	Area plani-metered in between Isohytes Interval(3) Hactares.	Product of Col.(2) and Col.(3) in HM
< 1000	1000	51995.52	51995.52
1000-1050	1025	82051.2	84102.48
1050-1100	1075	234550.4	252141.68
1100-1150	1125	142439.68	115244.64
1150-1200	1175	135833.60	159964.48
1200-1250	1225	62988.80	77161.28
>1250	1250	4972.80	6216
	Total	674832	742072.08

Average depth in mm. $= \frac{742072.08 \times 10^{3}}{674832}$ = ~~k199=64 mm.~~ 1099.64 mm



AVERAGE DEPTH OF RAINFALL FOR
74 YR. AV. NORMAL RAINFALL DATA
BY THEISSEN POLYGON METHOD
o ...... RAINGAUGE STATION

THEISSEN POLYGON
FOR NORMAL RAINFALL
FIGURE NO: 2.5

TABLE No.2.4

AVERAGE DEPTH OF NORMAL RAINFALL IN STUDY AREA BY THEISSEN POLYGON METHOD (Fig.2.5).

Stationer	Precipitation in mm.	Percentage of area	Weighted PPTN. in MM.
Mohania	1082.6	0.0472	51.06
Manoharpur	1085.1	0.1056	114.61
Buxar	1050.8	0.0510	53.69
Sikraul	1053.1	0.0565	59.50
Ramnagar	988.4	0.1363	134.75
Arrah	1167.4	0.1230	143.67
Ageon	1189.6	0.0737	87.67
Koath	1079.8	0.1302	140.58
Baruhi	984.5	0.0540	53.20
Dehri	1122.6	0.0503	56.53
Sasaram	1226.6	0.0427	52.43
Chenari	1337.8	0.0233	31.22
Bhabua	1156.3	0.0059	6.82
Kargahar	1110.3	0.0983	109.10
		Total	1094.83 MM

TABLE 2.5

NORMALS OF TEMPERATURE

Month	Mean daily maximum temperature 0°C.	Mean daily Minimum temperature 0°C.	Highest maximum recorded 0°C.	Lowest minimum recorded 0°C.
January	23.9	11.4	30.6	4.4
February	27.6	14.2	34.4	6.7
March	33.7	19.1	41.1	11.7
April	38.9	23.9	44.4	17.2
May	41.6	27.7	43.2	20.6
June	38.6	28.2	46.1	20.8
July	32.7	26.4	41.4	22.2
August	32.1	26.2	36.1	23.3
September	32.0	25.5	34.6	20.6
October	31.5	21.9	35.6	14.7
November	28.3	15.2	33.9	9.4
December	25.1	11.6	30	7.6
Annual	32.2	21.2	-	-

Source : Delhi [illegible] , [illegible] of [illegible]

2.6.4 TEMPERATURE

Meteorological data are available for Dehri, Arrah and Buxar. Dehri is the only observatory now existing in the district as the other two were closed down long ago. As the data of all the three stations show similar features the data for Dehri only are included in this summary.

From the middle of March temperature begins to rise and hot dry westerly wind blow. May is the hottest month. Towards the peak of summer preceeding the onset of the monsoon maximum temperature can reach values as high as 47°C(117°F) on individual days. With the setting in of the monsoon day temperature drops by about 8 to 9°C without appreciable drop in night temperatures. After the withdrawal of the monsoon by the beginning of October, temperatures begin to decrease reaching the lowest value in January which is the coldest month with minimum temperature something going down to 4 or 5°C.

2.6.5 HUMIDITY WINDS

Humidity: The summer months are very dry and relative humidities can be as low as 20 percent to 25 percent in the afternoon. In the monsoon season air is very humid, during the rest of the year humidity average about 50 percent in the afternoon.

Winds: Light south-westerly or westerly winds prevail in the winter and early summer months. Towards the end of summer easterly wind set in and continue throughout the monsoon season.

TABLE No.2.6

RELATIVE HUMIDITY AND MEAN WIND SPEED

Month	Relative Humidity		Mean wind speed Km/hr.
	at 0830 hours IST Percentage	at 1730 hours IST in percentage	
January	74	60	4.2
February	63	39	5.6
March	45	26	6.9
April	38	23	7.4
May	47	26	7.4
June	64	50	7.6
July	84	77	6.4
August	85	80	5.3
September	84	80	5
October	74	66	3.5
November	68	52	3.2
December	72	49	3.4
Annual	67	51	5.5

Source : Deptt. of Statistics [illegible] [illegible].

2.6.6 POTENTIAL EVAPOTRANSPIRATION

The potential Evapotranspiration values were obtained by the help of Penman's formula and were calculated by Rao, George and Ramasastri (1972) for this area. The values are shown in Table 2.7.

TABLE No.2.7

POTENTIAL EVAPOTRANSPIRATION VALUES IN MM

Month	PE in m.m.
January	65.5
February	94.1
March	149.7
April	189.5
May	217.1
June	180.7
July	119.9
August	111
September	111.1
October	118.4
November	81
December	62.1
Annual	1500.7

The PE values indicate that PE loss is more during hot season i.e. from March to June when the wind speed is maximum and relative humidity values are lowest.The highest PE month is May.

The loss is less during winter due to decrease in wind speed and increase in relative humidity.The lowest value of PE is 62.1m which corresponds to the month of Nbvember.

2.7 DROUGHT

A sustained period of time without significant rainfall is called drought. From agricultural point of view the drought is caused by the absence of rain particularly during the transplantation period. Drought generally creates a crisis for the supply of drinking water and food production. Many existing wells dry up and the irrigation water based on surface water sources proves to be inadequate for agricultural needs.

From the data available for 110 years i.e. from 1864 to 1973 it is found that Shahabad district as a whole suffered 21 numbers of droughts and the year of the droughts are as follows: 1864-65, 1865-66,1866-67,1869-70,1873-74,1874-75,1896-97,1908-09, 1914-15,1918-19,1932-33,1940-41,1949-50,1950-51,1951-52,1957-58 1958-59,1966-67,1970-71,1971-72,1972-73,1973- 74.

It is observed that Drought has occurred in consecutive years which vary from 2 to 4 years in the present case.

Blockwise assessment of rainfall and crop loss have revealed that the following blocks of the district are drought prone pockets:.

Ramgarh; Dargauti; Chand (@),Chainpur(@); Bhabhua; Bhagwanpur(@) Chenari(@),Adhaura(@),Nauhatta(@); Kudra.

The blocks marked (@) lie outside the study area. All these blocks are clustered in the South and Sout-west part of old Shahabad district. Due to high evapotranspiration needs and the comparatively inadequate rainfall in these areas, conditions conducive to drought are felt.

The groundwater feature, irrigation facilities, geology, cropping pattern, classification of land and area under crops are dealt in chapters 3,4 and 5.

-

CHAPTER - 3

EXISTING DEVELOPMENT OF WATER RESOURCES

3.1 AREA AND POPULATION

The total geographical area of the old Shahabad district is 11320 square Kilometres, which is now divided into two administrative districts namely Bhojpur and Rohtas. The geographical area of Bhojpur is 3971.10 sq.kms. and that of Rohtas is 7348.90 sq.kms. The total population of the old Shahabad district, according to 1971 census, is 3939034. The density of population for the district is 348 persons per sq.km.

The study area is composed of whole Bhojpur district and a part of Rohtas district (about 2777.125 sq.kms). The population of the Bhojpur district is 1995146 according to District census Handbook, 1971. The population for 2777.125 sq.kms. area on the basis of density of population, works out to 966439.

Hence total population in 1971 of the study area
= 1995146 + 966439 = 2961585.
Assuming 10% increase in population. So, the population of the area during 1974-75 will be = 2961585 +296158 = 3257743.

3.2 WATER CONSUMPTION FOR DOMESTIC AND INDUSTRIAL PURPOSES

3.2.1 DOMESTIC UTILIZATION

The domestic utilisation of water has been wokred out on the basis of consumption rate of 40 gallons per head per day.

So the present domestic consumption

= 40 x 3257743 = 130309720 gallons per day

= 21622 HM per year

3.2.2 INDUSTRIAL UTILIZATION

Although agriculture continues to be the main occupation of the people, a number of large-scale industries has come up and there is particular large scale industrialisation in Dalmianagar (Dalmia group of Industries) near Dehri. The main factories or plants are of sugar, paper, cement, pulp, chemical, sulphuric acid, asbestos cement, vulcanised fibre, coated board, steel casting and power plant with capacity of 100 million units.

The total consumption of water (on the basis of correspondence with the concerned authorities) is found to be 4500 HM.

Hence the sum total of water consumption for domestic and industrial purposes = 21622+4500 = 26122 HM on enquiry from the concerned authorities it is found that the water used for domestic and industrial purposes is from subsurface source.

3.3 LAND USE AND CLASSIFICATION OF LAND

The total geographical area under study is 6748.225 sq.km. and the classification of this area on the basis of land use is given in Table 3.1.

TABLE 3.1

LAND USE	AREA	REMARKS
(i) Forest	250 hactres	ubr Land available for cultivation = 77170 hactres.
(ii) Barren and uncultu-rable land.	14720 hactres	
(iii) Land put to non-agri-cultural uses	62,200 "	
(iv) Permanent pasture and other grazing land.	525 hactres	Cult[illegible]ble waste land = 59036 hect[illegible]
(v) Cultivable waste other than fallow land	5120 "	
(vi) Land under miscilla-neous trees and groves	4071 "	
(vii) Other fallow land	10,048 "	
(viii) Current fallow	39,272 "	
(ix) Net area sown	5,38,616 "	
(x) Area sown more than once	1,46,940 "	
Hence total area sown =	685556 "	

Source : Deptt of Agriculture, Govt of Bihar.

EXPLANATIONS

(i) FOREST: All actually forested areas on the land classed or administered as forest under any legal enactment dealing with the forest whether state-owned or private are included under this head. If any portion of such land was not actually wooded that portion is included under the appropriate heading of cultivated or uncultivated land.

(ii) BARREN AND UNCULTURABLE LAND

All barren and unculturable land like hills, deserts, etc. fall under this head. Land which cannot be brought under cultivation except under prohibitive high cost is also classed as unculturable waste irrespective of fact whether such land is isolated block or within cultivated holding.

(iii) LAND PUT TO NONAGRICULTURAL USES

All lands occupied by buildings, roads, railways or under water i.e. rivers, canals, tanks, *bhars* and other lands put to use other than agriculture are classed under this head.

(iv) PERMANENT PASTURE AND OTHER GRAZING LAND

This represents all grazing lands whether they are pasture or meadows.

(v) CULTIVABLE WASTE OTHER THAN FALLOW LAND

Cultivable area not cultivated for more than five years is classed under this category. All lands available for cultivation but not taken up for cultivation and abandoned after five years for one reason or the other are classed as culturable waste.

(vi) OTHER FALLOW LAND

Other fallow lands are those lands which were under cultivation but are temporarily out of cultivation for a period of not less than one year and not more than five years.

(vii) CURRENT FALLOW

This represents area which were cultivated in the previous year but are kept fallow during the year under review.

There is, however, a close relationship between the fallow land and net area sown, since there are frequent changes from one to the other. Good and timely rainfall and favourable weather conditions affect the area under fallow land, adversely.

3.4 AREA UNDER CROPS AND DEVELOPMENT OF AGRICULTURE

The three annual cropping seasons may be classified as Kharif, corresponding to the period from June to October, Rabi from November to March and hot weather from April to May. The crops of the district fall under three main harvests, the aghani, bhadai and rabi. The aghani is the winter crop which is cut in the month of Aghan and is composed mainly of winter rice. The bhadai is the early or autumn crop, reaped in the month of Bhado (August-September) consisting of 60 days rice (Sathi), Marua, Maize, millets and less important grains; while the rabi crop includes such cold weather crops as wheat, barley, gram, pulses etc.

During the year 1974-75 thenet area sown was 538616 hactres and the area sown more than once as 196940 hactres corresponding to the study area.

The area under principal crops including commercial crops for the year 1974-75 is given in Table 3.2.Here for the sake of computations,hot weather is included in the rabi crops.

TABLE 3.2

Name of crops	Area under crops	Cropping Season
Sugarcane	6200 hactres	Rabi and Kharif
Bhadai(Autumn)Paddy	3441 "	Kharif
Aghani paddy	311050"	"
Autumn Maize	10,000 "	"
Bhadai Paddy	15049 "	Rabi
Wheat	173200 "	"
Barley	10916 "	"
Gram	34700 "	"
Bhadai Maize	2000 "	"
Pulses	110500 "	"
Potato	7500 "	"
Tobacco	1000 "	"

Total cropped area = 685556 hactres

Source: Agriculture Deptt., Govt. of Bihar.

The total water requirement by these crops have been computed on the basis of informations available from the Sone area Development Authority, Government of Bihar and the computations are given in Table 3.3.

TABLE 3.3

COMPUTATION FOR CROP WATER REQUIREMENT

Name of Crop sown in the area	KHARIF (June to Oct.) Area under crops in hactres	Depth of water required in mm.	Total water require-ments in mm.	RABI (Nov. to May) Area under crops in hact.	Depth of water required in mm.	Total water requirements in Hm
Sugar cane	6200	384	2381	6200	1116	6919
Autumn paddy	3441	900	3097	-	-	-
Aghani paddy	311050	960	298608	-	-	-
Autumn maize	10000	275	2750	-	-	-
Bhadai paddy	-	-	-	15049	1575	23702
Wheat	-	-	-	173200	350	60620
Barley	-	-	-	10916	225	2456
Gram	-	-	-	34700	275	9542
Bhadai maize	-	-	-	2000	575	1150
Pulses	-	-	-	110500	180	19890
Potato	-	-	-	7500	400	3000
Tobacco	-	-	-	1000	400	4000
Total			306836HM	Total	-	131279 HM

The crop water requirement in kharif and rabi has to be met from the existing irrigation system in the study area. At present the irrigation is mainly done with sone canal system, canal systems of Durgauti-weir,Kao-weir and Kumhari-weir schemes, Minor Irrigation units consisting of Privatetubewells,pumping sets, and open wells,state tubewells and other sources like tanks,ponds, Ahars(small reservoir) and Pynes(channels). The details about area irrigated and water utilization from these irrigation sources are dealt under art.3.5, 4.6,3.7.

3.5 EXISTING DEVELOPMENT OF IRRIGATION

3.5.1 SURFACE-IRRIGATION

The area under study falls under the command of following irrigation schemes:

1. Sone Barrage Project
2. Durgauti weir project
3. Kao weir project
4. Kumhari weir project

3.5.1.1 SONE PROJECT

Organised irrigation development in Shahabad district started with the Sone canal ex-Dehri Anicut.The idea of using the water of Sone for irrigation was first thought of around 1850 by Col.C.H.Dickens and for many years the subject was under disuussion. The project was ultimately completed in the year 1879.The project consists of an anicut across the river Sone at Dehri.The length of the anicut is nearly 4 km.(12,469 feet) and two short canals namely the western and eastern main canals, 20 km. and 11 km. in length respectively take off on either side of the anicut.Two navigation canals,the Buxar and the Arrah canal take off from the western main canal while the Patna canal takes off from eastern canal. The western and eastern canals with fully supply capacity of 130.3 cumecs and 73.6 cumecs respectively command an area of nearly 0.6 million hactres.The annual irrigation is of the order of 0.35 million hactres.Sone canal system provides irrigation to parts of old Shahabad,Gaya and Patna districts (now Bhojpur,Rohtas,Aurangabad,Gaya and Patna districts).

To meet the increasing demand for water in the command area of the Sone canal and to improve the existing irrigation system,the Bihar Government undertook,during the second plan period,the construction of a barrage across the Sone about 8 km. upstream of the anicut at Dehri.The existing canals are connected to the barrage by means of link canals.The scheme also includes remodelling of the Sone canals.In addition to stabilizing irrigation in the old command,irrigation of 0.125 million hectares is provided for.The remodelling of Sone canal system was completed in 1965-66. Under remodelling scheme discharge in main western canal was increased from 130.3 cumecs to 187.5 cumecs and in main eastern canal from 73.6 cumecs to 85.2 cumecs.

The Bihar Government has also proposed the construction of high level canals ex-Sone Barrage for makinguse of the regulated releases from the Rihand Dam in Uttar Pradesh. The scheme envisages the construction of Eastern and Western High level canals taking off at 8 km. of the link canals on the right and the left flanks of the Sone Barrage.Execution of Sone High level canal was taken up in 1968. The work is in advanced stage. As a matter of fact irrigation from these canals in head reaches have already started in 1974. It is planned to complete the work in phases so that benefit may accrue even during construction period.

The total command of western sone canal system and a part of total command of western high level canal fall in the study area.

3.5.1.2. <u>SONE WESTERN HIGH LEVEL CANAL</u>

Western High level canal forms the southern boundary of the study area. The total length of the canal is 88 km.(29000 ft) with 160 km.distribution system and 825 km.water courses.Gross command area is 0.826 lakh hactres and CCA is 0.578 lakh hactres in Rohtas district.

The length of canal lying within the study area is upto RD 175.25 i.e. about 53.4 Km. when the canal crosses river Durgauti at right angle.

3.5.1.3 AREA IRRIGATED IN 1974-75

Area irrigated during 1974-75 by Sone western canal system including western High level canal system in the study area is as follows:

Canal system	Area under Kharif irrigation.	Area under Rabi plus Hot weather
Sone Western Canal system including WHLC	250320 hactre	138620 hactre

Hence total area irrigated = 250320 +138620 = 388940 hactres.

3.5.1.4 DURGAUTI WEIR PROJECT

A weir has been constructed few Kilometres upstream of Kudra R S across river Durgauti.It has gross command of 16188 hactres(40,000 acres) and the whole command lies within the study area and is situated near western border of the area.The area irrigated during 1974-75 kharif is 8903 hactres.

3.5.1.5 KAO WEIR PROJECT

A weir has been constructed across this river which lies south of Western Sone high level canal.The command of this weir falls within the study area and is situated south of the Sone western canal and north of Sone western high level canal. The Gross command is 1820 hactre which irrigates about 405 hact. during Kharif.

The area irrigated in 1974-75k kharif by this weir is 405 Hactres.

3.5.1.6 KUMHARI WEIR PROJECT

The command of this weir falls in the north-eastern portion of the study area, few kilometres south of Arrah. The weir is constructed across the river Kumhari whose catchment at the weir site is (65 Km²) 25 square miles. Its gross command is 1430 hact. ~~acre~~
The area irrigated during 1974-75 kharif is 607 hactres.

3.5.1.7 AREA IRRIGATED AND WATER UTILIZED BY THE CANAL SYSTEM

The area irrigated and the quantity of water diverted during 1974-75 in the canal systems of above mentioned schemes/ project are given in Table 3.4.

TABLE 3.4

Project/Scheme	Kharif Period ([illegible] '74)		Rabi period ([illegible] '75)	
	Area irrigated in Hact.	water utilized in HM	Area irrigated in hact.	water utilize in HM
Sone canal system	250320	196411	138620	110647
Durgauti weir scheme	8903	6784	-	-
Kao weir scheme	405	308	-	-
Kumhari weir scheme	607	462	-	-
Total	260235	203965	138620	110647

Hence total annual irrigation from canal system = 398855 hactres
Total annual imported water in the study area for irrigation purpose = 314602 HM

3.5.2 IRRIGATION FROM GROUND WATER SOURCE

At present, subsurface water is being utilized mainly by open wells, open wells with boring, private tube-wells and state tube-wells. In the Bihar state Irrigation Commission Report 1971, following criteria have been adopted to workout the utilization of subsurface water resources for irrigation.

Type of well	Area irrigated per unit in Acs	Mean discharge in cusecs.	Working hour in a year in hrs.	Utilization per year in Acre ft.
State Tubewell	300	1.5	3.600	450
Private Tubewell	20	0.2	2,400	40
Open boring (pumping set)	5	-	-	10
Well	2	-	-	5

The existing number of State Tubewells, Private Tubewells, open boring and surface wells are given in the Table 3.5 with present status of utilisation of subsurface water for irrigation on the basis of above criteria.

TABLE 3.5

STATUS OF SUB-SURFACE IRRIGATION FOR 1974-75

Type of Well	Existing number	Area irrigated annually in hactares	Utilisation per year in hactare-metre.
State Tubewell	460	55848	25461
Private Tubewell	1990	16107	9791
Open boring	12000	24282	14760
Open Well	18000	14569	11070

Total annual subsurface utilisation of water for irrigation = 61082 HM

3.5.3. IRRIGATION FROM OTHER SOURCES

The other sources of irrigation in this area are Ahars and pynes.Tanks,Small streams and emergency river pumping sets (ERP sets). Irrigation from these sources are possible only during monsoon period.Very little irrigation during the non-monsoon period is possible through ERP sets.These mobile pumping sets utilize supplies in the rivers and streams by direct pumping.

Ahars are artificial reservoirs suiting the topography of the area and are meant to collect the rain water.The ahars are filled by the surface-drainage of the adjacent lands during rainy season.They are of the shape of long shallow tank and are protected by small embankments.From the ahars water channels (pynes)are constructed to the nearest stream or water-course. Pynes also supply water to ahars.The water flows through a weir from the ahars to the channels leading to the field, when the water is low it is taken from the ahars by means of the lifting arrangements.

AREA IRRIGATED FROM OTHER SOURCES

Following figures indicate the area irrigated by other sources during 1974-75.

Sources	Area irrigated Kharif	Rabi	Total area irrigated
Tanks,ponds etc.	19,250 hactres	-	19,250 hactres
Pynes,Ahars) ERP sets etc.)	45,650 "	5805 hact.	51,455 "
Sum total :	64,9000 hactres	5805 hact.	70,705 hactres

Hence annual irrigation from other sources = 70705 hactres

WATER UTILIZED FOR IRRIGATION FROM OTHER SOURCES

Assuming 25 cm (10 inches) depth of watering by other sources during kharif and 16 cm (6 inches) depth of watering during Rabi,the water utilisation has been worked out as follows:

Period	Water utilisation in HM
Kharif	0.25 x 64900 = 16225 HM
Rabi	0.16x 5805 = 929 HM

Total annual water utilisation = 16225+929 =17154 HM

3.6 AREA IRRIGATED AND WATER UTILISED BY ALL SOURCES

In the Sone Canal Command area the water requirements by the crops during Kharif period is met partly from rainfall and from surface and subsurface sources of irrigation. ~~In this project it is proposed that out of total crop water requirements 65% is fulfilled by the existing canal system and the rest by the monsoon rainfall and from the minor sources of surface and subsurface irrigation.~~ These sources are Minor Irrigation Units (comprising of private tube wells, open wells and pumping sets) and other sources of irrigation as mentioned in art.3.5.3.

The State tubewells are provided in the areas outside the canal command. one State tubewell in this area irrigates about 48 hactres during Kharif and 73 hactres during Rabi,(x) Season As the number of Minor Irrigation Units in the Canal command and the State tubewell command is not known, so for the present study it is assumed that these units are proportionately distributed on the basis of ~~area irrigated in canal command~~ Gross Canal command and ~~in~~ State tubewell command. On the above basis following distribution for MI Units has been worked out:

Command of	~~Area irrigated in hactres~~	Water utilisation in HM
CANAL	~~50410~~	32673
STATE TUBEWELL	~~4648~~	2948

(x) Source: Report of Sone Area Development Authority

The water carried by the MI Units and the other minor sources are used to supplement for the irrigation by the existing canal system. It is generally found that the irrigation from other sources like Pyne and Ahars are not reliable because availability of water in such system is entirely dependent upon the monsoon rainfall.

The existing status of water utilisation from different sources for the irrigation requirements of crops is given in Table 3.6.

TABLE 3.6

STATUS OF WATER UTILISATION FOR IRRIGATION IN 1974-75

Source of Irrigation	Kharif (June 74 to Oct.74)		Rabi (Nov.74 to May 75)	
	Water utilisation in HM	Water requirement by crops in HM vide T.3.1.	Water utilisation in HM	Water requirement by crops in HM vide T.3.1.
Canal system	203965	306836	110647	131279
State Tube well	10184		15277	
Minor Irrigation units	32673		2943	
Other sources	16225		929	
Total	263047 HM	306836HM	129801 HM	131279 HM

It is seen from Table 3.6 that the water requirement by the crops during Rabi period has been met by the existing irrigation systems. However, during the Kharif period there is a shortfall of 43789 HM of irrigation water for the crops. This shortfall in water requirement is about 14% of the total irrigation requirement which is likely to be met by the monsoon rainfall in the area.

3.7 EXISTING STATUS OF DEVELOPMENT OF WATER RESOURCES

Hence the status of development of water resources for the period 1974-75 can be summarised as follows;

Purpose	Annual water utilisation
Irrigation	392848 HM
Domestic	21622 HM
Industrial	4500 HM
Total	418970 HM

so, total water utilised for all purposes during June 1974 to May 1975 in the study area = 418970 HM

CHAPTER - 4

GEOLOGY OF THE AREA

4.1 INTRODUCTION

The entire area under study is a part of Indo-Gangetic plain consisting of alluvial fall which has been deposited by rivers during the Quarternery era. These deposits are recent to Sub-recent age derived from either Vindhyan or Archaean rocks. Lithologically this entire loose, unconsolidated sequence is composed of finer material like clay and silt and various grades of sand, often cemented to form 'pans', with coarser grades of sediments, including gravel, pebbles and boulders. The lithological sequence is controlled by the depositional environment and that is why immense lateral and vertical variations in texture and composition of the sediments deposited are noticed from the bore hole sections. The detailed analysis of the variations has been done in this chapter to depict their geohydrological characteristics.

4.2 REGIONAL GEOLOGY

The Indo-Gangetic plain occupies roughly an area of 300,000 square miles (7,80,000 square kilometres) and consists of unconsolidated alluvium (Pliestocene and sub-recent) which are derived mainly from Himalayan mountains by various rivers emerging out of them and have been deposited in the depression called the Indo-Gangetic basin or trough. The deposition began after the final upheaval of the Himalayan and it has continued all through the pleistocene upto the present time.

4.3 ORIGIN

There are various views regarding the origin of the Ganga basin but people like Suess (1910), Burrard(1912) Oldham(1917) and Glennie(1932) were able to reach some vital conclusions which have been found to be true by later workers. These are (i) Formation of Indo-Gangetic trough is intimately connected to the origin of the Himalaya, (ii) Depth of the Gangetic trough reduces south-wards, (iii) Plumbline deflections and gravity anomalies of the area are released to deep crustal, and possibly subcrustal anomalies.

Recently V.V.Sastri et.al (1971) have suggested tectonic framework and subsurface stratigraphy of the Ganga basin on the basis of studies from aeromagnetic, ground magnetic, gravity and seismic surveys and the deep drilling logs. Based on these data the Ganga basin has been defined as a major platform depression and classified into seven tectonic zones viz. Monghyr-Saharsa ridge, East Uttar Pradesh shelf, Gandak depression, Faizabad ridge, west Uttar Pradesh shelf, Sarda depression and Delhi-Hardwar ridge. This classification is based on the continuation of major tectonic trends from the Peninsular shield into the Ganga basin, the variation in the thickness of sedimentary cover and the basement configuration as deduced from different surveys.

Sastri et al (op.cit) have concluded that there are three main stages of Ganga basin tectonic evolution. 'The oldest is represented by the metamorphic basement and on purely regional tectonic consideration the basement in the Ganga basin may have widely different precambrian tectonic history as well as structural trends'.

'The second major stage is represented by a platform association of Limestones, shales and quartzarenites, probably corresponding to the Vindhyan group. They may range from upper Proterozoic to Palaeozoic. The sequence is generally folded and several well developed structures are present. Many faults of varying magnitudes and extent have been traced in these sediments. The regional structural patterns within these sediments demonstrate that the folding and faulting within these sediments are essentially controlled by differential movements of basement blocks.'

The upper stage in the evolution of Ganga basin is marked essentially by a thick development of Neogene terrigenous clastic sequence (Siwalik group). The interval between the second and the upper stage is represented by a marked hiatus in the deposition and probably leading to considerable local erosion of the pre-existing sediments.

This inter-pretation seems to be essentially valid in the shallower parts of the Ganga basin namely the west Uttar Pradesh shelf and the East Uttar Pradesh shelf whereas in the more depressed parts of Sarda and Gandak depressions, presence of additional sedimentary sequence(probably late Palaeozoic,mesozoic and paleogene) cannot be ruled out. and if such sequences are present they may represent additional stages in the evolution of the Ganga basin.

As the tectonic history of the basin has a direct bearing upon the occurrence,thickness,continuity and texture of the alluvial deposits beneath the plain,comprehensive study of the ground water hydrology of the alluvial fill must include effort to identify and interpret the effects of structural deformation.

4.4 NATURE AND PATTERN OF ALLUVIAL FILL

By its origin alluvium soil is composed of a number of different textural lithological units viz. sand,gravel,silt and clay etc. In the Ganga basin the depositional history of alluvial fill which includes its distribution, continuity and occurrence are thus the function of stream morphology, stream erosion, transport and deposition. This is further influenced by other factors like gradient, fluctuation in stage and discharge, sediment load and water temperature of the stream. The effects of climatic changes, time-factor and tectonic movements have also direct bearing upon the depositional envrionment of the alluvial fill.

According to Jones and Hofmann(1967) the distribution of sediment types and textures areally and with depth indicates that periods of widespread braided-stream deposition, in which medium to coarse-grained sand blanketed large segments of the plain, were followed by periods in which most of the plain was traversed by meandering streams having wide seasonal variation in stage. Vast interfluvial flood basins occurred between major rivers. Along the stream meander belts, coarse-grained sediments were deposited. The sediments formed by meandering streams occur as longitudinally continuous strips and reflect long established stream courses.

There are no distinctly marked stages in the deposition of the alluvium. The whole of the alluvium is, in fact, one continuous and conformable series of fluiviatile and subaerial deposits whose accumulation is, to some extent, still in progress.

The alluvium consists chiefly of beds of clay either sandy or calcareous corresponding to the silts,mud and sand of the modern rivers. Besides these,beds of gravel,compact sand,kankar are also met with;kankar nodules are formed in the zone of the subsoil where there is wide fluctuation of water table.It is generally accepted that during the dry part of the year,water rises up above the watertable by capillary action and quickly evaporates out leaving behind the solute deposited around a nucleus of soil particle. With continuation of this process, kankar nodules are formed when the subsoil water have been surcharged with calcium bicarbonate.

4.5 THICKNESS OF THE ALLUVIUM

The thickness of the Indo-Gangetic alluvium has been estimated by the help of seismic survey and by deeper drilling conducted by the Oil and Natural Gas Commission in the various parts of Punjab,Haryana,U.P. and Bihar.According to the Oil and Natural Gas Commission the maximum thickness of alluvium is less than 10,000 feet i.e. 3050 metres.

The thickness of the alluvium in Bihar has been demarcated from borehole logs and geophysical refraction studies as well as electrical resistivity traverses over the major parts of Shahabad,Gaya,Patna,Bhagalpur and Muzaffarpur districts. The main alluvial basin where considerable alluvial thicknesses are noticed lie north of 25 degree latitude across the entire breadth of Bihar. However, in the area South of Gaya an exception is noticed east of longitude 86 degree,where the Kharagpur and

Rajmahal hills from the main features with an intervening patch of relatively shallow alluvial fill.

According to data given by Roy and Sinha(1968) in the main basin~~basin~~, as geophysical data indicates, south of the Ganga, the alluvial thickness ranges to a maximum of 700 metres. Approximately north of latitude 25 degree the depth to bedrock ranges from 100 metres northwards to a range of 500 to 700 metres near the Ganga. The deepest tract south of the Ganga spreads between Buxar in the west to 86 degree longitude in the east near Mokameh. The geophysical traverses run in the district of Muzaffarpur and Saran indicate that the alluvial basin is much thicker being of the order of 1000 to 2500 metres. The geophysical traverse also tentatively draw a line between the Vindhyan and Archaen basement. This conjectural line passes parallel to the Sone river, a few miles to its east, stretching from south to north. The basement below the alluvium in Saran and Muzaffarpur districts also appears to belong to the Vindhyan system.

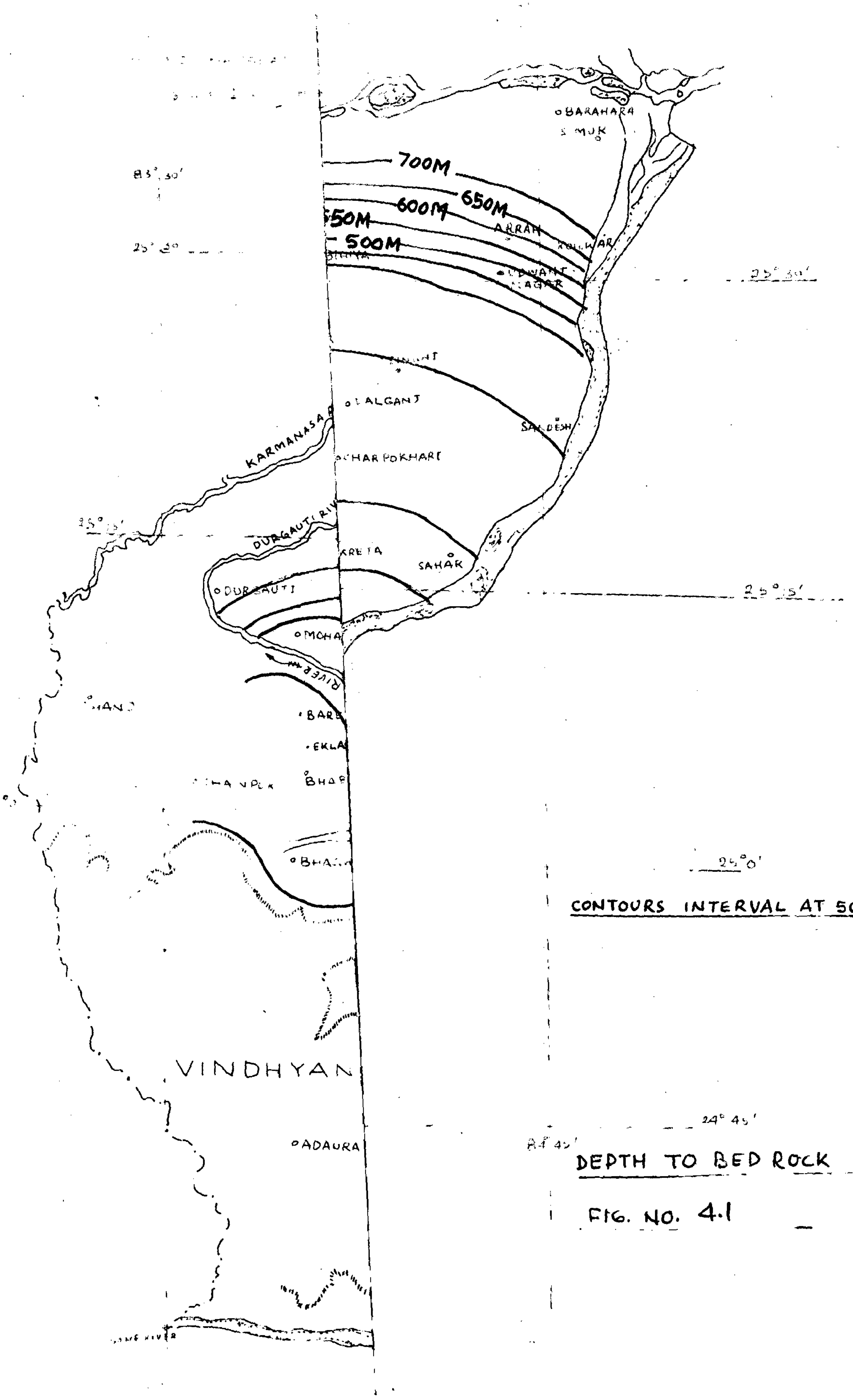
4.6 <u>GEOLOGY OF THE AREA UNDER STUDY</u>

As mentioned earlier, geologically the study area forms a part of the Ganga basin, which merges westwards into the Uttar Pradesh basin and east-wards into the basin of northern west Bengal. Only few kilometres south and south-west of the study area(i.e. outside the doab but forming the southern part of Rohtas district) moderately prominent hills and flat-topped plateaus of Vindhyan system are present. Vindhyans are ancient sedimentaries, slightly metamorphosed showing little or no major deformations or disturbances but well cemented(silcified) by load metamorphism.

The study area, which comprises of entire Bhojpur and northern part of Rohtas district(i.e. nearly entire alluvial plain of old Shahabad district), has good groundwater potentialities due to presence of considerable granular zones with effective porosity, because the alluvial deposits, which mainly consists of variable proportions of sand, gravel, clay etc. by virtue of their loose, unconsolidated nature are the best reservoir of groundwater.

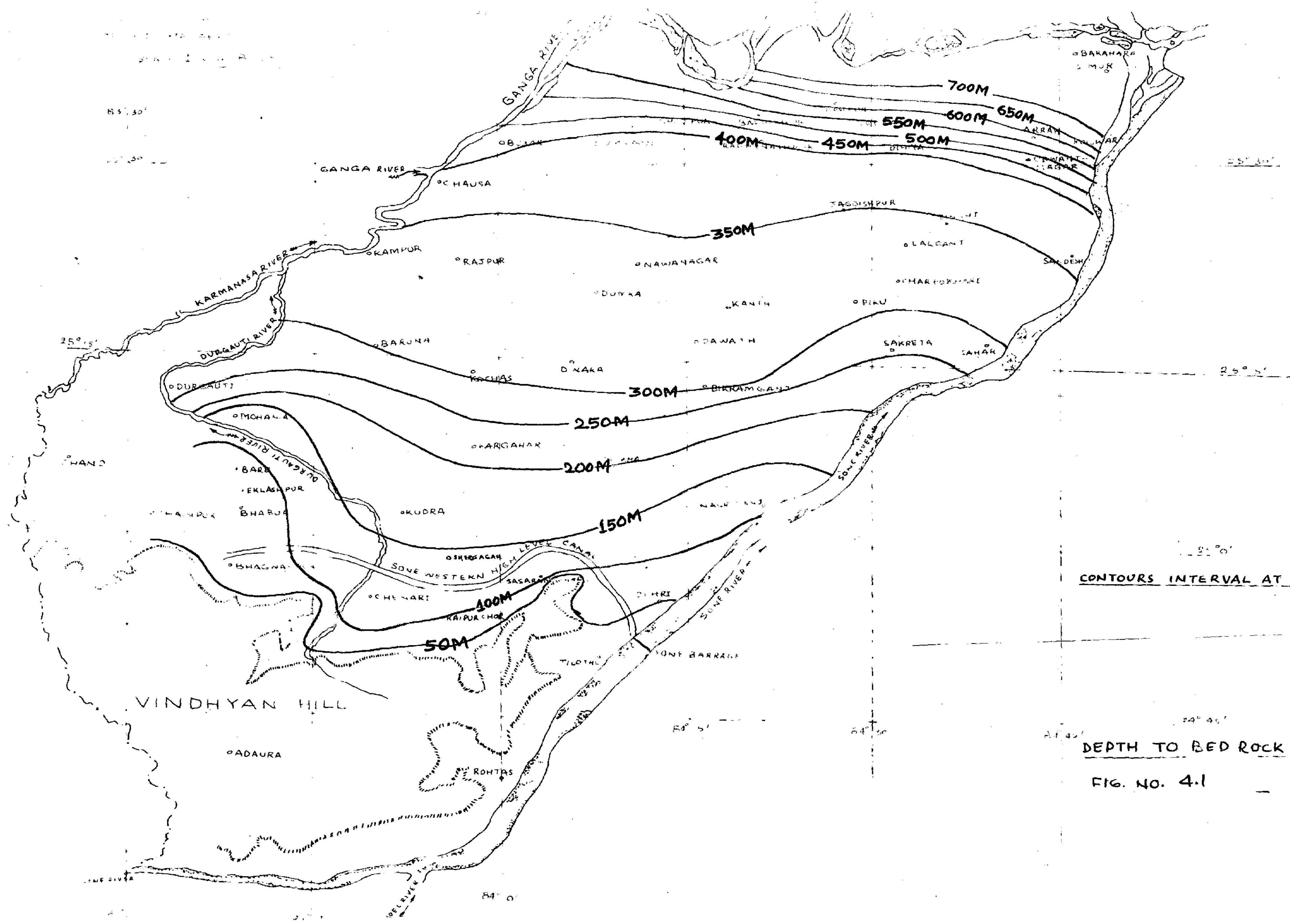
TECTONIC FRAME WORK

Sastri et.al. (op.cit) have concluded that this area lies in the East Uttar Pradesh shelf which is delineated by the Monghyr-Saharsa ridge to the east and Faizabad ridge to its west. The outcroping Vindhyans of the Sone Valley and the basement form the southern border of this zone. This shelf merges to the north into the Gandak depression. This shelf zone is mainly characterised by east west trending aeromagnetic contours indicating several easterly pluging highs and lows. The basement here is assumed is to be the continuation of the Satpura folded



DEPTH TO BED ROCK MAP

FIG. NO. 4.1



CONTOURS INTERVAL AT 50M

DEPTH TO BED ROCK MAP

FIG. NO. 4.1

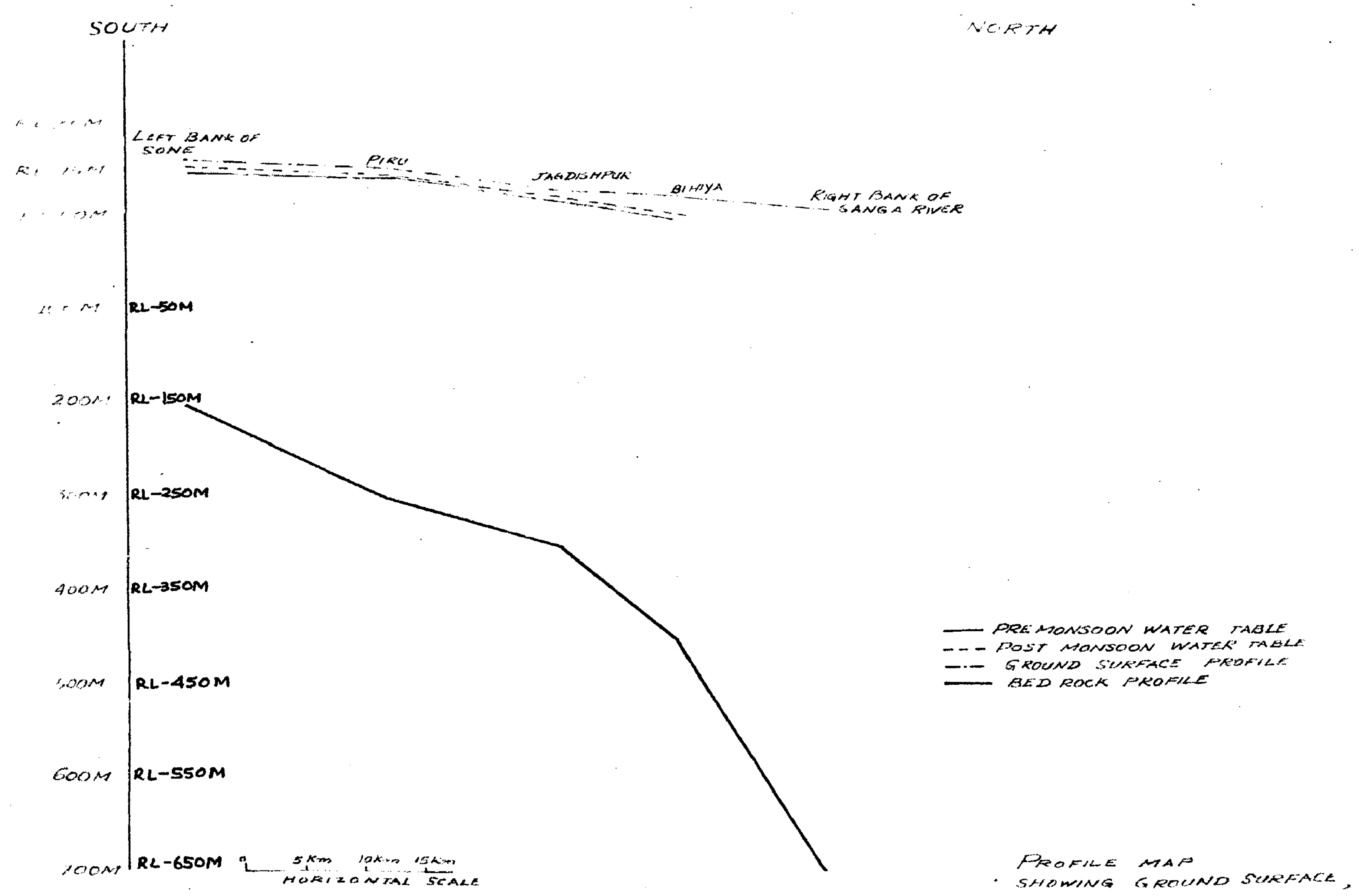
belt overlain successively by the Vindhyan and Neogene sequences. A major north easterly trending fault, with a downthrow to the South-east is traced from near Sasaram(west of Sone river) in the Southwest through Muzaffarpur district upto the Indo-Nepal border. This fault zone appear to have controlled the orientation of river Sone.

THICKNESS OF THE ALLUVIUM

The information about the thickness of alluvial material is mainly derived from geophysical soundings carried out by the Geological survey of India and by deeper exploratory boreholes. [Roy and Sinha(op.cit.)] On the basis of these data, a map of depth to bedrock has been prepared and contours of equal depth are plotted as shown in figure. 4.1 . The contours indicate that the depth to bedrock increases progressively towards the north attaining a value of the order of 700 m. on the south of the Ganga. Two profiles(Fig. 4.2 and 4.3) have also been drawn to show the ground slope, bed rock and position of water table.

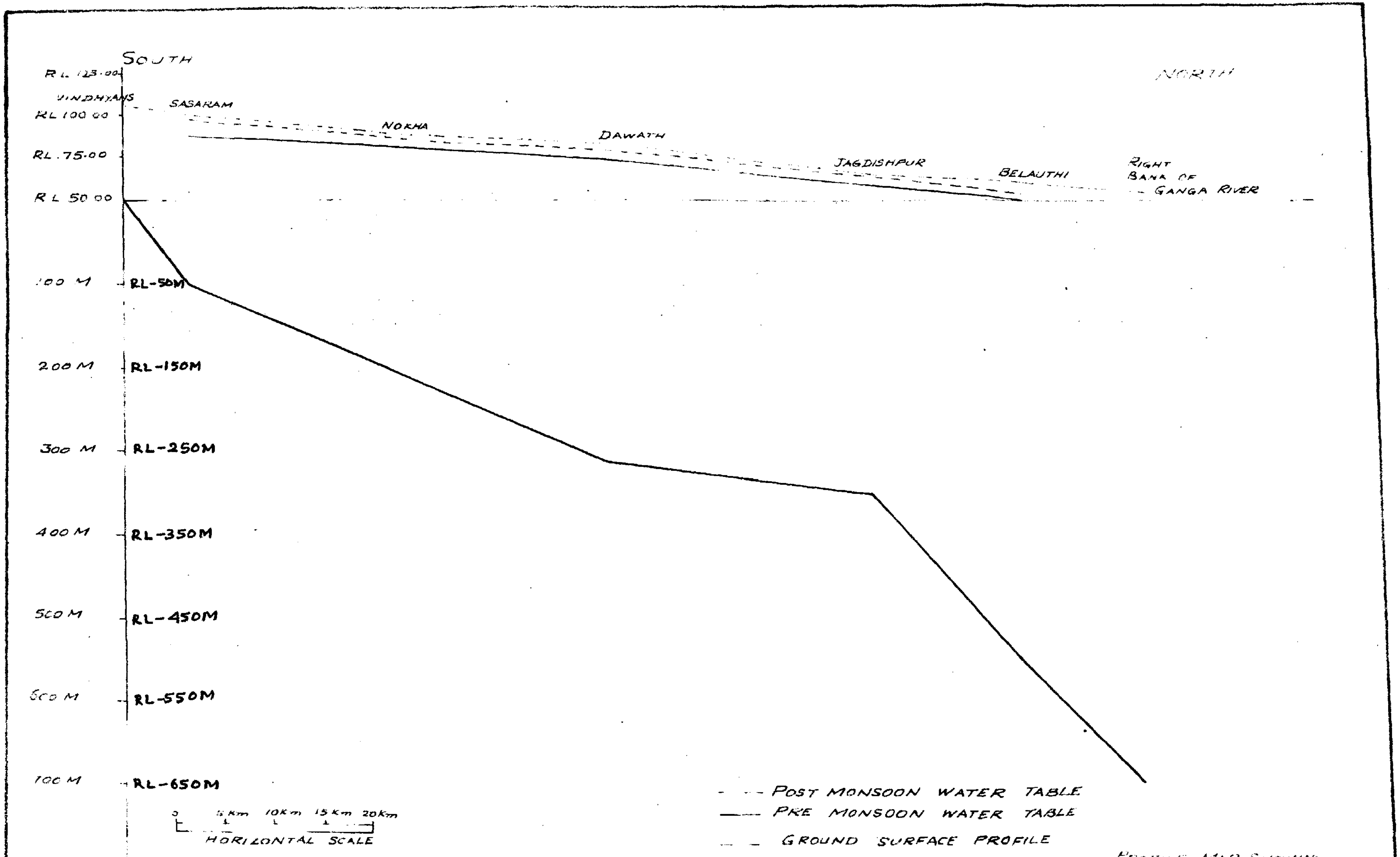
The main features concluded from the map (Fig. 4.1)and profile (fig. 4.2 & 4.3) are as follows:

(i) The bed rock slopes uniformly from the foot of its outcrop to the central portion i.e. upto latitude 25 degree 30 minutes north. Beyond 25°30'N latitude the thickness of



PROFILE MAP SHOWING GROUND SURFACE, BEDROCK, PRE AND POST MONSOON WATER TABLE.

Fig 4.2



PROFILE MAP SHOWING BEDROCK, GROUND SURFACE PRE AND POST MONSOON WATER TABLE

Fig 4.3

alluvium abruptly increases from 350 to 700 metres within a distance of about 12 km. This may be due to local East-West fault in the basement with its downthrow towards north.

(ii) A sharp change in the course of river Ganga towards east, seems to be controlled by the East-West fault in the basement which may be active during the recent period also.

(iii) The E-W trend of the contours is parallel to the outcrop of the Vindhyan rock.

(iv) As the depth to bed rock increases north-ward it may be broadly concluded that a distinct increase in the percentage of aquifer horizons could occur northwards from the marginal terrain adjoining the outcrop area of the older rocks in the south.

4.7 SUB-SURFACE GEOLOGY OF THE AREA

As the present study is also directed entirely towards the unravelling of water-yielding porous granular horizons of the alluvial and detrital covers of the plains lying to the north and northeast of the hardrock areas, so the sub-surface geological informations as obtained from well logs are analysed and interpreted keeping the above view in mind.

Lithologs from about 200 well logs were available for the study out of which 8 of them were deep enough down to the

the basement. It is inferred from the study of these well logs that the alluvium is made up of clays(brown and grey) sand and kankar. The other lithological members are gravel(Bajri) and Lahel (clay mixed with silt). [redacted] .

The geological formations exercise considerable control on the geohydrological conditions. As a result, the groundwater reservoirs with adequate potentialities are restricted in the alluvial tract. As mentioned earlier the alluvial deposits mainly consists of variable proportions of sand, gravel and clay. Clayey materials have very low effective porosity and permeability. It is the sands, gravels and coarser fragments and their admixtures which turn out to be the dependable aquifer zones. The relative preponderance of coarser and finer materials regulates the hydrological characteristics of aquifers. Unassorted materials are inferior to uniformly graded materials as water yielders.

4.7.1. SUBSURFACE FEATURES THROUGH LITHOLOG SECTION

Based on the available lithologs of the area, three sections are drawn to decipher the subsurface geology and correlation of aquifer horizons. However, correlation based entirely on lithologs has serious limitations unless electrical logs are also available.

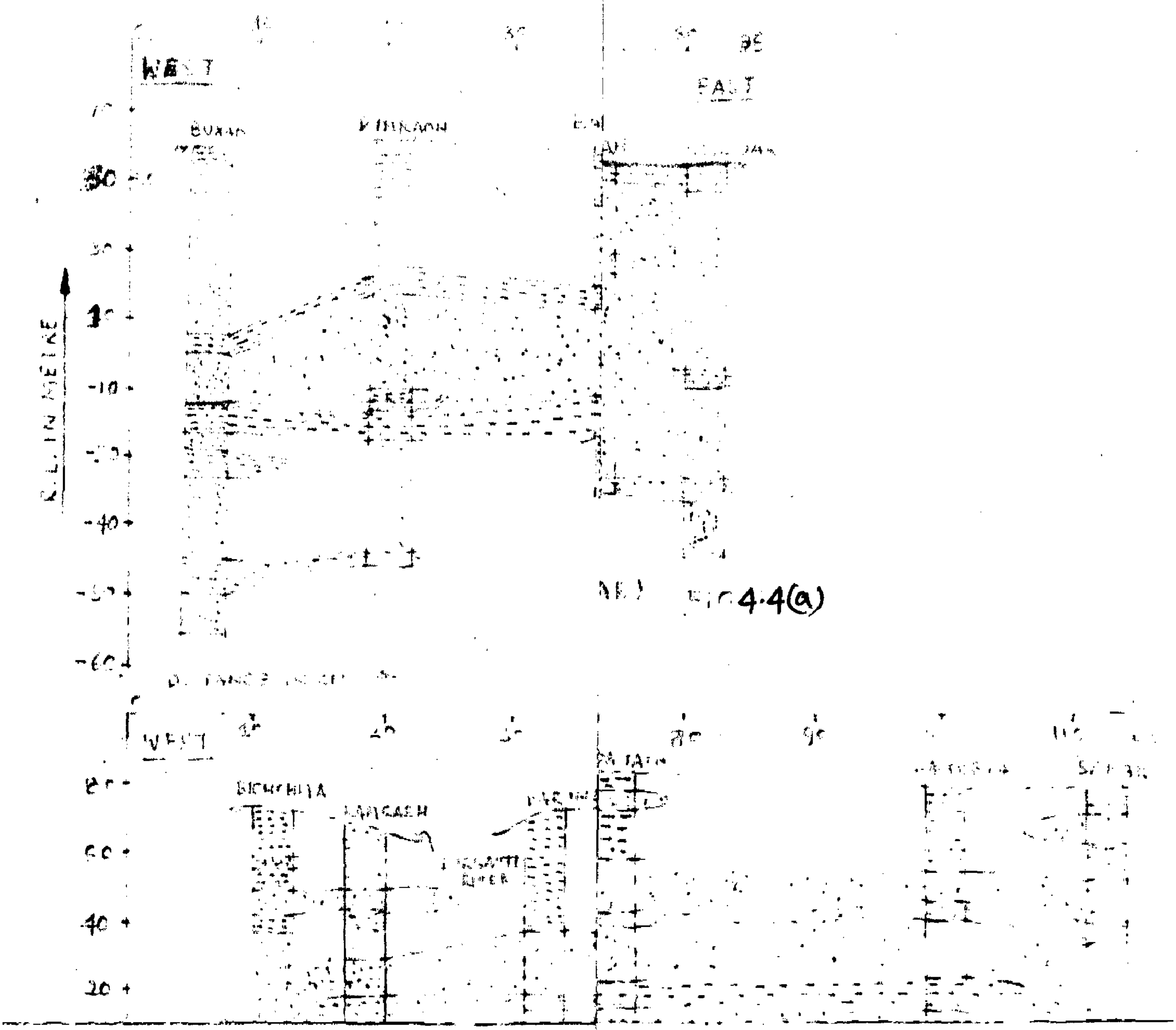
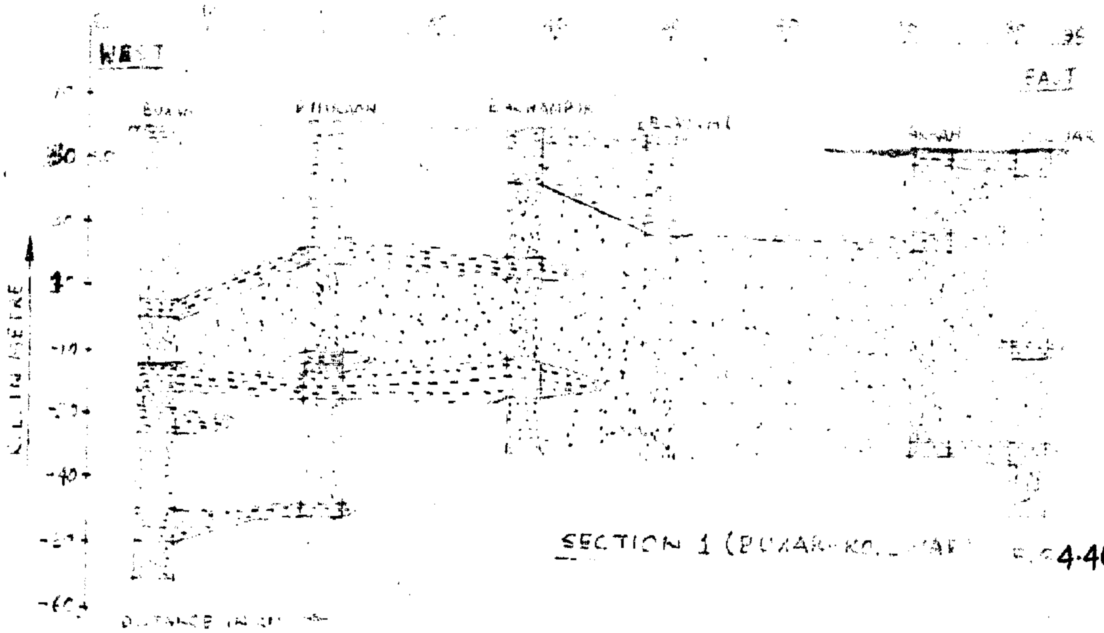
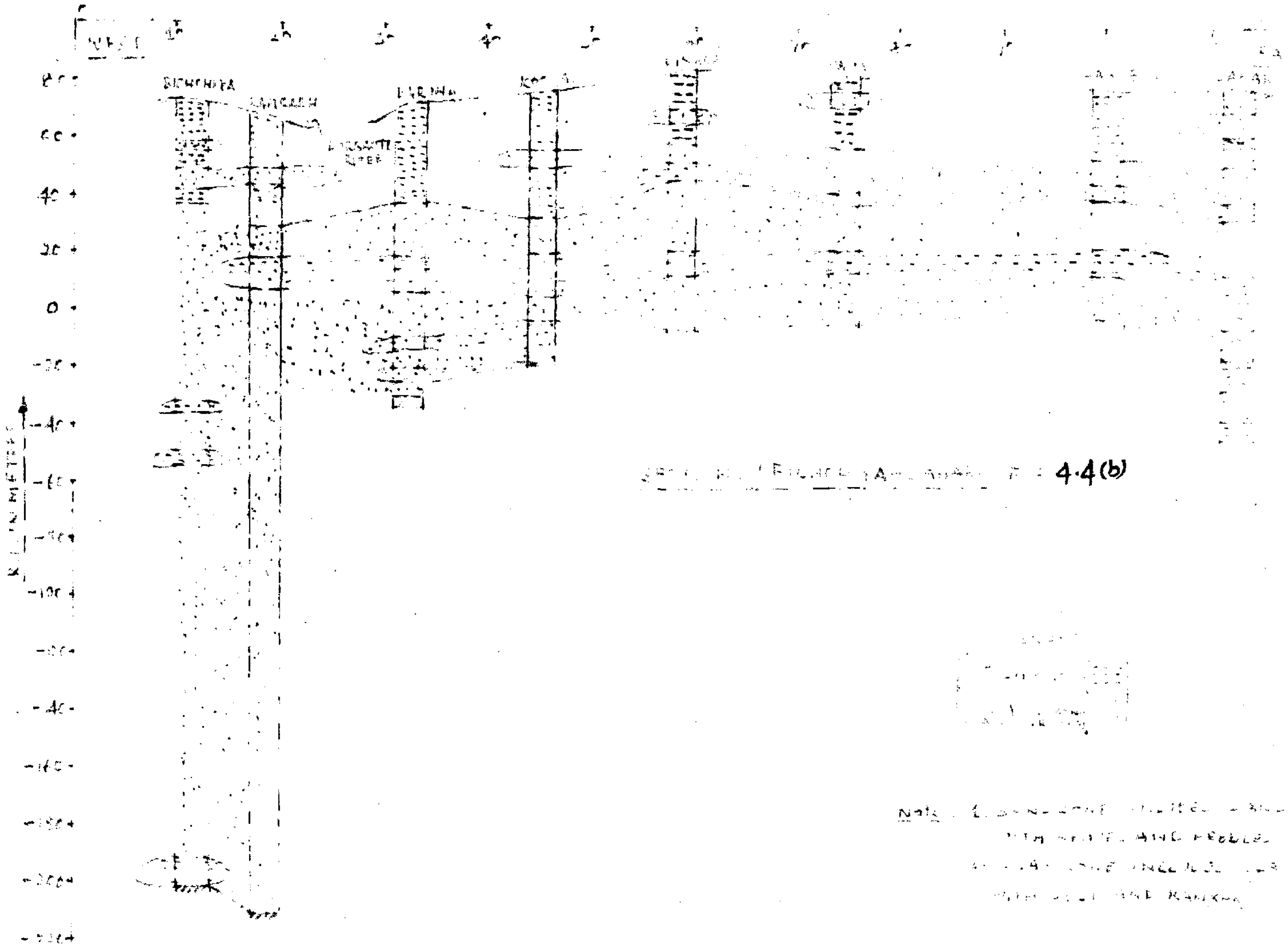


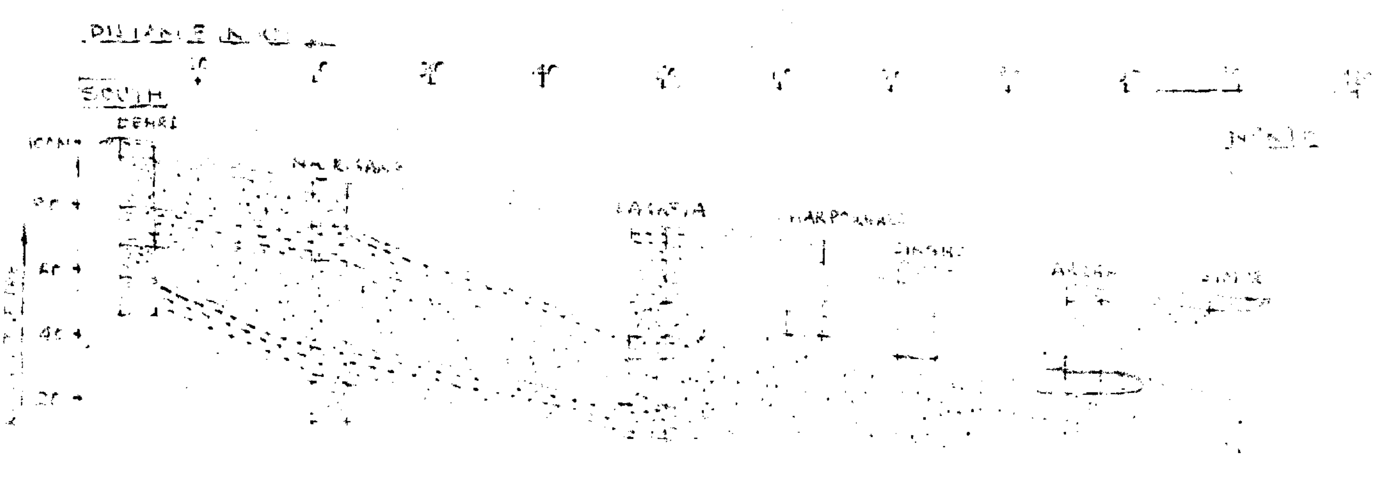
FIG 4.4(a)



SECTION 1 (BUXAR-KO[illegible] 4.4(a)



[illegible] 4.4(b)



4.7.2 SECTION-1 (BUXAR-KOILWAR AREA)

The section (1) as shown in figure 4.4(a) representing the northern part of the area runs just north of latitude 25°30' in a E-W direction in between Buxar and Koilwar(Ganga to Sone) passing through,Buxar,Dumaraon,Barhampur,Belauti,Arrah and Koilwar.

The section reveals the presence of one major aquifer zone below a clay capping of about 4.5 m. to 6 m. in the west and east (at Buxar in the western part and near Arrah to Koilwar in the eastern part). In the central portion(Dumraon to Belauti) thickness of top clay increases. This shows that near the river Ganga in the west and near the river Sone in the east,the thickness of top clay is much less as compared to the central part of the area.

At Buxar the top aquifer horizon is at the depth range of 4.5 m. to 42 m. but at Dumraon which is about 15 km. east of Buxar this top aquifer is absent as there is 45 m.thick clay capping.Further east at Brahampur the clay capping reduce to 15 m. and top aquifer is found at the depth range 15 m. to 36 m. as at Buxar.Beyond Belauthi and upto Sone river the thickness of clay capping reduces and top aquifer horizons are encountered in the depth range of 3 to 30 m. at Arrah and at 6 m. to 75 m. at Koilwar.The second clay layer at Buxar seems to be continuous upto Brahmpur,beyond this upto Sone river the clay layers are isolated and are local in horizontal and vertical extent. Similarly the third clay horizon pinches out near Brahampur. All the three aquifer horizons encountered at Buxar can be correlated with those met at Dumaraon and Brahampur. However, further towards east i.e. near Belauthi on account of the absence of intervening clay layers only one thick aquifer zone is encountered in the depth range of 22 m. to 92 m. beyond which depth drilling has not been done. Here all the three aquiferzones which are met at the western part, merge together. Beyond Belauthi upto Koilwar the thickness of sand horizon increases much more as compared to clay horizon.

It could be broadly concluded that more clay zones are encountered in the central part of the area(doab) while near western and eastern portion i.e. near to river Ganga and Sone the percentage of granular (aquifer) horizon is very high

4.7.3 SECTION 2 (BICHHIYA-SAHAB AREA)

This section as shown in fig.4.4(b) lies just north of latitude 25°15' in a E-W direction in between Bichhiya and Sahar (river Durgauti to Sone) and passes through Bichhiya, Hamgarh, Baruna, Kochas, Dinara, Dawath, Sakreta and Sahar. In this section Bichhiya and Ramgarh lie outside the study area, but as the lithologs at these two places are available upto bed rock so these have also been considered.

The top clay layer lies in the depth range of 4 to 27 m. and the distribution of the capping is somewhat erratic. The thickness of clay capping increases gradually,eastward from 13m. at Bichhiya to 18 m. at Ramgarh and 27m. at Baruna.At places there are isolated thin sand lense within the clay capping.There seems to be a lateral East-West continuity of the clay horizon at the depth range of 18 to 23 m. in the central and eastern portion.It is found that the top aquifer which occurs in the depth range of 4.5 to 27 m. show a similar continuity. The second and third aquifer horizons can be correlated in all the bore-holes of this section. The cumulative thickness of clay horizon is comparatively more in the central portion than in the eastern and western portion.

4.7.4 SECTION 3 (SIMPUR-DEHRI AREA)

The section (3) as shown in the fig.4.4(c) runs in the N-S direction from Ganga river in the north to western high level canal in the south and it passes through Simpur,Arrah,Singhi, Charpokhari,Sakreta,Nasriganj and Dehri. Simpur lies in the northern portion while Dehri is situated in the southern part of the section.

The clay capping which,increases from 2.4 m. thickness at Simpur to 33 m. thickness at Charpokhar (lying in the central portion) is reduced to 2 m. at Nasriganj and 4.5 m. at Dehri.

The three aquifer horizons which are encountered in the central portion at Sakreta and Nasriganj,merge together to from thick aquifer zone in the range 2.4 m. to 93 m. at Simur and in the range 25 m. to 97 m. at Arrah,both representing northern part of the study area. As the clay capping is in the range of 27 m. to 33m. at Singhi and Charpokhari so the top aquifer horizon is absent at these two places. However,further southwards at Sakreta and Nasriganj all the three aquifers are encountered. At Dehri only first and second aquifer horizons are present due to presence of bed rock at 54 m. depth.

It is found that the clay is more in the central and southern portion while it is very less in the northern portion of the section.

4.8 CONCLUSION BASED ON SUBSURFACE LITHOLOGICAL SECTIONS

By comparing the E-W (1 and 2) and N-S(3) sections following conclusions regarding subsurface lithology can be made.

(i) The amount of clay is more in the central and southern part of the area while it is less in the northern portion.

(ii) The aquifer and aquicluds horizons show greater lateral continuity in the East-West direction especially in the northern portion.However, in the North-South direction this extent is more of local character. This can also be observed from the centre of gravity map(fig. 4·8) drawn by further analysing the lithologs vide Art.4.8, Art.4.9 and Art.4.10.

(iii) In the central and southern portion there are more number of clay layers inbetween the aquifer horizons.

(iv) The total thickness of clay in the southern part of the area i.e. towards the outcrop areas of Vindhyan rocks, is more while the total thickness of sand horizon is greater near the present river (Ganga and Sone) courses i.e. in the eastern, northern and western part of the doab, such a conclusion is in conformity with the vertical variability maps vide Art.4.9 and Art.4.10.

4.9 SUB-SURFACE LITHOLOGICAL MAP

4.9.1 INTRODUCTION

For geohydrological studies, the subsurface maps are prepared to ascertain the position and thickness of the various horizons.

The conventional faceis maps are designed to show the areal variation in a stratigraphic unit. However, no single number or symbol completely expresses the whole character of a stratigraphic section. The variety of rock types present, their repeated position in the stratigraphic interval and the varying thicknesses of beds from top to bottom of the section present a complex inter relationship that is difficult to reduce to any single summary

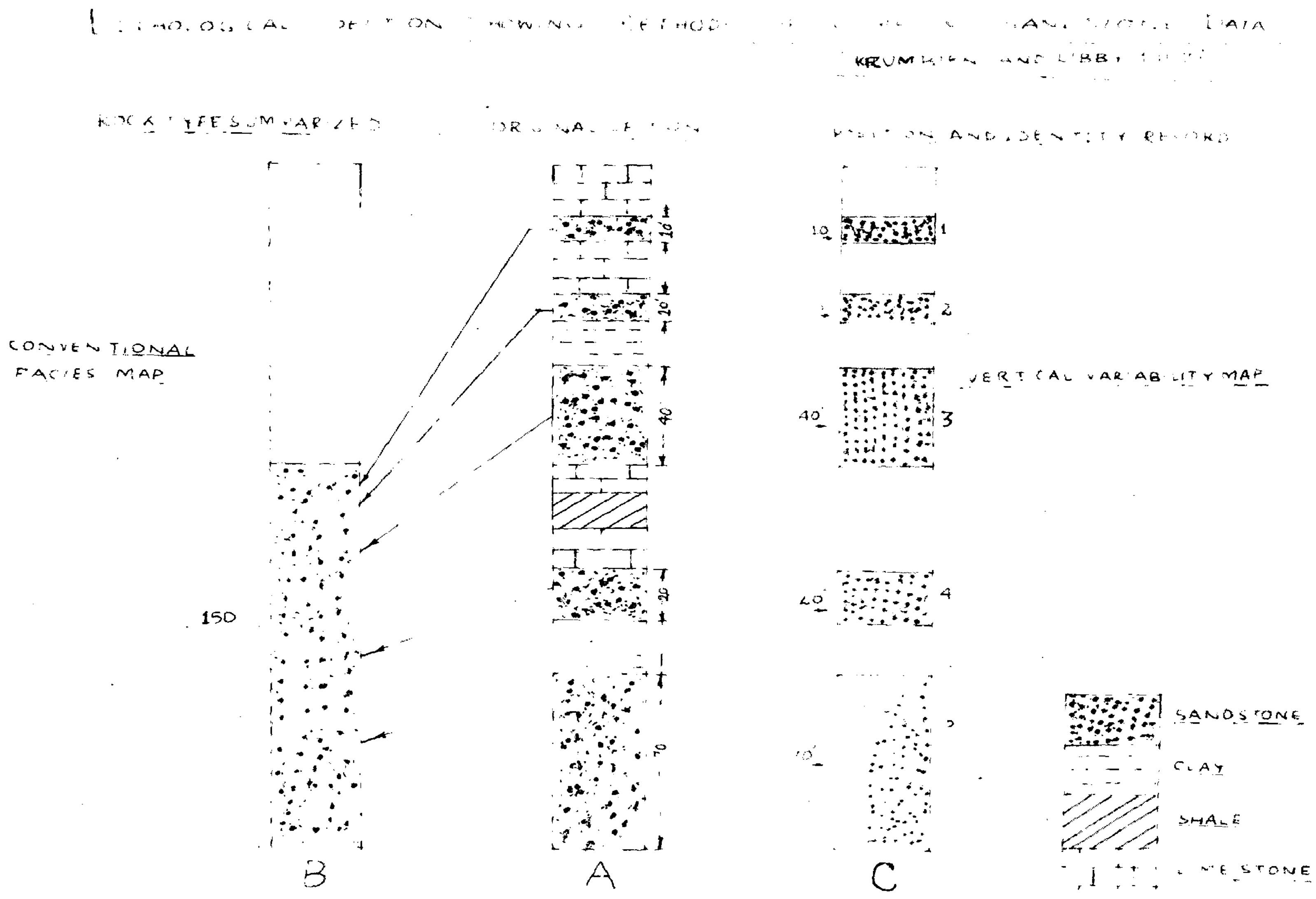

KRUMBEIN
CONVENTIONAL
FACIES MAP
150
VERTICAL VARIABILITY MAP
40
20
3
4
SANDSTONE
CLAY
SHALE
B
A
C

Fig 4.5

number. Therefore, a series of maps are needed each communicating information on the selected features of the overall aspect. A map that shows the areas variation in percentage of sand in a stratigraphic unit communicates no information on whether the sand occurs as a single body or many or whether it is near the top or bottom of the unit.

The distinction between conventional facies maps that show the areal variations and vertical variability map is that,the latter takes account of individual beds and their placements in the section. They may be illustrated by compiling the stratigraphic data from the out crops and from well logs respectively.

Fig.4.5 (A) shows hypothetical litholog showing sandstone, shale and limestone distribution(Domenico et al.1964).In preparing the conventional facies maps of any unit e.g.sandstone, the total amount of sandstone present in the unit is obtained by adding the thickness of each sandstone occurrence and expressing the result as a total footage.This combines all the sandstone into a single aggregate as has been shown in fig.4.5 (B).

By this process the total thickness of the sandstone is computed and from this,it could be possible to prepare conventional maps of sandstone thicknesses,percentage of sandstone in section or various ratios involving the sand content.

For vertical variability maps, the sandstones are retained in their original positions and thicknesses as shown in fig(C). Preservation of sandstone identities permits preparation of maps showing the number of sandstones in the section,the average thicknesses of the sandstone or the average position of the sandstone in the section.

4.9.2 TYPES OF VERTICAL VARIABILITY MAPS AND METHOD OF THEIR PREPARATION

The vertical variability maps have been divided into two categories (Domenico et.al.1964).

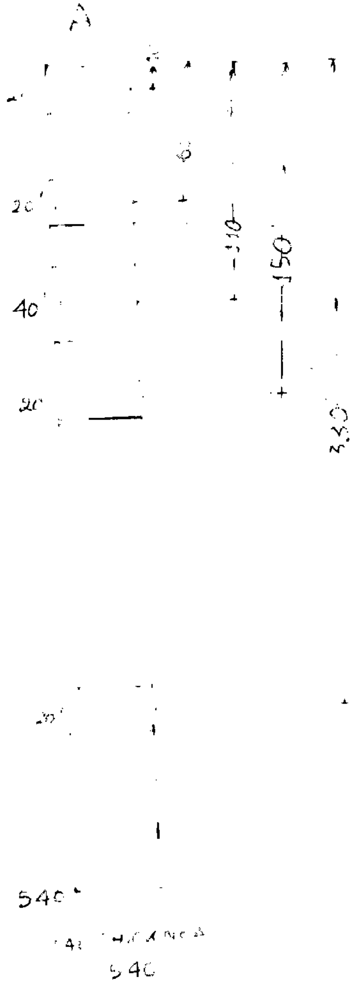
(i) Maps designed to show the degree of differentiation of a section into discrete units of different lithologic parts.

(ii) Maps that show relative position of one lithologic type withi a given section.

In the case of second type of maps, the moments have been applied to express the positional relations of the beds as a continuous variable.(Krumbein and Libby,1957).It includes 'centre of gravity' and 'standard deviation' maps.Variations in the gross lithology can be described by mapping the relative centre of gravity and the relative standard deviation around the centre. By superimposing the centre of gravity and standard deviation maps, a vertical variability map can be prepared.

M… … CENTRE OF GRAVITY AND STANDARD DEVIATION (KRUMBEIN AND LIBBY 999)

A



B

BAND NO	DISTANCE FROM TOP x	THICKNESS t	t·x	t·x²
1	10	20	[illegible]	[illegible]
2	60	20	[illegible]	72000
3	110	40	4400	484000
4	150	20	3000	450000
[illegible]	330	20	6600	2178000
SUM		120	15400	3186000

CENTRE OF GRAVITY … 128

RELATIVE CENTRE OF GRAVITY $100 \times \frac{28}{540}$ 24 %

APPROXIMATE VARIANCE $\frac{\sum x^2/x}{x}$ = 10,081

APPROXIM. STANDARD DEVIATION = $\sqrt{10081}$ 100

RELATIVE STANDARD DEVIATION $\frac{100}{540}$ 19 %

Fig 4·6

CENTRE OF GRAVITY (MEAN POSITION)MAP

The relative centre of gravity expresses the average position of selected units within a larger unit either as a distance in metres from a predetermined datum plane or as a percentage of total thickness of the section also measured from the datum plane.

The method of computing the mean position of sands in a stratigraphic unit is illustrated in fig.4.6 .The position of each sand unit is indicated on a sample log as shown in the Fig. (A). The distance from the top of the stratigraphic unit to the centre of sand horizon is measured and recorded for each sand occurrence,as is the thicknesses of the individual sand. The distance from the top 'h' for each sand is multiplied by the sand thickness 't' to obtain the product h.t. The products are summed and divided by the total sand thickness.This is the centre of gravity of the sands below the top of the section, expressed as a weighted mean that takes into account the thickness of the individual sands. Centre of gravity also represents the weighted arithmetic mean position of the sand.

The centre of gravity can be expressed as a relative value by dividing it by the thickness of the section and multiplying the result by 100 to obtain the percentage of the distance from the top of the unit to the position of the centre of gravity.

Similar relative values can be plotted on a base map for each control point, and contours of equal values can be drawn through the points.

Centre of gravity indicates the changing position of the sand below the top of the unit,but they do not indicate whether the individual sands occupy a narrow zone within the stratigraphic unit or whether they are distributed throughout the unit. So it is desirable to supplement the centre of gravity map with another type of map that indicates how widely,on the average,the sands are distributed through the section. This can be done by computing the second moment of the sand distribution which is called the standard deviation map.

4.9.3. STANDARD DEVIATION(AVERAGE DISPERSION)MAPS

The centre of gravity represents the first moment of the distribution. The second moment describes the average spread of the distribution and can be used to compute the standard deviation of the sand bodies about the centre of gravity.The standard deviation is that interval which when added to and substracted from the centre of gravity,provides a range that contains,on the average,about two third of the sands in the distribution.

The method of computing the standard deviation is shown in the Fig.4.6. When the standard deviation is expressed relatively as a percentage of the total thickness,it provides an easily visualised measure of the dispersion of sands through the unit.

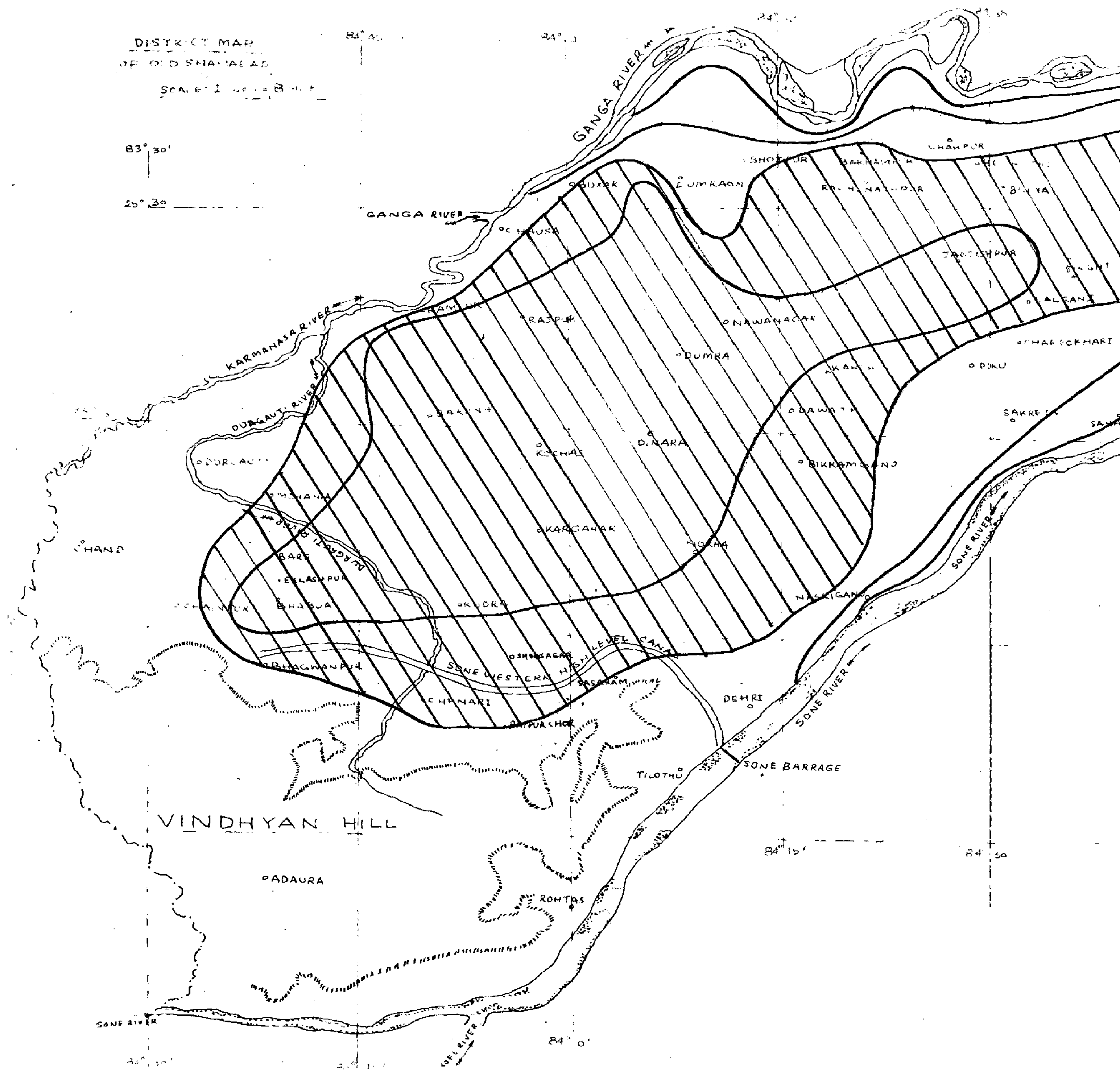
A combined pattern map based on the centre of gravity and standard deviation can be prepared to show how the two aspects are related.

4.10 SUBSURFACE MAPS OF THE AREA

In this study an attempt has been made to draw the centre of gravity map, standard deviation map, vertical variability pattern map and percentage of cumulative sand thickness map in order to find the lateral and vertical distribution of the aquifer (sand) horizons. These maps have been drawn on the basis of some 200 lithologs available for different parts in this area.

As the chief water yielding formation in the area are sand with gravel and kankar, they have been grouped together to form sand unit. On the other hand, clay and silt together with kankar have been grouped together as the impermeable horizons, representing the other i.e. clay unit. It is found from the lithologs of various well that the major water yielding sands which have been tapped by the state tubewells lie within a depth of 250 feet(75 m), from the ground surface. So, the mapping unit chosen for preparing these maps is the interval upto 75 m. depth below the ground surface.

Based on the values of relative standard deviation and relative centre of gravity(computed as described above), contour maps have been prepared as shown in Fig. 4.7 and 4.8. After



RELATIVE STANDARD DEVIATION MAP OF SAND HORIZON

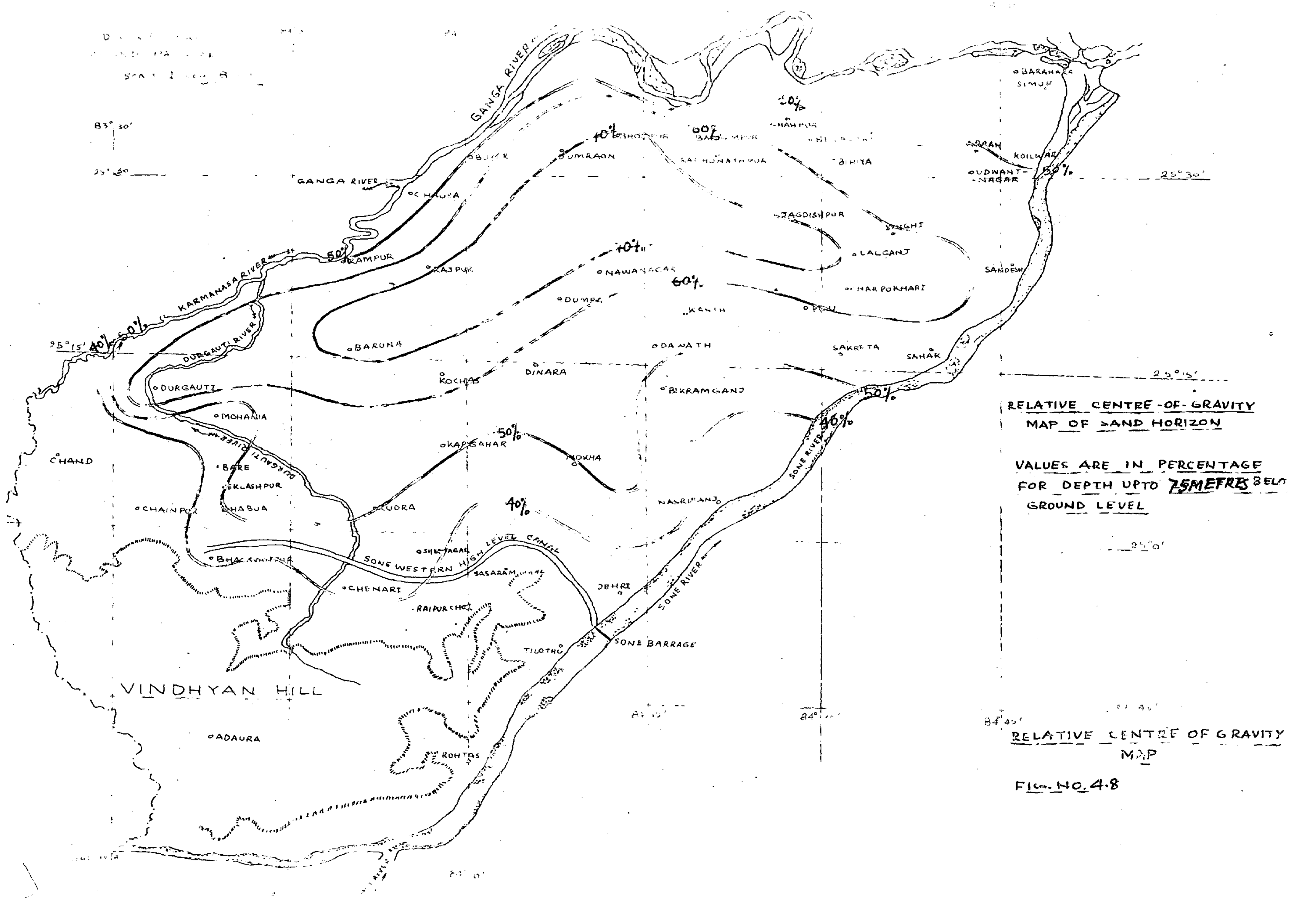
VALUES ARE IN PERCENTAGE

THE SPREAD (S.D.) IS FOR DEPTH UPTO 75 METRES BELOW THE GROUND SURFA[CE]

SHADED AREA DENOTES SPREAD > 20

RELATIVE STANDARD DEVIATION MAP

FIG. NO: 4.7



RELATIVE CENTRE OF GRAVITY MAP

FIG. NO. 4.8

superimposing the centre of gravity and standard deviation maps, a vertical variability pattern map has been prepared. To supplement the vertical variability pattern map, cumulative sand thickness percentage map (conventional facies map) for depth upto 75 m. has also been prepared (Fig. 4.10).

4.11 INTERPRETATION OF DATA

In the vertical variability pattern map (Fig. 4.9) which is prepared by superimposing, the centre of gravity and standard deviation maps, various classes can be identified which show the variation in the distribution of aquifer horizon based on the relative centre of gravity and relative standard deviation values.

Relative centre of gravity	Relative standard deviation
20% to 40% (High position)	0 % to 2% (small sprea-d)
40% to 60% (Medium position)	20% to 40% (large spread)
60% to 80% (Low position)	

Thus six possible combinations can be made each of which has been described below:

4.11.1. CLASS-I

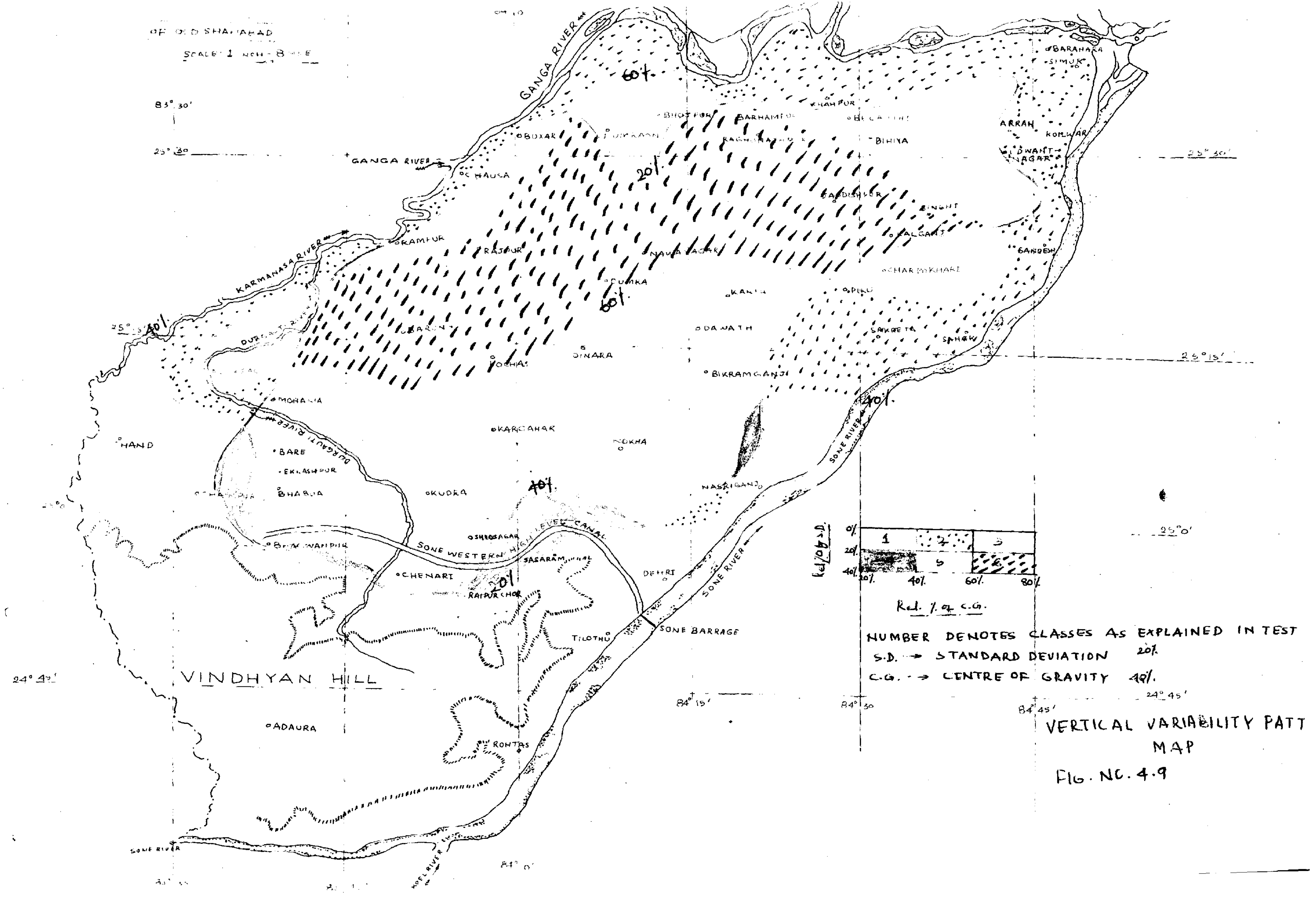
CHARACTERISTICS

Relative centre of gravity = 20% to 40% (high position)

Relatige standard deviation = 0% to 20% (small spread)

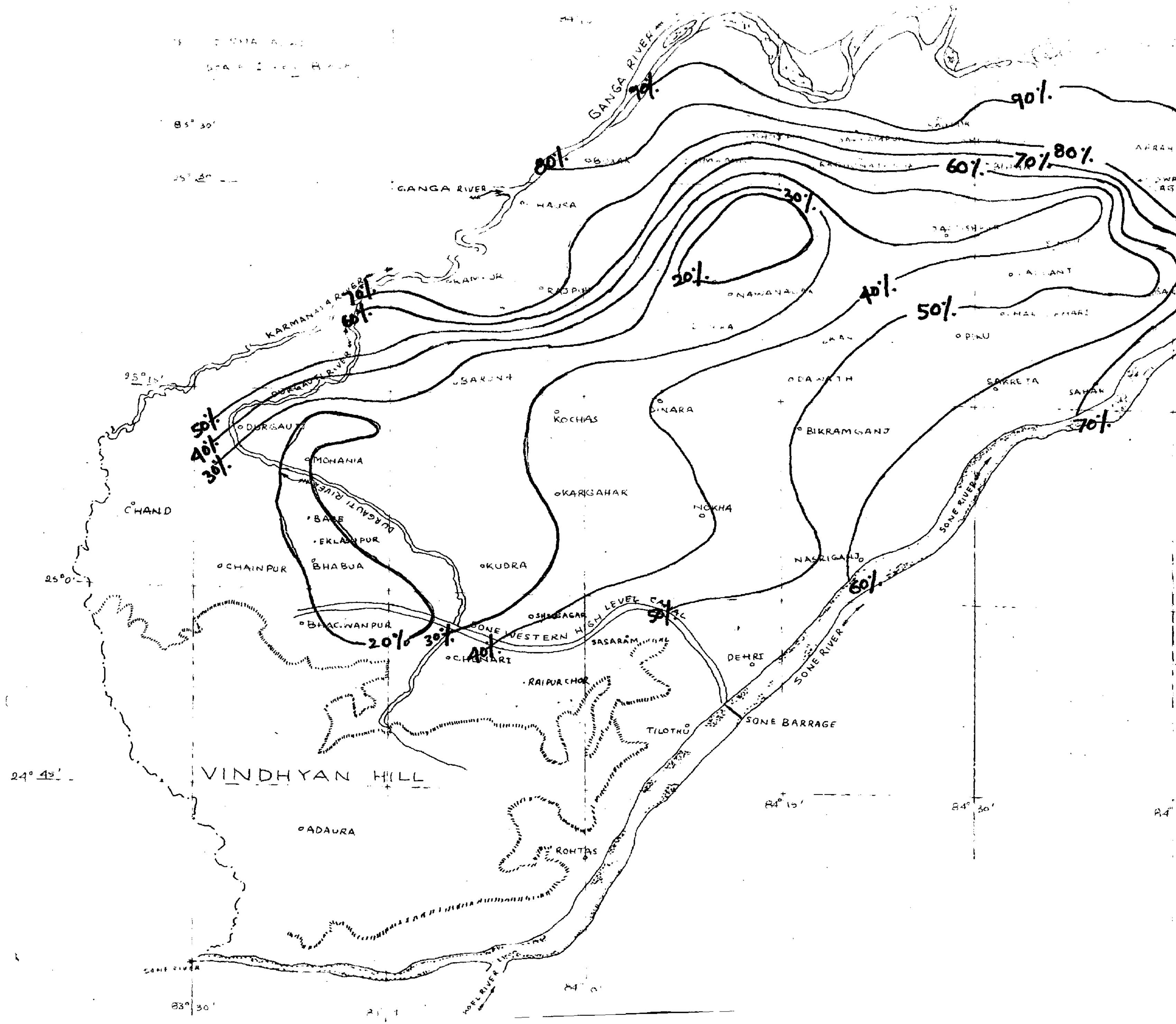
Average percentage of permeable material

i.e. percentage of cumulative sand thickness = 55%



VERTICAL VARIABILITY PATT
MAP

FIG. NO. 4.9



SAND (CUMULATIVE) PERCENTAGE MAP FOR DEPTH UPTO 75 M BELOW GROUND-SURFACE

PERCENTAGE OF PERMEABLE HO MAP —

FIG. NO. 4.10

The above interpretation indicate that the main sand and gravel development occurs in the upper porition of the section and generally consists of one or a few thin lenses interbedded with the materials of negligible permeability.In reference to the ground surface the centre-of-gravity is between 15 to 30 m. in depth. As the percentage average 55% the permeable materials occur as relatively thick lenses interbedded with almost equal thickness of clay lenses.

4.11.2 CLASS-II

CHARACTERISTICS

Relative centre of gravity = 40% to 60% (Medium positio

Relative standard deviation = 0% to 20%(Small spread)

Average percentage of permeable materials in the north and north west is 85%(very high) while it is 70%(high) in east and is low i.e.35% in the West.

The area under class II occurs as three different zones - one in the north and north east along river Ganga,the second in the east along river Sone and the third in the west along river Karamnasa.

Northern Zone - The main sand and gravel development occurs in the middle porition of the section and in reference to ground surface the centre of gravity is between 30 m. to 45m. below ground surfacel The very high percentage of sand indicates very thick lenses of sand and very thin interbedded layers of silt and clay.

North west and Eastern zone

The centre of gravity and spread are similar to the northern portion as described above.The high percentage of sand indicates large body of sand interbedded with relatively thin lenses of silt and clay formation.

The above mentioned two portions lie adjoining to the river Ganga,Sone and Karmanasa.The interpretation seems to be logical as in those portion the proportion of sand horizon is always much higher as compared to the clay formation. As these areas lie near to the river,therefore in the recent past they might have been the course of the river.

Western Zone The mean position and spread are similar as described above but the percentage of sand horizon is relatively small(35%) indicating low sand-clay ratio.It means that in the middle portion thin lenses of sand spread from 0 to 15 m. either side of the centre of gravity which is about 30 to 45 m.below ground surface.

4.11.3 Class III

CHARACTERISTICS

Relative centre of gravity = 60% to 80%(low position)

Relative standard deviation = 0% to 20%(small spread)

Average percentage of permeable material in the northern and western part = 35% and in the eastern part = 50%.

The main development of permeable materials is in the lower portion of the interval and consists of thin lenses spread from 0 to 15 m. either side of the centre of gravity,which is about 45 to 60m.below ground surface.

4.11.4 CLASS IV

CHARACTERISTICS

Relative centre of gravity = 20% to 40% (high position)
Relative standard deviation = 20% to 40%(large spread)
Average percentage of permeable material = 20% to 35%(Low)

The main development of permeable materials occurs in the upper portions of the interval with a spread of 15 to 30m. either side of the centre of gravity.The low percentage of permeable materials coupled with a large spread indicates that there are many thin lenses of sand horizon with large quantities of material of negligible permeability (clay) interspread.

4.11.5 CLASS-V

CHARACTERISTICS

Relative centre of gravity = 40% to 60%(Medium position)
Relative standard deviation = 20% to 40% (Large spread)

Average percentage of permeable material in north west is 60% (high) while it is 35%(low) in the southern part.

The large spread combined with a relatively high percentage of materials indicate a general alternating sequence of sand-gravel and silt-clay throughout the total section with the main development near the middle of the section.

North west zone - The high sand and gravel percentage indicates relatively thick sequence of sand as compared to the clay horizon.
Southern zone : The low percentage of permeable material indicates that thin lenses of sand are interbedded alternatively with relatively thick clay units.

The spread is from 15m to 30m. either side of the centre of gravity which lies between 30m. to 45m. below the ground surface.

4.11.6 CLASS VI

CHARACTERISTICS

Relative centre of gravity = 60% to 80% (low position)
Relative standard deviation = 20% to 40%(Large spread)
Average percentage of permeable material is 25%(very low)

The very low sand and gravel percentage coupled with large spread indicates relatively thin lenses interspread with large quantities of silt and clay. The spread is15 m. to 30 m. either side of the centre of gravity which is 45 m. to 60 m. below the ground surface. In this class the main development of permeable material is in the lower porition.

4.12 DISCUSSION

The above pattern of distribution of sand and clay horizons indicate that these are mainly deposited by the shifting courses of river Ganga. The central part of the doab shows a higher concentration of sand in the lower portion while clay is predominant at higher levels. This may indicate that the deep sand horizon in zone (5) and (6)(Fig. 4.9) represent the channel sand deposited by the ancient river course while the clay in the upper horizon is mainly a result of flood plain deposit.

As the course of river Sone was mainly restricted further towards east it has not played any important role in the sedimentation of alluvium in the doab under study.

CHAPTER - 5

GROUND WATER

5.1 INTRODUCTION

As mentioned earlier the study area lies within the main alluvial basin of Bihar which forms a part of the Ganga basin. Such areas under alluvial tract are generally endowed with vast groundwater reserves. The rain water which percolates downwards finds its place in the alluvial formations below the soil capping. Fresh groundwater occurs in the interstices between the grains of granular material. These unconsolidated granular materials are usually composed of sands of various grades, gravels and pebbles. Besides, recharge from rainfall the other sources of recharge of ground water reservoir in the alluvial terrain are (a) inflow from neighbouring basins, (b) artificial recharge due to irrigation water and (c) natural recharge by rivers and streams during high floods.

5.2 GROUND WATER IN ALLUVIAL TRACTS OF BIHAR

The alluvial deposits of Bihar by virtue of their loose, unconsolidated nature are the best reservoir of groundwater.

The thickness of the alluvial material ranges from 20 to 3 metres near the southern hard rock areas to nearly 2500 metres in the north Bihar. A considerable proportion of this thicknessconsists of granular material capable of yielding good water supplies. The main alluvial basin where considerable alluvial thicknesses are noticed lie north of 25° latitude across the entire breadth of Bihar. However, in the area south of the Ganga, an exception is noticed east of longitude 86°, where the Kharagpur and Rajmahal hills form the main features, with an intervening patch of relatively shallow alluvial fill.

The total alluvial area of Bihar, which comprises almost entire north Bihar and the greater areas in Patna, Shahabad (excepting the Adhaura plateau in the South) Gaya (excepting the Chotanagpur plateau and its vicinity), parts of Monghyr (western par and north Bhagalpur, is about 94,000 square kilometres which is 54% of total ground area of Bihar. The high yield zone has been compute as about 75,000 square kilometres which is 43% of total ground area of Bihar. The normal annual rainfall in the alluvial plains of Bihar is 1242 mm. Assuming 20 percent of annual rainfall as recharge to groundwater reservoir, the annual average recharge due to rainfall in the alluvial tracts of Bihar works out to 2.33 million hactre metre. The utilization of annual draft till 1974-75 works out to 0.40 million HM, which is about 17% of the annual recharge. In this rough estimation recharge due to other minor recharging agents, as mentioned in Art.5.1, has been neglected.

Hence it is seen that about 83% of the annual recharge due to rainfall remains unutilized. So, there is immense prospect of utilising this ground water resource through proper planning exploration and development for enhancing the agro-economic potentialities of the state. Fortunately, the areas of maximum demographic growth coincide with the tracts endowed with rich soils and adequate groundwater reserves.

5.3 GROUND WATER CONDITION IN STUDY AREA

The valley of rivers Sone and Ganga and its tributaries are excellent water-bearing zones. The alluvial fill ranges from shallow depth of 20 to 30 m. near terrain adjoining the hard rock areas of Kaimur plateau to 500-700 m. depth range near the southern bank of river Ganga. So, there is distinct increase in the percentage of aquifer horizons north-wards.

The study area has large potentialities of ground water. About 90 percent of the area lies within the high yield zone and rest of the area in the southern portion is of moderate yield type. The Sone basin comprising of Dehri-Arrah and area along south of Ganga i.e. Arrah-Buxar are among the best granular zones. The pioneer high yielding tubewells were taken up in this area, much before independence.

There is ample scope of groundwater exploitation on large scale. At present the groundwater utilisation on large scale are limited to (i) area inbetween the south bank of the Ganga and Main line of Eastern Railway from Koelwar to Buxar, (ii) from Chausa to Mohania along the right bank of Karamnasa river and (iii) along a linear tract along the rivery Sone in Dehri-Tilouthu areas and Dehri-Sasaram areas. The existing annual withdrawal of groundwater in the area is of the order of 61082 HM for irrigation purpose whereas the surface water utilisation for the same purpose is of the order of 314612 HM. The percentage of groundwater utilisation is 19.4% of the surface water for the irrigation purpose. So, there is good prospect for supplementary irrigation by tubewells particularly in the tail reaches of the canals of Sone command, where shortage of water is being experienced at present.

5.4 OCCURRENCE AND NATURE OF GROUNDWATER RESERVOIR

The principal groundwater reservoir in the area is the unconsolidated alluvial deposits consisting mainly of inter-bedded and lenticular sands, silts and clay as revealed from geological cross-sections. The geological cross-section donot indicate any confirning layers which may be continuous over very large distances. The various clay layers show local confinement only.

PRE MONSOON DEPTH TO WATER TABLE CONTOUR MAP FOR 1974

FIG. NO: 5.1

Groundwater in the area occurs under unconfined condition in shallow aquifers and under unconfined to semi-confined conditions in the deeper aquifers. The general gradient of the water tables is towards north and river Ganga and Sone are generally of effluent nature. The depth to water table generally varies from 1.5 to 13 metres in different parts of the year. The average seasonal fluctuation of water table is of the order of 2 to 4 metr

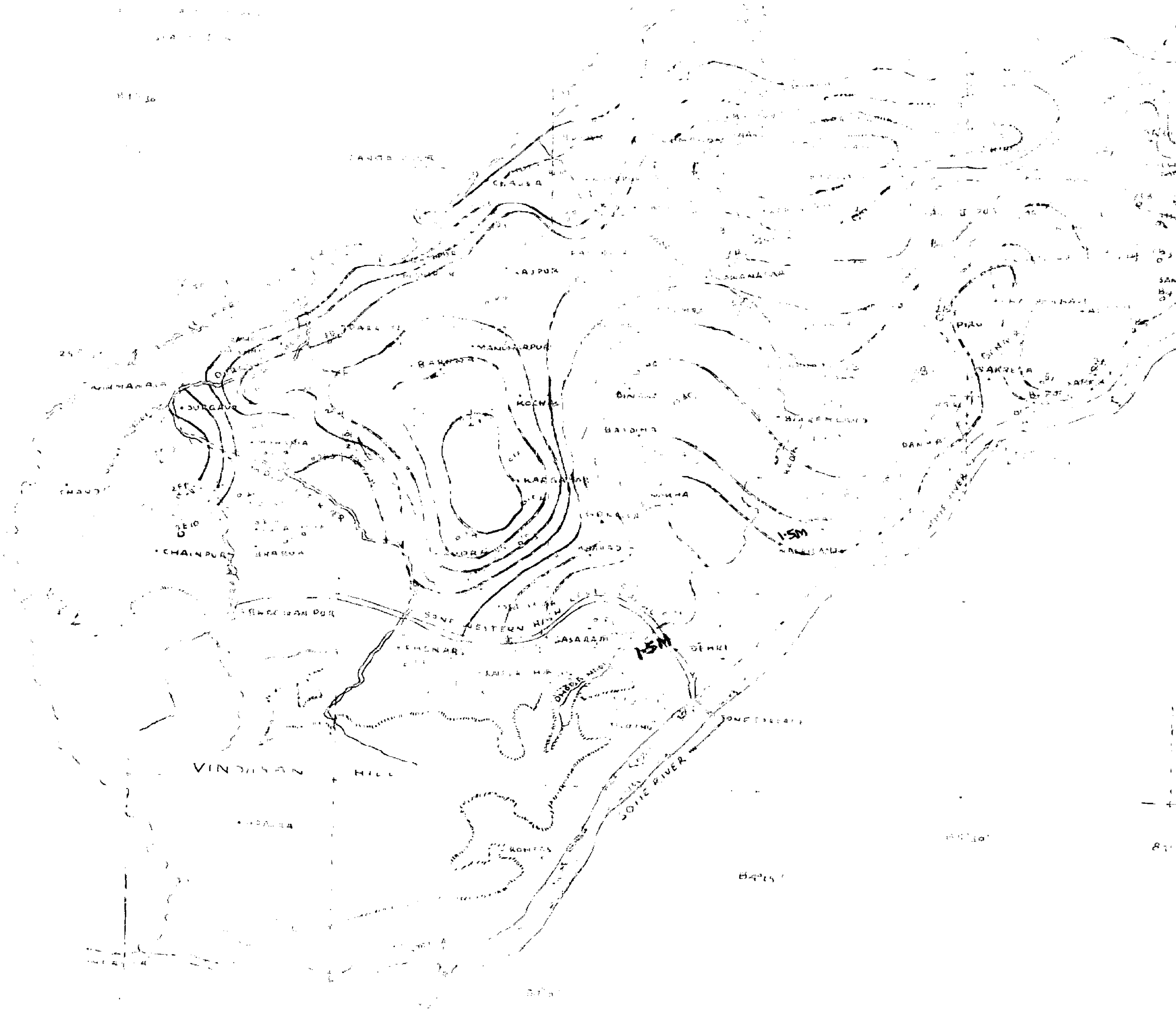
The shallow aquifers are usually tapped by open wells and shallow tubewells, while deeper aquifers are at present tapped by deep tubewells.

5.5 CONDITION AND NATURE OF WATER TABLE DURING 1974-75

Data regarding groundwater levels have been plotted in a number of maps ~~(Fig.)~~ indicating the depth to water level, seasonal water level fluctuation and water table contours. A detailed discussion is given below.

5.5.1 PRE MONSOON WATER TABLE DEPTH

In figure (5.1), which shows the premonsoon depth to water table contours, it is seen that the depth of ground water varies within the range of 4 m. to 13 m. The depth of groundwater level in the northern and north-east portion of the area is 4 m. to 10 m. while in the south and south-west it lies within



POST MONSOON DEPTH TO WATER TABLE CONTOUR FOR 1.5

AREA UNDER 1.5M CONTOUR
= 45252.48 Hactres

○ …LOCATION OF OBSERV…

[ ] TOPOSHEET NUMBER

… WATERLOGGED AREA

FIG. NO: 5.2

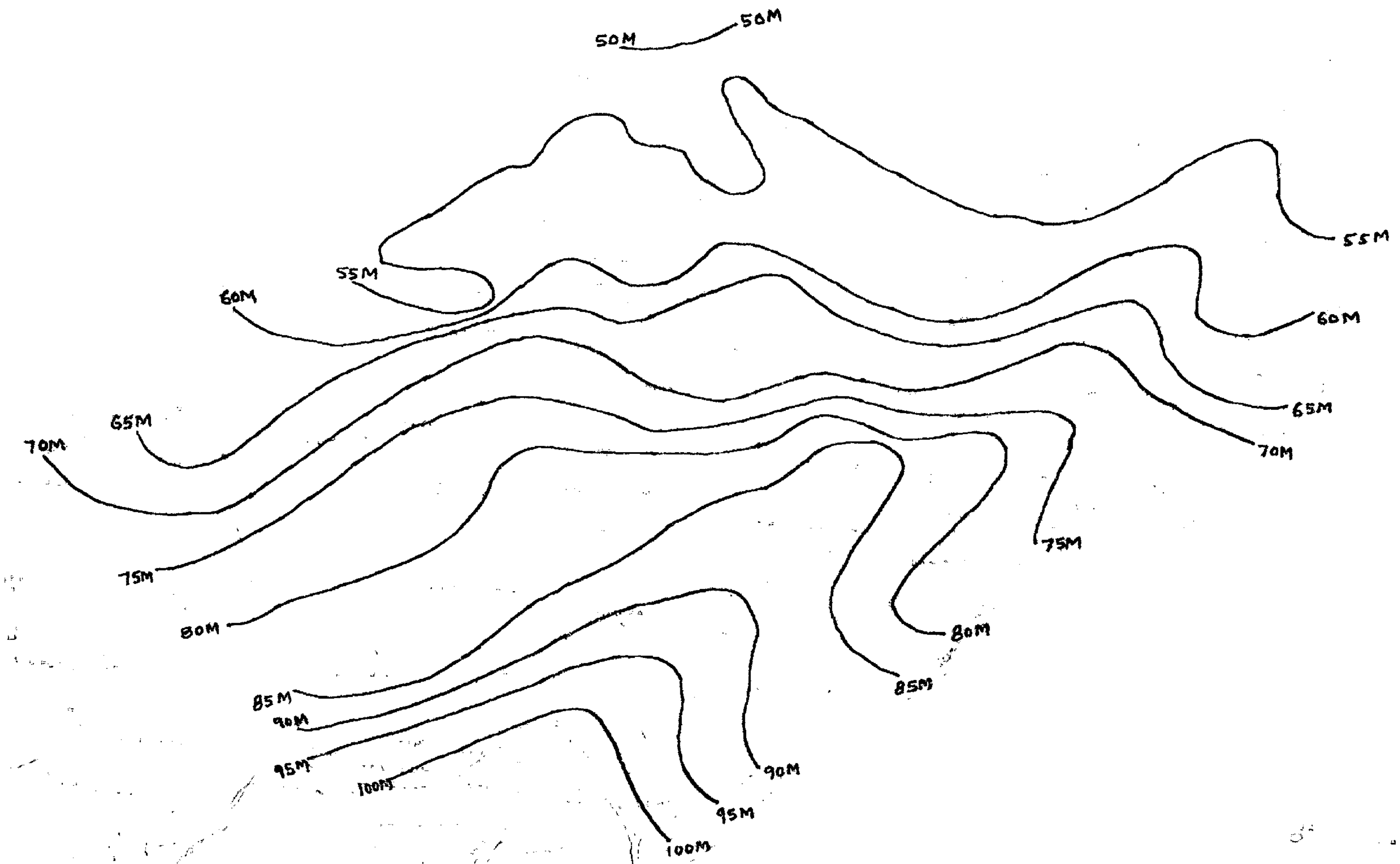
4m. to 13 m. It is noticed that along the bank of main rivers viz.Ganga and Sone, the depth to water-table reduces but it increases towards the central and the southern portion of the area.There are three localised zones viz.at Nokha in the South,at Piru in the east and around Arrah-Udwantnagar in the north-east,where the depth to water-table is minimum i.e. within 4m.

The average depth to water-table,during pre-monsoon period of 1974,as has been worked out in table 5.1 is 7.2454 metre

5.5.2 POST MONSOON WATER TABLE DEPTH

The post monsoon depth to watertable contours,as shown in figure(4.2),indicate that the depth of groundwater level lies within the range of 9 m. to less than 2 m. The maximum depth of 9 m. is localised at Kargahar in the south-west portion of the area while in the north the maximum depth of 8 m. and more is localised within the area bounding Raghunathpur and Ekrasi.

The areas within which the depth to watertable is less than 1.5 m. are prone to waterlogging.The waterlogged area is located within a tract which passes through Sasaram,Dehri, Nokha,Rajpur,Nasriganj,Piru,Lalganj,Charpokhari,Sakreta,Sahar, Sandesh and Khangam.This stretch of area roughly follows the course of the river Sone.



PRE [redacted] MONSOON WATER TABL CONTOUR

55M ... POST MONSOON WATER TAB CONTOUR

WATER TABLE CONTOUR MA FOR POST AND PRE MONSOON

FIG. NO: 5.3

The average depth of water table for this period as has been worked out vide Table 5.3 is 4.8922 metres

5.5.3 PREMONSOON WATER TABLE CONTOURS

The water table contours for Premonsoon of 1974 have been plotted in figure (5.3). The water table contour map gives an idea about the hydraulic gradient and direction of groundwater movement.

The contours indicate that the hydraulic gradient in the eastern part of the area is towards NE while in the remaining part it is towards NW i.e. mainly towards river Ganga. The river Sone, Karmanasa, Durgauti and Ganga are all effluent in nature. The general pattern of the water-table contour conform approximately to the topography of the area. The groundwater contours range from the elevation of 95 m. in the southern portion to 50 m. in the northern portion of the area. The highest elevations are met with in the southern and south-eastern part, of the area i.e. close to hardrock outcrop. The direction of groundwater movement is practically parallel to the flow of the river Sone along its western bank. The water table gradient is steeper near the outcrop area and it flattens out towards the central and northern portion of the doab.

TABLE 5.1

AVERAGE PREMONSOON WATER TABLE DEPTH IN 1974-75

Sl. No.	Contour interval in metres	Average contour interval in metres	Area in hactres	Product of Col.(3) x col.(4) in H.K.
(1)	(2)	(3)	(4)	(5)
1	Less than 4 M	4M	19062.62	76250.48
2.	4M-5M	4.5M	72512.61	326306.74
3.	5M-6M	5.5M	144356.15	793958.82
4.	6M-7M	6.5M	103043.6	669783.4
5.	7M-8M	7.5M	90755	680662.5
6.	8M-9M	8.5M	86462.12	734928
7.	9M-10M	9.5M	70950	674025.08
8.	10M-11M	10.5M	43187.87	453472.64
9.	11M-12M	11.5M	25616.67	294591.68
10.	12M-13M	12.5M	5556.48	69486
11.	More than 13M	13M	3375	43872
		sum Total	664878.12 hactres	4817307.1HM

Hence average depth to water table

$$= \frac{4817307.1}{664878.12} = 7.2454 \text{ metres.}$$

TABLE 5.2

AVERAGE POST MONSOON WATER TABLE DEPTH IN 1974-75

Sl. No. (1)	Contour Inter-vàl in metres (2)	Average contour interval in metres (3)	Area in hactres (4)	Product of Col(3) and Col.(4) in HM (5)
1	Less than 2M	2M	59996.925	119993.85
2	2M-3M	2.5M	102958.72	257396.80
3	3M-4M	3.5M	87684.85	306897.01
4	4M.5M	4.5M	93713	421710.0
5	5M-6M	5.5M	103548.21	569515.20
6	6M-7M	6.5M	118984.61	773400.0
7	7M-8M	7.5M	68862.933	516472.0
8.	8M-9M	8.5M	35104.564	298388.8
9	Greater than 9M	9M	4426.31	39836.80
	Sum Total		67580.11 hactres	3303610.4HM

So average post monsoon depth to water table

$$= \frac{3303610.4}{675280.11}$$

$$= 4.8922 \text{ metres.}$$

TABLE 5.3

FLUCTUATION IN DEPTH TO WATER TABLE DURING PREMONSOON TO POST MONSOON PERIOD OF 1974-75

Serial No.	Contour interval in metres	Average contour interval	Area in hactres	Product of col.(3) and (4) in HM
(1)	(2)	(3)	(4)	(5)
1	Less than 1M	1M	173348.28	173348.28
2	1M-2M	1.5M	196435.99	294653.98
3	2M-3M	2.5M	138421.38	346053.45
4	3M-4M	3.5M	75089.28	262811.5
5	4M-5M	4.5M	48225.77	217016
6	5M-6M	5.5M	27872.72	153300
7	More than 6M	6M	16066.833	96401
	Sum Total		675460.25 hactres	1543584.2HM

Hence, average rise in water table depth from non-monsoon to monsoon period of 1974-75

$$= \frac{1543584.2}{675460.25} = 2.285 \text{ metres}$$

TABLE 5.4

CHANGE IN DEPTH TO WATE TABLE IN A YEAR 1974-75

The following observation shows the difference of depth to water table during May 1974 and May 1975 i.e.Premonsoon'74 and Premonsoon'75.

Sl. No.	Contour Interval in metres	Average contour interval in metres	Area in hactres	Product of Col.3. amd col.4 in HM
(1)	(2)	(3)	(4)	(5)
1	< -1 M	-1M	53360	- 53360
2	-1 -0M	-0.5M	130896	-65448
3	0M- 1M	+0.5M	300688.64	+150344.32
4	1M-2M	+1.5M	126806.4	+190209.9
5	2M-3M	+2.5M	53438.4	+133595
6	>3M	+3M	16576	+49728
	To sum Total		681765.44	+523876.92 - 118808.0
				= 405068 HM

Hence net rise in depth to water table during

the year 1974-75 $= \frac{405068}{681765.44}$

= 0.594 metre

==========

5.5.4 POST MONSOON WATER TABLE ~~XXXXXXX~~ CONTOURS

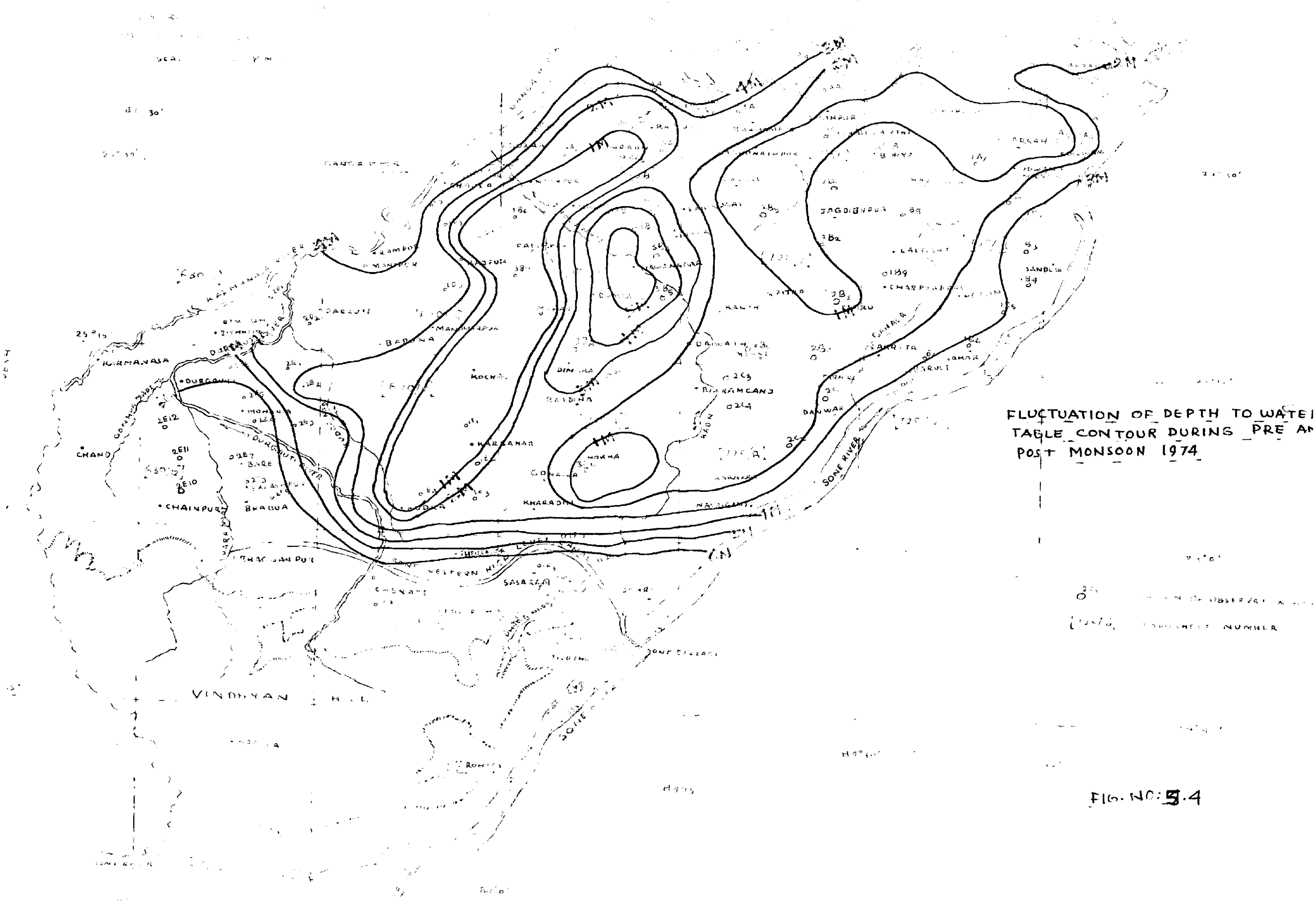
In Fig.(5.3) along with premonsoon water table contours, post monsoon water table contours for the year 1974 have also been plotted. The groundwater contours range from 100 M in the southern part to 50M near the northern boundary of the area. The highest elevations are met with in the southern part and south-eastern part of the area. A perusal of Fig. 5.3 where both pre and post-monsoon water table contours are plotted, shows that the contours show a complex system of ground water ridges aligned parallel to the main irrigation canals. This is indicative of excessive seepage from these unlined canals.

In comparison with the pre-monsoon water table contours it is observed that:

(i) The hydraulic gradient of post-monsoon water table is steeper.

(ii) Considerably minor deviations of the contours are noticed locally, as a contrast to the relatively smooth non-monsoon contour trends. Such irregularities or deviations are probably due to the effect of irrigation and local water logging.

(iii) Effect of water courses is more pronounced during post monsoon than pre-monsoon, because even non-perennial streams have water in them during the beginning of post monsoon period i.e. October.



FLUCTUATION OF DEPTH TO WATER TABLE CONTOUR DURING PRE AND POST MONSOON 1974

FIG. NO: 5.4

5.5.5 WATER TABLE FLUCTUATION

Figure(5.4) shows the contours of water table fluctuation i.e. the difference of pre and post monsoon depth to water table. The contours indicate that the rise in water table ranges from 1M to 6M. The rise is more near the southern portion of the area, where it varies from 4M to 6M. A localised zone where the rise in the depth is 5 M, is noticed in the central portion within the area around Nawanagar. This is the area where there is greater percentage of clay(fig.4.10)indicating a low specific yield. Thereby it is but natural to expect a larger fluctuation. Higher fluctuation of water level near the rivers is can be explained due to recharge during the flood period.

The average rise in the depth to water table for the period premonsoon and postmonsoon 74 has been worked out as 2.285M vide Table 5.3.

5.5.6 CHANGE IN DEPTH TO WATER DURING THE PERIOD PRE-MONSOON'74 AND PRE-MONSOON'75

Figure(5.5) shows the difference of depth to water table contours during May 1974 and May 1975. It shows the change in the depth of water-table during a year. The contours vary from -1M to +3M. The minus contour shows depletion in water-table i.e. recharge is less than withdrawl whereas the plus contour show rise in water table. The zero contour shows no change in the depth of water-table.

In the areas along the major rivers i.e. Ganga and Sone the rise in water table is upto 2 M while towards the Southern and Western portion i.e. the areas along Western high level canal and Durgauti river the rise is upto 3M. In the Central portion i.e. the area around Kargahar, Nokha, Kochas and Basdiha, there is depletion of 1M in the depth of water table. Beyond the 25°15' latitude line towards north and north-east the variation in depth ranges from 0 to 1M except for a localized zone towards north-east around Undwantnagar where a depletion of 1m. in depth of water table has been noticed.

The average rise in the depth of water table during 1974-75 has been worked out as 0.594 metres vide Table 5.4.

5.6 AQUIFER CHARACTERISTICS

5.6.1 DEFINITIONS

TRANSMISSIBILITY

The transmissibility is the product of the average permeability and the thickness of the aquifer. The permeability (k) is the amount of flow per unit cross-sectional area under the influence of a unit gradient. Consequently transmissibility is the rate of flow under a hydraulic gradient equal to unity through a cross-section of unit width over the whole thickness of the aquifer. It is designated by the symbol T. It has the dimensions of $(\text{Length})^2/\text{Time}$.

STORAGE COEFFICIENT AND SPECIFIC YIELD

The storage coefficient and the specific yield are both defined as the volume of water released or stored per unit surface area of the aquifer per unit change in the component of head measured normal to that surface.Both are designated by the symbol S and are dimensionless.

The storage coefficient refers only to the confined parts of an aquifer and depends on the elasticity of the aquifer material and the fluid.

The specific yield refers to the unconfined parts of an aquifer.In practice,it may be considered to equal the effective porosity or drainable pore space because in unconfined aquifers the effects of the elasticity of aquifer material and fluid are generally negligible.

5.6.2. DETERMINATION OF AQUIFER CHARACTERISTICS

The knowledge of the geohydrological structure of the aquifer is essential for the evaluation of safe yield from groundwater reservoir.This information regarding the structure can be obtained by determining the geohydrological constants of the aquifer,which comprise of the determination of coefficient of transmissibility and the estimate of specific yield of storage coefficient.For different conditions of aquifer i.e. confined,unconfined or leaky(a confined aquifer whose confining layers are semi-pervious having a limited resistance to vertical water movement), a systematic analysis is required for the determination of these constants.This analysis consists of carrying out a pumping tests and analysing the test data for which a number of methods are available.

In the study area only short duration pumping tests have been done by the Geological survey of India. Some step-drawdown tests were also carried out by the Central Ground Water Board. The short duration pumping tests have been shown that the aquifer is under confined condition. The short duration tests are likely to give erroneous results regarding aquifer characteristics. Geological cross-section based on lithologs of existing tube-wells have revelaed that the aquiclude are of localised nature and thereby the aquifers do not appear to be of confined character.

Singhal(1967) has suggested that systematic long range pump tests should be carried out to evaluate the hydraulic characteristics of the deeper aquifers in the Indo-Gangetic Plain.He has further suggested that 'at least two observation wells should be put for noting the drawdown, one of these should tap only the shallow aquifer and other the same horizon as the pumping well. Draw-down in the shallow observation will indicate water-table conditions for the tested aquifer and a change in the values of coefficient of storage can be explained either due to the delayed gravity drainage or due to the heterogeneity of water bearing material. If the pumping from the deeper aquifer does not appreciably influence the water-level in shallow observation well, a change in the values of coefficient of storage would indicate leaky artesian condition. In order to decide the real nature of an aquifer the sub-surface geology and sedimentation conditions should also be given due importance.

Since no long duration pumping test has been carried out in the study-area and moreover the short duration pumping test analysis will not give the true representative values of aquifer characteristics, so, values of S and T have been adopted on the basis of analysis done over similar type of aquifer in the adjoining area of Uttar Pradesh. In this regard it is worthwhile to mention that Chatterjee and Roy(69) have found that the ground-water characteristics of the Ganga-Sone alluvial tract of Bihar do not deviate from the same of the Ganga alluvium of Uttar Pradesh, Punjab and West Bengal. The aquifers are mostly semi-confined or free and yields vary from place to place depending mostly upon facies variations'.

5.6.3 VALUES OF S AND T IN INDO-GANGETIC PLAIN

The values of 'S' and 'T' in different parts of Indo-Gangetic plain are as follows:

Sl. No.	Place	'T' in Cm^2/Sec.	'S'
1.	Ganga-Hindon Doab	215	0.132
2.	Ramganga-Ganga Doab	205	0.118
3.	Ganga-Yamuna Doab at Meerut	187	0.110
4.	Gomti-Sai Doab in Eastern UP	136	0.096
5.	North Varanasi	140	0.096

5.6.4. VALUE OF 'T' BY STEP DRAW DOWN TEST

The Central Ground Water Board has carried out step draw-down tests in the study area and the values of 'T' as obtained are given below:

Sl. No.	Place	'T' in cm^2/Sec.
1.	Akolhi	164
2.	Basantpur	184
3.	Mohania	197
4.	Ratwar	207

The average value of T works out to 188 cm^2/sec.

5.6.5 VALUES OF 'S' AND 'T' ADOPTED

For the present study the values of transmissibility 'T' and specific yield'S' have been adopted as 188 cm*/sec.and 0.11 respectively. The value of specific yield has been adopted on the basis of the subsurface lithology of the area,which reveals unconsolidated alluvial deposits of sand,silt and clays and constituting a very extensive hetrogeneous unconfined aquifer. The behaviour of water table and its fluctuations to a minimum value in the month of May/June before monsoon and rising af to a maximum value in month of October/November just after rainy season also confirms the unconfined nature of aquifer.

5.7 CHEMICAL QUALITY OF GROUND WATER

The chemical quality of ground-water in the area has been studied in detail by the Central Ground Water Board. A large number of water samples from the shallow as well as deeper aquifer have been analysed. The general range of chemical components is given below:

PH	7 to 8.8
EC	180 to 940 micro ohm at 25°C
Chloride	8 to 68 ppm
Bicarbonate	150 to 500 ppm
Total hardness as ca Co_3	70 to 550 ppm
TDS	90 to 400

The results indicate that the groundwater is generally fresh and potable.

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CHAPTER-6

WATER BALANCE

6.1 INTRODUCTION

The International Hydrological Programmes include systematic groundwater investigations in selected basin.

This involves identification of representative and experimental basins or other units, where co-ordinated hydrological and hydrogeological studies could yield quantitative data on the recharge of ground-water systems and water balance which is essential from the point of view of water resources evaluation on which any programme of future development has to be based.

6.1.1 WATER BALANCE

The term 'water balance' means a quantitative expression of the hydrologic cycle and its components. It is basically a statement of the law of conservation of matter as applied to the hydrologic cycle. It states that in a specified period of time all water entering a particular area must either enter into storage within its boundaries, be consumed therein, be exported therefrom or flow out either as surface or subsurface flow.

In one of its more general forms, the water balance may be expressed as follows:

Inputs	Outputs
(i) Precipitation on area	(i) Evapotranspiration from area
(ii) Surface water flow	(ii) Surface water outflows
(iii) Groundwater inflow	(iii) Ground water outflow

The water balance requires that the various inputs balances the various outputs, any difference being accounted for by the aggregate changes in surface water, soil water and groundwater storages. Sokolov and Chapman (1974) have given a good account of methods of water balance computations.

6.2 WATER BALANCE EQUATION

In the present study most of the terminology used is as suggested by Sokolov and Chapman (op. cit).

In the equation form, the water balance for an area may be stated as follows:

$$P + Q_{UI} + Q_{SI} = Q + E_t + Q_{uo} \pm \Delta G \pm \Delta S_s$$

P = Precipitation in the area

Q_{SI} and Q_{UI} are respectively surface and Groundwater inflow from areas outside doab boundaries.

Q = Streamflow both surface and sub-surface

E_t = Evapotranspiration from area

Q_{uo} = Ground-water exported to areas outside the boundaries of the study-area.

ΔG = change in Groundwater estorage

ΔS_s = Change in soil moisture storage

The longer the period over which the hydrologic equation is drawn, the closer the several items approach the steady state due to the approach to an average value for climate conditions. Since complete long term data for the area under study is not available the balance for year 1974-75 has been worked out.

6.3 PRECIPITATION

The average rainfall for the area under study has been worked out by Thiessen polygon method(Fig.6.1) for the period June,1974 to May 1975.It is found to be 869.83 mm.which is about 79.5% of 75 years average annual rainfall value(1094.83 mm) The computation for average depth of rainfall during 1974-75 is shown in Table 6.1.

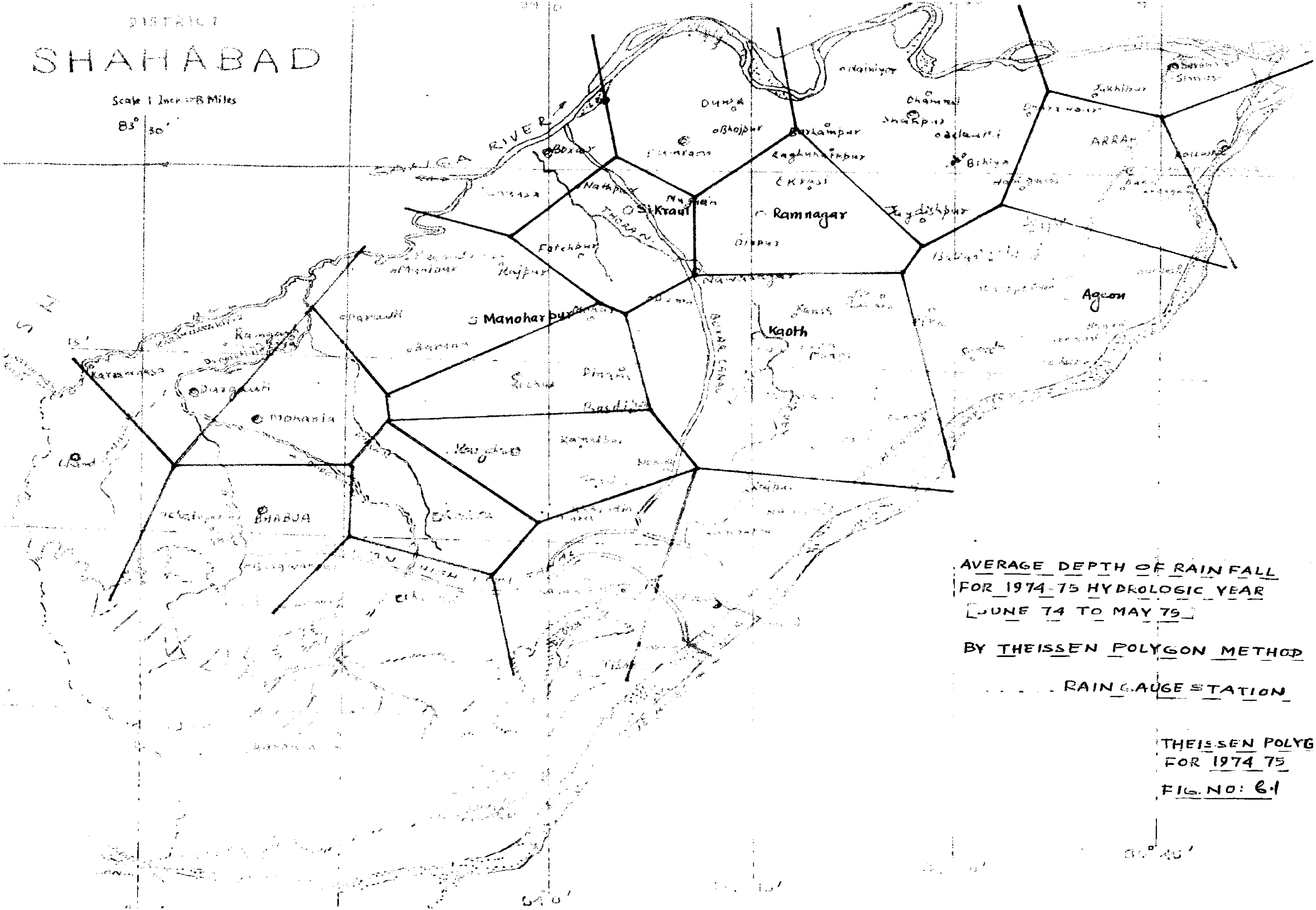
6.3.1. WATER INPUT DUE TO PRECIPITATION

The area under study = 674822.5 hactres; Av. depth of Rainfall = 870.25 mm vide Table 6.1 and 6.2.

Hence water input due to precipitation during 1974-75

$$= \frac{870.625}{1000} \times 674822.5$$

$$P = 587517.33 \text{ HM}$$

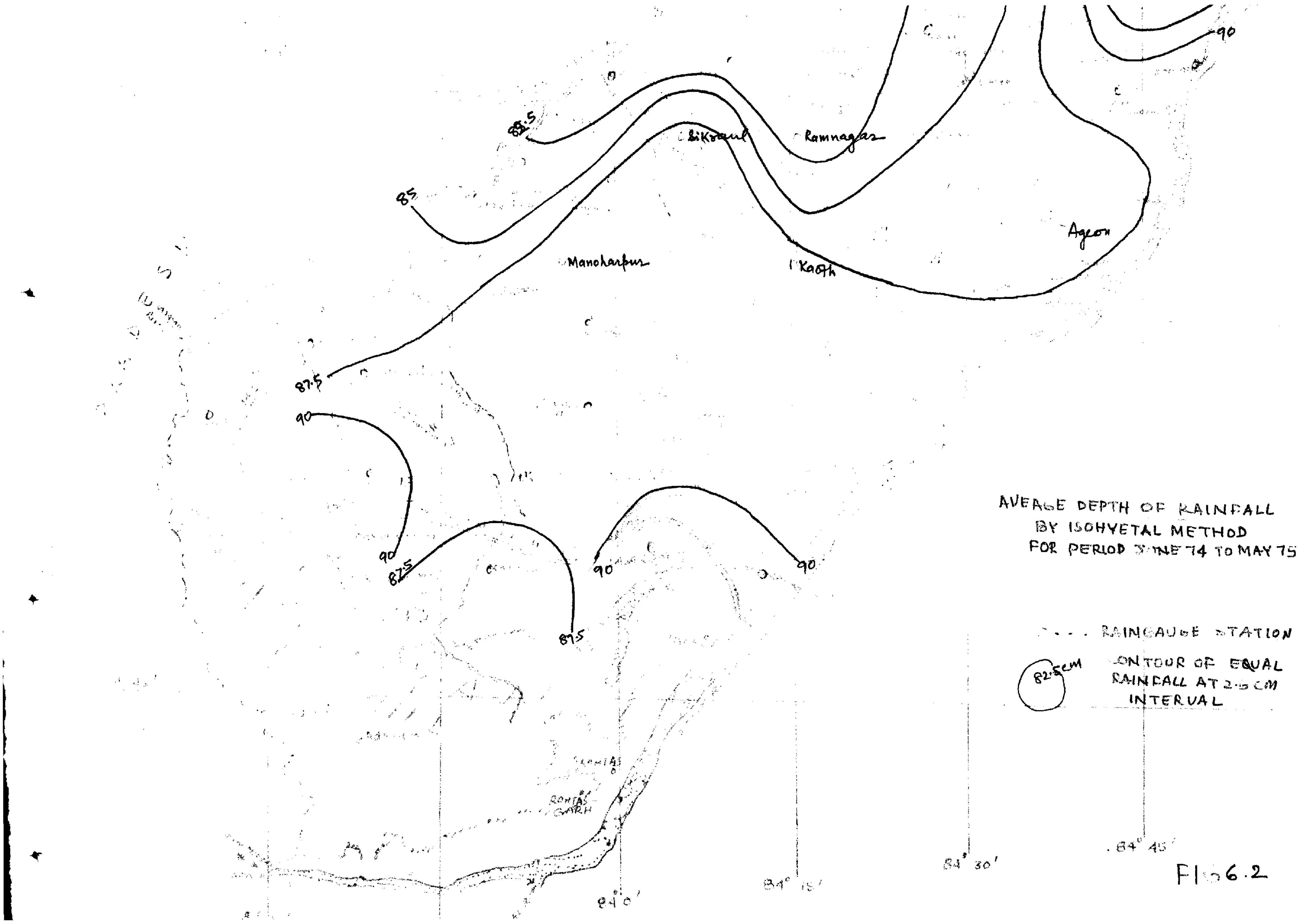


THEISSEN POLYG
FOR 1974 75
FIG. NO: 6.1

TABLE 6.1

Average depth of rainfall in the area by Thiessen Polygon Method

Station	Precipitation in mm.	Percentage of area	Weighted precipitation in mm.
Durgauti	872	0.0098	8.56
Mohania	879.21	0.0368	32.39
Manoharpur	885	0.0783	69.34
Ramnagar	811.23	0.0638	51.81
Buxar	819.11	0.0316	25.96
Sikraul	892.17	0.0491	43.83
Dumraon	822	0.05552	45.43
Shahpur	837.31	0.0933	78.16
Barhara	960	0.0294	28.29
Koilwar	883.2	0.0147	13.02
Udwantnagar	880	0.056	49.28
Ageon	870.2	0.104	90.63
Kaoth	878.32	0.1447	127.07
Dehri	905.2	0.0515	46.70
Sasaram	912.11	0.0312	28.45
Kargahar	893.1	0.0589	52.65
Kudra	891	0.0356	31.73
Chenari	863.4	0.0049	4.24
Kochas	879	0.0459	40.37
Bhabua	979.59	0.00196	1.92
		Total	869.83 mm.


90
82.5
85
Bikramganj
Ramnagar
Ageon
Manoharpur
Kaoth
87.5
90
90
87.5
90
90
87.5
ROHTAS
ROHTAS GARH
AVERAGE DEPTH OF RAINFALL
BY ISOHYETAL METHOD
FOR PERIOD JUNE 74 TO MAY 75
RAINGAUGE STATION
82.5CM
CONTOUR OF EQUAL RAINFALL AT 2.5 CM INTERVAL
84° 0'
84° 15'
84° 30'
84° 45'
FIG 6.2

The average depth of rainfall in the study are for the period June 1974 to May 1975 has also been computed by Isohyetal method(Fig.6.2).The average depth of precipitation comes to 871.42 mm.as given in Table 6.2.

TABLE 6.2

AVERAGE DEPTH OF RAINFALL BY ISOHYETAL METHOD

Isohyetes interval in mm.	Average Isohyetes in mm.	Area inbetween Isohyetes interval in Hact.	Product col (2) x col (3) / 1000 in HM
(1)	(2)	(3)	(4)
< 825	825	82477	68043
825-850	837.5	67482	56516
850-875	862.5	151002	130241
875-900	887.5	334913	297235
900-925	912.5	27492	25086
925-950	937.5	2501	2344
>950	950	99997	9497
	Total	675864	588962

Average depth in mm. $= \frac{588962 \times 1000}{675864}$

$= 871.42$ mm.

So, for the present study the average depth of rainfall adopted $= \frac{871.42 + 869.83}{2}$

$= 870.625$ mm.

6.4 SURFACE AND SUBSURFACE INFLOW

The water utilized in the area through surface irrigation system is the surface inflow Q_{SI}.

Q_{SI} = 314612 HM (Art.3.5.1.7 Table 3.4)
Hence total input in the study area during 1974-75.

$= P + Q_{SI}$

$= 587517.33 + 314612$

$= 902129.33$ HM

The ground water inflow (Q_{UI}) from the south has been neglected because the southern boundary is demarcated by rock exposures of Vindhyan age. Along the other sides it is bounded by well defined water bodies i.e. river Ganga, Sone, Karmnasa, Durgauti which are of effluent nature.

6.5 TOTAL RUNOFF(Q)

This includes total streamflow in the area carried by the rivers draining the area of the doab. In this case the four bounding rivers i.e. Ganga, Sone, Karamnasa and Durgauti carry all the runoff(both surface and sub-surface) from the study area. So, the stream-flow has been determined by substracting the upstream discharge from downstream discharge and additing to them the evapotranspiration loss at potential rate for the reach of the river under reference.

The computation for streamflow has been given in Table 6.3. The discharge data are taken from article 2.4.

TABLE 6.3

TOTAL RUNOFF DURING 1974-75

Name of River	Total annual flow generated through both the banks in HM	Stream flow contribution from study area in HM	Evapotranspiration loss at PE rate in the reach of river vide Table 6.4. in HM	Total stream flow contribution from study area col.3 + col.4. in HM
(1)	(2)	(3)	(4)	(5)
Ganga	284307	170584.05	32400	202984.05
Sone	123620.6	43620	14710	58330
Karmanasa	27429	20571.75	1406.25	21978
Durgauti	36306	18153	1800	19953
			Total	303245

6.5.1. The value of total run off generated during 1974-75 from the study area Q = 303245 HM.

6.6 EVAPOTRANSPIRATION (E_t)

Potential evapotranspiration values for the area under study are given vide Table 2.7 article 2.6.6. The evapotranspiration at potential rate will occur from the water-logged area and areas under forest, tall trees, tanks, ponds and lakes area under minor streams and rivers and areas adjacent to major perennial rivers. The evaporation from perennial river courses has been already accounted in Table 6.3.

(i) E_t from water logged area

The water logging occurs when the water table comes within 1.5 m. depth from ground surface. Assuming that the water table remains under this range of depth from August to March, the ET values have been worked out as follows:

Water logged area = 45252.48 hactres vide fig. 5.2

Evapotranspiration at PE arate during August to October

= 340.5 mm. vide Table 2.7

E_t value during Monsoon period

$$= \frac{340.5}{1000} \times 45252.48$$

= 15,408.47 HM / 2 = 7704.1 HM (assuming linear variation)

Rate of potential Evapotranspiration during November to March = 452.4 mm.

E_t value during Non-monsoon period

$$= \frac{452.4}{1000} \times 45252.48$$

= 20,472.22 HM / 2 = 10236 HM (assuming linear variation)

So, annual E_t = value from water logged area

= 15,408.47 + 20,472.22 = 35880.69 HM

= 17970.35 HM

(assuming linear variation)

(ii) <u>E_t from area under forest and tall trees</u>

From article 3.3 (a) the area under forest = 250 hactres and (b) area under miscillaneous trees and groves = 4071 hact. Assuming that 50% of (b) consist of tall trees. So, the area under tall trees = 0.5 x 4071 = 2035 hactres.

Total area = 2035 +250 = 2285 hactres

The evapotranspiration from this area occurs at potential rate throughout the year.

Hence

E_t value during monsoon period i.e. June to October

$$= \frac{641.1}{1000} \times 2285$$

= 1464.91 HM

E_t value during non-monsoon period i.e. November to May

$$= \frac{859}{1000} \times 2285$$

= 1962.82 HM

So, annual E_t value = 1464.91 + 1962.82 = 3427.73 HM

(iii) <u>Area under tanks, ponds lakes</u>

The area under tanks, ponds and lakes = 15,000 hactres. From enquiry it is found that the approximate number of ponds and lakes in the area = 20,000. Assuming area under one pond as 0.75 hactre, the total area works out to 15,000 hactres.

E_t during monsoon period

$$= \frac{641.1}{1000} \times 15,000$$

$$= 9615.5 \text{ HM}$$

E_t during non-monsoon period

$$= \frac{859}{1000} \times 15,000$$

$$= 12,885 \text{ HM}$$

Annual Et value = 9616.5 + 12,885 = 22501.5 HM / 2 (assuming linear variat…

= 11250 HM

(iv) <u>Area under Perennial rivers</u>

The evapotranspiration from perennial rivers i.e. Ganga, Sone, Karmnasa, and Durgauti, has been considered while computing the total runoff(Q) from the study area (article 6.5). So E_t value from these areas has not been considered under Evapotranspiration. However, the computation for the same is given in Table 6.4.

TABLE 6.4

COMPUTATION FOR EVAPORATION FROM PERENNIAL RIVERS

River	Effective length in HM.	Average width in KM	Percentage of drainage contribution from study area for the reach of River	PE Annual rate mm.	ET value Product of Col.2.3, 4,5 in HM
(1)	(2)	(3)	(4)	(5)	(6)
				[1301]	
Ganga	120	3	60%	1500.1	32400
Sone	109	2	45%	1500.1	14710
Karmnasa	25	0.5	75%	15000.1	1406.2
Durgauti	80	0.3	50%	15000.1	1800 [1548]

(v) <u>Area under minor streams and rivers</u>

Total length of all minor streams and rivers

= 300 km.

Average width of the river = 0.25 KM

Period of flow = 3 months

Effective area for Evapo~~transpi~~ration

$$= \frac{3}{12} \times 300 \times 0.25 \times 100$$

= 1875 hactres

Annual E_t from this area $= \frac{1500.1}{1000} \times 1875$

= 2812.5 HM

(vi) <u>Areas adjacent to major perennial rivers</u>

Evapotranspiration at potential rate will also occur from the areas adjacent to perennial rivers i.e. Ganga, ~~Sone~~ Karmnasa and Durgauti. It is assumed that 1/4 km. width of land along these rivers is effective for ~~HE~~. E_T. ⊗

So effective area along the river bank

= 0.25 (120+[illegible]+25+80) x 100 = 5625 Hactres

~~= 8350 hactres~~

~~Potential~~ Evapotranspiration during monsoon period

$= \frac{641.1}{1000} \times$ ~~8350~~ 5625 = ~~5352.18 HM~~ 3606 HM

⊗ Area along river Sone has been neglected as this area is already covered under waterlogged area vide Fig 5.2

PE_t during non-monsoon period

$$= \frac{859}{1000} \times \overset{5625}{8350} = 7172.66\ HM \quad 4832\ HM$$

2416 HM [assuming linear variation]

Annual E_t value = 5352.18 + 7172.65 = 12525.83 HM

= 3606 + 2416 = 6022 HM

Hence Total of annual E_t value at Potential rate

= 35880.69 + 3427.73 + 22501.5 + 12525.83

= 74335.75 HM

6.6.1. ACTUAL EVAPOTRANSPIRATION DUE TO RAINFALL

Total runoff generated from the area = 303245 HM (vide 6.5. This total runoff contains contribution both from the rainfall and the inflow of surface water from area outside the doab. Assuming the contribution from the surface inflow(QSI) to the total runoff(Q) as 15% of QSI then the net total runoff from the area due to rainfall = 303245 - 47287 = 255958 HM

As input due to rainfall P = 587517.38

Hence percentage of rainfall converted into runoff

$$= \frac{255958}{587517.33} = 43.4\%$$

say 43%

Now out of total precipitation over the area about 43% is converted into runoff and is not available for evapotranspiration except PE from water surface which has already been taken into account. Further out of remaining 57% during the rainy season, substantial amount percolates deep down the earth to join the water table and is not available for Et except in cases of water logged area, areas under tall trees and forest, areas adjoining to the perennial river, which have already been taken into account as art. 6.6. The average percolation as measured in similar catchment in Uttar Pradesh by tritium injection method (Saksena, 1974) comes to about 22% of rainfall.

Soil moisture accretion of 100 mm (Saksena '74) after November has been taken which shall be available for ET in the subsequent month. Based on this criteria the monthly values for actual E_t has been calculated in Table 6.5

TABLE 6.5

COMPUTATION OF EVAPOTRANSPIRATION DUE TO RAINFALL

Sl.No.	Month	PE in m.m.	Rainfall in mm.	Runoff = 0.43 x col(4) in mm.	Percolation to Ground water =0.22 x col.(4) mm.	Rainfall available for ET in mm. = col.(4) - col(5+6)	Soil moisture acretion available for ET in mm.	Total of col.(7)+(8) in mm.	Actual ET lesser of col.(9) and (3) in mm.
1	2	3	4	5	6	7	8	9	10
1.	June	180.7	76.88	33.05	16.91	26.92	-	26.92	26.92
2.	July	119.9	283.59	121.90	62.39	99.30	-	99.30	99.30
3.	Aug.	111.	290.36	124.81	63.88	101.68	-	101.68	101.68
4.	Sept.	111.1	127.36	59.06	30.21	48.09	-	48.09	48.09
5.	Oct.	118.4	26.29	11.06	5.80	9.46	-	9.46	9.46
6.	Nov.	81	1.2	0.504	0.26	0.432	.	0.432	0.432
7.	Dec.	62.1	5.3	2.22	1.16	1.9	21.0	22.90	22.90
8.	Jan.	65.5	8.84	3.71	1.94	3	13.70	16.70	16.70
9.	Feb.	94.1	5.32	2.23	1.17	1.91	12.60	14.50	14.50
10.	March	149.7	17.13	7.20	3.90	6.17	52.70	58.87	58.87
11.	April	189.5	6.25	2.62	1.37	2.25	-	2.25	2.25
12	May	217.1	1.4	0.59	0.31	0.50	-	0.5	0.50
						Total	100mm	401.602mm	401.602 mm

so, actual rate of annual evapotranspiration during 1974-75

= 401.602 mm.

Area available for the Evapotranspiration

= Total area - paved area - area already taken for PE

= 674822.5 - 2500 - (45252.48 +2285 + 15000 +1875 + 8350) hactres

= 674822.5 - 75262.48 = 599560 hactres

As part of this area is covered with vegetation,so while computing for ET, the factor of cropping,intensity has to be considered.

The existing cropping intensity in the area = 103 %

so the annual evapotranspiration in the area due to rainfall

at actual rate $= 1.03 \times \frac{401.602}{1000} \times 599560$

$= 248008$ HM

6.6.2 ADDITIONAL EVAPOTRANSPIRATION IN IRRIGATED AREA

In irrigated areas,due to application of additional water through canals,tubewells and other sources increased evapotranspiration takes place limited to the maximum value of PE.

The existing canal system in the area are unlined.Looses in transit through such system will mainly comprise of seepage in the sub-soil and little of evaporation loss.It has been assume in the present study that about 80 percent of the transit looss is due to seepage and 20% of the transit looss is caused by evaporation.The rate of transit losses have been adopted on the basis of the Bihar Irrigation Commission Report and it is of following order:

Transit Losses in main canal = 10% of the canal head discharge

" " " Distributaries and minors = 15% of distributaries head discharge.

" " " Water courses and field channel = 20% of outlet discharge.

X

The transit losses, seepage and evapotranspiration have been computed on above basis vide Table No. 6.6, 6.7., and 6.8.

TABLE 6.6

COMPUTATION FOR TRANSIT LOSSES

Source of irrigation	Water available at canal head in HM	Loss in main canal (HM)	Loss in Distributaries HM.	Loss in Field channel	Total loss (3+4+5) (HM)	Water available in the field	Period under consideration
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Surface source (Canal System)	203965	20396.5	27535.275	31206.646	79138.42	124826.59	Kharif
	110647	11064.7	14937.345	16928.99	42931	67715.964	Rabi
Subsurface source	42857	-	-	8571.4	8571.4	34286	Kharfi
	18225	-	-	3645	3645	14580	Rafi

Total transit loss during Kharif = 79138.421 + 8571.4 = 87709.8 HM

Total transit loss during Rabi = 42931+3645 = 46576 HM

TABLE 6.7

COMPUTATION FOR EVAPORATION AND SEEPAGE DURING TRANSITION (in HM)

Period under consideration	Total transition loss	Seepage to Ground water	Evaporation loss
Kharif	87709.8	70167.84	17541.95
Rabi	46576	37260.8	7452.16

Annual Evaporation loss = 24994.11 HM

TABLE 6.8

COMPUTATION FOR EVAPOTRANSPIRATION AND RECHARGE FROM IRRIGATED FIELD (in HM)

Source of Irrigation	Water available	Kharif		Rabi		
		Evapotranspiration	Recharge	Water available	Evapotranspiration	Recharge
Surface (canal system)	124826.59	93619.942	31206.648	67715.964	50786.973	16928.991
Sub-surface	34286	25714.5	8571.5	14580	10935	3645
Other source	16225	12168.75	4056.25	929	696.75	232.25
Summation	175337.59	131502.67	43834.4	83224.96	62418.72	20806.24

Annual Evapotranspiration loss from irrigated field = 131502.67+62418.72

= 193921.39 HM

The total water available at the cultivators field for irrigation is equal to 258562.55 HM and assuming that 75 percent of water applied in the field has been used up by plants for transpiration and by surrounding soil for evaporation and the remaining 25% of water is the recharge to the groundwater from the irrigated field. Based on this interia the computations has been done in table 6.8.

The annual Evapotranspiration loss from irrigated field works out to 193921.39 HM.

The annual Evapotranspiration due to irrigation water

= 24994.11 + 193921.39

= 218915.5 HM

6.6.3 TOTAL EVAPOTRANSPIRATION

The total annual Evapotranspiration on all accounts is given as follows:

(i)	Potential Evapotranspiration	= 74335.75 HM
(ii)	Actual Evapotranspiration from rainfall.	= 248008 HM
(iii)	Additional Evapotranspiration	= 218915.5 HM
	Total Evapotranspiration	=541259.25 HM

so, annual Evapotranspiration during 1974-75

E_t = 541259.25 HM

6.7 CHANGE IN GROUND WATER STORAGE

The change in ground water storage has been computed by the help of the difference of depth to water table contours during May 1974 and May 1975. The contours are shown in fig.5.5. Detail description of the contour and the computation for average rise in depth to water-table during the year has been dealt in article 5.5.6. and Table 5.4. The net rise in depth to water-table during the year 1974-75 has been worked out as 0.594 metre.

Since specific yield = 11%(vide art.5.6.5)

Area of the study = 674822.5 Hactres

Hence increase in groundwater storage

ΔG = 0.110 x 0.594 x 674822.5

= 44092.90 HM

6.8 CHANGE IN SOIL MOISTURE STORAGE (ΔS_s)

The change of the soil moisture in the period involved is negligible and so value of ΔS_s has been taken as zero.

6.9 GROUND WATER OUTFLOW TO AREAS OUTSIDE THE DOAB(Q_{uo})

The outflow of ground water from the area is governed by the hydraulic gradient and the transmissibility of the aquifer. This gradient of the aquifer can be determined by taking the slope of the water table normal to water table contours. The outflow is then determined by the following relationship.

$$Q = \sum^{L} Ti\Delta$$

where T is the transmissibility

i is the hydraulic gradient average over a length

L isthe total length of the contour fline

The out flow as has been worked out in Table 6.9, comes to 2885 HM.

TABLE 6.9

COMPUTATION FOR Q_{UO} (GROUND WATER OUT FLOW)

Period	T, Transmissibility cm^2/sec.	No. of days	Average hydraulic Gradient	Length of contour	Out flow of HM = product of 2,3, 4 and 5.
1	2	3	4	5	6
Monsoon period	188	153	3.41×10^{-4}	13.12×10^{4} metres	1111.85 HM
Non-monsoon period	188	212	3.56×10^{-4}	14.464×10^{4} metres	1773.15 HM
				Total	2885 HM

6.7 WATER BALANCE RESULT

The water balance equation is modified for the present study as

$$P + Q_{SI} = Q + E_t + Q_{uo} + \Delta G$$

The items on left hand side of the equation represent input components while the right hand side items are output components. It is to be seen that for an equilibrium to exist the left hand side must be equal to right hand side of the above equation.

The Input component = 902129.33 HM (art. 6.4)

The output component = ~~303245~~ + 541259.25 + 2885+440[illegible].9

= 891482.15 HM

The difference of left hand side and right hand side

= 902129.33 - 891482.15

= 10647 HM. This is unaccounted water.

6.8 UNACCOUNTED WATER

The unaccounted water may be due to the following reasons:

(i) The subsurface lithologs have indicated that the confining layers are comprised of lenses of silt and clay and therefore it is possible thatthis water may be leaking through the bottom most confining layer and may not reflect itself in rise of water table.

(ii) It is possible that the specific yield of 11% as adopted, may not be truely representative for the area if this value is corrected in the light of unaccounted water as follows:

$$\text{Correct specific yield} = \frac{\Delta G + \text{unaccounted water}}{\text{Average rise of depth} \times \text{Area}}$$

$$= \frac{44092.90+10647}{0.594 \times 674822.5}$$

$$= 0.136 *$$

$$= 13.6\%$$

Now we arrive at a specific yield value of 13.6% as given above. However, this is quite on the higher side keeping in view the lithology of aquifer.

(iii) There may be under estimation in the estimated value of total runoff(Q), Evapotranspiration(E_t) and Ground Water outflow (Q_{uo}).

However, out of the above three reasons the maximum weightage is to be given to (i) and thus unaccounted water is to be taken as leakage through bottom most aquiclude and the water balance equation is rewritten as

$$P + Q_{UI} + Q_{SI} = Q + E + Q_{uo} \pm \Delta G \pm \Delta S_s + L$$

Where L is the leakage of ground water through bottom most aquiclude.

The groundwater balance for this period has been given in Chapter 7.

CHAPTER-7

GROUND WATER BALANCE

7.1 GENERAL

Ground water hydrology deals with the hydraulic characteristics of aquifers and the hydraulic function of aquifer in response to recharge and discharge of water-natural or induced. The mass movement of water within an aquifer system containing water is a function of the gradient in gravity head, of the ability of the aquifer to transmit water, and of its storage function. The interval complexities of aquifer are to some extent offset by influent and effluent seepage along stream channels and canals, which redistribute the water resources more readily than can occur within the aquifer themselves. In this setting, the wide seasonal range of stage of the rivers results in massive recharge of the ground water reservoir during monsoon and massive discharge from it during the winter and summer. This annual cycle of recharge and discharge combines with the groundwater flow beneath the interfluvial areas in the general direction of the land-surface slope.

The nature of recharge and discharge in a ground-water basin could be studied by analysing the hydrologic data of a number of years preferably covering one cycle of a dry and wet years. This will enable to determine the recharge for an average year, so that ground water potential of the area is known. Any development of the area beyond this average recharge would cause 'Mining' of ground-water and this will not only increase the cost of pumping but also effect the surface supply of the bounding streams. It is, therefore, necessary to limit the exploitation, of ground water reservoir to the safe yield of the aquifer.

7.2 GROUND WATER BALANCE EQUATION

In terms of the hydrologic cycle for a particular groundwater basin, a balance must exist between the quantity of water supplied to the basin and the amount stored within or leaving the basin. The groundwater balance equation provides a quantitative statement of such balance. It contains following components.

ITEM OF RECHARGE

(i) Precipitation infiltrating to the water table

(ii) Natural recharge due to influent seepage from streams. lakes and ponds.

(iii) Artificial recharge from canals, reservoirs, return flow of irrigation water, spreading operations and seepage due to subsurface irrigation.

ITEM OF DISCHARGE

(i) Evaporation from capillary fringe and in waterlogged area or shallow water table areas and transpiration by phreotophytes.

(ii) Natural discharge i.e. effluent seepage and spring flow of streams, lakes and ponds.

(iii) Ground water outflow to areas outside the boundaries of specified area.

(iv) Artificial discharge by pumping, flowing wells, or drains and other consumptive use.

The ground water balance requires that the total items of recharge, balance the total items of discharge, any differences being accounted for by changes in ground water storage.

The ground water balance equation can be written as follows:

$$(R_p - R_n + Ra + QUI) - (E_t + D_e + D_c + QUO + Gi) = \pm \Delta Gs \ldots (7.1)$$

where

R_p = Recharge to ground water due to rainfall

Rn = Natural recharge from streams, lakes and ponds i.e. influent seepage.

Ra = Artificial recharge from canals, reservoirs, spreading operation and injection wells, and return flow of irrigation water.

QUI = Ground water inflow from area outside the basin boundary.

Et = Evaporation from capillary fringe in water logged or shallow water table areas and transpiration by phreotophytes.

De = Natural discharge by seepage and spring flow of streams, lakes and ponds i.e. effluent seepage loss.

Dc = Artificial discharge by pumping or other lifting devices or flowing wells and other consumptive use.

QUO = Ground water outflow.

Gl = Ground water leakage from the bottom-most aquiclude.

ΔGs = Change in ground water storage for the period considered.

7.3 PERIOD CONSIDERED FOR BALANCE

The ground water balance considered for the monsoon and non-monsoon period separately as follows:

(a) June 1974 to October 1974 (Monsoon period)

(b) November 1974 to May 1975 (Non-monsoon period)

7.4 GROUND WATER BALANCE FOR MONSOON PERIOD

7.4.1. RECHARGE DUE TO RAINFALL (R_p)

Part of the rainfall on the ground is infilterated into the soil while other runsoff. The fraction of water that infiltrates is utilized partly in filling the soil moisture deficiency and part of it is percolated down reaching the water table. This water reaching the water-table is known as the recharge from rainfall to aquifer.

As direct measurement of this element is extremely difficult it is being generally estimated by emperical formulae or indirectly by estimating all other items of groundwater balance equation(7.1) and solving equation for probable value of R_p. In the present study both the approach have been utilized to determine R_p.

EMPERICAL FORMULAE

Three emperical relationships has been utilized to determine the recharge from rainfall data.

(i) CHATURVEDI FORMULA

This formula was developed in the Ganga Yamuna Doab in 1936 and gives recharge as a function of annual precipitation.

$$R = 2(p-15)^{2/5} \qquad . \qquad (7.2)$$

Where R is the net recharge due to precipitation during the year in inches

and P = Annual precipitation in inches.

(ii) U.P.IRRIGATION RESEARCH INSTITUTE,ROORKEE FORMULA

It is a modification of Chaturvedi's formula and is expressed as

$$R = 1.35\ (P-14)^{1/2} \qquad .. \qquad . \qquad (7.3)$$

(iii) AMRITSAR FORMULA

This formula has been developed by Irrigation and Power Research Institute, Punjab, Amritsar in the form, Bxxx8x5

$$R = 2.5\ (p-16)^{1/2} \quad .. \quad (7.4)$$

The computation for Rp has been given in Table 7.1. The recharge is calculated for the annual rainfall during 1974-75 and also for 74 year average annual rainfall.

7.4.2. NATURAL RECHARGE (INFLUENT SEEPAGE)Rn

The seepage of water from the rivers both major and minor during the period of high flood is considered as natural recharge or influent seepage. The rate of recharge or seepage to the ground water has been assumed as 1.5 cumecs per million square metres of wetted area. The computation for Rn is given in Table 7.2.

7.4.3 ARTIFICIAL RECHARGE (Ra)

The recharge to ground water from the canal system and from the irrigated field are considered under artificial recharge. The recharge from these systems have already been calculated in Tables 6.6, 6.7, and 6.8 vide art. 6.6.2. The recharge from canals during transition in monsoon period (kharif) = 70167.84 HM. The recharge from irrigated field during kharif = 43834.4 HM, Hence RA, artificial recharge = 70167.84 + 43834.4 = 114002.24 HM

TABLE 7.1

COMPUTATION FOR RECHARGE DUE TO RAINFALL (R_p)

Formula used	for the year 1974-75			For 74 year average rain fall		
	Annual av. rainfall p;. in mm.	Recharge R in mm.	Percentage of annual rain fall	74 yr. Annual av. rainfall P in mm.	Recharge R in mm.	Percentage of Annual rainfall.
Chaturvedi formula	870.625	165.60	19.03%	1094.83	193.04	17.63%
U.P.Irrigation Research Institute formula	870.625	154.305	17.73%	1094.83	185.17	16.92%
Amritsar formula	870.625	271.15	31.17%	1094.83	330.708	30.2%

TABLE 7.2

River	Effective length metre	Effective wetted area in M^2	Rate of seepage loss cumecs/m^2.	Period of high flood in days	Natural recharge = Product of col.3,x 4x5. in HM
(1)	(2)	(3)	(4)	(5)	(6)
Ganga	120×10^3	60×10^6	(*) 1.5 cumecs per 10^6 sq.m.	30	23328 HM
Sone	190×10^3	27.25×10^6	"	20	7063.2HM
Karmnasa	25×10^3	6.25×10^6	"	15	1215 HM
Durgauti	80×10^3	20×10^6	"	15	3888 HM
Minor rivers	300×10^3	15×10^6	"	7	1360.8 HM
				Total	36855 HM

Hence, Natural Recharge R_n = 36855 HM.

The recharge from lakes and ponds are omitted because they are mostly effluent in character.

7.4.4 GROUND WATER INFLOW(QUI)

The ground water inflow from area outside the boundary has been neglected because the study area ia bounded from all sides by well defined water bodies.Moreover, it is observed that the hydraulic gradient of the water table contour is from south to north and in the southern portion Vindhyan hill is situated, therefore due to presence of ground water barrier,the inflow of ground-water in the study area from the Southern portion can be neglected.

7.4.5 EVAPOTRANSPIRATION (E_t)

The evapotranspiration from ground water will take place in case of water logged areas,areas covered with forest and big trees,areas under ponds,tanks and lakes adjacent to major perennial rivers.The value of E_t from above mentioned areas have been calculated vide art.6.6 and this value for monsoon period works out to 15,408.47 + 1464.91 + 9616.5 + 5353.18

i.e. E_t = 31843.16 HM

7.4.6. NATURAL DISCHARGE (EFFLUENT SEEPAGE) De

The total flow in the study area on this account is carried away by the main bounding rivers,Ganga, Sone,Karmanasa and Durgauti.The difference in monthly flows in these rivers in betwee the points upstream and downstream of the reach of the rivers falling within the study area are known vide art.2.4. The effluen seepage from the doab has been determined by computing the base flow component from the hydrograph of the rivers (Fig.2.24,2.3) and is given in Table 7.3. There will be also evaporation loss in the reach of the river falling within the study area. The evaporation loss is assumed as 10% of the discharge value.

TABLE 7.3

NATURAL DISCHARGE (EFFLUENT SEEPAGE)DE

River	Effluent seepage in HM	Evapotranspiration loss in the reach of river	Natural discharge = col(2)+Col.(3) in HM
(1)	(2)	(3)	(4)
Ganga	13122	1312	14434
Sone	4340	434	4774
Karmanasa	1645	164	1809
Durgauti	1452	145	1597
		Total	22614 HM

Hence, natural discharge during monsoon period

$$De = 22614 \text{ HM}$$

7.4.7. ARTIFICIAL DISCHARGE (Dc)

The withdrawl of ground water by tubewells and open wells for irrigation, domestic and industrial purposes will constitute the artificial discharge Dc.

The withdrawl from existing state tube wells, private tubewells, open boring and dug wells have been computed vide Table 3.6 art.3.6 for irrigation purpose and vide art.3.2 for domestic andindustrial purposes. The values obtained are as follows:

Drawl during monsoon (kharif) period for

irrigation purpose = 42857 HM

for domesic and industrial

purposes $= \frac{5}{12} \times 26122 = 10884$ HM

Hence artificial discharge, Dc during monsoon period

= 42857 +10884 = 53741 HM

7.4.8 GROUND WATER OUTFLOW (Q_{UO})

The ground water outflow as computed vide art.6.9, Table 6.9 works out to 1111.85 HM for monsoon period.

so, Q_{UO} = 1111.85 HM

7.4.9 GROUND WATER LEAKAGE (Gl)

It has been found that there is a leakage of 10647 HM (vide art.6.8) of water from the bottom most aquiclude as a discharging factor i.e. output components of water balance equation.

The ground water leakage for monsoon period is computed as follows

The annual leakage = 10647 HM

Hence leakage during June to October $= \frac{5}{12} \times 10647$

Gl = 4436 HM

7.4.10 CHANGE IN GROUND WATER STORAGE (ΔGs)

Fig. (5.4) shows the fluctuation contour i.e. the difference of pre and post-monsoon depth (May/June 74 to Oct.'74) to water table contours. The detail description and computation are given in art. 5.5.5. and in Table 5.3.

The average rise of water table works out to 2.285 metre

Specific yield = 11%

The area of study = 674822.5 Hactres.

Hence, change in ground water storage

ΔGs = 0.11x2.285x6748822.5

= 169616.63 HM

7.5 GROUND WATER BALANCE RESULT FOR MONSOON PERIOD

Recharging factors.

1. Recharge due to rainfall = Rp HM
2. Natural recharge, Rn = 36855 HM
3. Artificial recharge, Ra = 1140[illegible]2.24 HM
4. Inflow from Southern boundary, QUI = Nil (assumed)

Total = (Rp + 140857.24) HM

Discharging factors

1. Evapotranspiration loss E_t = 31843.06 HM
2. Natural discharge (effluent seepage) De = 22614 HM
3. Artificial discharge (Pumpage) Dc = 53741 HM
4. Ground water outflow Q_{uo} = 1111.85 HM
5. Groundwater leakage, Gl = 4436 HM

Total = 113745.91 HM

Additional storage, ΔGs = 169616.63 HM

Taking Recharge – Discharge = Additional storage

i.e. Rp + 150857.24 – 113745.71 = 169616.63

or , Rp = 169616.63 – 37120.33

∴ Rp = 132496.3

Net input due to rainfall P, vide art.6.3.1.= 587517.33HM

∴ Percentage of rainfall to recharge = 22.55%

7.6 The percentage of rainfall which recharge the ground water reservoir as computed by the emperical formula vide Table 7. are as follows:

Formula used	Recharge as percentage of rainfall
Chaturvedi formula	19.03%
U.P.Irrigation Research	17.73%
Amritsar formula	31.17%

The variation in percentage is from 14.19% to 31.17%. From the present study this values comes to 22.55%.

To determine the best applicability of the above values, the water balance for the remaining 7 months period viz.from November 1974 to May 1975 shall be made and the value which fits most in this water balance shall be the true representative for the study area. However, it may be made clear that much reliance should not be placed on values obtained from emperical formula as these were developed for areas outside the study area boundaries.

7.7 GROUND WATER BALANCE FOR NON MONSOON PERIOD

The non-monsoon period is from November to May. The same water balance equation shall be applied here to workout the balance by equating the items of recharge to the items of discharge. Further in this period the rainfall is of the order of 46 mm. which is spread over a period of 7 months, and the intensity and duration of rainfall is such that there will be hardly any percolation to water-table and so for this period the recharge due to rainfall shall be nil. Thus the water-balance equation (7.2) is modified for this period and it will be as follows:

$$G_s + G_{UI} + R_n + R_a = E_t + D_e + D_c + D_l + \Delta \quad .. \quad (7.5)$$

Here, Gs = Ground water storage available at the beginning of the period.

ΔG = change in ground water storage during a year

Other terms are already defined in art.7.2.

7.7.1. GROUND WATER STORAGE AVAILABLE (Gs)

This has already computed in art.7.4.10 as change in ground water storage (ΔGs) and equals to 169616.63 HM.

7.7.2 GROUND WATER INFLOW(QUI)

The ground water inflow QUI is assumed as nil and it is neglected.

7.7.3 NATURAL RECHARGE (Rn)

The rivers are mostly effluent during the non-monsoon period and so the influent seepage has been neglected and is assumed nil for this period.

7.7.4 ARTIFICIAL RECHARGE (Ra)

The recharge from the canal system and from irrigated field have been computed in tables 6.6; 6.7; 6.8 vide art.6.6.2. The recharge from canals during transition in

non-monsoon (Rabi) period	= 37260.8 HM
and recharge from irrigated field	= 20806.24 HM
Hence, Ra artificial recharge	= 372608+20806.24
	= 58067.04 HM

7.7.5 EVAPOTRANSPIRATION(E_t)

The evapotranspiration from ground water source have been calculated vide art.6.6 and this value for non-monsoon period works out to 20472.22+1962.82+12,885+7172.65

i.e. Et = 42492.69 HM

7.7.6. NATURAL DISCHARGE(EFFLUENT SEEPAGE)De

The difference of upstream discharge from thed down -stream discharge has been given in art.2.4.This difference of two gauge readings correspond to the contribution of the river flow from the both banks in the reach of the river lying within the study-area. During the non-monsoon period, this difference of discharge in the river reach is entirely contributed by ground water (effluent seepage).

From river basin map the percentage of drainage contributed by the study area to each bounding rivers are known as mentioned in art.2.4. Now by multiplying the difference of discharge data with the percentage of drainage contribution for each bounding river and then adding to it the evapotranspiration loss in that reach of river, the effluent seepage from study area can be worked out as given in Table 7.4.

TABLE 7.4

COMPUTATION FOR NATURAL DISCHARGE, De

River	Difference of U/s discharge from D/S discharge in HM	Flow generated in the river reach from study area in HM	Evapotranspiration loss in the river reach in HM	Total effluent seepage = col.3+4 in HM
(1)	(2)	(3)	(4)	(5)
Ganga	70355	42213	18900	61113
Sone	27198	12239	8580.83	20819
Karmanasa	5486	4114	820	4934
Durgauti	7261	3630	1040	4670
			Total	91536.12HM

Hence natural discharge during non-monsoon period

De = 91536.12 HM

7.7.7 ARTIFICIAL DISCHARGE D_c

The withdrawl from existing state tube wells, private tube wells, open boring and dug wells have been computed vide Table 3.1 art.3.5.2 and vide art.3.2 for irrigation and domestic and industrial purposes respectively. The values obtained are as follows:

Withdrawl during monsoon (Rabi) period for irrigation purposes = 18225 HM

and for domestic and industrial purposes $= \frac{7}{12} \times 26122 = 15237.83$ HM

Hence artificial discharge, D_c = 18225+15237.83

= 33462 HM

7.7.8 GROUND WATER OUTFLOW (QUO)

The ground water out flow as computed vide art.6.9, Table 6.8 works out to 1773.15 HM for non-monsoon period

so, QUO = 1773.15 HM

7.7.9 GROUND WATER LEAKAGE (Gl)

The ground water leakage for non-monsoon period is computed as follows:

The annual leakage vide art.6.8 = 10647 HM

Hence leakage during November to May $= \frac{7}{12} \times 10647$

Gl = 6211 HM

7.7.10 CHANGE IN GROUND WATER STORAGE (ΔG)

The change in ground-water storage is computed by solving the ground-water water balance equation for the non-monsoon period. The value obtained is then compared with the value of ΔG as computed in art. 6.7. The two values should be in close agreement for a good water balance.

7.8 GROUND WATER BALANCE RESULTS FOR NON-MONSOON PERIOD

Recharging factors

1. Water available in storage, Gs	=	169616.63 HM
2. Ground water inflow, Q_{UI}	=	Nil (assumed)
3. Natural recharge, Rn	=	Nil (assumed)
4. Artificial recharge, Ra	=	58067.04 HM
	Total	227683.67 HM

Discharging factors

1. Evapotranspiration, E_t	=	42492.69 HM
2. Effluent seepage, De	=	91536.12 HM
3. Artificial discharge, Dc	=	33462. HM
4. Ground water outflow Q_{UO}	=	1773.15 HM
5. Ground water leakage, Gl	=	6211 HM
	Total	175474.96 HM

Now, from water balance equation (7.5),

$$227683.67 = 172621.84 + \Delta G$$

i.e. change in storage during 1974-75, ΔG

$$= 227683.67 - 175474.96$$

$$= 52208.71 \text{ HM}$$

CHAPTER - 8

CONCLUSION

8.1 The present study has been taken up to assess, understand and evaluate the various components related to water balance of the doab with a view to workout the water resources of the area for the water year June 1974 to May 1975. An attempt has also been made in this study to prepare a subsurface vertical variability pattern map of the area to show the distribution of sand horizon.

As a result of the study carried out the following important conclusions are brought out:

8.2 The subsurface vertical variability pattern map(fig.4.9) indicates that the subsurface lithology of the area is mainly built up by the shifting courses of river Ganga. The map further reveals that the central part of the area has higher concentration of sand in the lower portion while clay is predominent at higher levels. It may be concluded that the deep sand horizon represent the channel sand deposited by the ancient river course while clay in the upper horizon is mainly a result of flood plain deposit. In contrast to this, in areas close to the present river courses, sand is predominant near to the surface while clay is at deeper levels. This also indicates that the clay in the lower levels represent flood plain deposits of the ancient river course.

8.3 The depth to bedrock map(fig.4.1) and the profile(fig. 4.2 and 4.3) showing the bed rock topography, ground slope and position of water table, indicate that the depth to bedrock increases from south to north. Beyond 25°30 'N latitude the thickness of alluvium abrutly increases from 400M to 700 M within a distance of about 12 km. This may be due to local East West fault in the basement with its downthrow towards north. The sharp change in the course of river Ganga towards east seems to be controlled by the E-W fault in the basement which may be active during the recent period also.

Another fault has been postulated by Sastri et.al.(op.cit.) to be parallel to river Sone in a NE-SW direction.

8.4. The subsurface lithological sections(fig.4.4) show that the amount of clay is more in the central and southern part of the area while it is less in the northern portion. The aquifer and aquicludes horizons show greater lateral continuity in the E-W direction while in the N-S direction this extent is more of local character. This feature can also be observed from the centre of gravity map(fig.4.8).

The total thickness of clay in the southern part of the area is more while the total thickness of sand horizon is greater near the river Ganga and Sone, such a conclusion is in confirmity with the vertical variability map(fig.4.9).

8.5 The subsurface lithology shows that the doab consists of unconsolidated alluvial deposits which constitute an extensive heterogeneous unconfined aquifer. The behaviour of water table and its fluctuations to a minimum value in pre-monsoon period and rising to a maximum value in post monsoon period also confirms the unconfined nature of the aquifer.

The average value of Transmissivity, T, has been computed to be 188 cm^2/Sec. and specific yield has been assumed to be 11% on the basis of subsurface lithology of the area.

The configuration of water table contours indicate that the general gradient of water table is towards the present river courses. There are also groundwater ridges along the unlined canals which are result of seepage from these canals. The average water table fluctuation from premonsoon to postmoon 1974 is +2.285 M(Table 5.3) and the water table fluctuation from the period pre-monsoon 1974 to premonsoon'75 is +0.594M.

8.6 A major part of the present study is devoted for computing water balance for the period June'74 to May '75. Various elements of hydrologic equation have been evaluted within the limit of

(vi) Annual deep percolation or groundwater leakage through the bottom most aquiclude = 10647 HM

(vii) Annual change in ground water storage = 52208 HM

(viii) The following quantities are expressed as percentage of ground water recharge

((a) Ground water outflow i.e.natural discharge

$$= \frac{114141 \times 100}{341420.58} = 33.43\%$$

(b) Ground water withdrawl or Groundwater draft

$$= \frac{87204}{341420.58} \times 100 = 25.54\%$$

(c) Evapotranspiration loss from Ground water

$$= \frac{74335.75}{341420.58} \times 100 = 21.78\%$$

(d) Ground water leakage $= \frac{10647 \times 100}{341420.58} = 3.11\%$

(e) Annual change (rise) in ground water storage

$$= \frac{52208.7}{341420.50} \times 100$$

$$= 15.30\%$$

accuracy and availability of pertinent data. A good hydrologic water balance (art.6.7) for 1974.75 hasbeen obtained.The water balance has also indicated that there is leakage of groundwater through the bottom most aquiclude because the confining layers are comprised of lenses of silt and clay.

8.7 From the groundwater balance(art.7.8) study following conclusions may be drawn

(i) The total rainfall falling in the area is distributed as follows*

(a) Total Runoff	= 43%
(b) Percolation to Groundwater reservoir	= 23%
(c) Evapotranspiration and other losses including soil moisture retention	= 34%
Total	100%

(ii) Total annual Ground water recharge from all the sources in year 1974-75 = 341420.58 HM

(iii) Total annual ground water withdrawal(pumpage) in yr 197.. from all sources = 87204 HM

(iv) Total annual effluent seepage including ground water outflow [redacted] discharge = 114141 HM

(v) Total annual Evapotranspiration losses from ground water reservoir = 74335.75 HM

(vi) Annual deep percolation or groundwater leakage through the bottom most aquiclude = 10647 HM

(vii) Annual change in ground water storage = 52208 HM

(viii) The following quantities are expressed as percentage of ground water recharge

((a) Ground water outflow i.e.natural discharge

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(d) Ground water leakage $= \frac{10647 \times 100}{341420.58} = 3.11\%$

(e) Annual change (rise) in ground water storage

$$= \frac{52208.7}{341420.50} \times 100$$

$$= 15.30\%$$

(ix) The breakup of total annual groundwater recharge is as follows:

(a) Recharge from Rainfall $= \frac{132496.2 \times 100}{341420.58}$

$= 38.80\%$

(b) Recharge from influent seepage (Natural recharge)

$= \frac{36855 \times 100}{341420.58} = 10.80\%$

(c) Recharge from irrigation water or artificial recharge $= \frac{172069.28 \times 100}{341420.58}$

$= 50.4\%$

8.8 It is seen from art.8.7 that out of total annual recharge only about 25% of ground water is withdrawn and about 55% of groundwater is lost through effluent seepage and evapotranspiration.The analysis further indicates that there is a net rise in groundwater storage of about So there is good prospect for utilizing the groundwater by providing more number of tubewells for irrigation purposes particularly in the tail reaches(northern portion) of the canals of Sone command, where shortage of water is being experimnced at present.

It is necessary that water balance study for more number of years should be dome so that a better quantitative evaluation of water resources and its fluctuations can be assessed. This would also require correct assessment of geohydrological characteristics and systematic collection of hydrological data both for surface water and ground water.

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