Geomorphology of Khari River Basin

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by

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Under the supervision of

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CERTIFICATE

I feel great pleasure in certifying that the thesis entitled '*Geomorphology of Khari river basin'* by Deepti Jain under my guidance. She has completed the following requirements as per Ph.D. regulations of the University.

a. Course work as per the university rules.

b. Residential requirements of the University (200 days).

c. Regularly submitted annual progress report.

d. Presented her work in the departmental committee.

e. Published/ accepted minimum of one research paper in a referred research journal

I recommend the submission of thesis.

Date-

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ABSTRACT

Geomorphology is defined as the science of description of various forms (morph) of the earth's surface. Geomorphology may be defined as the scientific study of surface features of the earth's surface involving interpretive description of landforms, their origin, development, nature and mechanism of geomorphological processes which evolve the landform with a view that all landform can be related to a particular geologic process, or set of processes, and that the landforms thus developed may evolve with time through a sequence of forms dependent in part on the relative time a particular process has been operating.

Present study with the title *'Geomorphology of Khari river basin'* is a study to understand the present landforms and to establish a marked relation between the past and present evolution of these existing landforms in the terms of environment complexities. Drainage basin is being frequently selected as an ideal areal unit for the analysis of forms and processes of a region delineated by the basin perimeter. River basin study is important because of their significance for human use.

Present thesis have been divided into seven chapters, *first chapter* provides a introduction, methodology, aim of the study, nature of study, and details of study area. *Second chapter* deals with geology of the area within which the various geological formations in chronological order along with the distribution of various rock types have been dealt with. *Third chapter* provides a basic frame work of Climate and Soils of the basin. The Climatic condition of basin have been described through different seasons namely, summer season, s.w. monsoon season and winter season. The factors affecting soil have been described in the second section. Classification of soil along

with four type of soils have been described in this chapter. In *fourth chapter* geomorphic environment of Khari river basin has been studied. Various type of land forms have been analysed and studied through different morphometric techniques like relative relief, contour map and by analysis of slope. Different denudational and depositional land forms also have been described. *Fifth chapter* deals with the fluvial morphometry of the Khari river basin. Stream ordering, Bi-furcation ratio, stream length, sinuosity index, stream frequency and drainage pattern have been specified. In the *six chapter* deals with the environment problems in Khari river basin. Different causes of environment degradation in area like climate change, deforestation, human interference have been described. Industrial development, urbanization and agricultural development and their impact on environment was also studied.

Candidate's Declaration

I hereby, certify that the work, which is being presented in the thesis entitled *'Geomorphology of Khari river basin'* is in partial fulfilment of the requirement for the award of the degree of Doctor of Philosophy carried under the supervision of Associate Professor Dr. Ajay Vikram Singh Chandela and submitted to the University of Kota, Kota represents my ideas in my own words and where other ideas or words have been included I have adequately cited and referenced the original sources. The work presented in this thesis has not been submitted elsewhere for the award of any other degree or diploma from any other institute. I, also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will cause for disciplinary action by the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Date- (Name)

This is to certify that the above statement made by Deepti Jain (Registration no. Rs/558/10) is correct to the best of my knowledge.

Date- (Name)

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Deepti Jain

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List of abbreviations

cms	-	centimeters
kms	-	kilometers
km^2	-	square kilometer
fig	-	figure
mm	-	millimeter
mts	-	meters
max	-	maximum
min	-	minimum
no	-	number
nw	-	north west
sw	-	south west
^{0} C	-	Degree centigrade
DF	-	Delhi fold
SDFB	-	South Delhi fold belt
AFB	-	Aravalli fold belt
BGC	-	Banded Gneissic complex
GBF	-	Great Boundary fault
G.A.	-	Giga annum
P.E.T.	-	Potential evapotranspiration

Chapter - I

Introduction

INTRODUCTION

Geomorphology has been defined as the study of terrestrial geomorphology and the forms and features that result from it (Peel, 1967). Geo scientist treat it as a bridge between geology and geography as a matter of fact it harmonises the basic concepts which constitute the philosophical and methodological bases of these sister disciplines and offers a convincing and logically sustainable interpretation of geomorphic processes, forms and associated features.

Some Geo scientists considered geomorphology as a study of forms of the earth's surface and their origin and effects. This has led to the form process approach. Another group of geo-scientists considered it as the study of processes and resultant forms and features. As a result process-form approach emerged. These development created a dichotomy. Thus a vexed controversy analogous to chicken and egg persists in geomorphology methodology. As a matter of fact the geomorphic reality is a unified whole whose appreciation essentially requires the interpretations from both the points of view.

Similarly a group of geo-scientists treated geomorphic units in a cycle manner whereby they originate, grow and decay. This was elucidated in terms of a trinity principle and expressed that landscape is a function of structure, process and stage. This school was developed by Devis (1899, 1909) and supported by a host of others. This facilitated not only the forms existed in the past on the basis of the preset geomorphic forms and processes but also helped in visualizing the feature geomorphic pattern. Penck (1924) marked a departure from the cyclic model and treated the land scape as a manifestation of interaction between tectonic forces and denudation processes occurring simultaneously.

Geomorphology describes the canopy of the surficial features drown out of the trinity principal of structure, process and time. It joins the hardy hands with geology and geography or both. Although the evolutionary history of the subject is a continuous and long narrated conceptual rhythmic change yet the recent most inclusion of the system's approach is a significant factor to evaluate the geometry, planimetry and relief as well as areal parameters inherited in the dynamic planer surface. Leaving aside the traditional empirical methed of study enunciated and studied by old stalwarts of geography like Ratzel, Russel, Semple, Devis, Penck etc.

The importance of geomorphology can very well be realized as a resource denominator, evolutionary indicator and surficial viewer. The experiences of geomorphic appraisals in planning projects reveal that a drainage basin is the most ideal and fundamental unit for any regional planning (Chorley, 1969).The Present study is an attempt in the same direction.

(i) Aim of the study

The main aim of the study is understand the present land forms and to establish a marked relation between the past and present evolution of these existing landforms in the terms of environment complexities. The main objectives of study are as follow:

(a) To draw the evolution of land forms in the area.

(b) Understand and illustrate the physiographic character of the river basin.

(c) Explain and understand the geomorphic forms and process of the basin.

(d) To evaluate environment change and evolve a strategy for combating the geo-environment degradation and assure balanced economic development of the region under study the work has been taken in hand.

(e) To find the active environment hazards and remedial measures to minimize them.

(f) To provide a development prospectus in the region for prosperous living.

(g) The region is badly experiencing natural hazards in the form of famines, flow of epidemics and man-made changes in land scape which have led to environment degradation hence to investigate this anthropogenic and environment change and it's severity, this work has taken in hand.

(ii) Review of literature

The science of geomorphology as a discipline can be defined as the study of terrestrial denudation and the forms and features that result from it. A great deal of new research development in geomorphology has taken place recently. Applications of space photograph, remote sensing and computers have widened the scope of this subject in solving environmental problems.

The American and European Scientists have done considerable amount of work in geomorphology. In the field of quantitative geomorphology the contributions of Horton (1945) Strahler (1950, 1952, 1954, 1956, 1958) Milor (1953) Schumom (1956) Melton (1957, 1958) Smith (1958) Morisawa (1959) Abrahams (1972) Gardiner (1977) Douglas (1976) Embleton and king (1980) Sugden and John (1968) Eyeles (1983) are worth mentioning.

In India too, considerable work has now been done in the field of geomorphology by geographers and geologists. Early studies have been conducted by Chatterji (1975) Verma (1957) Singh (1968) Bose (1961) West (1962) Sen (1965) and Choubey (1966).

Besides these senior geologists and geographers significant contribution to this field has been made by Vaidyanadhan (1964). His work is mainly concentrated on various aspects of cuddapah basin and coastal form and process of the Krishna and Mahanadi deltas (Rao and Vaidyanadhan 1974).

After 1970, substantial contributions in this field have been made by younger scholars like Pal (1972) Sings (1982) Sharma H.S. (1972, 1976, 1980, 1982) and De N.K. (1982) Bandhopadhyay (1972) Rao, Padamja (1976) Dhinwa (1981) Sharma M.L. (1986) Mukhophadhyay (1969) and Rai (1970-71).

(iii) Methodology

Geomorphic studies aims to understand the shape, structure, form and process at work at a given time in a given area. Therefore it needs intensive field work, observations and classifications regarding the field of study. Geomorphology is essentially a field study and therefore the present study is based mainly on field observations. Several successive trip to the field were arranged in different seasons to measure the planimetric surfaces, dimensions of the special features like relief, slope, flood situation and sediment systems. The hill slope elements, verification of the result of quantitative technique and the break up in valley slopes were also studied through these field surveys. The photographic interpretation of the landforms of divergent nature is also an outcome of field investigation.

The entire basin area covers 10 topo sheets of survey of India on the scale of 1:50,000. The basin area was demarcated by finding out water divides and using spot heights and contours of the area. The topo sheets used for the study were 45 K/5, 45 K/9, 45 K/13, 45 O/L, 45 O/5, 45 G/14, 45 K/2, 45 K/14, 45 O/2.

The toposheets on scale 1:2,50,000 were also studied with the help of theses sheets various morphometric technique have been applied to the river basin. The drainage basin area, stream frequency, village map, relief contour map etc. were prepared.

After the demarcation of the study area, various climatological, geological, geomorphic and land use data was collected from different government and Non-government agencies and they were analysed with the help of different geographical tools such as maps and graphs.

Various geomorphic regions and relief features were identified and by visiting the study area environment problems related to each unit were identified and the causes for them were ascertained, accordingly action plan to check environment degradation was suggested.

(iv) Study area

(a) Location

The study area of research work is Khari river basin. Khari river is a left bank tributary of Banas river. The Banas river originates from Khamnor hills near Kumbhalgarh in Rajsamand district. Khari river originates from hills of Bijral village near Devgarh tehsil in Rajsamand district.

The basin in situated in south-east part of Rajasthan State and spreads over in Devgarh and Bhim tehsils of Rajsamand district and Beawar and kekeri tehsils of Ajmer district and Asind, Hurda, Mandal, Banera, Shahpura tehsils of bhilwara district and Tonk tehsil in Tonk district.

This basin stretches between $25^0$27’ north to $26^0$7’30” north and $73^0$5’ to $75^0$7’30” east covering on area of 6,133 square km. The length of the basin from north to south 65.9km and width from east to west is 152km. The eastern part of the basin belongs to lowland where the height is below 375 mt. The central and western uplands are also almost flat and cover approximately one half area of the basin.

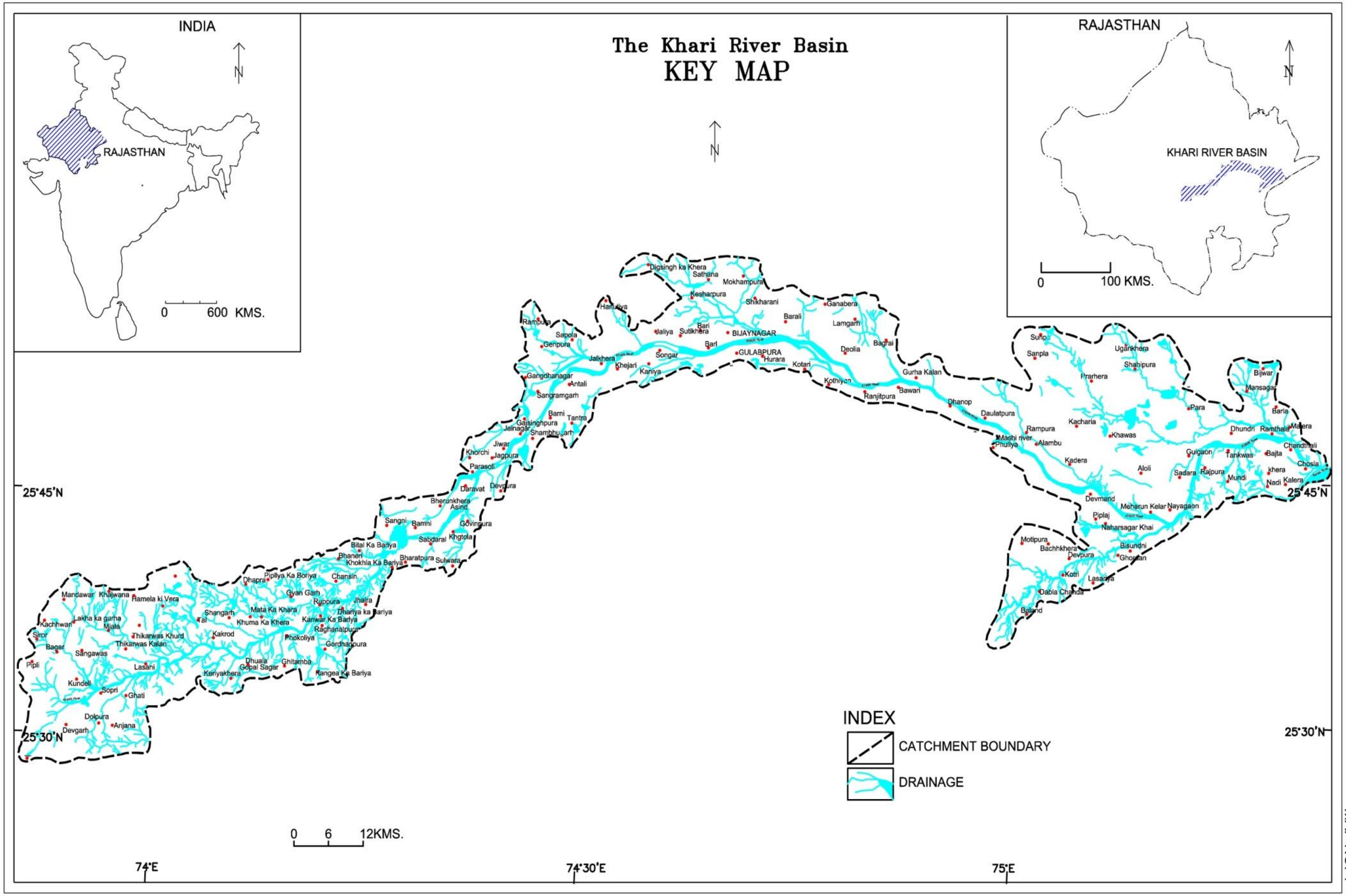
It lies in an important geological and geomorphic region between the Aravalli hill range in the northeast and the Vindhyan plateau in the southeast. It comprises various rock types of different ages and contains contrasting geomorphic, land-cover and tectonic attributes. The western part belongs to western upland, highland, and high rugged terrain, the height varies from 450mt to 955mt.

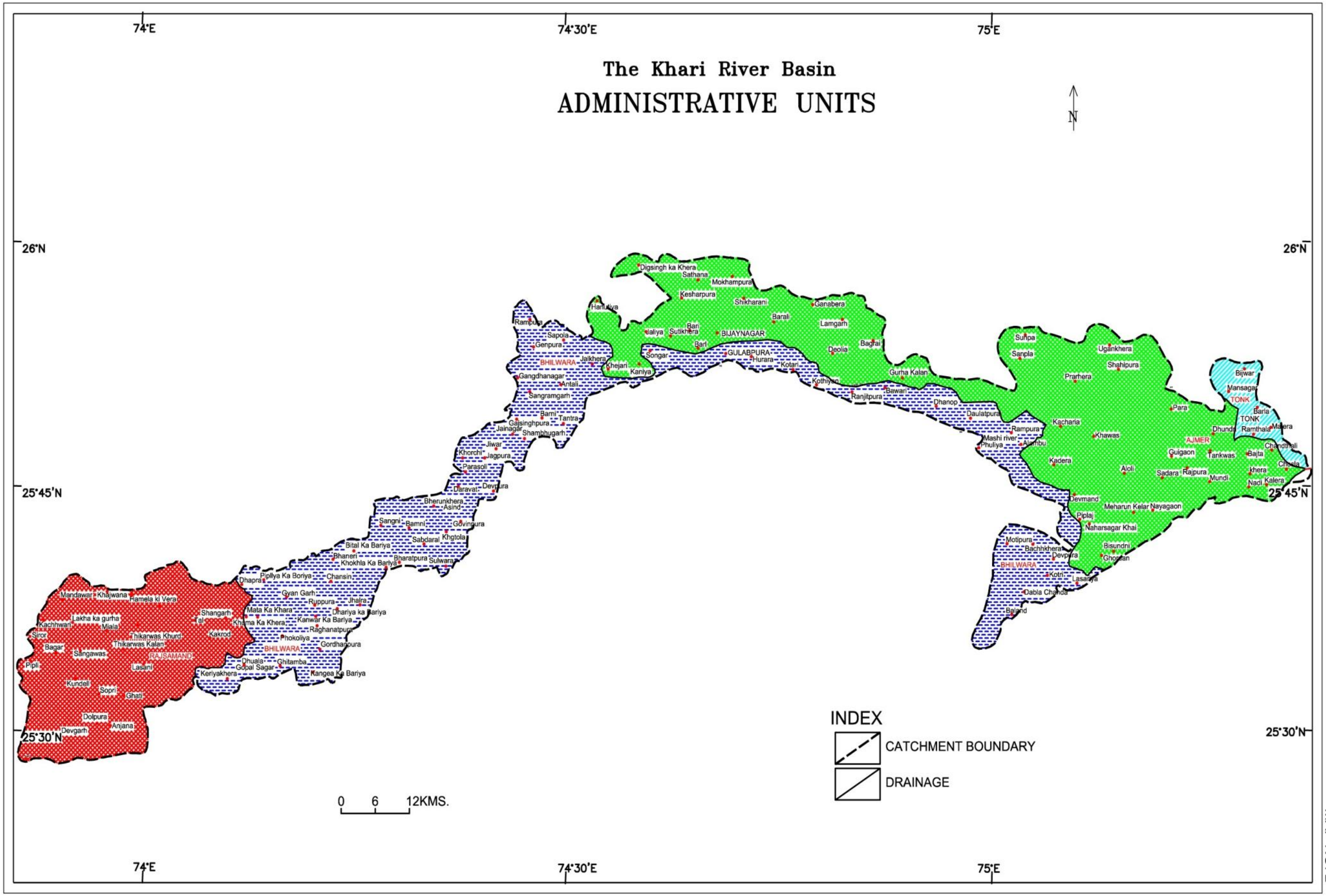
Key map of Khari river basin is presented in map no. -1.

(b) Administrative set-up

Administratively, Khari river basin extends over parts of Ajmer, Bhilwara, Rajsamand, and Tonk following 135 Town and villages. Ajmer district is divided into 6 sub divisions. The sub divisions have further divided into 9 tehsils namely Ajmer, Beawar, Nasirabad, Kekri, Kishangarh, Masuda, Bhinai, Pisangan and Sarwar. The Bhilwara district is divided into 7 sub division under these sub-division there are 16 tehsils namely, Bhilwara, Banera, Mandal, Mandalgarh, Beejoliya, Kakri, Shahpura, Jahajpur, Sanada, Raipur, Kareda, Asind, Hurda, Badnor, Hamirgarh and Puliakalan. Administratively Rajsamand is divided in to 7 sub-divisions, The sub divisions have further divided in to 9 Tehsils Namely Nathdawra, Bhim, Rajsamand, Khumbhalgarh, Devgarh, Rail-magra, Amet, Khamnor, Gaddor. Tonk district is divided in to 7 sub – divisions. Under these sub-division there are 8 tehsils Namely Deoli, Duni, Uniara, Newai, Malpura, Todaraisingh, Tonk, Piplu.

The present study area is spreads over in Devgarh and Bhim tehsils of Rajsamand district and Beawar and Kekri tehsils of Ajmer district and Asind, Hurda, Mandal, Banera, Shahpura tehsils of Bhilwara district and Tonk tehsil of Tonk district Administrative units of Khari river are presented in map no. -2 . Total number of villages shown in the Table-1.1


The Khari River Basin
KEY MAP
N
INDIA
RAJASTHAN
0 600 KMS.
N
RAJASTHAN
KHARI RIVER BASIN
0 100 KMS.
N
INDEX
CATCHMENT BOUNDARY
DRAINAGE
0 6 12KMS.
74°E
74°30'E
75°E
25°45'N
25°30'N
MAP NO. 1
Digsingh ka Khera
Sathana
Mokhampura
Kesharpura
Shikharani
Ganabera
Barali
Lamgarh
Bagrai
Deolia
BIJAYNAGAR
GULABPURA
Hurara
Kotari
Kothiyan
Ranjitpura
Bawari
Gurha Kalan
Dhanop
Daulatpura
Rampura
Mashi river
Phuliya
Alambu
Kadera
Kacharia
Khawas
Prarhera
Sunpa
Sanpla
Ugankhera
Shahipura
Para
Aloli
Dhundri
Ramthala
Bijwar
Mansagar
Baria
Chandthali
Chosla
Bajta
Tankwas
Guigaon
Sadara
Rajpura
Mundi
Nadi
Kalera
Devmand
Meharun Kelar
Nayagaon
Piplaj
Naharsagar Khai
Bisundni
Ghoshan
Motipura
Bachhkhera
Devpura
Kotri
Lasadiya
Dabla Chanda
Balund
Rampura
Sapola
Genpura
Jalkhera
Khejari
Songar
Kaniya
Jaliya
Sutikhera
Bari
Barl
Gangdhanagar
Antali
Sangramgarh
Barni
Tantra
Gaisinghpura
Jainagar
Shambhugarh
Jiwar
Khorchi
Jagpura
Parasoli
Daravat
Devpura
Bherunkhera
Asind
Govindpura
Sangni
Bamni
Sabdarai
Khgtola
Bharatpura
Sulwara
Bital Ka Bariya
Bhaneri
Khokhla Ka Bariya
Dhaprai
Pipliya Ka Boriya
Chansin
Gyan Garh
Ruppura
Jhaira
Mata Ka Khara
Dhaniya ka Bariya
Shangarh
Khuma Ka Khera
Kanwar Ka Bariya
Raghanatpura
Tal
Kakrod
Phokoliya
Gordhanpura
Dhuala
Gopal Sagar
Ghitamba
Kangea Ka Bariya
Keriyakhera
Mandawar
Khajwana
Ramela ki Vera
Kachhwari
Lakha ka gurha
Miala
Sirori
Bagar
Thikarwas Khurd
Thikarwas Kalan
Sangawas
Pipli
Lasani
Kundeli
Sopri
Ghati
Dolpura
Devgarh
Anjana


MAP NO. 2
The Khari River Basin
ADMINISTRATIVE UNITS
N
74°E
74°30'E
75°E
26°N
25°45'N
25°30'N
BHILWARA
AJMER
TONK
RAJSAMAND
BIJAYNAGAR
GULABPURA
INDEX
CATCHMENT BOUNDARY
DRAINAGE
0 6 12KMS.

MAP NO. 3

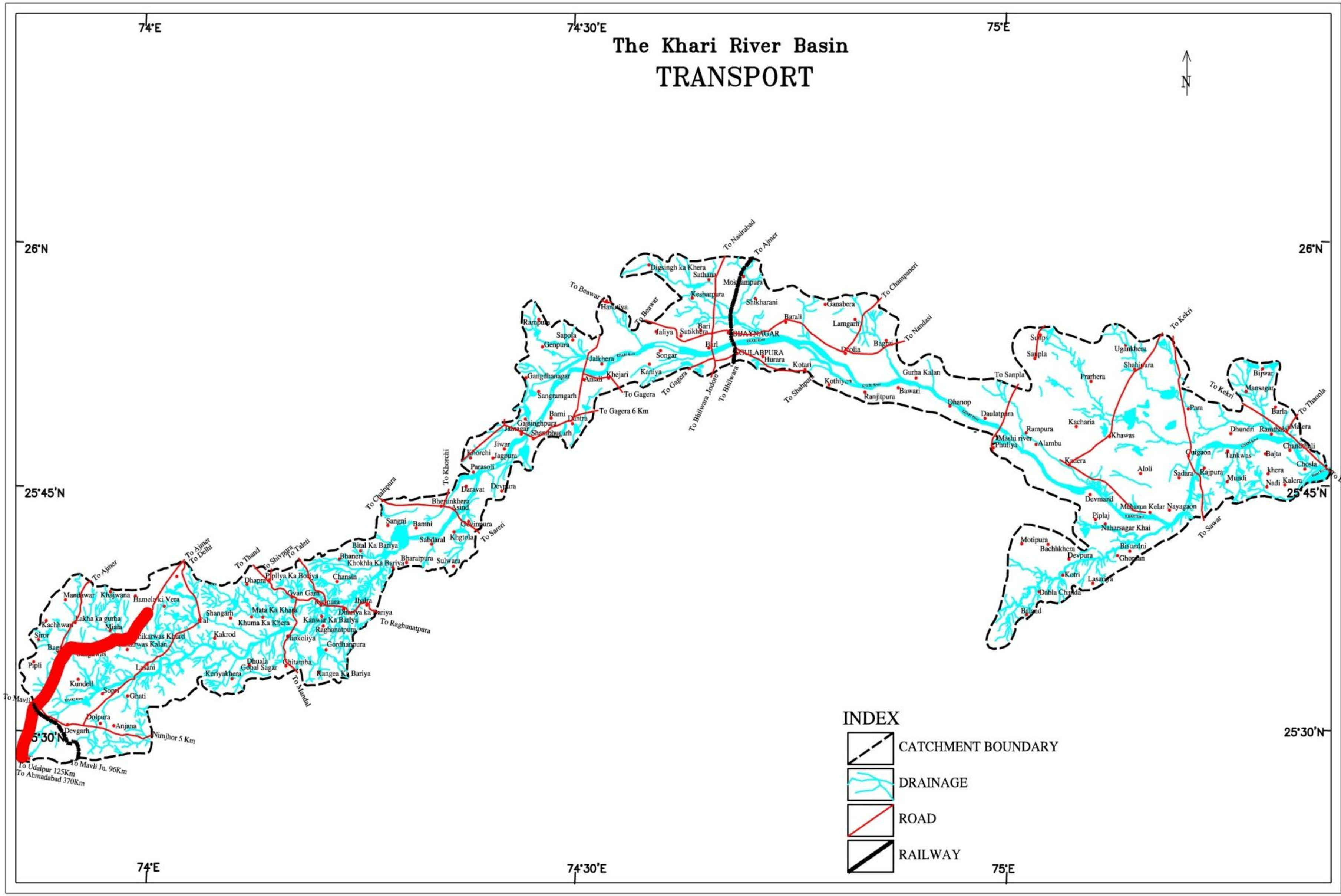

The Khari River Basin
TRANSPORT
N
INDEX
CATCHMENT BOUNDARY
DRAINAGE
ROAD
RAILWAY
74°E
74°30'E
75°E
26°N
25°45'N
25°30'N
BIJAYNAGAR
GULABPURA
To Ajmer
To Nasirabad
To Beawar
To Bhilwara
To Bhilwara, Indore
To Gagera
To Gagera 6 Km
To Shahpura
To Champaneri
To Nandasi
To Kekri
To Thaonla
To Bundi
To Sawar
To Sanpla
To Khorchi
To Chainpura
To Sareri
To Thand
To Shivpura
To Taleti
To Delhi
To Raghunatpura
To Mandal
To Mavli
Nimjhor 5 Km
To Mavli Jn. 96Km
To Udaipur 125Km
To Ahmadabad 370Km

Plate - 1

Hills of Bijral village (Khari river originates from here)

Plate – 2

Khari river in Bijral village

Table -1.1

No. of Villages of Study Area

District Name	No. of Tehsil	Total No. of Villages
Rajsamand	2	22
Bhilwara	5	63
Tonk	1	6
Ajmer	2	44

(c) Demographics

According to the 2011 census, Ajmer district has a population density of 305 inhabitants per square km. Its population growth rate over the decade 2001-2011 was 18.60%. Ajmer has a ratio of 951 females for every 1000 male, and a literacy rate of 69.3%. Bhilwara district has a population density of 230 inhabitants per square km. Its population growth rate over the decade 2001-2011 was 19.20%. Bhilwara has a sex ratio of 973 females for every 100 males and a literacy rate of 61.41%. Rajsamand district has a population density of 248 inhabitants per square km. Its population growth rate over the decade 2001-2011 was 17.1 %. Rajsamand has a ratio of 990 females for every 1000 males and a literacy rate of 63.14%. Tonk district has a population growth rate over the decade 2001- 2011 was 17.30%. Tonk has a population density of 198 inhabitants per square km. Tonk has a ratio of 952 females for every 1000 males and a literacy rate of 61.60%.

Demographic maps of the districts of Khari river basin are presented in map no. – 4 to 6.

Other demographics data about study area are shown in the Table No.-1.2

Table No.-1.2

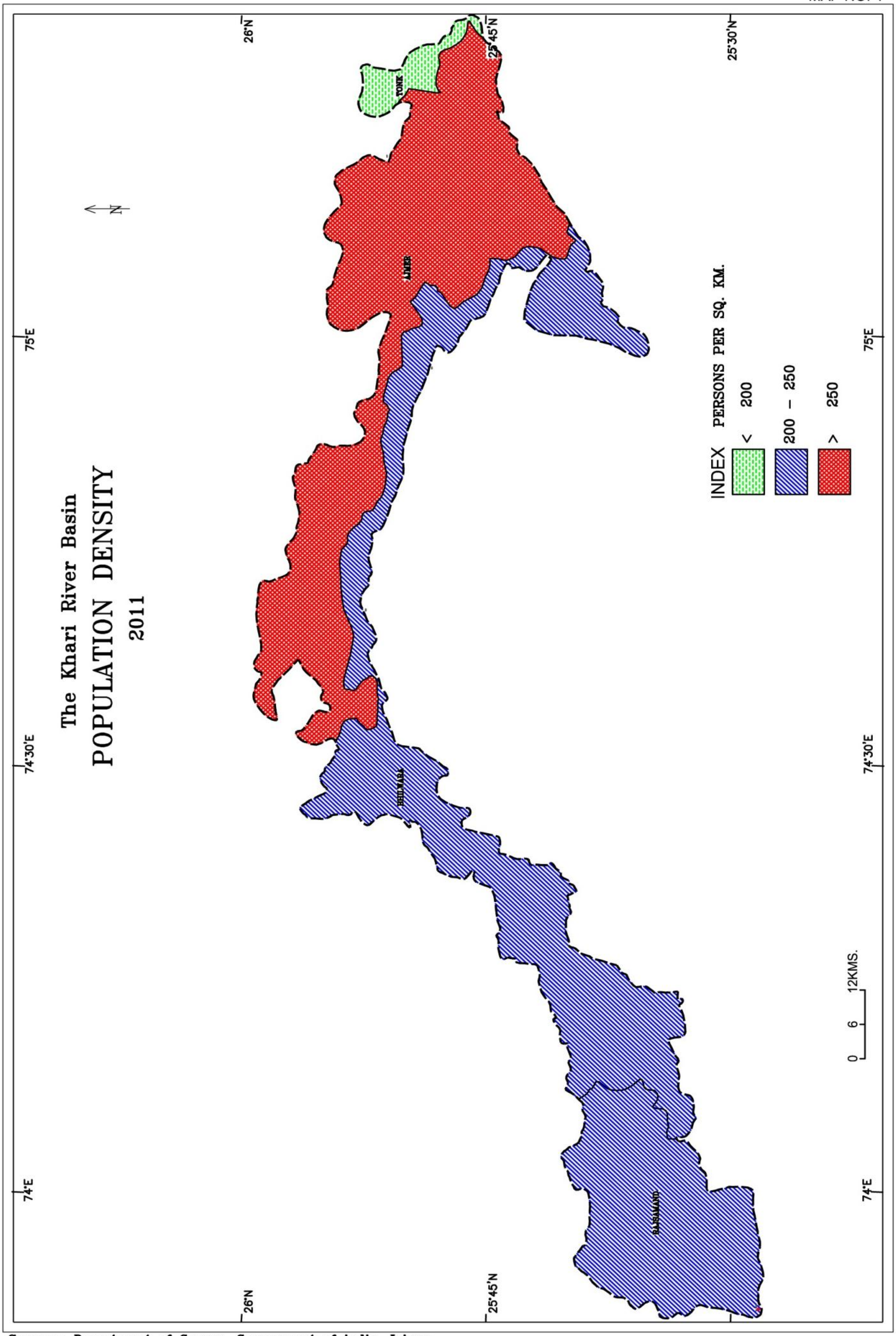
Census-2011 (Demographics)

(Khari River Basin)

District	Population density	Sex Ratio	Literacy (%)	Population growth (%) (Ten Years)
Ajmer	305	951	69.3	18.60
Tonk	198	952	61.60	17.30
Bhilwara	230	973	61.4	19.20
Rajsamand	248	990	6314	17.7

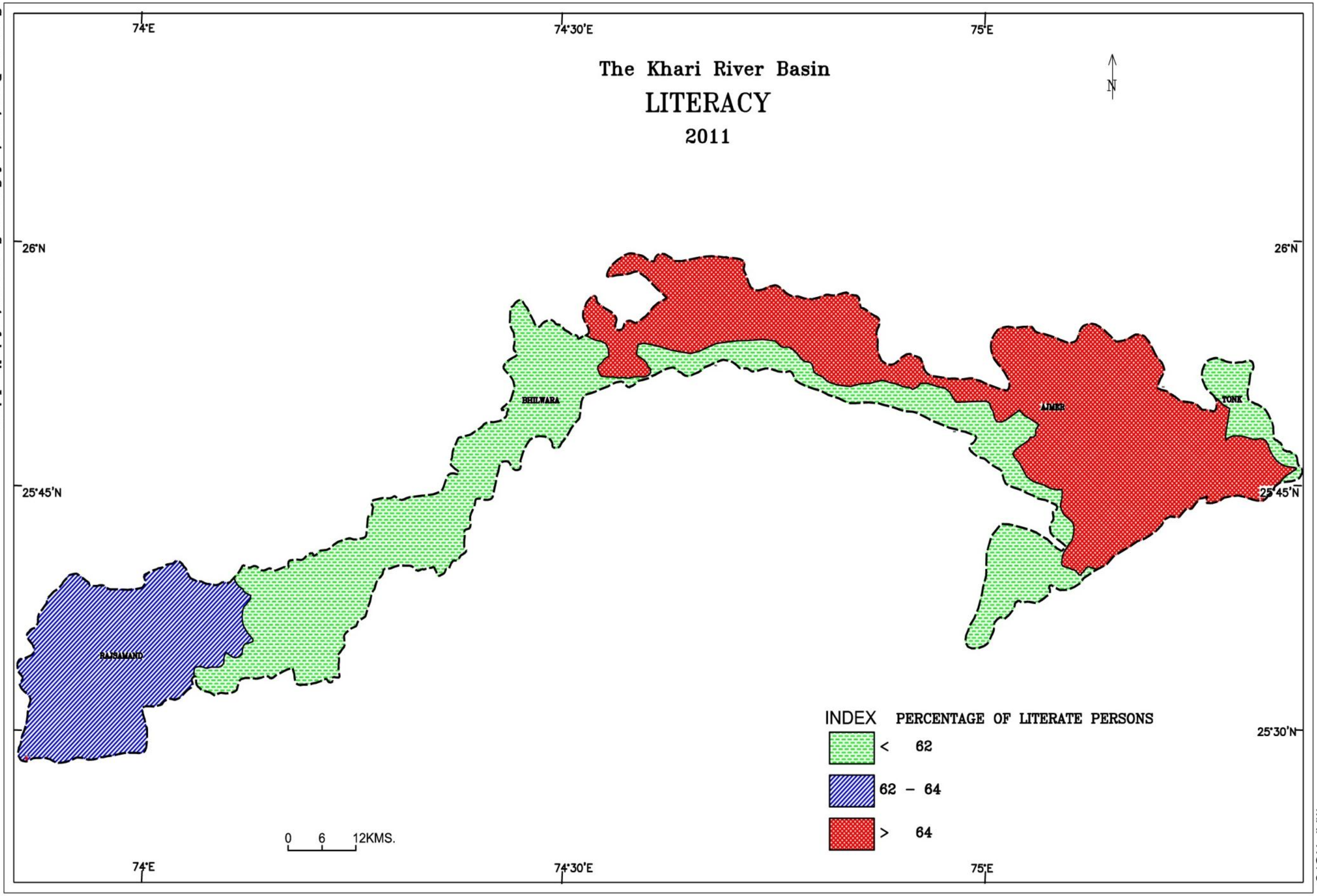
Source: District census handbook, 2015

MAP NO. 4



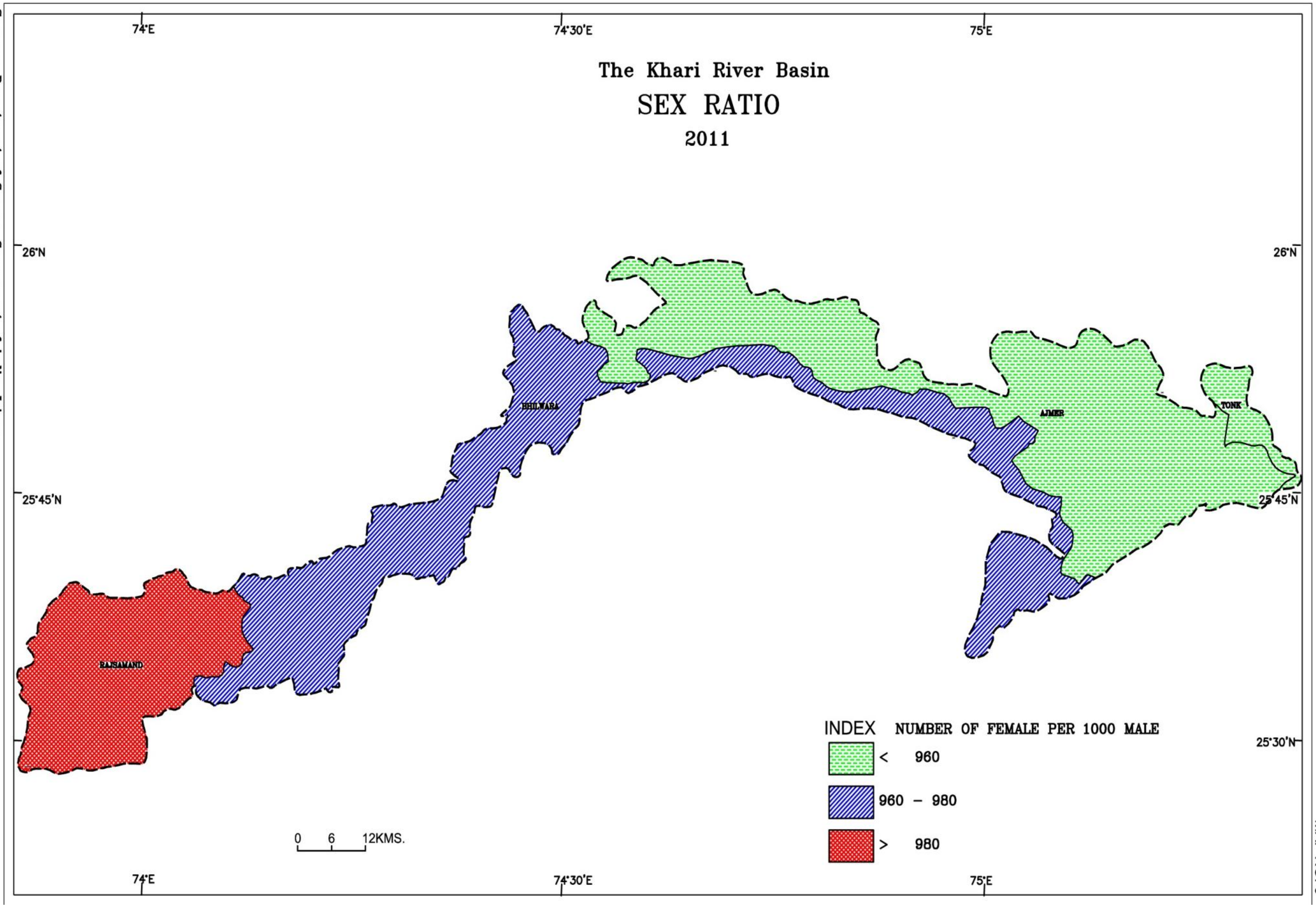
Source:- Department of Census, Government of india, Jaipur.

MAP NO. 5



Source:- Department of Census, Government of india, Jaipur.

MAP NO. 6



Source:– Department of Census, Government of india, Jaipur.

Plate -3

Confluence of Khari and Mansi river in Dhaneshwar village

Plate – 4

Confluence of Khari river and Banās near Nekedia village

(D) Geology

The geology of the study area belongs to Proterozoic Age. Geologically speaking the study area comprises of Bhilwara supergroup, Aravalli supergroup, Delhi Supergroup and Vindhyan supergroup. Stratigraphy of area is shown in the table no.1.3

(E) Physiography

The Khari river basin is situated in south-eastern part of Rajasthan. River originates from hills of Bijral village near Devgarh Tehsil of Rajsamand. River's part of Rajsamand district consists of monotonously rolling topography intersected by shallow valleys. There are intermontane plateaus, structural hills, pediment, buried pediment, aggradational plains, denudational plains, valley fills, flood plains etc. The river's area of Bhilwara district generally slopes gently except in western and northwestern part where slope is high. Major physiographic units of this district are pediment, buried, intermontane valley pediment, plateau, sandy plain. Other part of basin area is characterized by general Flat to undulating topography with small isolated ridges. The shape of the basin is elongated.

(F) Drainage

Khari river a left bank tributary of Banans river, originates from hills of Bijral village near Devgarh tehsil in Rajsamand district. In the Khari river basin area, there are two seasonal rivers, the Khari and the Mansi river. The Khari river, flow from west to east. There are several nallahs join the river on the left bank, while mansi river and other two nallahs join the river on the right bank. The Khari river as well as tributaries are ephemeral and flow only in response to heavy precipitation.

The predominant drainage pattern in the western hill ranges is rectangular to sub – rectangular and it is dendritic to sub-dendritic in rest of the area. Drainage pattern in the western hill region is controlled by fractures and joints and in the rest of the area by subsurface lineaments.

A complex ground slope direction pattern is shown by the Khari-sub basin where in the middle part of the basin, the directions vary from westerly to easterly and southerly to northerly. The southern and southwestern margin of the Khari sub-basin generally has higher slope (0.9-1.5%) than that of its southeastern, northeastern and northwestern boundaries.

Table no.-1.3

Stratigraphy of study area

Erol/period	Super group	Group	Formation	Lithounit
Proterozoic	Delhi (South)	Bhim	Dungarkhera Todogora	Pelitic and semi pelitic schist calc-gneiss and marble
		Rajgarh		Pelitic schist with quartzite
		Sendra		Metavolcanics, impure marble, pelitic schist
		Barotiya	Barotiya	Metavolcanics, impure marble
			Nanana	Marble
			Barr	Mica schist, conglomerate
			Gogunda	quartzite
	Aravalli	Debari	Zawar / Jhazpur, sawar	Pb – Zn bearing dolomite
			Rampura – Agucha, pur-Banca	
			Rajpura – Dariba	
			Udaipur	Greywack, phyllite
			Umra	Carbon phyllite
			Jhamarkotra	Phosphorite bearing dolomite
			Debari/ Jaisamand	Conglomerate, quartzite arkose
Archaean		Mongalwar complex		
	Bhilwar/Banded Gneissic Complex	Sandmata complex		Two pyroxene granulite, leptinite, charnockite-en-derbite, pelitic granulite

Source - Geology of Rajasthan, book by S. Sinha-Roy

(G) Climate

Climatically the Khari river basin is a part of the Semi-arid climatic region of Rajasthan where there are extremes of temperature, low rainfall, greater evaporation and evapotranspiration and scarcity of natural vegetation.

The area receives an erratic annual rainfall of 50-70cm and constitutes the southeast margin of Thar Desert. Most of the rainfall is received during the months of July and August. These months remain the wettest ones. The area turn hot during the months of march, April and May. Dry landwinds prevail in this area and therefore the temperature is the highest. May is the warmest month in this area. The highest temperature is recorded in the month of May is 41.8^0C and the lowest temperature is 25.8^0C.

The area is cold from November end to February. December and January are the coldest months. The mean average, maximum and minimum temperature are 17^0C, 24.8^0C and 8.9^0C respectively. The recorded rainfall in this area in the month of January was 4 mm.

The relative humidity is lowest in April-May period around 25% it increases to about 75% during the peak monsoon activity in August.

(H) Vegetation

Climatically Khari river basin is a part of semi- arid climatic region. A semi arid climate is the climate of a region that receives precipitation below potential evapotranspiration but not as low as a desert climate. Semi-arid is too dry to support forests of trees, but scattered vegetation that requires less water can be found here. The major and minor forest produce are timber cold, fire wood, gum, tendu, katha, honey, wax. The area has a large variety of flora and fauna. Among the common species are found in the forest babul, mango, bargad, dhok, gugal, neem, saloon, khejari, peepal and other trees bahera, sitafal, timaru, karonda, thor etc are found.

The main vegetation which is found in this area are vachellia nilotica (babul), grass butea monosperma (palash) prosopis cineraria (dhokda) capparis decidua (kair) bamboo, araja, charas, papadi, sarvala, mehndi etc.

(I) Soil

The Soils of Khari river basin area varies from place to place. Generally The soils of the Khari river basin have been classified into four categories – (1) Red and yellow Soil (2) Older alluvial Soil (3) Red- gravelly Soil (4) Brown Soil.

Red and yellow soil found mostly north and central part of basin. Western Part of Rajsamand, Ajmer and Bhilwara has this soil type. Red-gravelly soil is found in western Part of basin area. Older alluvial soil found higher up in the plains at river terraces away from rivers. Brown soil is mainly found in different tehsils of Bhilwara and Tonk.

(J) Land use

The socio, cultural and economic factors have significant influence over land use, both in rural and urban areas. Land forms, relief of land form, slope, nature of soils and natural resources are some of the important factors which control the land use pattern of the district.

The land use pattern of the districts of Khari river basin are given in Table no.1.4

Table No.- 1.4

Land use data (2015-16) (%)

Land use	Rajsamand	Ajmer	Bhilwara	Tonk
Forest	5.79	6.85	7.18	3.76
Fallow land	6.86	5.34	1.36	10.72
Other uncultivated land	9.84	11.77	17.03	10.89
Culturable waste land excluding fallow land	38.79	17.26	11.50	11.84
Total cultivated area	39.10	59.33	63.20	62.97

Source – District sensus handbook 2015

Chapter - II

GEOLOGY

GEOLOGY

Introduction

The geological evolution of any segment of the earth crust is linked with endogenetic and exogenetic geological processes that operated through geological time measured in the scale of millions of years.

Geological structure forms the foundation of the landforms of any area. The diverse nature of geological units occurring in the region lead to the development of typical landforms. Therefore, it is quite necessary to understand the geological history of a particular region for the evaluation of the landforms. So the main object of writing the geological history of a region is to present the areal variation of the different geo-lithological units and to indicate the role of these rock formations in the manifestation of the present day basin morphology. The particular effects of rocks, their regional uplift, more unequal uplifts or tilts in different parts of the basin, lead to the development of marked topographic expression within the basin.

The geology of Rajasthan is well known for its varied assortment of litho assemblages and different phases of tecto – magmatic sedimentational history. Since the days of Hacket (1877 and 1881) the belt has revealed several complicated stratigraphical structural, petrological and geochemical problems. Before dealing with the geological formations occurring within the limits of the present area, a brief description of the details of the regional geology is essential for better understanding.

(i) Regional geology

The predominantly rocky and arid state of Rajasthan is unique from the point of view of its geology. Geologically this state constitutes the north –western part of the peninsular India comprising one of the oldest mountain chains of the earth, 'The Aravalli mountain Range'. Apart from this, it is perhaps the only state in India possessing a stratigraphy representing all the eras of the geological time scale. The NE-SW trending Aravalli mountain range possibly marks a line dividing the older groups of rocks in the east and the younger ones in the west.

Geologically, the Rajasthan region is characterised by a wide range of lithostratigraphic unites, belonging to proterozoic, palaeozoic, mesozoic, tertiary and quaternary eras. The proterozoic rocks are predominantly confined to the mountain range and the peneplains of eastern Rajasthan, categorised as Bhilwara, Aravalli, Delhi, Vindhyan supergroup of rocks and associated intrusives. The palaeozoics are represented by the marwar supergroup of rocks. The mesozoic, tertiary and quaternary group or rocks are of course well developed, however due to lack of continuity of surficial outcrops because of the dunal sand cover, these litho units have not been assigned the supergroup status.

The geological history of the Rajasthan region covers a wide span of time from ca. 3.5.Ga to 0.5 Ga. This craton incorporates a wide variety of lithological and tectonic units representing the basement rocks (Banded gneissic complex of Heron , 1953) proterozoic fold belts (Aravalli and Delhi) and late proterozoic igneous suites (Malani, Jalore and Siwana) basement rocks, comprising the gneissic terrain of the sandmata complex (SC), the mangalwar complex (MC) and the Hindoli group (HG) forming the Bhilwara supergroup (BSG Gupta, 1981) is essentially archaean in age. Pull apart basin of South Central Rajasthan is presented in map no.-7

(a) Mangalwar Complex

The MC of the BSG terrain contains varied lithologic assemblages and tectonic units of a greenstone like sequence (Sinha-roy, 1985) and comprises ultramafic bodies and mafic igneous bodies of volcanic and plutonic precursors, now represented by amphibolites, highly diverse metasediments such as metapelitic and aluminous paragneiss, fuchsite-bearing quartzite and low mg-marble and calc silicate gneiss, coarse clastics such as greywacke and tuffaceous sediment represented by graphitic schist, granodioritic and tonalitic gneiss (Untala, Gingla) represent the consolidation of the early crust at ca. 2.9 Ga and the end archaean cratonisation is indicated by the Berach granite (Ca 2.6 Ga, Chaudhary, 1984). Although archaean cratonisation event is well documented in BSG rocks of Rajasthan, some authors put controvertible arguments against this end-archaean event and believe that the HG is not a part of the archaean basement on the equvocal premise that the Berach granite (2.6 Ga) forms the basement for the HG in SE Rajasthan (Bose and Sharma, 1992) Sharma and Roy 1986, Roy 1988). Nevertheless, the archaean – proterozoic boundary can be constrained to a slot of 2.5 to 2.6 Ga in Rajasthan from the available field, geochronologic and thematic data-base. It may however be mentioned that the stratigraphic relationships of the different lithologic assembalges of the BSG are not clear as the different rock units are usually demarcated by prominent ductile shear zones (DSZ) running for kilometers.

Thus, during that proterozoic period, the archaean crust (BSG) was extensively reworked through the development of DSZs and granitic activity. The MC is Presumed to represent an archaean primary granite-green- Stone belt wheras the HG is suggested to represent a secondary granite- green stone belt in NW Indian shield (Sinha- Roy,1985).

(b) Hindoli group

The HG occurs in an arcuate belt containing felsic and mafic metavolcanics (Bose and sharma , 1992) and metagrey wacke forming a turbidite sequence. The end – archean Berach granite intrudes the HG (Raja Rao, 1971) a feature that has, however, been contested by Sharma and Roy (1986), Roy (1988) and boss and Sharma (1992)

(c) Proterozoic fold Belts

The proterozoic geologic history of south-central Rajasthan is contained in a number of distinct fold belts. The Principal fold belts are lower to middle Proterozoic Aravalli fold belt (AFB) and middle to upper proterozoic south Delhi fold belt (SDFB). Other time equivalent early proterozoic cover sequences in this region include Jahazpur group, Pur-Banera- Rajura- Dariba- Bhinder groups, Sawar group and others.

The proterozoic history is marked by significant secular changes in terms of basin development, lithocharcters, and mineralization types.

- **Aravalli fold belt**

The stratigraphic succession of the Aravalli fold belt is given by many workers (Sen 1981, 1983, Roy 1988, Gupta 1992, Sinha-Roy 1993a and 1993b, Guha and Garkhal, 1993) most workers have proposed two major stratigraphic sequences within the AFB, a shelf- facies with basic lavas and coarse clastics at the base (Delwara and Debari groups) in the east and deep sea turbidite facies (Jharol Group) with ultramafic slivers in the west, the latter occurring in a zone approximately marking the contact between the two facies. This zone (Rakhabdev Lineament) has been considered a suture in the AFB (Sinha- Roy, 1988) unconformable relation between the archaean basement and the overlying grit-arkose a first order erosional unconformity which in Rajasthan, represents the archean proterozoic boundary.

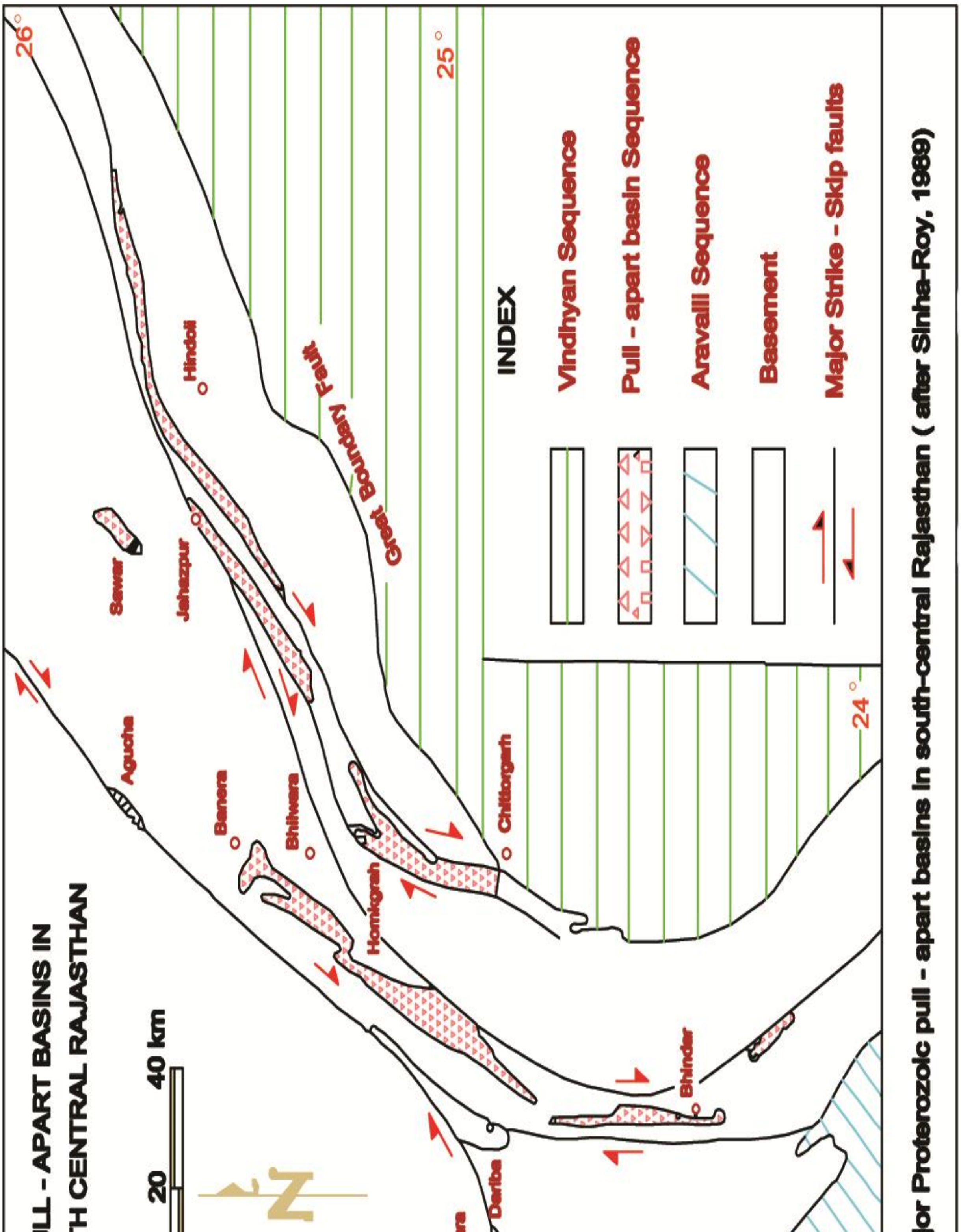
Plate - 5

Rock types in study area

Plate - 6

Rock types in study area

Map no. - 7



Major Proterozoic pull - apart basins in south-central Rajasthan (after Sinha-Roy, 1989)

- **Delhi fold belt**

The middle to upper proterozoic Delhi supergroup rocks occur in two belts, namely (i) the north Delhi fold belt (NDFB) in north east Rajasthan (ii) the south Delhi fold belt (SDFB) along the Aravalli hill range in central Rajasthan. The two belts are separated by a migmatitic gneiss tract around Ajmer in the south.

The rocks of SDEF are deposited in two sub- basins flanking a median basement inlier, west of Bhim. The eastern sub-basin contains pelitic and psammitic rocks of the Rajgarh group signifying a continental slope facies, and a platformal pelite-carbonate sequence of the Bhim group. The contacts between the different sequences are defined by prominent ductile shear zones and thrusts (Gupta 1991). Several conglomerate horizons, such as Shrinagar, Kishangarh and bar are developed within SDFB which signify erosional unconformities.

An important attribute of the SDFB is the phulad ophiolite (Gupta 1981) which is best developed in the southern part of the fold belt. The ophioilite zone is interpreted as dismembered fragments of oceanic crust developed within the south Delhi rift basin (Sinha-Roy, 1988) and is considered to represent a suture zone where high p- low T metamorphic imprints are recognizable (Sinha-Roy and mohanty, 1988) from tectonic development and presence of prominent DSZ, and basement slivers, the SDFB appears to represent a mélange zone.

(d) Late Proterozoic

The late proterozoic event in Rajasthan is marked by the opening of the Sirohi basin with in the pre-Delhi terrain to the west of the SDFB in the trans – Aravalli region. Two lithologic units, namely, Punagarh and Sindreth group are identified by recent workers (Gupta et at 1981, Chore, 1990, Mukhopadhyay, 1990). These two groups occur in isolated basins, unconformably overlying the Sirohi group metasediments and the migmatites of the Erinpura granite affinity. The Sirohi group it self occurs as isolated inliers within the unclassified sequences of the Erinpura craton (Chore, 1990), however, the Sirohi group has been tentatively correlated on litho-structrual grounds with the Jharol group of the Aravalli super group (Mukhadhyay, 1990). The Punagarh and the Sindreth group are represented in the trans Aravalli range primarily by biomodal acid basic volcanics, volcaniclastics and terrigenous sediment, and are presently place at the top of the SDFB sequence (Chore, 1990, Mukhopadhyay, 1990, Sinha- Roy et, al. 1993a)

In SE Rajasthan, the Great Boundary Fault (GBF), a prominent dislocation zone, marks the boundary between the HG basement rocks and the paratectonic vindhyan supergroup rock of proterozoic age. The Vindhyan equivalent Sediments also developed in NW Rajasthan in a seprate basin and are grouped within the marwar supergroup composed of molass-type sediments and evaporites. After the Delhi orogeny, the NW Indian craton across the Aravalli range, withnessed large-scale magmatic activity represented by felsic and mafic malani volcanics jalor and Siwana plutons of late proterozoic age (Pareek, 1981, Kochar 1984, Bhushan 1985)

(e) Phanerozoic

The culmination of the Mesozoic witnessed large scale outpouring of basaltic lavas in southeastern Rajasthan. These volcanic rocks from the northern extension of the Deccan traps. This volcanic activity however, did not affect the sedimentation in the northwestern Mesozoic basins where deposition of marine and continental sequences continued uninterrupted during the Cenozoic period.

(II) Tectonic and sedimentation

South-east Rajasthan contains a mosaic of Proterozoic fold belts within a reworked archaean basement complex. These fold belts, characterised by resurgent tectonics are demarcated by prominent crustal dislocations marked by ductile shear zones. Moreover there are prominent shear zones and thrusts within the fold belt which are either vestiges of Proterozoic sutures or ophiolitic melange zones.

(A) Aravalli fold belt

The Aravalli fold belt has tectonic contact with the basement gneisses which , in fact is a tectonised unconformity, marked prominently in the north where the Delwara sequence of the basal Aravallis is tectonically juxtaposed against the BGC, along a reworked unconformity. This tectonic zone, the Delwara dislocation zone (DDZ), extends south and southeast along the Aravalli basement interface and truncates a number of litho units. Another important tectonic feature of the Aravalli fold belt is the Rakhabdeo suture zone (RSZ) which divides the Aravalli fold belt into two contrasting segments, namely, the platform sequence in the east and deep-sea facies in the west. The RSZ marked by tectonised serpentinite bodies and minor metagabbro and amphibolite is consider the Aravalli suture along which the dismembered Aravalli oceanic/transitional crust was obducted and the eastern and the western domains were sutured (Sinha-Roy 1988)

The northern limit of the Aravalli fold belt is controversial. While Naha and Roy (1983) opined that the Aravalli sequence extends across the Banas river into the BGC terrane as high-grade rocks, Sinha – Roy (1993b) contended that the Aravalli fold belt is delimited in the north by a dislocation, the Bonas dislocation zone (BDZ) which is also a depositional boundary of the Aravalli sequence in the north. The BDZ is a strong ductile shear zone in the northeast, and it can be traced along the contact of the Hindoli sequence and the Mangalwar complex. From the nature of penetrative structures within the BDZ it appears that it represents a deep crustal feature. The BDZ has been imaged as a west – dip – ping prominent reflection zone by deep seismic reflection profiling in the Jahazpur sector (Reddy 1995).

Generalized geological map of Aravalli fold belt is presented in map no.- 8

(B) Delhi fold belt

The South Delhi fold belt (SDFB) has developed on an interacratonic rift basin which was floored by on oceanic/ transitional crust. The remnants of this crust are preserved as dismembered ophiolitic mélange (Phulad ophiolite, Gupta 1981). Apart from the DSZs related to the ophiolitic zone. The SDFB contains on upthrust basement wedge flanked by two prominent thrust zones. All these tectonic features make the SDFB an imbricate thrust zone which should have deeper crustal significance. The western boundary of the SDFB is defined by a dislocation zone, the phulad dislocation zone (PDZ) against the basement rocks, while the eastern boundary is a prominent thrust zone (Kaliguman dislocation zone, KDZ) which separates the Delhi rocks from the Sandmata-Mangalwar complex rocks in the north and the Aravalli sequence in the south.

The imbricate tectonic signatures of the SDFB are also reflected in the tectonics of the adjacent Sandmata Mangalwar complex terrane where the granulite facies sand mata rocks are bound by imbricate DSZs within the amphibolite facies mangalwar rocks (Singha – Roy 1992). From tectonic relations it is suggested that the lower crustal rocks of the sandmata complex have been emplaced as tectonic wedges at various structural levels and the gravity high over the sandmata belt is a probable indication of this feature. The mangalwar complex to the east of the sandmata complex contains a number of Subparallel DSZs which are probable the expression of subsurface imbricate thrust zones between the lower and the upper crustal rocks.

Generalized geological map of South Delhi fold belt is presented in map no.-9.

(C) Great Boundary fault (GBF)

The GBF is an important dislocation zone in southeastern Rajasthan. The geological and structural setting indicates that the GBF, a reverse fault, is also on imbricate fault zone. Which sliced the vindhyan and pre-vindhyan rocks. The trace of the GBF is curvilinear, and it appears to be a rotational fault with the hinge located nearly 20 km south of Chittaurgarh. These features indicate that the GBF is related to indentaion tectonics caused by impingement of the Bundelkhand massif with the Vindhyan cover rocks on the precambrain terrane of Rajasthan, as a result of regional crustal deformation of the indian plate after the collision and jamming of the Indian and the Asian plates (Sinha-Roy, 1986). In this context the GBF has a regional crustal significance in the tectonic development of the NW Indian plate segment in late tertiary and quaternary times, and it is likely that this fault zone is still active.

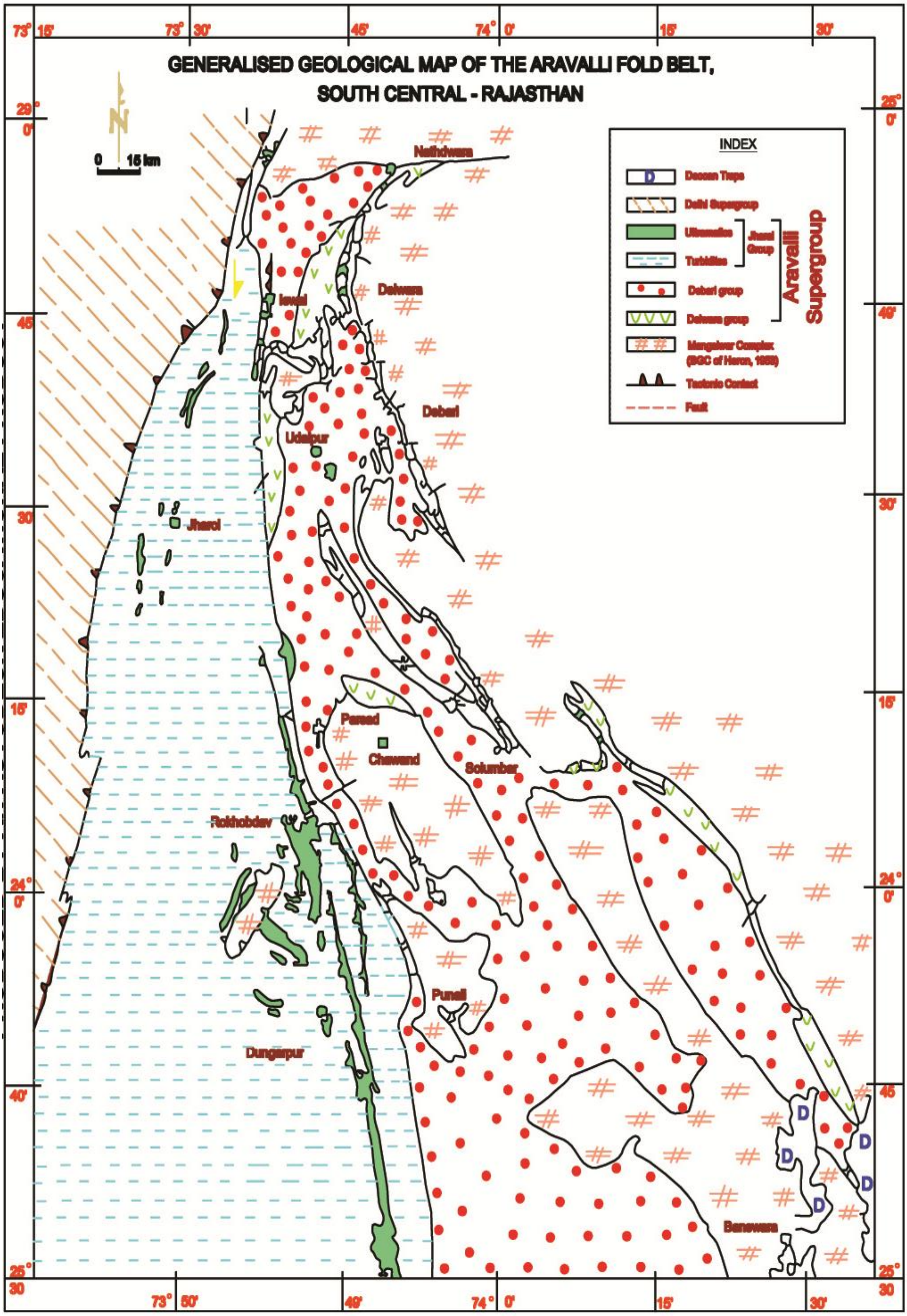
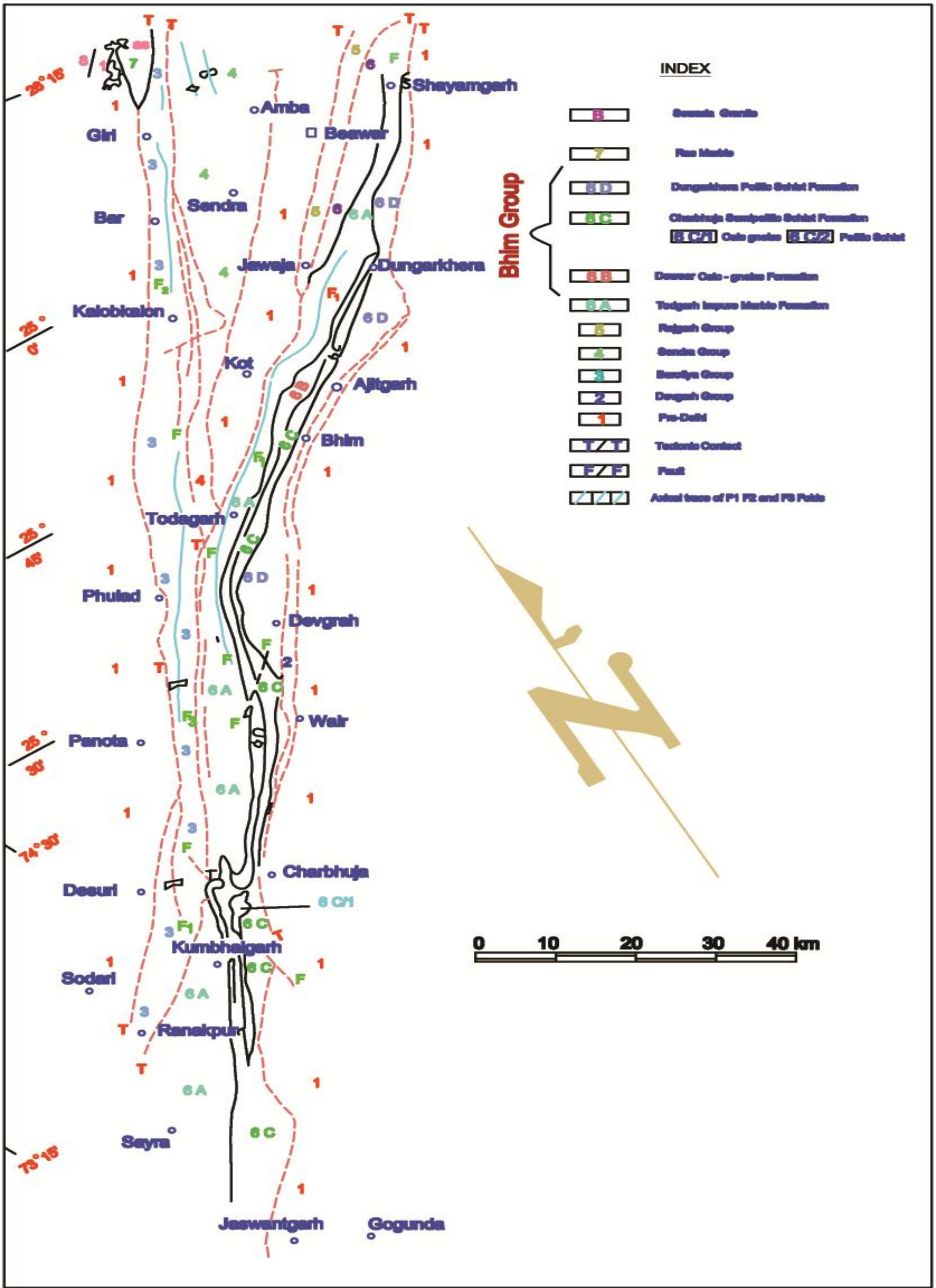

GENERALISED GEOLOGICAL MAP OF THE ARAVALLI FOLD BELT,
SOUTH CENTRAL - RAJASTHAN
0 15 km
INDEX
Deccan Traps
Delhi Supergroup
Ultramafics
Turbidites
Jharol Group
Debari group
Delwara group
Aravalli Supergroup
Mangalwar Complex
Tectonic Contact
Fault
Nathdwara
Iswal
Delwara
Debari
Udaipur
Jharol
Parsad
Chawand
Salumber
Dungarpur
Banswara

Plate – 7

Rock types in study area



Generalised geological map of the South Delhi Fold Belt (after Gupta etal. 1995)

(III) Geological structure of area and rock structure

The geology of the study area shows that it can be categorised in Proterozoic age rocks. Geologically speaking the study area comprises of Bhilwara supergroup (3200 – 2500 m.y.) Aravalli Super Group (2500 – 2000 m.y.) Delhi supergroup (2000 – 800 my) and Vindhyan super group (700 – 600 m.y.)

Bhilwara district has predominant geological formations. In this area rock types belonging to Bhilwara super group, Aravalli and Vindhyan super group. In Rajsamand rocks are belonging to Bhilwara super group, Aravalli super group and Delhi super group and alluvial deposits along the channels of river Banas, Khari and other rivers, in the form of valley fills. The oldest formations exposed in the area belongs to Bhim supergroup of archaean age. The northern, central and western parts of the area are occupied by the younger formations of Aravalli super group and Delhi super group of Proterozoic age. Quaternary and recent alluvium overlies most of the formations in isolated pockets, along river courses and in shallow depressions. River basin area of Tonk district is underlain by rocks of Bhilwara super group comprising mainly of mica, schist, gneisses, phyllites and quartzites having small intrusive granite. These hard rocks are overlain by the alluvium of Recent to Sub-recent age. Consisting mainly of clay, sand and silt. Ajmer district has predominat geological formations comprising mainly of schist, alluvium and gneiss.

Being the oldest sediments, the Proterozoic of Rajasthan have been studied in great detail. Each super group of this age is well defined by regional unconformities and structural discordances. The details on the various folding events reported within the Proterozoic rocks of this area, can be summarised as under. Stratigraphy of region is given in table no. 2.1

(a) Bhilwara Supergroup

The rocks of the Bhilwara super group (formally the B.G.C.) constitute the basement for the massive younger lithological sequences. The main rock types are various gneisses, schists, amphibolite, ultramafic and associated intrusive. The Bhilwara super group of rocks are predominantly occurring in the eastern and southeastern parts of Rajasthan around Bhilwara, Ajmer, Nathdwara, Mangalwar etc. These rocks exhibit a complex history of structural style and polyphase metamorphism. The details on the subdivisions of the Bhilwara super group, their lithologies and associated intrusive bodies are given in Table. 2.2.

Table No. 2.1

Stratigraphic succession

Erol/period	**Super group**	**Group**	**Formation**	**Lithounit**
Proteerozoic	Delhi (South)	Bhim	Dungarkhera Todogarh	Pelitic and semi pelitic schist calc gneiss and marble
		Rajgarh		Pelitic schist with quartzite
		Sendra		Metavalcanics, impure marble, pelitic, schist
		Barotiya	Barotiya	Metavolcanics, impure marble
			Nanana	Marble
			Barr	Mica schist, conglomerate
		Gogunda	quartzite	
	Aravalli	Debari	Zawar/Jahazpur, sawar	Pb – Zn bearing dolomite
			Rampura – Agucha, pur-Banera	
			Rajpura – Dariba	
			Udaipur	Greywack, phyllite
			Umra	Carbon phyllite
			Jhamarkotra	Phosphorite bearing dolomite
			Debari / Jaisamand	Conglomerate, quartzite arkose
Archaean	Mongalwar complex			
Bhilwara / Banded Gneissic Complex	Sandmata complex			Two pyroxene granulite leptinite, charnockite-en-derbite, pelitic granulite

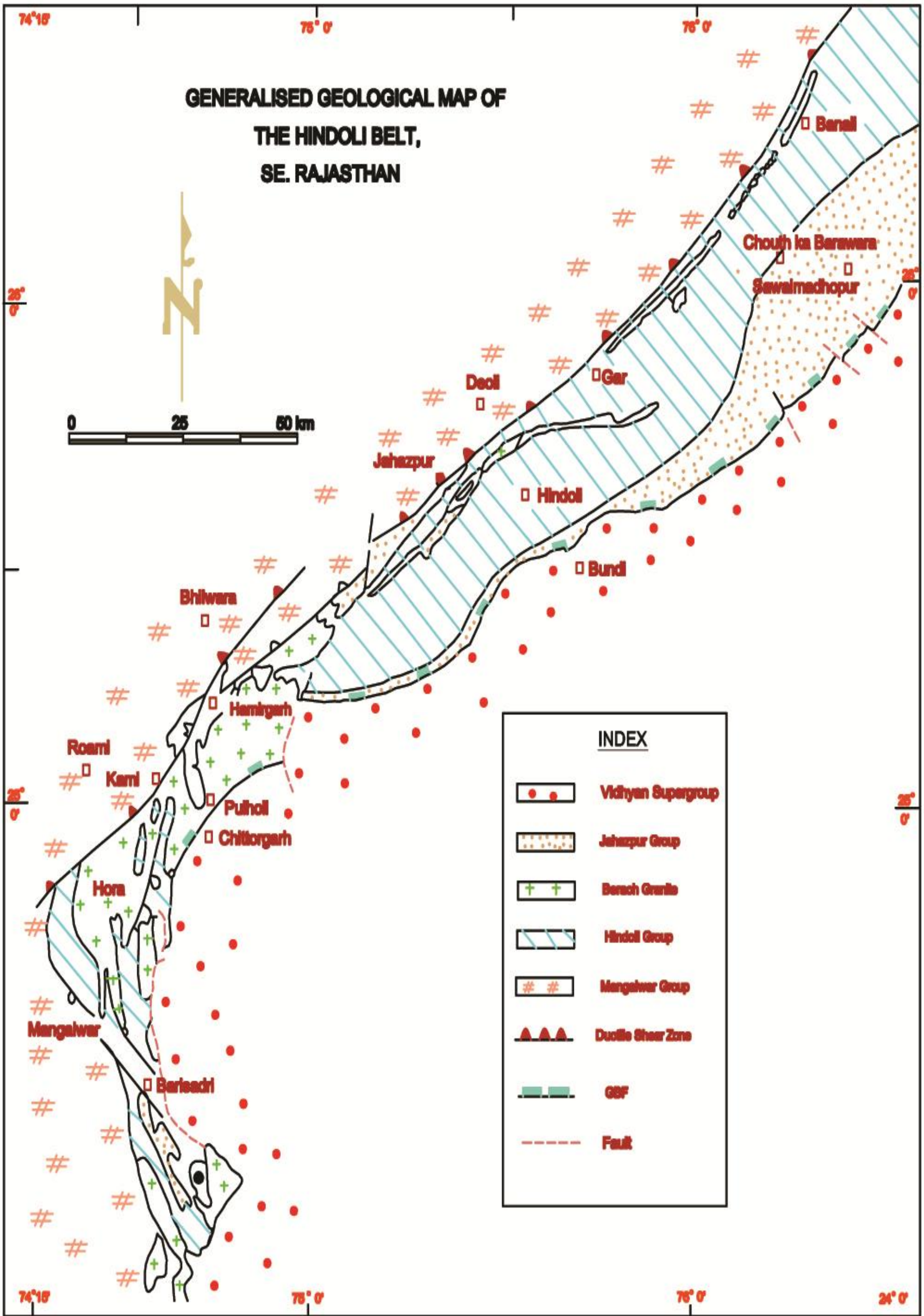
Source – Geology of |Rajasthan book by S. Sinha-Roy

Subdivision of Bhilwara group are as follow –

- **Hindoli group –** The stratigraphic status of this group is not unequivocal because of the uncertainty as to whether the Berach granite is the basement or is intrusive into these metasediments. A characteristic feature of the Hindoli group is the presence of both felsic and basic volcanics and volcaniclastics inter bedded with turbidities. The sequence is contained in an arcuate belt sandwiched between the cratonic BGC terrain on the west and platformal Vindhyan sediments on the east. The rocks have undergone greenschist to lower amphibolite facies metamorphism with local development of andalusite. The contact of the Hindoli metasediments with the mangalwar complex is variably interpreted as a migmatitic front (Gupta et al. 1981) and a thrust which has brought up and juxtaposed the Mangalwar migmatites against the Hindoli group (Sinha – Roy and Malhotra 1989).

  Generalised geological map of Hindoli Belt is presented in mapno.-10

- **Mangalwar complex –** A heterogeneous assemblage of amphibolite-facies metamorphites comprising migmatities, composite gneisses, feldsparthic mica-schist, garnetiferous biotite schist, staurolite garnet-biotite schist, sillimanite-kyanite-mica schist, hornblende schist, granite gneiss and amphibolite along with minor carbonates constitute the Mangalwar complex (Gupta et al. 1981). The area contains metasediments represented by corbonates, calc-silicate, rocks, quartzite iron formation and pelitic schists all of which occur as small bands and irregular enclaves within the granitoid rocks. The area around Kankroli to lawa Sardargarh represents the type area of the Mangalwar complex (BGCII, Gupta, 1934) occurring to the north of the Banās lineament chemical data of the gneiss from Devgarh area suggest their tonalitic composition. Further south of Ajmer region in Bhim-Karera areas the pelitic gneisses become progressively migmatitic and strong anatexis has taken place.
- **Sandmata complex –** The high grade metamorphites, comprising migmatities, composite gneisses, biottie-schist, garnet-silimanite-staurolite–biotite schist, dolomite marble, hornblende schist with associated granite, enderbite, charnockite, norite and pyroxene granulite, are included in the sendmata complex (Gupta, 1981) The boundary between the sandmata complex and the Mangalwar complex is marked by isograd roughly along the Delwara lineament.



Generalised geological map of the Hindoli Belt, SE Rajasthan (modified after Sinha - Roy and Malhotra, 1989)

Table No. 2.2

Litho – Stratigraphy of the Bhilwara supergroup

(3200 m.v. to 2500 m.y.)

Group	**Lithlogy**	**Intrusives**
Hindoli/Sawar	Slate, phyllite, metagreywacke and metavolcanics	Pegmatites granites and basic rocks (Berach, untala and gingla granites)
Mangalwar complex	Migmatitie, composite gneisses, feldspathised mica-schists, schists, amphibolite, dolomite, dolomitic marble and quartzite	
Sandmata complex	Migmatite, biotite schists, gneisses amphibolite, pyroxene, granulite, dolomitic marble and ultramafic rocks	

(B) Aravalli supergroup

The Sediments of the Aravalli supergroup, unconformably overlying the pre-Aravalli (Bhilwara supergroup) rocks, mainly include the rocks of the Aravalli system and raialo series put forward by Heron (1953). The Aravalli supergroup of rocks in their type area around Udaipur and south Rajasthan are composed of pelitic and calcareous metasediments with basic flows. These rocks have undergone polyphase deformation and metamorphism. A number of lithostratigraphic units have been recognised in the Aravalli rocks or both shelf and deep sea facies (Paliwal, 1981 and Roy, 1990). The rocks of Aravalli supergroup show a complex deformation history and have undergone four phases of folding viz, AF_1 AF_2 AF_3 AF_4 (Naha and Halyburton, 1977, Naha 1967, 1984) The Aravalli sediments are also characterised by a number of ductile shear zones and brittle faults. The rocks of Aravalli supergroup are also intruded by the Udaipur and Darwal granites in Udaipur area and ultramafic intrusives in Rakhabdav, gogunda area.

The Aravalli supergroup of rocks have been further subdivided into groups and formations. Litho-stratigraphy of the Aravalli Supergroup of rock shown in the table no. 2.3

Aravalli supergroup of rocks have been further subdivided into group and formation.

- **Lunawada group –** The rock sequence comprising coarse pelitic schist and quartzite with phosphoritic dolomite that occur in a roughly polygonal area in southern Rajasthan is referred to as the Lunawada group (Gupta, 1981), except for the coarsening of the lithotypes the rocks resemble the shelf facies sequence of the aravalli stratigraphy. As the Rakhabdav ultramafic line in the type area separates the deep sea Jharol group in the west and the shelf facies Dabari group in the east. It is most likely that the Lunavada group represents a part of the Jharol as well as Debari group.

- **Udaipur group –** The lithosequence comprising greywacke and phylite is best developed around Udaipur and hence, it is designated as the Udaipur group.

Table no.: 2.3

Litho-stratigraphy of the Aravalli Supergroup of rock (2500 M.y. to 2000 M.y.) [after Gupta et al. 1992]

Group	Formation				Lithology
CHAMPANER GROUP	Rajgarh Formation Shivrajpur Formation Jaban Formation Narukot Formation Khandia Formation Lambia Formation				Metasubgraywacke, phyllite, mica schist, quartzite, gneiss and petromict metaconglomerate, minor dolomitic limestone and manganiferous phyllites
LUNAWADA GROUP	Kadana Formation Bhukia Formation Chandanwara Formation Bhawanpur Formation Kalinjara Formation				Phyllite, mica, schist, quartzchlorite schist, metasemipelite, metaprotoquartzite and quartzite with minor dolomitic limestone, petromict metaconglomerate, manganiferous phyllite and phosphatic algal dolomite
UDAIPUR GROUP	Udaipur Sector Banswara Fm. Nimachmata Fm Balicha Fm Eklinggarh Fm. Sabina Fm.		Sarada Sector Zawar Fm. Baromogra Fm. Mandi Fm		Phyllite, metagraywacke, micaschist, migmatite, quartzite, dolomite, marble, phosphatic stromatolite bearing dolomite, chert and amphibole schist
DEBARI GROUP	Debari sec, jhamarkotra Fm. Berwar Fm. Jaisamand Fm. Delwara Fm. Gurali Fm.	Jaisamand Sec. Babarmol Fm. Dokankotra Fm. Jaisamand Fm. Delwara Fm.	Sarara Ki Pal Sec. Kathalia Fm. Sissmogra Fm. Jaisamand Fm. Delwara Fm.	Ghatol Sec. Jagpura Fm. Mukandpura Fm. Jaisamand Fm. Delwara Fm Gurali Fm	Petromict conglomerate, meta-arkose, quartzite, phylite, mica schist, basic metavolcanics with associated pyroclastics, calcareous quartzite, dolomites, limestone, calcitic marble, ferruginous chert, aigal phosphatic dolomite and chert, carbonaceous.

(Sinha-Roy 1993b). It shows extensive development in Nathdwara areas constituting the bulk of the shelf facies rocks.

- **Debari Group –** The litho-assemblage comprising coarse clastics, carbonates and pelites constitute the middle Aravalli sequence and is designated as the Debari group (Sinha-Roy 1993b)

(C) Delhi super group

Lying unconformably over the older sediments of Bhilwara and Aravalli super group, the Delhi supergroup of rocks form a major constituent of the Aravalli mountain range. These marine clastics with subordinate chemogenic sediments are characterized by a number of concordant/discordant intrusive as well as extrusive phases. The rocks of the Delhi supergroup extend in a NE–SW trending rectilinear belt from Delhi in the north to Himmatnagar in the south for almost 850 km length. These rocks forming the Aravalli orographic axis separate the plains of marwar in the west from the hilly tract of mewar in the east. They punctuate in the desert sands in northeast Rajasthan and from north of Sambhar lake, continue as isolated ridges into the main expanse of Delhi's in northeastern Rajasthan. In the southwest beyond Himmatnagar the solid geology is lost under the alluvial over.

The rocks of the Delhi super group were affected by multiple episodes of folding viz Df_1 (AF_2) DF_2 (AF_3) and DF_3 (AF_4) and polyphase metamorphism. The sedimentary and volcanic rocks of the Delhi's are found to have recrystallised first under regional metamorphism. Which was later superimposed by the thermal metamorphism.

Further classification of Delhi Super group of Rocks, Various groups, belonging to different sectors are shown in table no. 2.4

- **Sandra group –** It comprises interbanded metavolcanics, impure marble, subarkose, pelites and calc-schists with band of conglomerate. Juxtaposition of the Sendra group and the Bhim group occurring in the east of the SDFB has resulted from tectonic pinching of the central basement inlier, east of phulad. The Devgarh-phulad section gives a cross section of the phulad ophiolite belt. The sendra group is represented by marble, metachert, meta-rhyolite and meta-basalt, interpreted as volcanic are sequence. Bhim group represents the major part of the east Delhi sequence in central and Southern Rajasthan.

Table 2.4

Litho-stratigraphic classification of Delhi Supergroup (after Gupta et al., 1992)

<table>
<tr><td></td><td colspan="2">South-western Rajasthan and North-eastern Gujarat</td><td>Ajmer Sector</td><td>North-eastern Rajasthan</td></tr>
<tr><td rowspan="3">INTRUSIVES (Post Delhi)</td><td colspan="2">MALANI IGNEOUS SUITE
Plutonic and volcanic</td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td colspan="2">ERINPURA GRANITE</td></tr>
<tr><td colspan="2">GODHRA GRANITE GNEISS</td></tr>
<tr><td rowspan="7">DELHI SUPER GROUP 2000-740 M.y.</td><td>PUNAGARH GROUP (Sojat, Bambolal, Khambal and Sowania Formations)</td><td>SINDRETH GROUP (Angor and Goyali Formations)</td><td rowspan="3"></td><td rowspan="4">DADIKAR, BAIRATH AND SIKAR GRANITES</td></tr>
<tr><td colspan="2">SIROHI GROUP (Jiyapura, Reodhar, Ambeshwar and Khiwandi Formations)</td></tr>
<tr><td colspan="2">SENDRA AMBAJI GRANITE AND GNEISS</td></tr>
<tr><td colspan="2">PHULAD OPHIOLITE SUTTE</td><td>KISHANGARH SYENITE</td></tr>
<tr><td colspan="2">KUMBHALGARH GROUP (Todgarh, Beawar, Kotra, Ras, Barr, Sendra, Kalakot and Basantgarh Formations)</td><td>AJABGARH GROUP (Ajmer Formations)</td><td>AJABGARH GROUP (Kushalgarh, Sariska, Thanagazi, Bharkol and Arauli Formations)</td></tr>
<tr><td colspan="2">GOGUNDA GROUP (Richer, Antalia and Kelwara Formations)</td><td>ALWAR GROUP (Srinagar and Naulakha Formations)</td><td>ALWAR GROUP (Rajgarh, Kankwarhi, Pratapgarh, Nithar, Badalgarh and Bayana Formations)</td></tr>
<tr><td colspan="2"></td><td></td><td>RAIALO GROUP (Dogeta and Tehla Formations)</td></tr>
</table>

(D) Vidhyan Super group

Lying unconformably over the Aravalli supergroup of rocks is a thick pile of siliceous, argillaceous and calcareous sedimentary sequence designated as the Vindhyan super group. These sedimentaries, on account of their structural discordance with the Delhi sediments, have been considered to be the last member of the Proterozoic era, deposited in the eastern margins of the Aravalli orgenic complex around areas of eastern Rajasthan. At chittaurgarh and further northeastward, these horizontally to sub- horizontally disposed vindhyans are seen in contect with the highly folded Aravalli rocks, which is attributed to a major fault viz, 'The Great Boundary fault' (GBF) A generalized stratigraphy of the Vindhyan super group of rocks is given in table no. 2.5

Table 2.5

Generalized litho-stratigraphy of Vindhyan Supergroup

(after G.S.I., 1980)

Group	**Lithology**
Bhander	Shales, limestones, dolomites and sandstones
Rewa	Shales, sandstones and conglomerate
Kaimur	Quartzite-gritty to conglomeratic, shales, brecciea, sandstones, mudstones and siltstones
Semri	Shales, limestones, sandstones with basal quartzite and conglomerate

Igneous Intrusives/Extrusives

The rocks of the bhilwara, Aravalli and Delhi super group have been influenced by the episodic intrusions of igneous activities, either synchronous to the folding event or in the waning phase of the deformation few important igneous intrusives having significant bearing on the geological evolutionary history of the Rajasthan Proterozoics are as under:

(A) **Bhilwara Super group –** These basement rocks have been intruded by the acidic igneous activity around 2060 ma. Coinciding with the E-W. Aravalli B.G.C. folding (AF_1) and metamorphism (Sharma 1980). These potassic to granodioritic tonalitic granites the Berach, Untala and Gingla granites are occurring within the type area.

(B) **Aravalli Super group –** The igneous activities associated with the Aravalli sediments are characterised by the magmatic materials of doleritic, epidioritic basaltic sill and dyke type, ultramafic, amphiolitic and granitic composition. The Udaipur, Amet and Darwal granites are the important granitic bodies emplaced around 1600 ± 50 ma. Coinciding with the $DF+_1$ (AF_2) folding.

(C) **Delhi Super group –** igneous activities followed the uplift of Delhi super group rocks during the last stage DF_2 (AF_3) was the major one, affecting large areas of Aravalli proto – continent these metasediments have witnessed intrusions of meta basics, metavolcanics, ultramafics and nepheline syenities.

Chapter - III

Climate and Soil

[I] CLIMATE

Climate is a significant parameter which affects the various stage of the morphogenic process, erosion, transportation and deposition. The climate not only influences weathering but also does effect the processes of climate on the morphogenic process in reflected in two different ways in the nature of processes (qualitative manner) and in their intensity (quantitative manner). Atmoshpheric factors also affects the intensity of fluvial processes. The seasonal distribution of the Rainfall is one of the factors in the regime of a stream and it's influence is reflected in the intensity of a stream flow.

The climate in India keeps varying as per the latitude, altitude and season. The climate in Rajasthan keeps varying because of it's topography. Rajasthan is the driest region in India. Rajasthan is located in the north western part of India and thus, it is more prone to different climatic changes. The climate of Rajasthan state has varied contrasts and the presence of Aravallis is the greatest influencing factor. The western part of Rajathan is dry and infertile, while the southwestern part is hilly and wet. The climate of Rajasthan keeps verying throughout the state. In the desert areas, it is usually hot and dry in summer and cold during the winters. Coming to the Aravalli range, to the west, both rainfall and humidity are low. While to the east, weather can be characterized by high humidity and better rainfall.

Under the Koppen climate classification the greater part of Rajasthan falls under hot desert (BWh) and remaining portions of the state falls under hot semi Arid (BSh), the climate of the state ranges from arid to semi-arid. The state can be broadly divided into arid, semi arid and sub-humid regions on the basis of Rainfall intensities. Rajasthan receives low and variable rainfalls and thereby is prone to droughts.

The Khari river basin is situated in the South-eastern part of Rajasthan. Climatically the Khari river basin is a part of the semi-arid climatic region of Rajasthan where there are extremes of temperature, low rainfall, greater evaporation and evapotranspiration and scarcity of natural vegetation. Therefore the climatic analysis of this area will provide a sound understanding of various morphogenic processes transforming the existing topography. Meterological department of India has divided the whole year into four seasons-

(i) Pre monsoon or summer season (early march to last week of June.)

(ii) South-west monsoon season or Rainy season (end of June to mid September)

(iii) Post-monsoon (mid September to the last week of November)

(iv) North-east monsoon or winter season (Last week of November to the end of the February.)

(i) **Summer Season-** Due to northward migration of sun this season is marked by appreciable rise in temperature and decrease in barometric pressure during the months of March, April and May. Dry land winds prevail in this area and therefor the temperature is the highest. May is the warmest month in this area. The highest temperature is recorded in the month of May is 41.8^{0}C and the lowest temperature is 25.8^{0}C.

In the morning the sky is clear and visibility is good. As noon approaches dust starts scattering in the sky. By the afternoon, the visibility would, generally remain moderate to poor. Winds are generally westerlies, nights are generally pleasant and cool due to appreciable fall in the temperature.

Climate graph and temperature graph of different districts of study area are presented in fig. 1 to 8.

Fig. 1

CLIMATE TONK

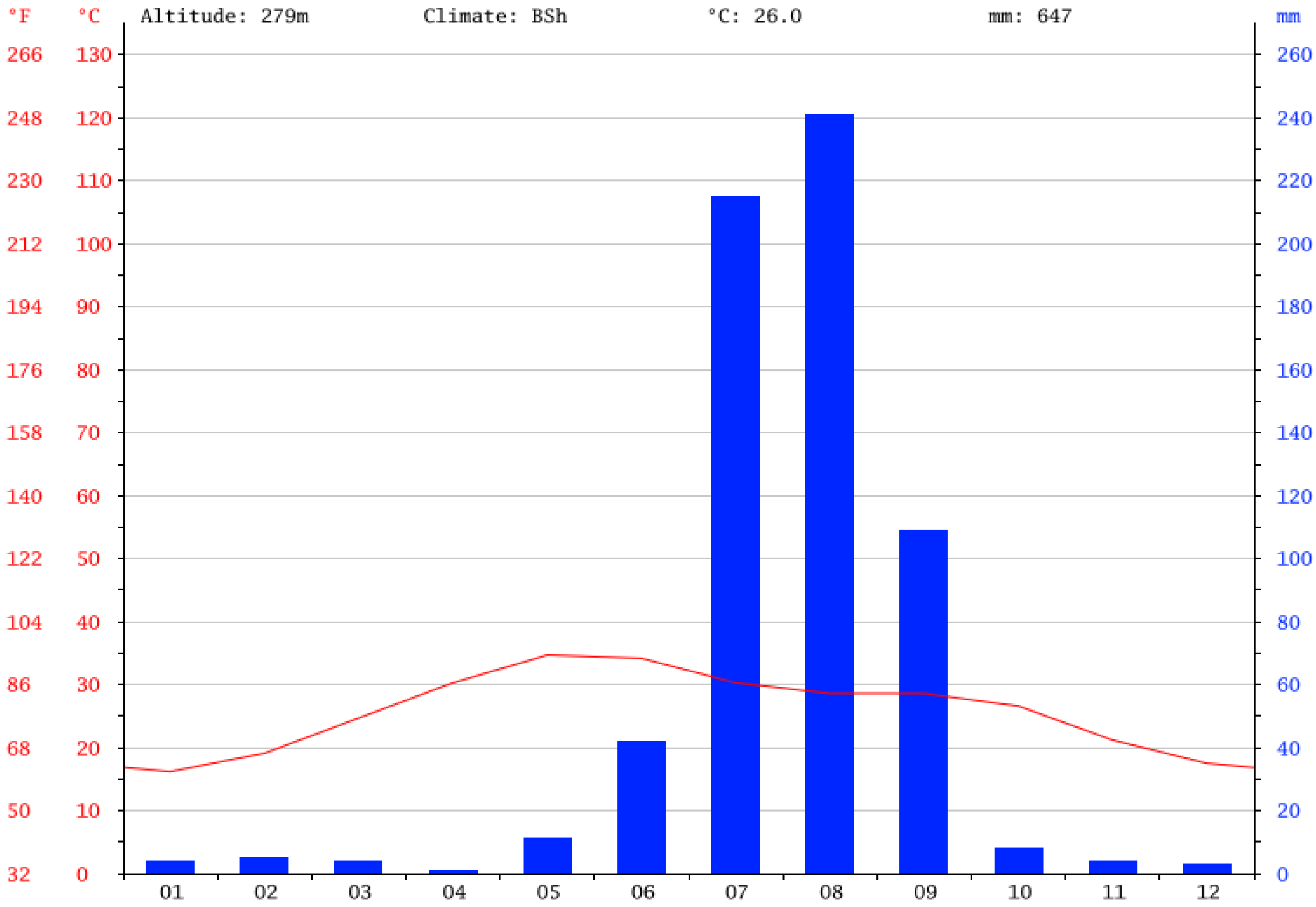


Fig.- 2

CLIMATE RAJSAMAND

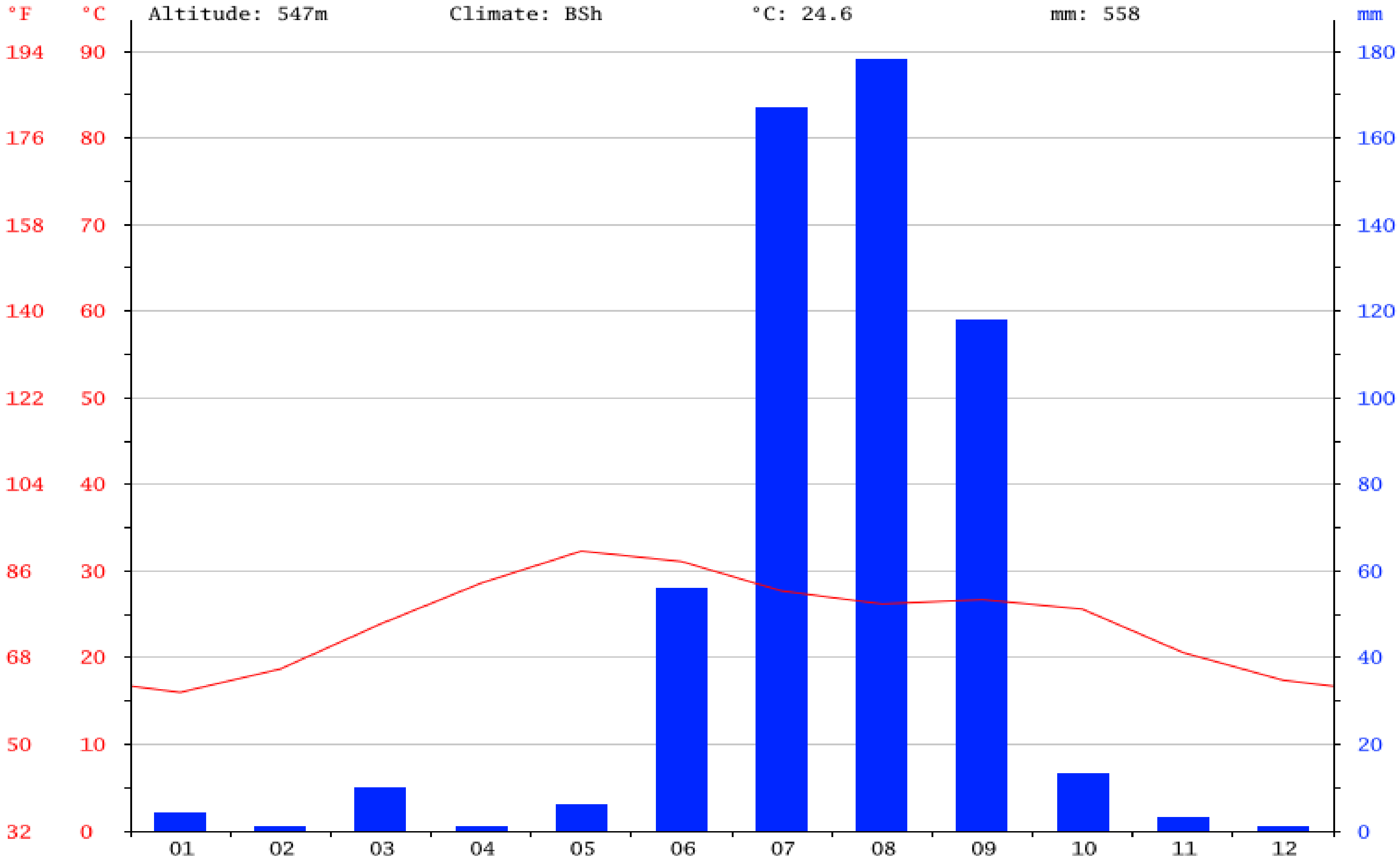


Fig.- 3

CLIMATE BHILWARA

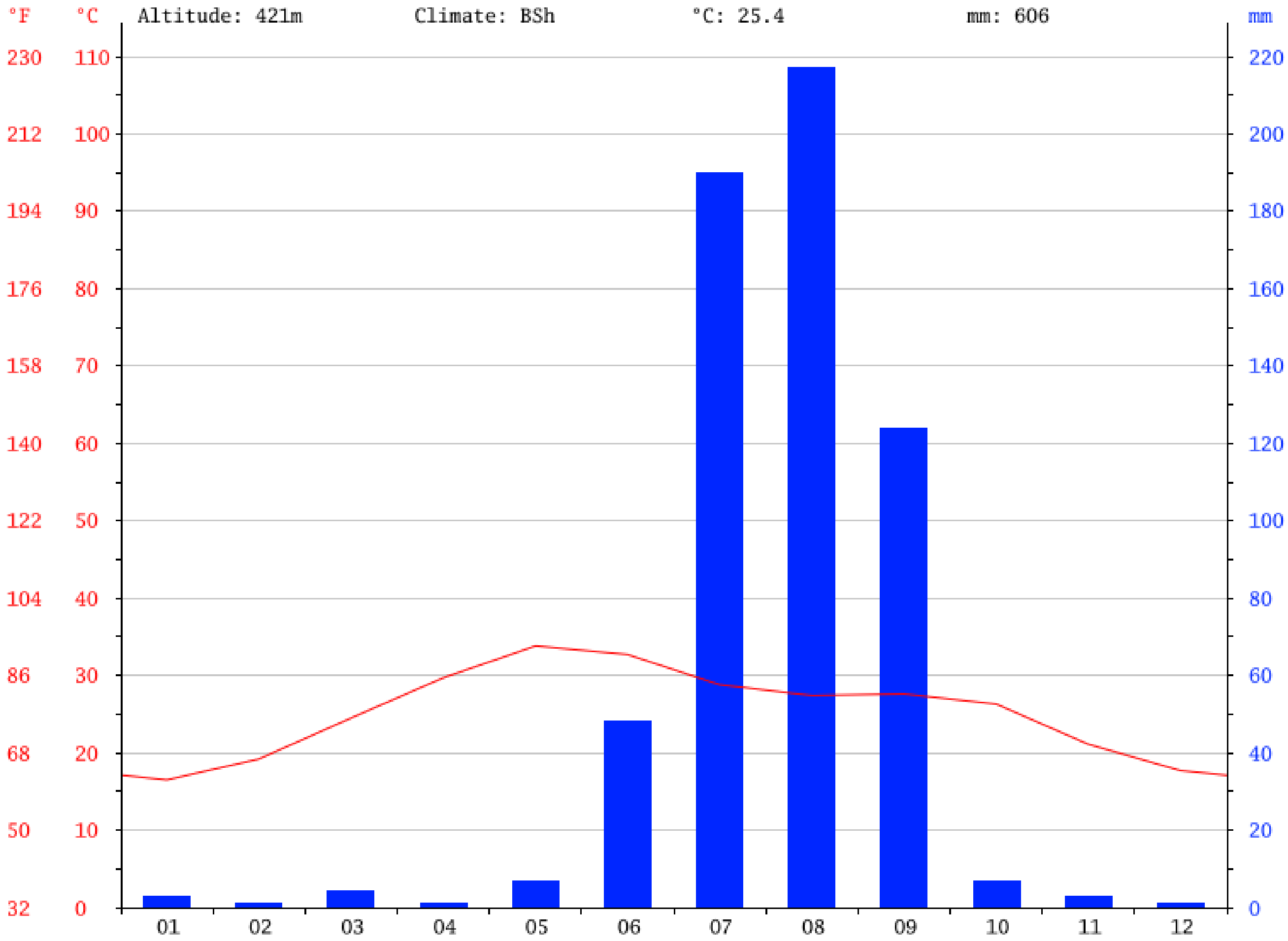


Fig.- 4

CLIMATE AJMER

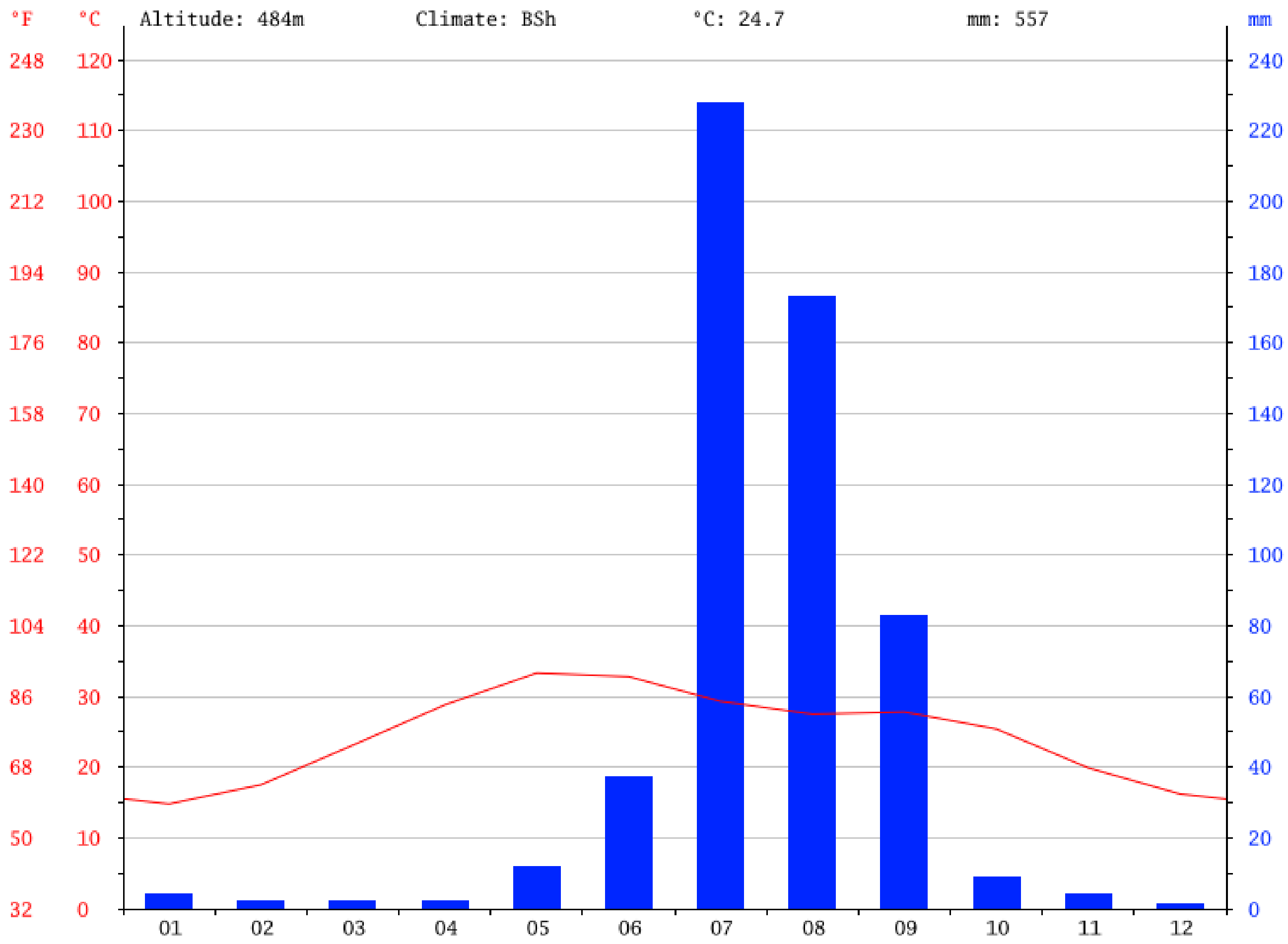


Fig.- 5

TEMPERATURE GRAPH TONK

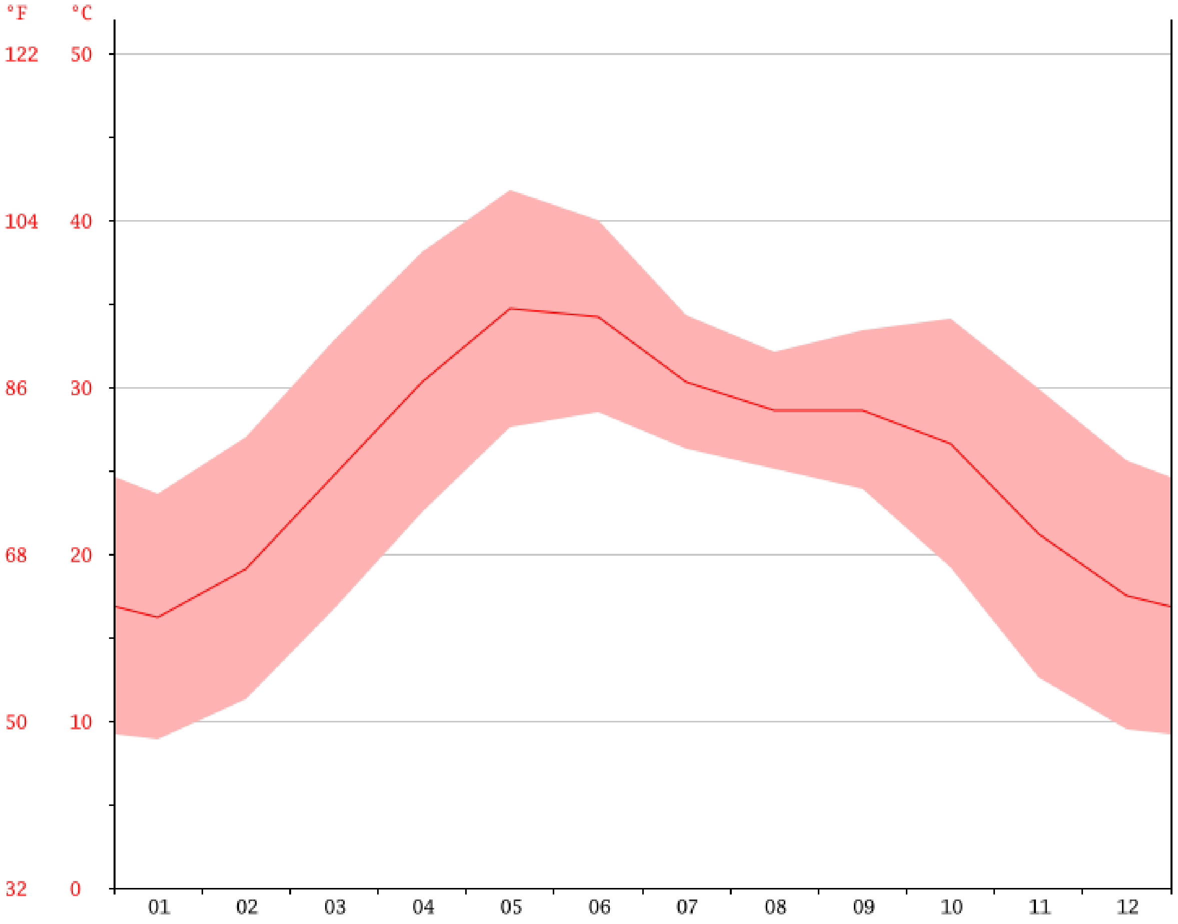


Fig.- 6

TEMPERATURE GRAPH RAJSAMAND

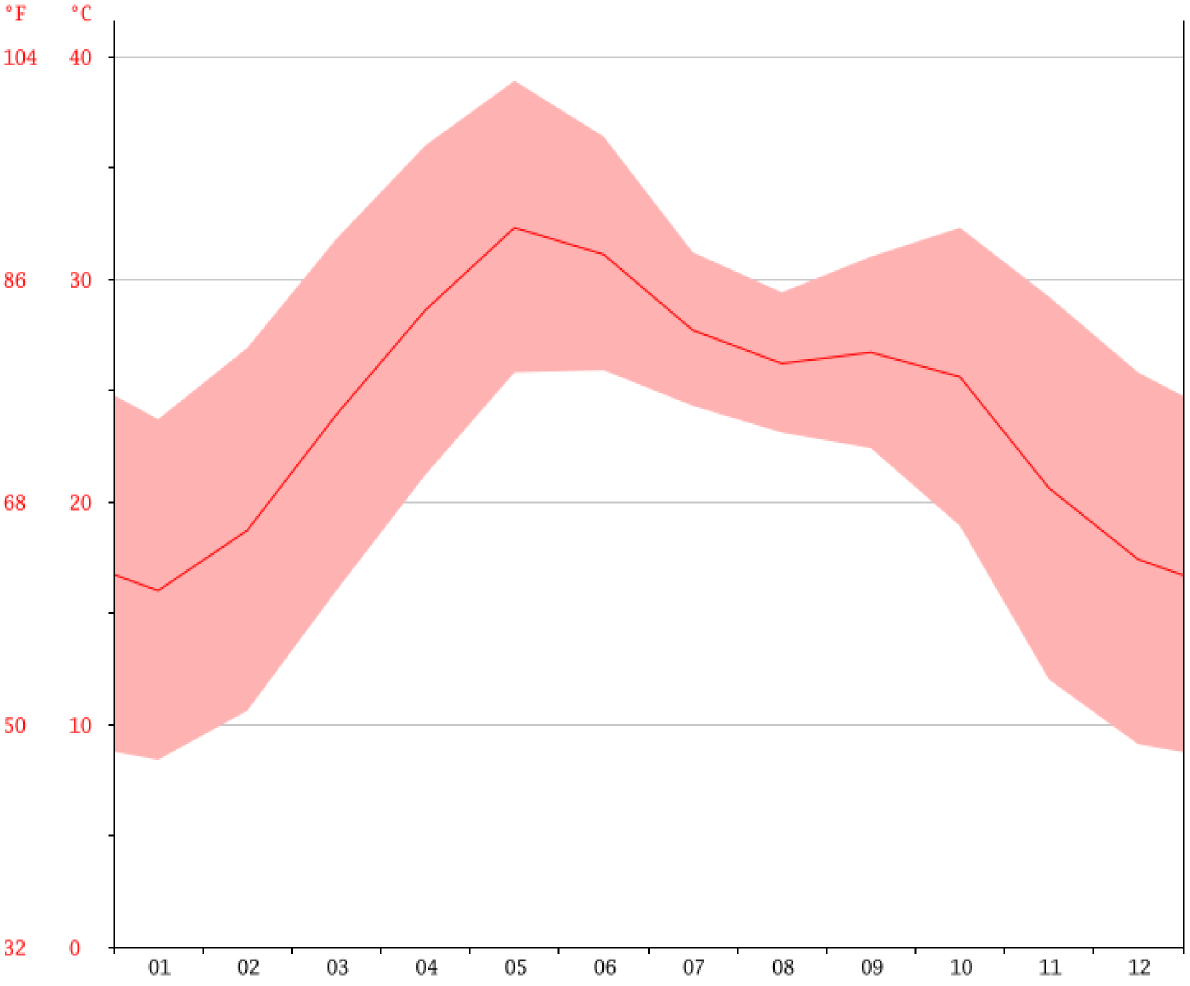


Fig.- 7

TEMPERATURE GRAPH AJMER

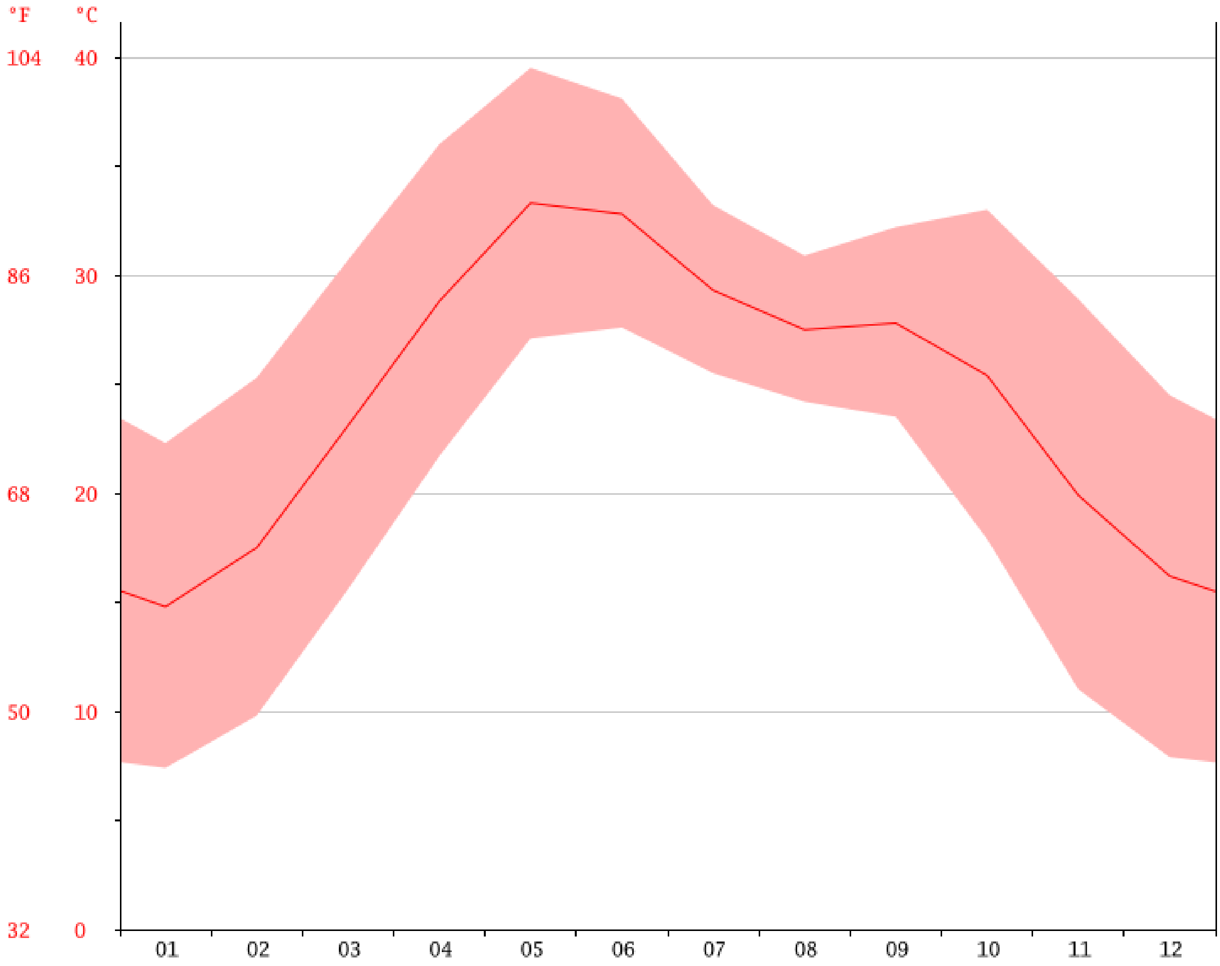
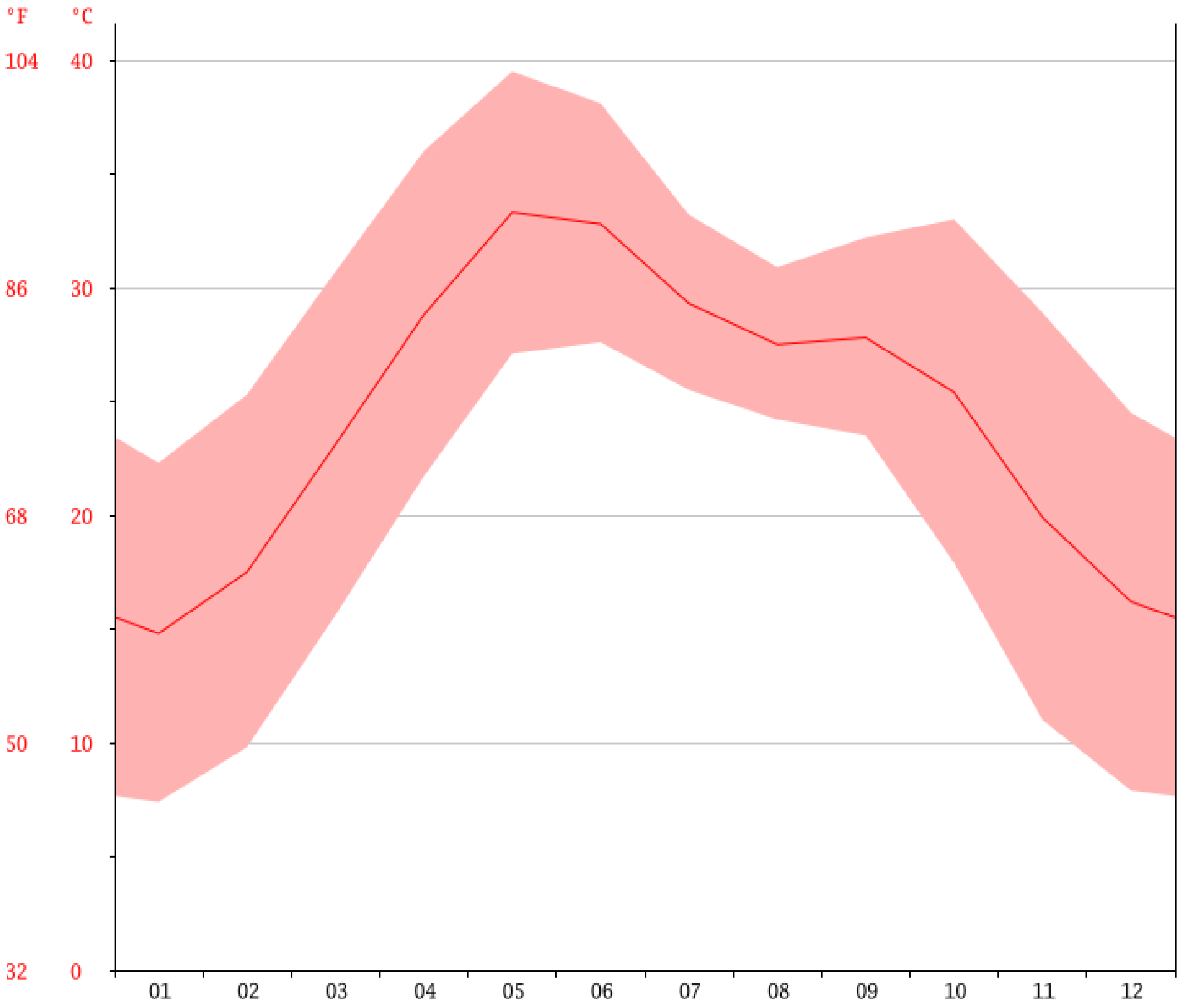


Fig.- 8

TEMPERATURE GRAPH BHILWARA



(ii) South-west monsoon season

Rainy season starts when the summer condition reach their Peak and Scorching heat. During the day time become almost unbearable. The max diurnal temperature in the month of May crosses the high of 40^0C. At this junction formation of low pressure in the area invites south west monsoon, which sets in by the end of June or at times by early July and as maintained earlier, it continues up to September end. Rainfall during the period is normal except occasional. Peak rainfall lies between July and August.

Actual rainfall of monsoon 2016 in Rainguage station of study area is given in the table no. 3.1

(iii) Post monsoon season

The SW monsoon starts retreating from the area by the end of September or early October. The retreat concluding itself by the end of November. The month of October and November are marked by the transient conditions preceding onset of a dry winter season. The phase of transition from the monsoon to the winter covers probably the most conducive weather conditions. The temperature remains rather uniform and sky remains clear. The mean monthly temperature recorded in this area during the months of October, November are 25.6^0C and 21.6^0C respectively. The fall in the temperature heralding the onset of winter season is slow steady and one is invariably spared of the temperature shocks.

(iv) Winter season

During winters, sun migrates to the southern hemisphere. Subtropical anticyclonic shell extends from west and it controls the pressure gradient, tempreature and wind condition, clear sky, fine weather, light north westerlies, low humidity, low tempreature and large day time variation of tempreature are the normal features of this season.

The settled conditions are broken at intervals by shallow cyclonic depressions which travel across the area. Their approach is marked by rise in temperature and their departure is marked by fall in temperature. Scanty rainfall due to North West

Plate – 8

Khari river in summer season

Plate – 9

Khari river in Rainy season

Table No.- 3.1

Actual Rainfall in Rainguage station of study area in 2016

District	Name of Station	Actual rainfall (MM)
Ajmer	Sarwar Thana	707
	Narain Sagar	584
	Beawar	526
	Ajmer	456
	Bandar Sindri	448
	Govindgarh	263
Bhilwara	Jetpura	1138
	Gangapur	991
	Kothari	901
	Naharsagar	869
	Ummed Sagar	845
	Meja Dem	843
	Agucha	824
	Arwar Dam	794
	Gulabpura	774
	Sareri Dam	563
	Patan Tank	562
	Chardrabhaga	536
	Khari Bundh	456
Rajsamand	Bharai	780
	Rajsamand	736
	Chikliawas	698
	Nandsamand	591
Tonk	Galwania Bundh	999.00
	Toda Raisingh	975
	Bisalpur Dam	899
	Niwai	845
	Motisagar	790
	Panwar Sagar	781
	Deoli	753
	Galwa Tank	742
	Mashi Tank	706
	Thikriya	688
	Peeplu	669
	Tonk	629
	Lamba Harisingh	607
	Nasirda	606
	Tordi Sagar	592
	Chandsen	516

Source- Monsoon Report-2016, water resources department of Rajasthan

disturbance is a common feature of this season. Occasionally heavy snowfall in the hills in north India causes a very cold weather and fall in pressure. The cyclone and a cold wave therefore result. The recorded rainfall in this area in the month of January was 4 mm and in the month of February was about 3 mm.

December and January are the coldest month the mean average, maximum and minimum temperature are 17^0C, 24.8^0C, 8.9^0C respectively.

Main Climatic conditions-

The climatologists have identified the following as key elements of the climate. As seasons are caused by a particular behaviurism of these elements detailed in the following paragraphs is the way these elements have been behaving in the area under study.

(A) Rainfall (trend and distribution)

As stated earlier most of the normal annual rainfall is received during the months of July and August. These months remain the wettest ones. The rainfall in the area is attributable to the South-West monsoon or the retreat there.

The characteristics of the monsoon rainfall can be better comprehended with the help of the graphs and table.

Average annual rainfall in Khari river basin is presented in map no-11. And average monthly data of rainfall is given in table no. 3.2. and presented in fig. 9. Average no of rainy days in months data is given in table no. 3.3. Average Annual Rainfall of Last Years in different Tehsils of Khari river basin area is shown in Table no. 3.4. and presented in fig. 10. Rainfall data recorded at all tehsil rainguage station 2016 is given in table no. 3.5. District Average Basis Rainfall-2016 is given in table no. 3.6 and presented in fig. 11.

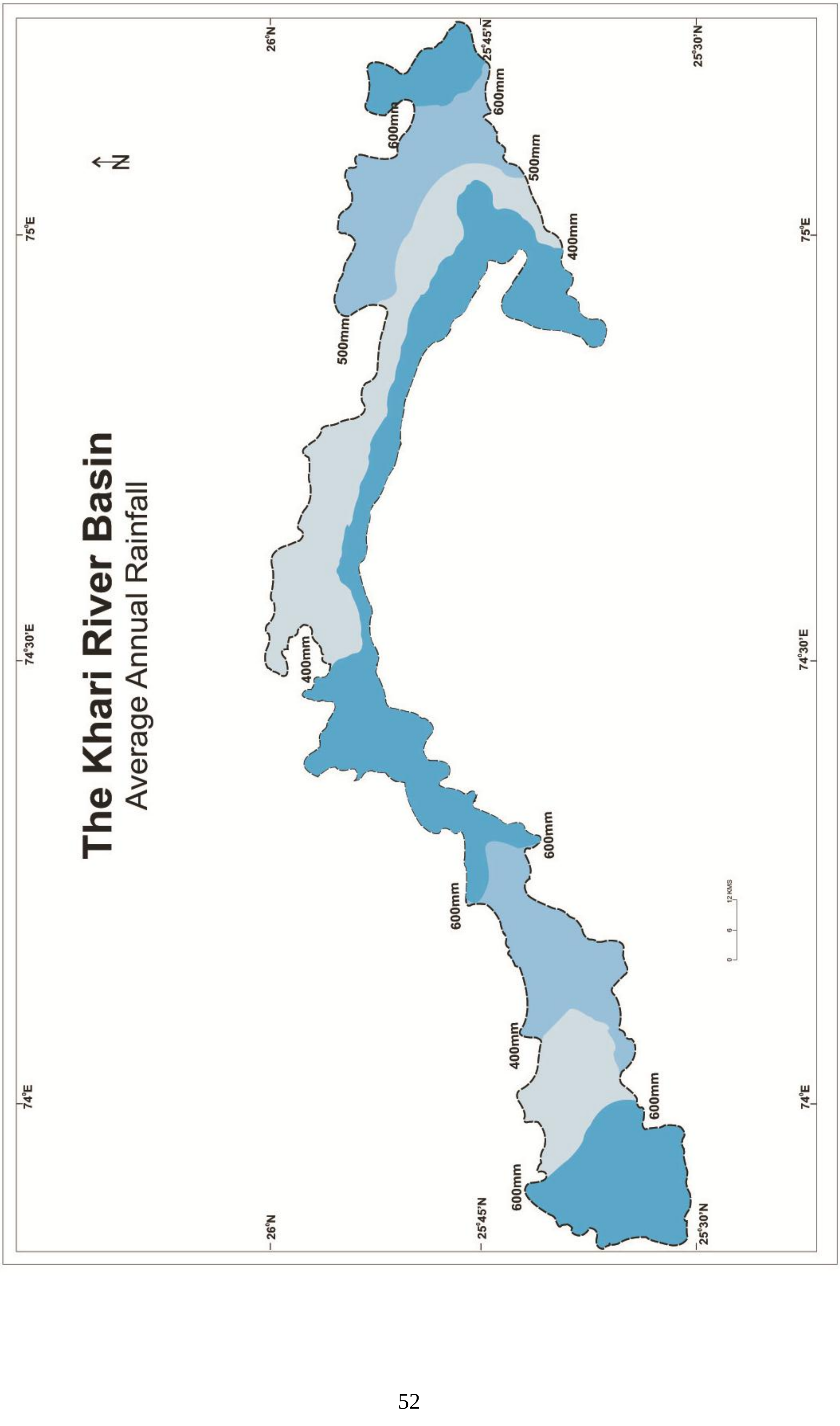

The Khari River Basin
Average Annual Rainfall
N
26°N
25°45'N
25°30'N
74°E
74°30'E
75°E
600mm
500mm
400mm
0 6 12 KMS

Table No.- 3.2

Average Monthly Rainfall (MM)

Tehsil	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**August**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Beawar	0	0	5	35	9	198	68	163	43	1	0	0
Kekri	0	0	0	27	18	128	71	66	71	3.2	0	0
Bhim	0	0	0	11	60	29	43	148	81	6	0	0
Devgarh	0	0	0	30	44	72	57	164	93	33	0	0
Tonk	0	0	0	0	32	105	130	172	75	4	0	0
Banera	0	0	1	19	7	159	140	65	130	0	0	0
Shahpura	3	0	0	8	9	104	256	132	91	3	0	0
Asind	0	0	0	15	10	148	49	59	43	0	0	0
Mandal	0	0	3	16	0	198	114	109	151	0	0	0
Hurda	0	0	0	20	44	93	66	63	130	1	0	0

Source- Water resources department of Rajasthan

Fig.- 9

Average Monthly Rainfall (MM)

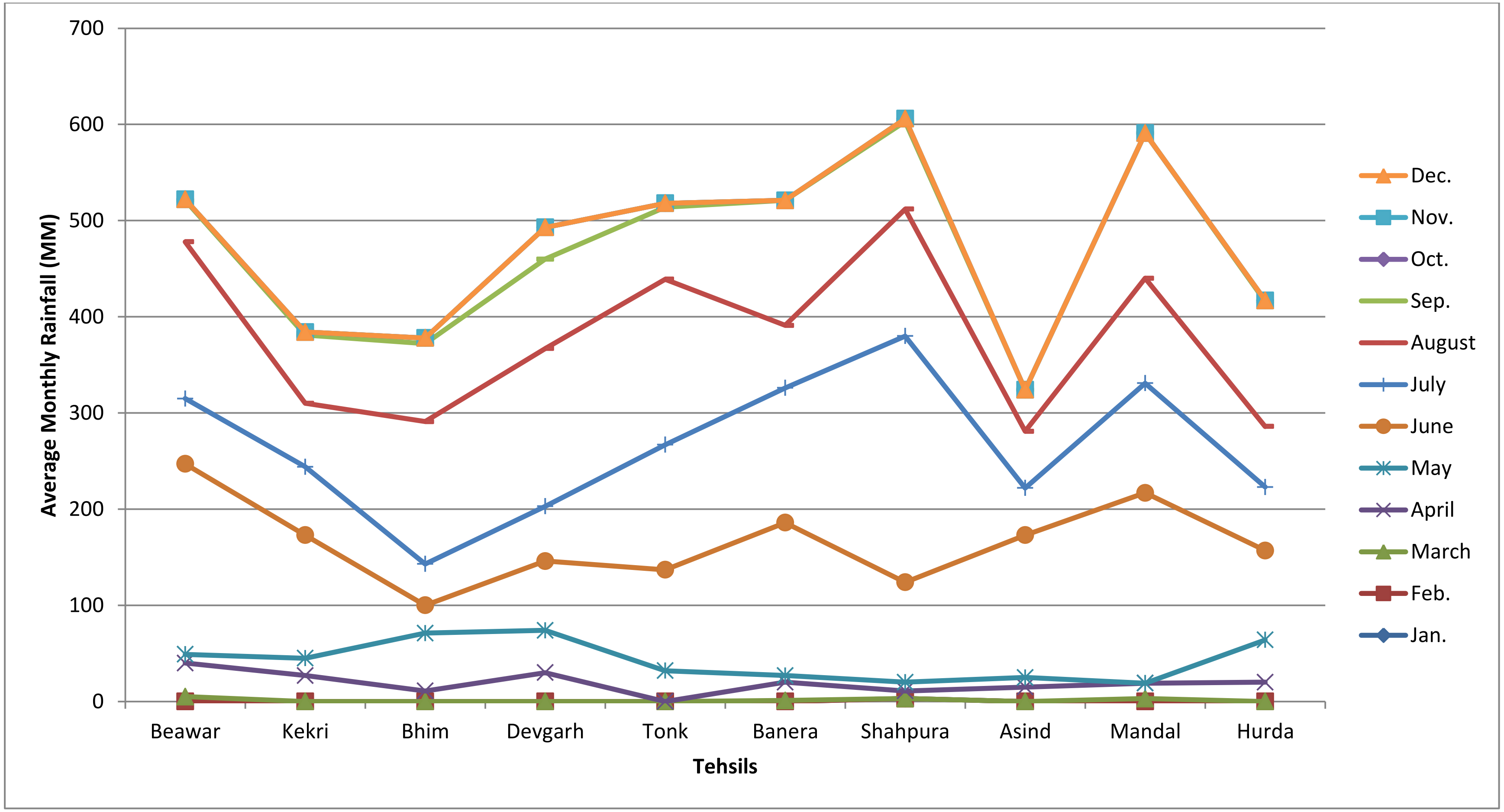


Table No.- 3.3

Average Number of Rainy days in months

Tehsil	Jan.	Feb.	March	April	May	June	July	August	Sep.	Oct.	Nov.	Dec.	Annual Rainy Days
Beawar	0	0	1	2	1	6	6	11	4	0	0	0	31
Kekri	0	0	0	2	2	10	6	6	8	1	0	0	35
Bhim	0	0	0	1	4	4	4	11	1	1	0	0	26
Devgarh	0	0	0	1	4	4	7	12	3	2	0	0	33
Tonk	0	0	0	0	3	7	10	8	5	1	0	0	34
Banera	0	0	0	1	1	7	9	6	8	0	0	0	32
Shahpura	1	0	0	1	1	6	10	5	4	1	0	0	29
Asind	0	0	0	1	1	8	5	6	3	0	0	0	24
Mandal	0	0	1	1	0	8	7	6	6	0	0	0	29
Hurda	0	0	0	2	4	8	8	6	8	0	0	0	36

Source- Water resources department of Rajasthan

Table No.- 3.4

Average Annual Rainfall of Last Years (MM)

Year	Asind	Banera	Hurda	Mandal	Shahpura	Bhim	Devgarh	Tonk
2001	645.0	710.0	556.0	670.0	618.0	774.0	280	630
2002	232.0	297.0	214.0	268.0	283.0	286.0	259	219.65
2003	321.0	448.0	624.0	535.0	575.0	416.0	485	700.20
2004	475.0	1179.0	548.0	841.0	1044.0	463.0	530	610.50
2005	531.0	505.0	461.0	390.0	556.0	656.0	680	551.90
2006	451.0	953.0	740.0	902.0	681.0	623.0	788	528.50
2007	463.0	460.0	581.0	439.0	593.0	452.0	509	566.30
2008	327.0	460.0	581.0	439.0	593.0	378.0	493	508.00
2009	568.0	681.0	676.0	632.0	677.0	377.0	321	515.50
2010	462.0	616.0	450.0	671.0	575.0	702.0	752	1089.50

Source- Water resources department of Rajasthan

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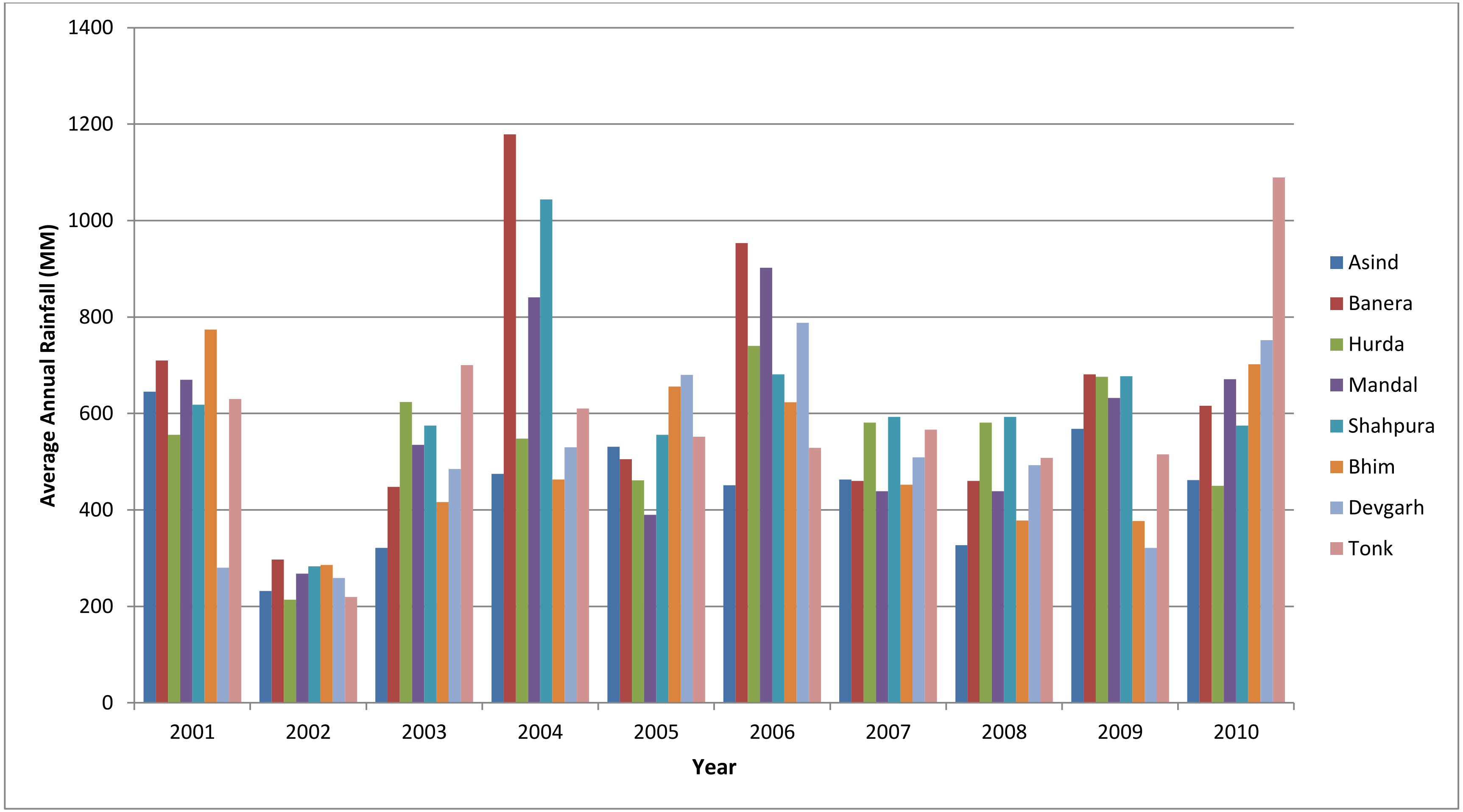
Fig.- 10

Average Annual Rainfall of Last Years (MM)



Total Rainfall Data Recorded at all Tehsil Rainguage stations from 1-06-2016 to30-09-2016 along with normal and percentage Deviation from normal figures.

Table No. 3.5

Rainfall Data recorded at all Tehsil Rainguage Stations (2016)

District	**Name of Station**	**Normal**	**Actual**	**Deviation**
		MM	**MM**	**%**
Ajmer	Beawar	429.60	555.00	29.2
	Kekri	429.60	553.00	28.7
Bhilwara	Asind	580.90	479.00	-17.5
	Hurda	580.90	891.00	53.4
	Mandal	580.90	869.00	49.6
	Banera	580.90	804.00	38.4
	Shahpura	580.90	866.00	49.1
Rajsamand	Devgarh	506.00	663.00	31.0
	Bhim	506.00	533.00	5.3
Tonk	Tonk	566.00	631.00	11.5

Source- Monsoon Report-2016, water resources department of Rajasthan

Table No. 3.6

Rainfall-2016 (District Average Basis)

District	Normal	Actual	Deviation
	MM	MM	%
Ajmer	429.6	534.8	24.5
Bhilwara	580.9	817.31	40.7
Rajsamand	506.0	794.86	57.1
Tonk	566.0	726.38	28.3

Source- Monsoon Report-2016, water resources department of Rajasthan

Fig. 11

Rainfall-2016 (District Average Basis)

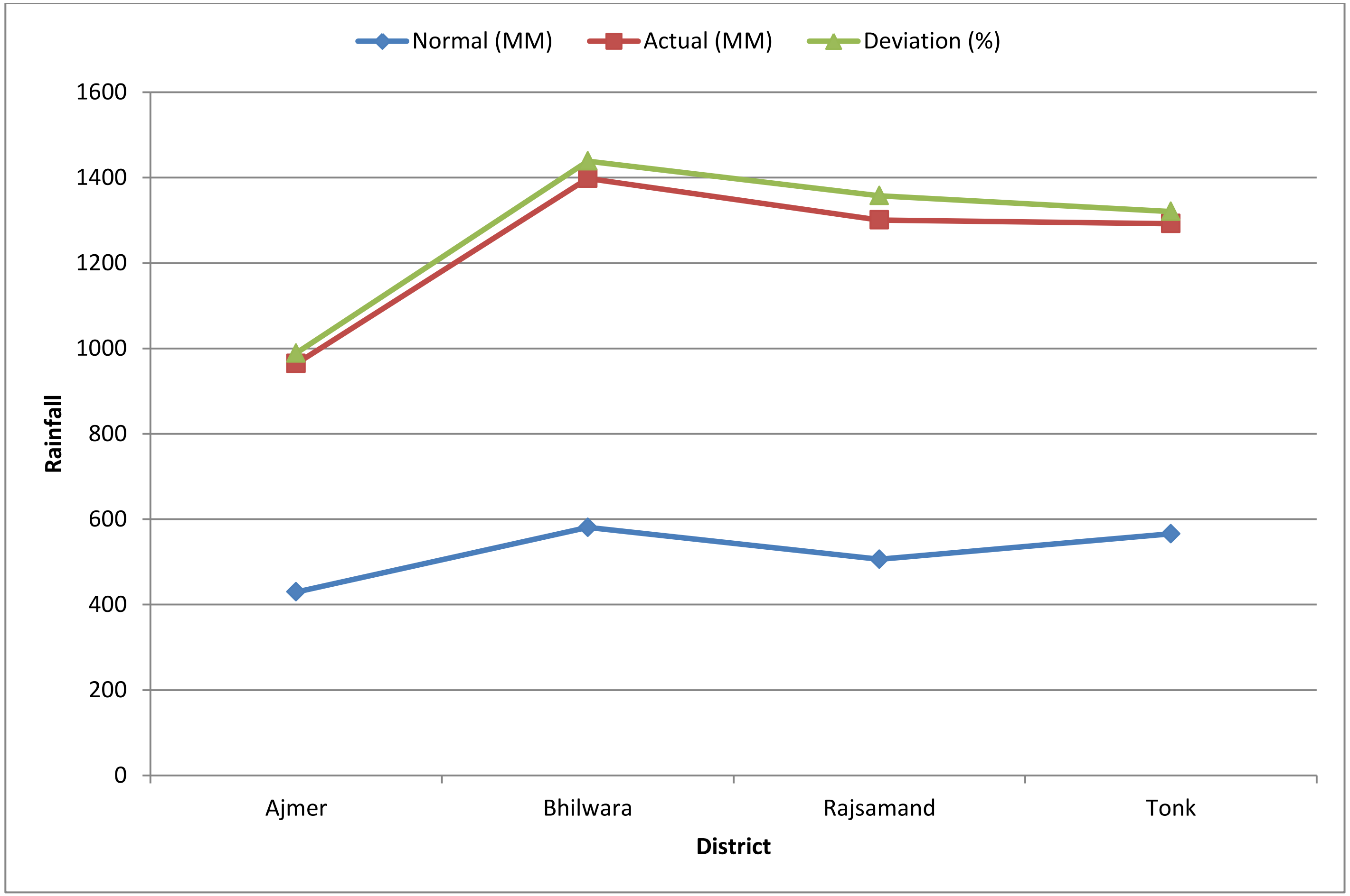


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Plate – 10

Khari river in Mehrukalan village in rainy season

(B) Humidity-

The relative humidity is lowest in April-May period around 25%. It increases to about 75% during the peak monsoon activity in August. It decreases considerably in October in conjunction with prevailing higher day temperature. In this area the humidity increase in December and then falls considerably in Jan to 35%. It increase in a little in the next month and then once again reaches a minimum in April.

(C) Cloudiness-

Skies are generally moderately to heavily clouded during the south west monsoon season being overcast on some days. During rest of the year, Skies are normally clear to lightly clouded, although cloudiness sometimes occurs during the winter due to passing western disturbances. During the month of July-August mean cloudiness is usually more then, being generally higher in the evening then the morning.

(D) Winds-

The predominant wind direction in this area are W, NW, N, NE and E. About 25% of the days are calm. Mean monthly wind speeds are generally high throughout January to October reaching a max in June and May or November and December are relatively less windy, the speeds being around.

(E) Evaporation and Evapotranspiration-

Evapotranspiration is the combined effect of loss of water through evaporation from soil and water surface and transpiration by the vegetation the gradient of such combined loss of water (or humidity) is known as PET (Potential Evapotranspiration) and employed as a key parameter for budgeting the water resources in any area.

Extensive studies of PET owe their origin to an empirical formula developed by Thornthwaite (Subramaniyam, 1956) and from now on integral part of environmental planning throughout India. PET as mentioned above indicates the likely rate at a given point of time of loss of humidity due to the combine effect of surface evaporation and vegtal transpiration.

In the context of the area under study the PET is highest in the month of May at 8.62 mm per day and at the lowest in the month of January at 5.09 mm per day. The PET varies directly with the temperature. Since the temperature range in the area remains High . The annual PET is also high. Infect the annual PET in this area is which is about three times the mean annual rainfall. Naturally therefor the parameters determining hydroscopic balance in the area remain distorted. As a result except for the months of July, August and September, when the rainfall is high, there is always a deficit of water. Soil remains devoid of humidity for most part of the year as the landscape is rather flat and lacks vegetal cover, the process of denudation is found to have a high intensity.

[II] SOILS

Soil is the product of physical, chemical and bio-chemical processes acting upon earth materials under various topographic and climatic conditions. Soil is a natural asset. It makes fertility. Soil fertility is a measuring yardstick for productivity owing to the presence of pre-cambrian geological formation it has added to the clue that the soil of the Khari river basin are also ancient in origin.

Factors of soil genesis-

Soil scientists attribute the formation of soil to five factors: parent material, climate, vegetation topography and time.

(A) **Climate-** climate is an important factor in soil formation. Temperature and precipitation influence the speed of weathering of parent materials and thus soil properties such as mineral composition and organic matter contant. Fluctuations in temperature increase physical weathering of rocks. Precipitation governs water movement in the soil. Water movement is influenced by the amount of water the soil receives and the amount of evapotranspiration that occurs.

(B) **Vegetation-** vegetation has a large effect on soil formation. Soils formed under forests tend to be more weathered because forests grow in higher rainfall areas. Biotic agents include organisms such as bacteria and gophers that live in the soil and vegetation growing on the surface. Organisms in the soil can speed up or slow down soil formation.

(C) **Time**- The formation of soils is a continuing process and generally takes several thousand years for significant changes to take place.

(D) **Parent material-** Soil parent material is the material that soil develops from, and may be rock that has decomposed in place or material that has been deposited by wind, water or ice. The character and chemical composition of the parent material plays an important role in determining soil properties, especially during the early stages of development.

(E) **Topography-** topography has a significant impact on soil formation as it determines runoff of water, and its orientation affects microclimate which in turn affects vegetation. For soil to form, the parent material needs to lie relatively undisturbed to soil horizon processes can proceed. Water moving across the surface strips parent material away impeding soil development. Water erosion is more effective on sleeper, unvegeted slopes.

Classification -

Soil characteristics vary through time and space. The classification of soils is designed to satisfy practical needs. In the later half of the 19^{th} century a fresh approach to pedology was initiated by a Russion scientist, V.V. Dokuchaiev Aligning with the dokuchaiev philosophy, Marbut developed a genetic soil class- system which utilized considerable Russion terminology. Marbut (1938) stressed upon the distinction between the dynamic (climate and biologic) and passive (parent soil topographic position and time) soil development factors. He also distinguished the soil proper form it's underlying geologic material and also recognized geological expression of soils Baldwin, Kellogg and Thorpstate also developed a classical treatise on soil classification in 1938. Later on Marbut (1949) also gave the latest and revised soil class. The system of marbut's (1938) USDA (United States Department of Agriculture) recognized the existence of three orders of soil - zonal, interazonal and azonal. Zonal soils are formed under conditions of good soil drainage through the prolonged action of climate and vegetation. Interazonal soils are formed under conditions of very poor drainage (such as in bogs, floodplain meadows in lake basins of deserts) on regolith with high calcium carbonate content, or where soluable salts or sodium or both are high.

Azonal soils have no well developed profile either because they have had insufficient time to development or because they are on slopes too steep to allow profile development. Azonal soils include lithosols, (thin soils on Bedrick of the earth's mountain regions) alluvial soils and dune sands.

During the 1950's the soil survey staff of the United States department of agriculture under the chairmanship of guy D. Smith assumed the responsibility of developing the united states comprehensive soil classification system as a direct response to the recognized weakness of methods currently in use. The case was documented in 1975 summary treatise titled soil taxonomy a basic system of soil classification for making and interpreting soil surveys.

The CSCS differs in important ways from the 1938 USDA system. The new system defines it's classes strictly interms of morphology and composition of the soils, that is in terms of the soil characteristics themselvs. Moreover, the definitions are made as nearly quantitative as possible. Every effort was made to use definitions in terms of features that can be observed so that arbitrary decisions as to classification of a given soil could be avoided. The classification system of the cscs is known as the soil taxonomy. It is based on a hierarchy of six categaries or levels of classification orders, suborders great groups, subgroups, families and series. Keeping the above classification in mind and with the help of the district census hand book of Rajasthan, the soils of the khari basin have been classified as under –

a) **Red and Yellow Soil-**

This type of soil is found mostly north and central part of basin. Western part of the districts of Rajsamand, Bhilwara and Ajmer has this soil type. Due to the higher degree of hydration of ferric oxide the soil has acquired yellow colour. Silty-loams to silty-clay loams are common in the region. The pH ranges from 5.5 to 8.5. The carbonate, Salt content and humus content in the soils are Poor. Nitrogen contents vary from 0.006 to 0.016 percent and organic carbon contents vary from 0.057 to 0.126 percent. Sometimes ferruginous concentrations are also found. The surface colour of the soil varies from light yellowish, through brown yellowish-brown to dark brown. In this area soil has been classified in to following types- sandy soil, shallow soil and dark medium heavy soil.

b) **Brown Soil-**

This type of soils found in different tehsils of Bhilwara and Tonk. The colour of soils ranges from greyish brown to yellowish brown. These are sandy loam to clay loam in texture. This type of soils are rich in calcium salts but have poor organic matter. Use of fertilizers becomes essential to get good harvest. The soil is alkaline and saline and has a high pH value. The pH of the soils and sands ranges between 7.2 and 9.2 and they are calcareous in nature. In this area various soil classes like coarse light soils, dark medium heavy soils yellowish – brown medium soils and brown medium soils are present.

c) **Older Alluvial Soil-**

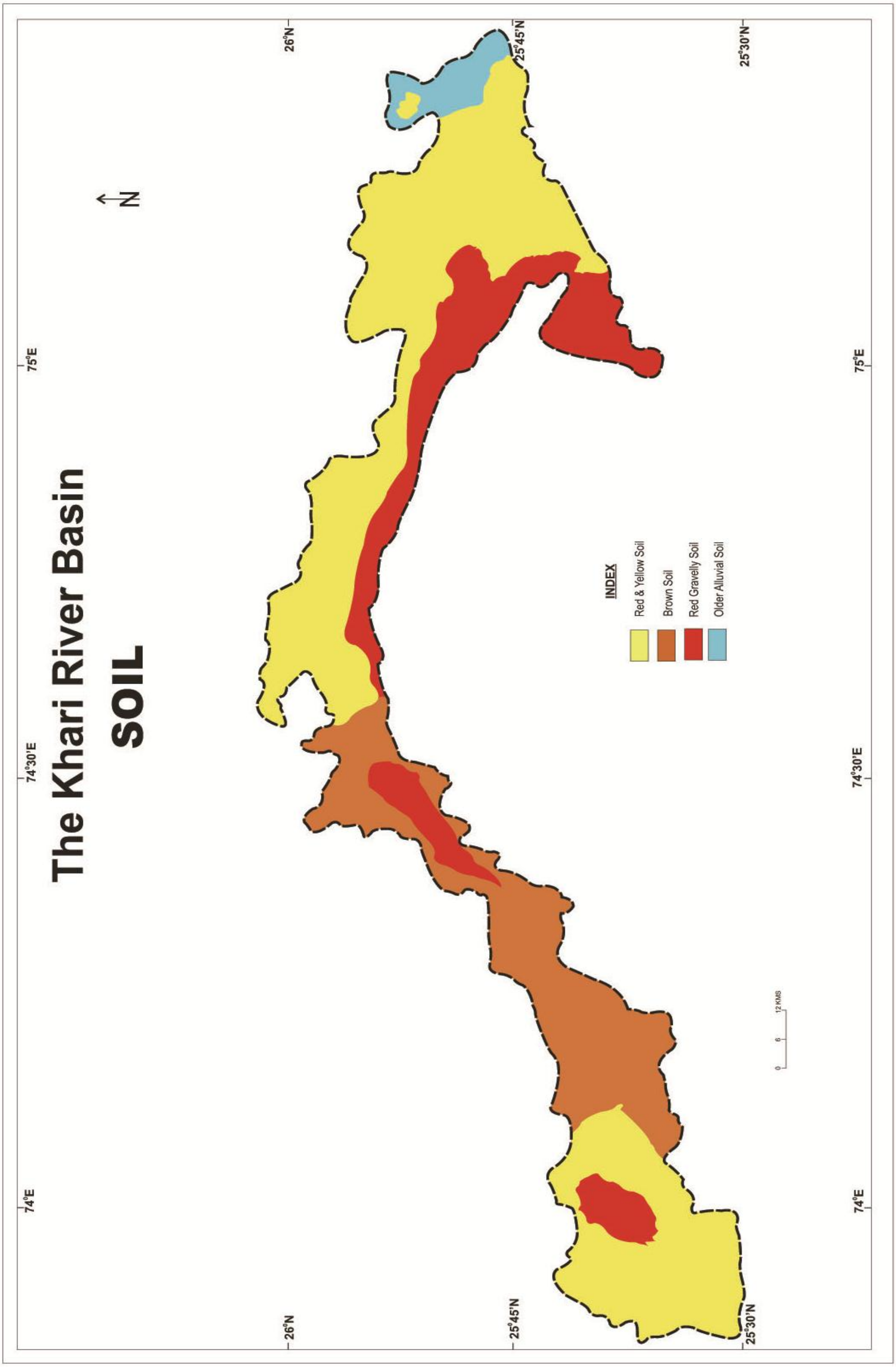
This type of soil found higher up in the plains at river terraces away from rivers. Mainly found in the different tehsils of Tonk district. These are clayey and non-porous in texture. These type of soils are less fertile due to old deposits. This is an old soil which is alluvial in nature and is above the flood levels of the rivers in the region. It is often seen in the structure of a terrace. This type of soil contains many calcareous deposits and also has many kankars within it.

d) **Red-gravelly soil-** This type of soil is found western part of besin mostly found in the different tehsils of Bhilwara and Rajsamand. The Indian council of agricultural research (ICAR) has divided red soils into four categories-

(a) Red soils (b) Red gravelly soils (c) Red and yellow soils and (d) Mixed red and black soils.

Red-gravelly soil is found in the some parts of Khari river besin. Gravel is a loose aggregation of rock fragments. Gravel is classified by particle size range and includes size classes from granule to boulder-sized fragments. This type of soil widely used both in agriculture and forestry.

Soil map of Khari river basin is presented in map no.-12


The Khari River Basin
SOIL
N
INDEX
Red & Yellow Soil
Brown Soil
Red Gravelly Soil
Older Alluvial Soil
0 6 12 KMS
26°N
25°45'N
25°30'N
74°E
74°30'E
75°E

Chapter - IV

GEOMORPHIC ENVIRONMENT

GEOMORPHIC ENVIRONMENT

Geomorphic environment mainly deals with the geomorphology of the area and geomorphic processes which are responsible for the creation of new land forms as well as new geomorphic units. Right from the very inception of the earth, the geomorphic processes have continuously been acting upon this earth, which is evident from the evolution of land forms and plantation surfaces.

The existing geomorphological features in the area under study are the outcome of long and continuous morphogenetic processes. The geomorphology of any area controls the drainage, ground water reservoirs, soils, natural resources etc. Therefore the study of geomorphic processes occurring in the area becomes inevitable in order to have a correct assessment of the environmental status of the area concerned.

The study area lies in the districts of Ajmer, Bhilwara, Tonk and Rajsamand. Aravallis are present in the western part of the study area. This part is in a shape, which can be technically called as environmentally degraded. P.C. Bakliwal (1993) of geological survey of India has mainly worked on the identification and delineation of various geomorphological units on the basis of their origin.

All the geomorphic units present in the study region have been divided into following main divisions:

(i) Denudational land forms

(ii) Depositional fluvial land forms

(iii) Physical features

(i) Denudational land forms:

Denudation involves the processes that cause the wearing away to the earth's surface by moving water, by ice, by wind and by waves, leading to a reduction in elevation and in relief of land forms.

These land forms features can be further categorized as:-

(A) Structural hills- Structural hills constitute the major geomorphology unit, which controls the drainage systems and conserves the bio-diversity of the area. The area is traversed with several faults and fracture zones of various magnitudes. These features have greatly influenced the landforms of the area under study.

Hill range surround the basin in northwestern part and eastern part of the Bhilwara town. In Rajsamand geomorphological units show linearity specially the structural hills which are aligned in the direction of Aravalli (NE-SW). Except these structural hills only isolated ridges are present. Ridges of gneisses, schist and quartizite rising to height of 190 m above the plains are seen underlying the intervening valley. These hills have been subjected to various erosional cycle, physical weathering, fluvial denudation. The area under study used to have rich forest having fodder, minor forest products, fuel wood and above all a very rich gene bank with variety of animal species. Unfortunately situation has changed significantly during the last few decades and depletion of resources has become a cause of concern.

(B) Denudational hills- The term denudational stems from the latin word denudare which means to uncover. It therefore, refers to a consequence of stripping of loose weathered material from the land scape by various processes of erosion and mass wasting. So denudation involves the exposing of deeper rock structures. Large dimensional hills without any structural bearing are named as denudational hills. In this unit the surface water goes as run off due to gravity and non-availability of pore spaces. Ground water availability in this unit is very less expect in some valley fills, which are developed by the process of fluvial action along the depressions. Some denudational hills are developed in Devgarh and bhim tehsils in Rajsamand district. Some low lying hillocks are seen in northwestern part of basin.

(C) Pediments- Due to limited thickness of the soil cover/weathered material, the water holding capacity of this unit is poor. This unit develops an all types of consolidated rocks. The pediments are developed all along the hill ranges. This category of land forms is seen along the hill in the area under study. An almost flat to gently undulating terrain with low to moderate slopes underlain by phyllites, schist rocks and amphibolites are present in this area.

The pediments are mainly present along the hills in Devgarh and Bhim Tehsils of Rajsamand, eastern and western part of Bhilwara.

Plate – 11

Structural hills in study area

Plate – 12

Pediments in study area

(ii) Depositional fluvial land forms

A variety of landforms may develop by the action of running water on the earth's surface in the region of higher slopes, river and streams erode their valley and consequently gorges, ravines, canyon and deep cut valleys are formed on the contrary in comparatively plain areas, the rivers deposit their load and various land form are the result. While doing so they therefore leave their signature behind. The depositional fluvial landforms in this area can be classified under following types.

(A) Alluvial fills-

The alluvial sand and silt which are apparently the product of gully erosion are found deposited along the major river and minor tributaries as well. Khari and Mansi river both has these type of alluvial fills.

(B) Flood plains-

When sediments get deposited in a valley by streams, a flat land is formed which is technically known as flood plain. Flood plains may also appear as a consequence of migration of river. The Flood plain that were marked on land sat imagery are incompatible with the present day ephemeral channels which clearly indicates that fluvial activity in the past was much more vigorous than present. The breadth of the new flood plains is replenished every year during the monsoon season through the usual flooding. The old flood plains, which are studies in river section, well section or from exploratory tube-wells shows that lower layers consist of coarser material and is topped by a sequence of fine grained materials but in some areas lower layers consist of only silt and fine sand and these are overlain by clay and blown sand.

Plate – 13

Structural hills in study area

Plate – 14

Rocky Bed of river basin

(iii) Physical features

Landscape is a function of structure, process and stage (W.W. Davis). The land scape in the Khari river basin is indeed resultant feature of structure and processes found in this area through the stages. The region mostly has gentle slope less then 2^0, the most of the basin area is plain. Generally the slope decreases from west to east. The region is hilly in the western part of the basin Khari river flows from west to east. The hills of bijral village are found in Devgarh tehsil from where this river originates. The eastern part of the basin belongs to lowland where the height is below 375m. The central and western uplands are also almost flat and cover approximately one half area of the basin.

(a) Contour Map

For preparing this the researcher has taken the 1:50,000 toposheets (45 K/5, 45 K/13, 45 O/2, 45 O/5, 45 K/2, 45 K/14, 45 O/1 45 K/9, 45G/14) and drawn the contours at 20 meter interval. The following main division have been evolved-

(i) Less then 320mt.

(ii) 320 to 420 mt.

(iii) 420 to 520 mt.

(iv) 520 to 620mt.

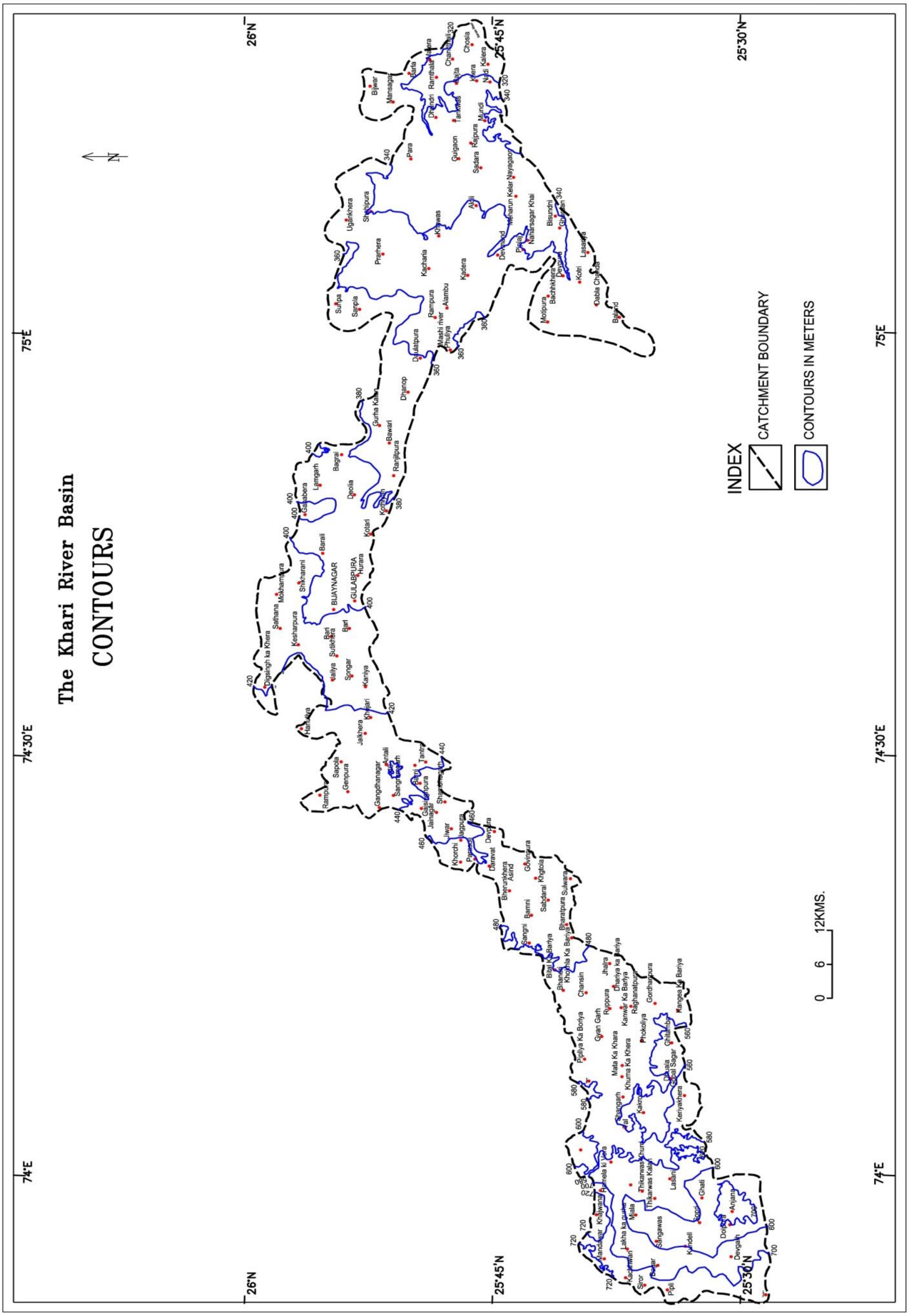
(v) 620 to 720mt.

Contour is a line drawn on a map that Joint points of equal height above sea level. The close together contours on a map show a steep slope and the spaced out countours show a shallow slope.

Contour map khari river basin shows that the eastern and central part of basin has shallow slope. Nadi and chandthali village in Ajmer district has a minimum elevation both places are connected by 320 meter contour line on map. In western part of basin has close contour lines that shows the area has steep slope. Some hills are present in Rajsamand and Bhilwara district. The area has a maximum height near Mandawar and Khajwana Village in Rajsamand district drawn by 720 meter contour line.

Contour map of Khari river basin is presented in map no. - 13

MAP NO. - 13



The Khari River Basin
CONTOURS
INDEX
CATCHMENT BOUNDARY
CONTOURS IN METERS
0
6
12KMS.
26°N
25°45'N
25°30'N
74°E
74°30'E
75°E

(b) Relative relief-

Relative relief, also termed as amplitude of available relief or local relief or local relief, is defined as the difference in height between the highest and the lowest points (weight) in a unit area, it may be grid square, rectangle or a minute-grid square. Relative relief is a very important morphometric variable which is used for the overall assessment of morphological characteristics of terrain and degree of dissection. W.S. Glock (1932) used the term amplitude of relief and defined it as the vertical of relief and defined it as the vertical distance from a horizontal fairly flat upland down to the intial grade of the streams.

Smith G.H. (1935), Glock W.S.(1932) Thawer A. (1995) Hammond (1968) have evolved this technique for measuring local relief. The researcher also applied the spot heights in preparation of the relief map of the basin. The contour area covered under each of the six categories was taken and the choropleth map of the basin showing relief was plotted. If we see the relief map of the basin it shows that the area covered under each category as follows: According to Height Area covered in khari river basin is shown in table no. 4.1

Table No. 4.1

According to Height Area covered

HEIGHT (mt.)	According to Height Area covered(%)
< 300	4
300-400	45
400-500	21
500-600	14
600-700	7
>700	8

On the basis of the above statistics map has been prepared for decipicting the basin area on the height available in the basin.

Relief map of Khari river basin is presented in map no. 14

MAP NO. -14

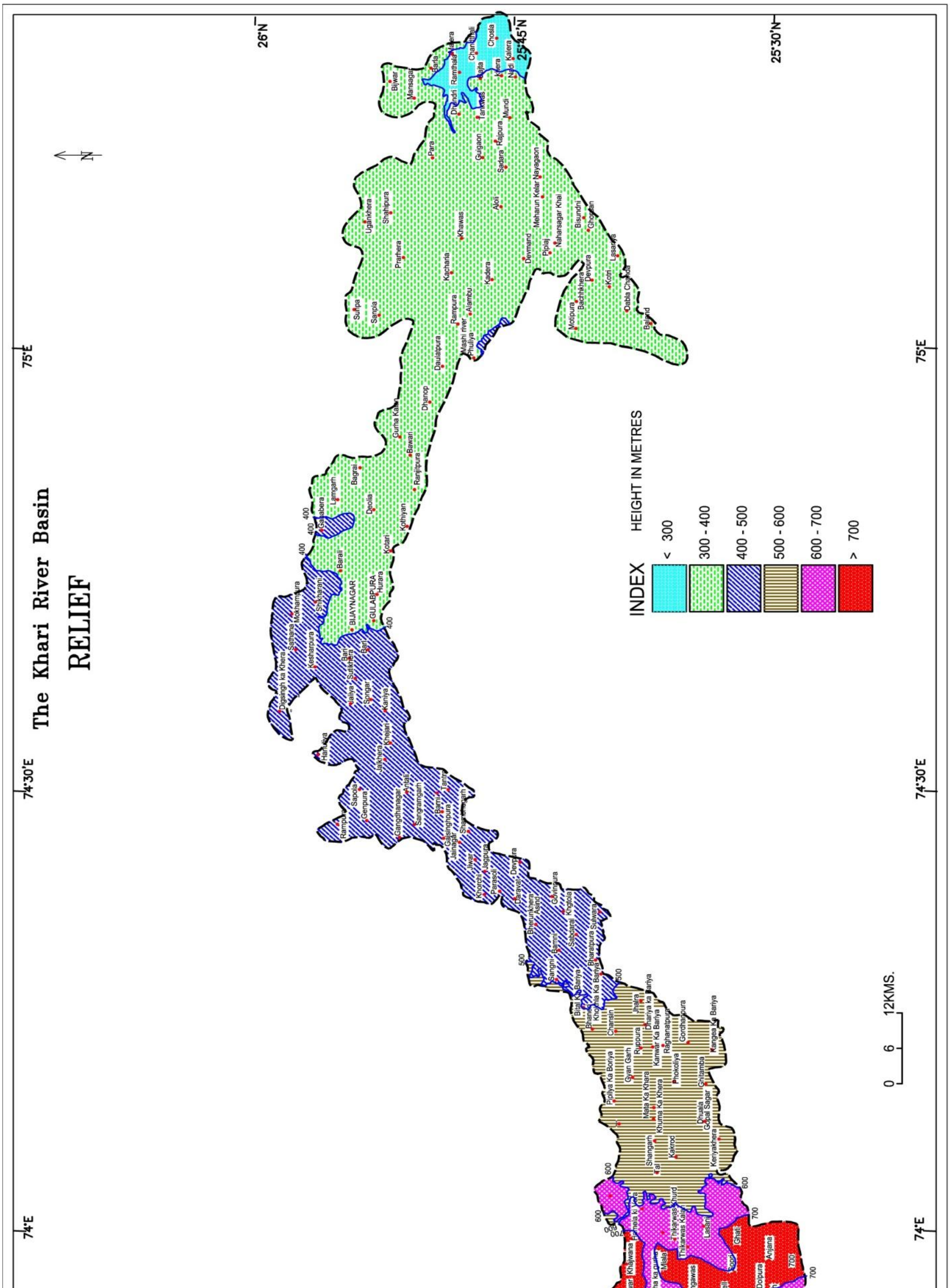

The Khari River Basin
RELIEF
N
INDEX
HEIGHT IN METRES
< 300
300 - 400
400 - 500
500 - 600
600 - 700
> 700
0
6
12KMS.
26°N
25°45'N
25°30'N
75°E
74°30'E
74°E

Plate – 15

Denudational hills in study area

Plate – 16

Denudational hills in study area

(c) Slope analysis-

The study of slope is very important aspect in geomorphological studies. The slope map provides a useful visual impression and it can be used to relate to some other geographical variables. A number of scholars contributed much towards the slope analysis. Finsterwaider (1890), Wentworth, C.K. Raisz and Henry J. (1937) Smith G.H. (1938) Robinson A.H. (1948) Miller, A.A. (1949) Strahler A.N. (1956) etc were among the eminent scholars who worked in this field.

The slope map of the basin has been prepared by applying Wentworth's method. It is observed in the map that most of the basin area is plain, with a gentle slope of less then $2^{0.}$ Maximum slope is found around Devgarh tehsil and Mandwar village and Hamela ki ber in Bhim tehsil of Rajsamand district that is more than 8'. Slope of 6^0-8^0 is found in around nayagaon, Tankwas villages in Ajmer, Pipllya ka Boriya village in Bhilwara. The slope of 4^0-6^0 is found around Rajpura, Mundi villages in Ajmer, Mata ka Khara, Khuma Ka Khara in Bhilwara, Khajwana, Thikarwas, Kalan lasani in Rajsamand. The slope of 2^0-4^0 is found around Bajita, Khera, Dhundri Shikharani, Kesharpura, Hanutiya in Ajmer. Rampura, Genpura, Sapola, Govinpura, Sangni Bhartpura, Sabdaral, Khokhla ka Bariya,Bamni chansin in Bhilwara. Dhapra, Gopal Sagar, Kakrod, Shangarh Anjana in Rajsamand.In Khari river basin generally the slope decreases from west to east.

The model on which slope map was prepared is as follows:-

$$tan\theta = \frac{N}{L} \times \frac{V.I.}{637} \ (went\ worth\ C.K. 1930)$$

Where N – Number of contour crossing in a grid

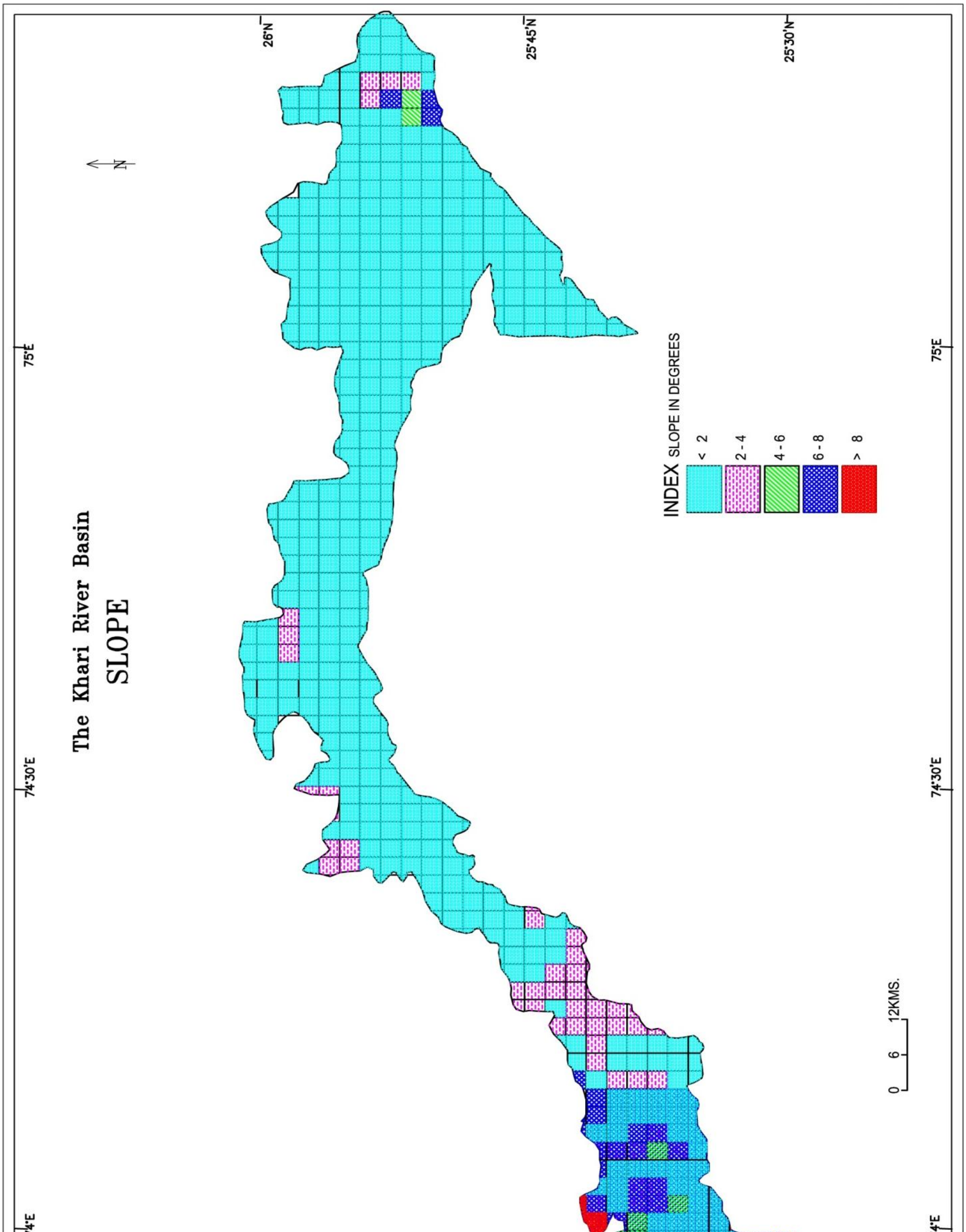
L – Length of the grid

V.I. – Contour interval

637 - Constant figure

with the help of above statistics slope map of the basin was plotted. Which is presented in map no. - 15

MAP NO. - 15



The Khari River Basin
SLOPE
N
INDEX SLOPE IN DEGREES
< 2
2 - 4
4 - 6
6 - 8
> 8
0
6
12KMS.
26°N
25°45'N
25°30'N
74°E
74°30'E
75°E

The area covered under various degree of slopes is shown in Table no. 4.1

Table No. 4.2

Slope area in (%)

Slope categorie	Area %
< 2	85.22
2-4	9.6
4-6	1.6
6-8	1.2
> 8	0.6

Altimetric Frequency Histogram

The altimetric frequency histogram deals with the frequency of occurrence of different elevations groups in a region. This diagram is quantitative and objective in nature and can be objected to statistical analysis (Clerk, 1967). The altimetric frequency Histogram has been prepared in order to show the frequency of spot height at different elevations. The altimetric frequency histogram of the Khari river basin gives an idea of the relative positions of percentage of different land surface of the basin.

It is quite obvious from that the land surface having 300-450 mt. elevation is dominant in the basin. It covers approximately 53% of the total geographical area of the basin. The western part of the basin is highly elevated where elevation is more than 900 mt (1% area of the basin). About one-fourth area is below 900mt., 600-750 and 750-900 mt. Thus the area can be categorized as undulated.

Altimetric Frequency Histogram of Khari river basin is presented in fig. 12

Fig. 12

Altimetric Frequency Histogram

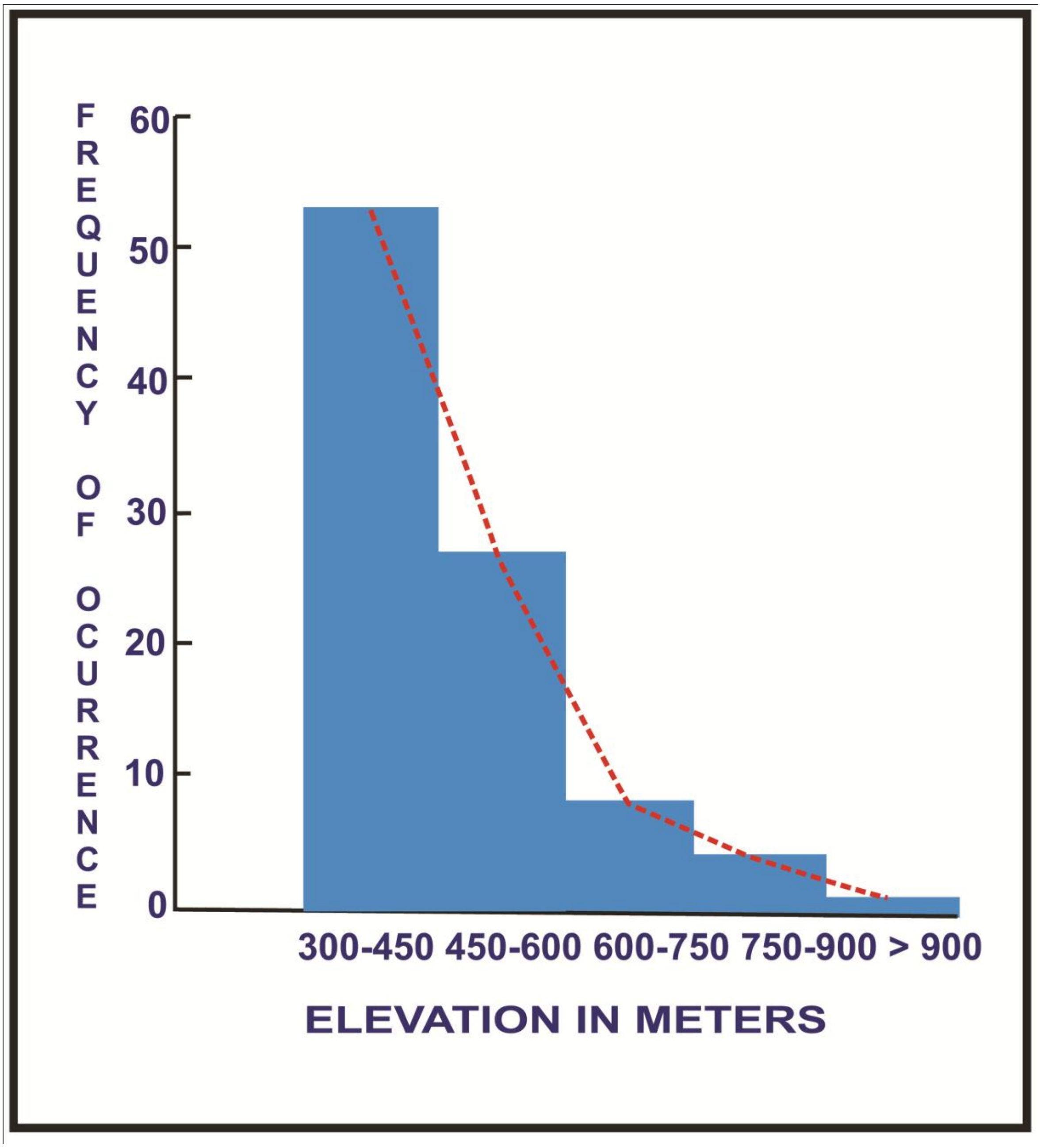


Plate – 17

Hills in Rajsamand district

Chapter - V

Fluvial Morphometry

FLUVIAL MORPHOMETRY

'Measurement of the shape or geometry of any natural form- be it plant, animal or relief features is termed morphometry' (A.N. Strahler, 1969)but in geomorphology 'Morphometry may be defined as the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimensions of it's landforms' (J.I Clarke, 1970).

In fact, morphometry incorporates quantitative study of the area, altitude, volume, slope, profiles of the land and drainage basin characteristics of the area concerned (Savindra Singh, 1972).

It has two distinct branches viz (i) Relief morphology (ii) Fluvial morphology. Relief morphology includes analysis of terrain characteristics while fluvial morphology includes the consideration of linear, areal and relief aspects of a fluvially originated drainage basin. The linear aspect deals with the hierarchical orders of the streams, numbers and length of stream segments and various relationship among them and related morphometric laws. The areal aspect includes the analysis of basin perimeter, basin shape, basin area, stream frequency, drainage density and drainage texture. The relief aspect incorporates besides hypsometric, Clinographic and altimetric analysis, the study of absolute and relative reliefs, relief ratios, average slope dissection index etc.

In the development of morphologic techniques many scholars have contributed not only abroad but also in our country. De martonne (1934) P.S. Javanovic (1940) C.P. Peguy (1942,1947, 1948) De Smet (1951, 1954) A.N. Strahler (1952, 1954, 1958) P. Birot (1955), H. Boulig (1957, 1959), R.E. Hortan (1932, 1945) J.L. Clarke and K. Orrell (1958) Dr. Coates (1958) Chorley R.J. (1958) Garetiner V. (1972, 1981) Bloom A.L. (1779) are some of the main contributors among eminent scholars. On the other hand in India Chatterjee S.P. (1969) Ahmad E. (1969), Mukhopadhyay S.C. (1974), Mukherjee A.B. (1976) Sharma H.S.(1976) Vaidyanathan R.(1979) Singh Savindra (1978), Sharma M.L. (1982) are among outstanding contributors.

(i) Stream ordering

Stream ordering refers to the determination of the hierarchical position of a stream within a drainage basin. A river consists of several branches (segments) having different positions in the basin area and they have their own morphometric characteristics and therefore it becomes necessary to locate the relative position of a segment in the basin ,so that the hierarchical organization of stream segments is visualized. Thus stream order is defined as a measure of the position of a stream in the hierarchy of tributary. (L.B. Leopold, M.G. Wolman and J.P. Miller, 1969)

It was Gravelius who made first attempt in 1914 to determine the orders of stream network where in he attempted to trace the streams from the outlet to the sources like an explorer. In 1932, 1945 R.E. Horton, presented his scheme of stream ordering. According to Horton’s scheme when two streams of same order meet, they form the next higher order and each stream can receive tributaries of lower orders than its own order. In other words, the streams order increases only when two stream of same order join together.

A.N. Strahler (1952, 1953, 1957) modified the Horton’s scheme of stream ordering. According to him each finger-tip channel is designated as a segment of 1^{st} order. At the Junction of any two 1^{st} order segments, a channel of 2^{nd} order is produced and extends down to the point, where it joins another 2^{nd} order segment where upon a segment of 3^{rd} order results and so fourth. Hierarchical order increases only when two stream segment of equal order meet and form a Junction.

The researcher adopted the strahler’s method to draw the level of magnitude in drainage network hierarchy of Khari river basin. The drainage map of Khari river and it’s tributaries has been such divided into channel segments according to orders. The numbers of each order are then counted to yield the figure. The order of stream segments is designated by the symbol ‘u’ the number of segments of a given order by the symbol ‘NU’. Number of stream according to their order are shown in the table no- 5.1

Table no 5.1

Number of stream

Stream order (μ)	Number of Streams (Nμ)
1	116
2	30
3	6

(ii) Bifurcation ratio (R_b)

Bifurcation ratio, a dimension less property of the drainage basin is supposed to be controlled by drainage density, stream entrance angles (Junction angles) lithological characteristics, basin shapes, basin areas etc.

The studies of bifurcation ratio in different regions of the world by different geomorphologists have revealed the following behavioural patterns of bifurcation ratio and these patterns have been examined by Savindra Singh, S.S. Ojha and S.P. Agnihotri on the basis of study.

E. Giusti and W. J Schneider (1965) have shown that bifurcation ratio within a given region tend to decrease with increasing order because as order increases the percentage of stream that coalesce into a higher order tributary also increases. This increase is due to the diminishing amount of area.

R.E. Horton 1945 have shown that mean bifurcation ratio vary from about 2.0 for flat or rolling basins to 3.0 – 4.0 for mountainous, hilly dissected basins.

Bifurcation ratio (R_b) which is related to the branching pattern of the drainage network is defined as a ratio of the number of streams of a given order (Nu) to the number of streams of the next higher order (Nu+1) and is expressed in terms of the following equation-

$$R_b = \frac{Nu}{Nu+1}$$

Where Nu = No. of stream of a given order

Nu+1 = No. of streams of the next higher order.

Bifurcation ratio of the Khari river shown in the table no. 5.2

Table no. 5.2

Bifurcation ratio

Stream order (μ)	Number of streams (Nμ)	Bifurcation ratio (R_b)
1	116	3.8
2	30	5
3	6	-

(iii) Stream length

Horton (1945) has stated this law as follows. The average length of streams of each of the different orders in a drainage basin tend closely to approximately a direct geometric series in which the first term is the average length of streams of the first order.

It suggests that as stream order increases so does the mean length of the stream which is apparent from a graph of mean stream length on the log scale against stream order plotted on the ordinal scale.

The distance is measured of all the segments of a given order on the map, than the total length is divided by the number of segments of that order yielding the mean length. This is in the form of formula:

$$\bar{L}\mu = \frac{\sum \bar{L}\mu}{N\mu}$$

Where $\bar{L}\mu$ = mean length

$\sum \bar{L}\,\mu$ = The sum length of all stream segment number of order 'μ'

N μ = Total number of segments in a particular order 'μ'

The stream mean length for 1st order is 384 km, 2nd order is 112km and for 3rd order is 33.4 km.

(iv) Sinuosity index

The shape of the open link in terms of geometric structure of drainage line involves the calculation of deviation of observed path (OL) from the expected path almost a straight line (E_L) of a river from the source to the mouth. In fact, no river in practice, show straight path in terms of open link as many causative factors force the drainage line to deviate from the straight path. These factors may be geological and hydrological controls, dip angles, slopes, absolute and relative relief etc.

The sinuosity of a stream denotes the degree of deviation of it's actual path from expected theoretical straight course. The analysis of deviation of the course of drainage line from the straight path, say sinuosity may help considerably in studying the effect of terrain characteristics on the river course and vice versa. Simultancously, the degree of sinuosity may give a vivid picture of the stage of basin development as land form evolution.

It is a ratio between the average channel length and average direct length. mathematically it can be expressed in the following formula-

$$SI = \frac{OL}{EL}$$

Where OL = observed (actual) path of a stream

EL = expected straight path of a stream

Researcher adopted the leopolds (1964) formula and calculated the S.I. .A stream showing sinuosity index over 1.5 may be treated as meandering stream and below it is non meandering stream or if close to this number than approaching to meandering. On the basis of this discussion it can be concluded that if a stream in it's young stage shows this value over 1.6, it may be attributed to the phenomenon of rejuvenation. The Khari river has S.I. 1.17 therefore it is a non meandering river.

(v) Stream frequency

Stream frequency or drainage frequency is the measure of number of streams per unit area (may be square meter, square km and so on) For the computation of Stream frequency the basin is conveniently divided into grid squares (more commonally one square mile/km) depending on map scale and areal coverage of the basin and the number of streams in each grid is counted, tabulated and quantified. The data of stream frequency are classified into certain categories depending upon the nature of data.

Harton (1945) was the first who coined the word stream frequency and represented it as ‘F’ indicating as the number of stream segments per-unit area. The value of ‘F’ is highest in the hilly areas similar to that of drainage density. Factors controlling drainage frequency according to melton (1959) are the climate lithology and vegetation of the area in question. The values of ‘F’ differ from place to place. The Empirical formula used for computing the value of ‘F’ is given below:

$F = N/A$

Where

F = Stream Frequency

N = Number of streams in a grid

A = Area of the grid

Total range of the stream frequency calculated has been divided into five categories:-

Low stream frequency, less moderate, moderate, high and highest frequency. The pattern of stream frequency in the area under study is obviously clear from given table-5.3

Table No.- 5.3

Stream frequency

Zone	Frequencies	% of Area of basin
Low Frequency	0 – 4	6.7
Less Moderate	4 – 8	17.37
Moderate	8 – 12	5.96
High Frequency	12 – 16	7.15
Highest Frequency	> 16 above	2.82

Drainage frequency of Khari river basin is presented in map no. - 16

MAP NO. - 16

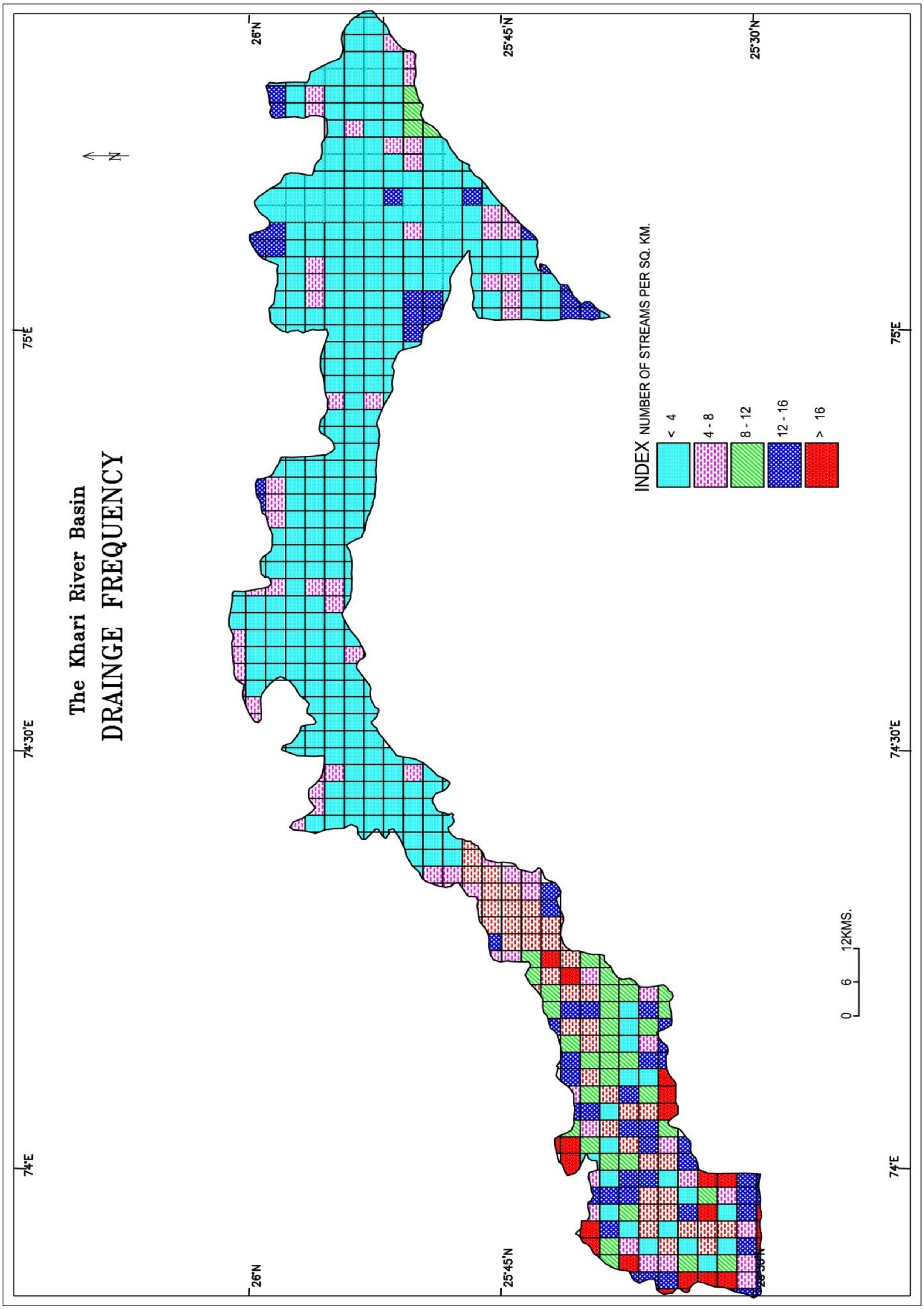

The Khari River Basin
DRAINGE FREQUENCY
N
INDEX NUMBER OF STREAMS PER SQ. KM.
< 4
4 - 8
8 - 12
12 - 16
> 16
0
6
12KMS.
26°N
25°45'N
25°30'N
75°E
74°30'E
74°E

Plate – 18

Khari river in Kadeda village

Plate – 19

Khari river between Ramthala and Nekedia village

(vi) Drainage pattern

The particular plan or design which the individual stream courses collectively form, is known as drainage pattern. The drainage pattern reflects the influence of such factors as initial slopes, inequalities in rock hardness, structural control, recent diastrophism, and the recent geology and geomorphological history of the drainage basin. Though the drainage patterns are influenced by numerous factors yet they are extremely helpful in the interpretation of geomorphic feature and structural and lithological control of land form evolution.

In the study area drainage patterns vary from place the place due to varying factors, which affect the land forms. The overall drainage pattern of the Khari river can be said to be dendritic. The drainage map of Khari river basin exhibits two types of drainage patterns- dendritic, ractangular.

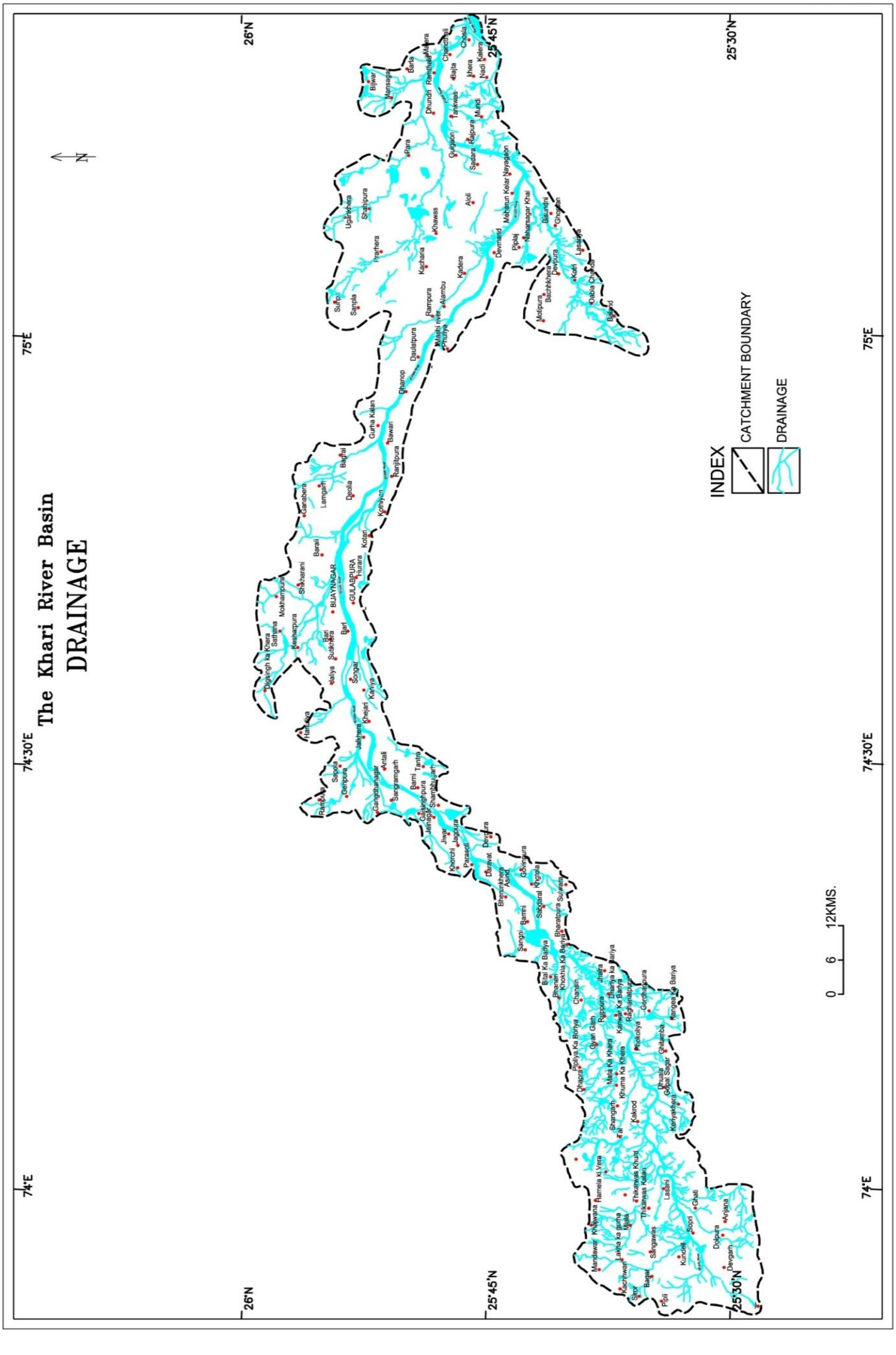
(a) Dendritic pattern

Dendritic or tree shaped drainage pattern is the most common and widespread pattern to be found on the earth's surface. The pattern is called dendritic on the ground that the network of tributaries of various orders and magnitudes of the trunck or master stream resembles the branches and roots and rootlets of a tree. The dendritic pattern is associated with the areas of homogeneous lithologies, horizontal or very gently dipping strata, flat and rolling extensive topographic surface having extremely low reliefs.

Slope and permeability of rocks very effectively control the number and extension of streams of dendritic drainage pattern. The drainage network of dendritic pattern becomes most extensive if the land surface is characterized by flat surface level to gentle slopes and impermeable rocks. In such environmental conditions the pattern extends both in length and width but if the region is characterized by higher slope angles, the pattern extends more in length than in width.

In Khari river basin dendritic drainage pattern is most common pattern. In the central and Eastern part of river develops dendritic pattern most. Khari and its tributaries develops dendritic drainage pattern.

Drainage map of Khari river basin is presented in map no. - 17


The Khari River Basin
DRAINAGE
N
INDEX
CATCHMENT BOUNDARY
DRAINAGE
0 6 12KMS.
26°N
25°45'N
25°30'N
74°E
74°30'E
75°E
BIJAYNAGAR
GULABPURA

(B) Rectangular pattern

Rectangular pattern is generally developed in the region where the rock joints form rectangular pattern. The rocks are weathered and eroded along the interfaces of Joints, fractures and faults and thus surface runoff collects in such long and narrow clefts and forms numerous small rills. These rills are further extended in length and width and become channels. With the march of time a network of streams is developed where in streams follow the lines of weakness (Joints and fractures). The tributaries join their master streams almost at right angles and thus a rectangular drainage pattern is formed. In western part of river, in Bhim and Devgarh tehsil of Rajsamand river developes this type of drainage pattern.

(vii) Development of drainage system

The study of the characteristics of drainage network of a particular region is approached in two ways e.g. (1) descriptive approach and (2) genetic approach. The descriptive approach involves the study of the characteristics of the forms and patterns of the streams of a given region while the genetic approach involves the investigation of the evolution of streams of a region in relation to tectonics, lithologies and structures. Thus drainage system refers to the origin and development of stream through time. The origin and subsequent evolution of any drainage system in a region are determined and controlled by two main factors (1) Nature of intial surface and slope and (2) geological structure (folds, faults, fractures, Joints, dips and strikes of rock beds and types of rocks) The example of drainage systems are consequent streams, subsequent streams, obsequent streams, resequent streams, antecedent and superimposed streams etc.

Khari river is a subsequent stream which follow the regional slope and are well adjusted to geological structure. Generally, it refers to the streams transverse to the master consequent.

Chapter - VI

Environment Degradation

ENVIRONMENT DEGRADATION

Environment degradation comes about due to erosion and decline of the quality of the natural environment. It is caused directly or indirectly by anthropogenic activities that extract various environmental resources at a faster rate then they are replaced, and thus depicting then. In this regard degradation means damage or reduction in quality of environment features, primarily influenced by human activities some natural events such as land slides and earth quakes may also degrade the nature of our environment.

Continued environment degradation can completely destroy the various aspects of the environment such as biodiversity, ecosystems, natural resources and habitats. For instance, air pollution can lead to the formation of acid rain which can in turn reduce the quality of natural water systems by making them acidic. This is a typical example of environment degradation. Environment degradation is therefore a concept that touches on a variety of topics namely deforestation, biodiversity loss desertification, global warming, animal extinction, pollution and many more.

The relationship between physical environment and the well-being of individuals and societies is multi-fold and multi-faceted with a qualitative as well as a quantitative aspect to it. The availability and use of natural resources have a bearing on the out come the pace of development process.

For an urbanized society, a large part of environment is man made. But even then, the artificial environment (building, roads) and implements (clothes, automobiles) are based on an input of both labour and natural resources. Commonly the term environment is restricted to ambient environment in that view, the indoor environment (home, work place) is regarded as isolated piece of environment to be treated on its own terms.

The indoor environment usually is under the jurisdiction of the public health authorities.

I- Causes Of Environment degradation

(a) Climate change

Climate change is a change in the statistical distribution of weather patterns when that change lasts for an extended period of time. Climate change may refer to a change in average weather conditions, or in the time variation of weather around longer term average conditions. Climate change is caused by factors such as biotic processes, variations in solar radiation received by earth. Certain human activities have also been identified as significant causes of recent climate change, often referred to as global warning.

Climate change is having a significant impact on ecosystem, economies and Communities. Climate change is a major cause of environment degradation. One of the most serious impact of climate change is it affect water resources badly. Water is intimately tied to other resource and social issues such as food supply, health, industry and ecosystem integrity.

The study area is a part of Semi-arid climatic region of Rajasthan. The area already facing many problem like low rainfall, extremes of temperature greater evaporation and evapotranspiration and scarcity of natural vegetation. These problems are somewhere result of climatic changes in last many years in this part of Rajasthan. The effects of climate change was not seen till 50 years ago, But with the advancement of technology changes is visible now.

(b) Deforestation

Deforestation means large scale cutting of forest. The forest lands are converted in to farms ranches and urban area through deforestation. Another cause behind the deforestation is the cutting of trees for fuel and timber. It essentially leads to extinction of vital things, and destroys the ecological balance of nature. Land use data shows that only 5.79 % of total geographic area is occupied by forest in Rajsamand district. In Ajmer 6.85%, Bhilwara 7.18 and Tonk 3.76 % area is left as forest area. Thus causing –

- **Heavy soil erosion –** The roots of the trees hold the soil firmly keeping it intact. With large scale deforestation soil erosion and landslides have become a normal phenomenon.
- **Global warming –** The tree absorb the harmful carbon dioxide and release the life sustaining oxygen, thus acting as natural friends of human. Deforestation increase the amount of carbon dioxide in the atmosphere leading to global warming due to greenhouse effect.

- **Flooding –** Trees absorb water in large quantity during heavy rains. But due to large scale deforestation. There are very less trees to retain water. This again leads to heavy floods causing heavy loss of life and property.
- **Desertification** – Deforestation is one of the causes behind the conversion of many fertile tracts of land to deserts. This phenomenon is known as desertification.
- **Relocation of wild life to urban areas –** Many wild animals have started relocating to urban areas as a result of massive deforestation. There have been many cases of various wild animals like snakes, bats etc. causing accidents in urban areas. Many time wild animals get killed in an effort to capture them.

(c) Human interference

Human is the only living being on the earth that is responsible for the destruction of the environment. This is because of his ability to exploit the natural resources beyond the limits of safety. Due to this there is a direct reflection in terms of change of climate. The climate change was not seen till 50 years ago, but with the advancement of technology increase in reliance on technology by humans. This change is visible now. Due to pressure of population and improvement in the standard of living the demand of fresh water for both agriculture and domestic use has substantially increased. This has led to a sharp increase in ground water withdrawal. The top layer of fresh water is also reducing every year. Six out of eight blocks in Ajmer district and four out of six in Tonk District and almost entire district of Bhilwara and Rajsamand are over–exploited, where stage of ground water development has exceeded 100%, leaving no further scope for ground water development.

The rise in human population, desire for luxurious life and dependence on technology impacts the environment. Besides there certain aspects which have environment impact on regular basis seen below-

- **Pollution –** Humans Pollute a lot and contribute to air Pollution, water, sound, radiation, light and even soil Pollution. This is due to many of the human activities like travel, power generation, industrial waste dumped into rivers, polyethylene waste, artificial method used in agriculture, cell phone, Wi-Fi etc. Because of wastage produce by marble, mining and many other industries Khari river basin area is getting Polluted. The study of Khari river basin reveals that the increasing urban population imposing a burden on the nature of the natural resources.

There are 352 Textile related industries located in Bhilwara and gulabpura Town. These industries consume huge quantity of water resulting in drinking problem water problem. Effluent is left untreated and allowed to mingle with ground water. Thus this ground water getting polluted.

This pollution is harmful not only for human but also to animals and plants around. Hence we can see that there is an extinction of many type of birds, plants, marine animal etc. Many animal die due to consumption of polythene covers. Also carbon emission is increased due to growth in vehicles and leading air, water and soil pollution.

- **Technology –** Though technology is making lives of humans easier and comfortable. It poses a great threat to the environment. The threat is due to pollution, radiation hazards, exploitation of natural resources etc.

  Radiation hazard is increasing day by day use of mobile phones and Wi-Fi around us. Hence we can notice that many small birds and insects like honey bees are not found around these days. Even governments are promising to give free Wi-Fi without realizing it's harmful effects on the humans and environment. Health risks are mainly linked to space heating, cooking and lighting. Low grade fuels, insufficient ventilation, and low or non-existing chimneys are often the main problems. Additionally there may be problems connected with moist, light, incidence, hazardous substances from building materials, lacquers and paint. Problem with drinking water, sewage and waste are not linked to the dwelling as such but rather due to lack of appropriate infrastructure. Statistics on indoor environment May be regarded as a subset of statistics on human settlements and the urban environment.

- **Deforestation –** Deforestation and widespread destruction of trees and plants in the name of expansion and urbanization drastically effect the environment around . we are exploiting the nature and environment, before the safe limits.
- **Excess use of commodities –** we use many commodities out of fantasy then really required we tend to own a hundred pairs of leather shoes, purses, belts etc. All of them are made of skin and hides of animals. Many animals like crows, buffaloes, ox are killed for their skin.

II-Industrial development and degradation

Industrialization to achieve economic development has resulted in global environment degradation. Industrial processes play a major role in the degradation of the global environment. Industrial activities and growing demand are putting pressure on the environment and the natural base. Problems linked to industrialization are emerging such as rising greenhouse gas emissions, air and water pollution, growing volumes of waste, desertification and chemicals pollution.

Rapid industrialization in study area India has not only led to the economic development on the other hand it has increased pollution of land, water noise and air.

- **Air pollution:**

  Industries and factories is considered a prime factors in air pollution. Electronics, Polythene, Plastic making and many other industries in study area which burn fossils fuels pollute the air emissions of poisonous gases affects the human health, animal plants. It is caused by the presence of poisonous gases such as carbon monoxide and sulphor dioxide.

- **Water pollution:**

  The untreated industrial waste effluents dumped into nearby water bodies by the factories lead to water pollution. This polluted water becomes unfit for human being and animals and also for irrigation.

  The textile industry of Bhilwara’s poor effluent management system has long poisoned the area’s ground water, affecting agricultural lands and people’s health. The pollution continues unabated even after pollution control authorities set a zero-discharge norm for the units and the government offered subsidies for effluent plants.

- **Soil pollution:**

  This is caused by the presence of man-made chemicals or other alteration in the natural soil environment. The Rupture of its type of Contamination typically arises from underground tank storage application of pesticides, oil and fuel dumping, leaching of wastes from landfills or direct discharge of industrial wastes to the Soil. The extensive use of pesticides in agricultural production can degrade and damage the community of microorganisms living in the Soil, Particularly when these chemicals are overused or misused. Agro chemicals like NPK (Nitorgnius, phosphetic and potashic) use in Rajsamand district was 7305 Tonnes in 2007-08 the numbers has reached to 9279 Tonnes in 2015-16

- **Noise pollution:**

  This is caused by the industrial and constructional activities, machinery, factory equipment generators etc. because of marbal industries in Rajsamand, the workers of marble factory getting badly affected by Noise induced hearing loss. Noise induced hearing loss in an increasingly prevalent disorder that result from exposure to high intensity sound, especially over a long period of time.

Industrial development and degradation in khari river basin

Textiles, bangl making, agriculture equipment, electronics oil, lime, soapstone, brick of mica, spices production, plastic, polythene are the major industries of this region. Bhilwara is rich in minerals, many mining activities happening there. The environmental impact of mining includes erosion formation of sinkholes, loss of bio diversity and contamination of soil, ground water and surface water by chemicals from mining processes. Besides creating environmental damage, the contamination resulting from leakage of chemicals also affects the health of the local population. Erosion of exposed hillsides, mine dumps, tailings dams and resultant siltation of drainages creeks and rivers can significantly impact the surrounding areas.

There are 53 major and 17920 small and medium industries in Bhilwara. Marble industries are main industry in Rajsamand district. There are around 350 unit for marble cutting at present time. The environment degradation during mining of marble is akin to any open cast mining activities. Degradation and removal of top soil, mined out pits disturbing local flora and fauna and water table of the area. In addition, the rejected blocks, unsized blocks and from over burden when dumped unsystematically pose serious hazards.

The processing waste of marble cutting plants comes out in the form of marble slurry. This marble slurry is being dumped by the processing plants at the nearest site available or in the notified area marked for dumping near the plants. The major environment problems due to marble slurry are listed below:

(A) The slurry when dumped on open land affects adversely the productivity of the land as it reduces the porosity and prevents ground water recharge.

(B) Areas with dumped slurry cannot support vegetation.

(C) After drying, the finer fraction of slurry becomes airborne and cause serious air pollution which is not only detrimental to human beings but also to vegetation and machinery.

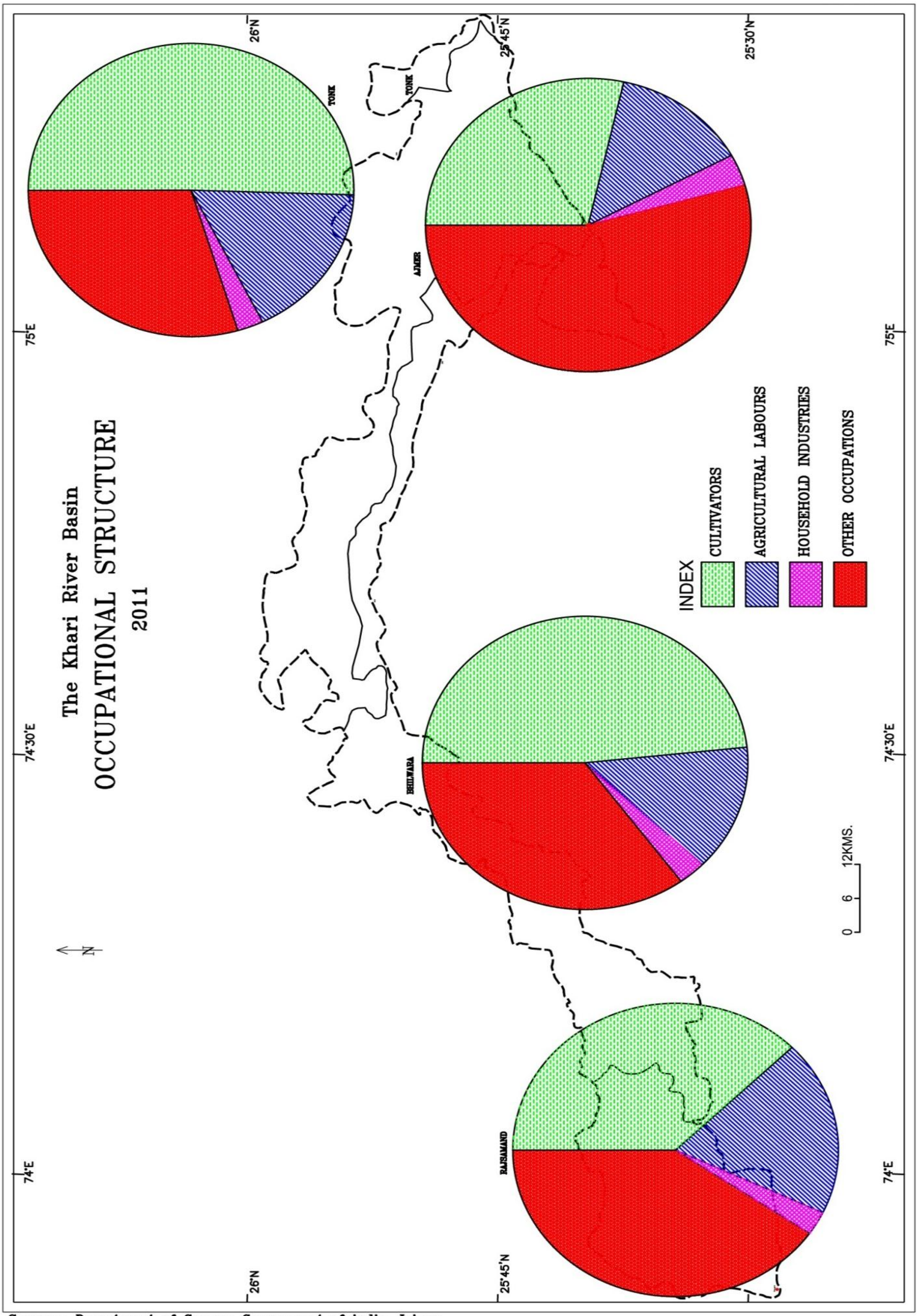
Other then this there are 343 registered industries in Ajmer district and 203 registered Industries in Rajsmand district and 289 small registered industries in Tonk district. Due to wastage produced by these industries environment of khari river basin is getting degraded, due to which there are so many problems have been occurred.

Occupational structure of Khari river is presented in map no. - 18

III- Urbanization and degradation:

Due to uncontrolled urbanization trend in India environment degradation has been occurring very rapidly and causing many problems like land insecurity, worsening water quality, excessive air pollution, noise and the problems of waste disposal.

Urban populations interact with their environment. Urban people change their environment through their consumption of food, energy, water, and land. And in turn, the polluted urban environment affects the health and quality of life of the urban population. People who live in urban areas have very different consumption patterns than residents in rural areas. For example urban populations consume much more food, energy and durable goods than rural populations.



Source:- Department of Census, Government of india, Jaipur.

This increased consumption is a function of urban labor markets, wages and household structure. Energy consumption for electricity transportation, cooking, heating is much higher in urban areas than in rural villages.

Urban consumption of energy helps create heat islands that can change local weather patterns and weather downwind from the heat islands. The heat island phenomenon is created because cities radiate heat back into the atmosphere at a rate 15 percent to 30 percent less than rural areas. The combination of the increased energy consumption and difference in albedo (radiation) means that cities are warmer than rural areas (0.6 to 1.3C) and these heat island become traps for atmospheric pollutants. Cloudiness and fog occur with greater frequency. Precipitation is 5 percent to 10 percent higher in cities, thunderstorms and hailstorms are much more frequent but snow days in cities are less common.

Some urban environment problems include inadequate water and sanitation, lack of rubbish disposal, and industrial pollution. Unfortunately, reducing the problems and ameliorating their effects on the urban population are expensive.

The health implications of these environment problems include respiratory infections other infectious and parasitic diseases. Capital costs for building improved environment infrastructure for example, investment in a cleaner public transportation system such as a subway and for building more hospitals and clinics are higher in cities, where wages exceed those paid in rural areas, and urban land prices are much higher because of the competition for space.

Plate – 20

Khari river in Nekedia village

Plate – 21

Khari river in Gulgaavn village

Urbanization and environment degradation in khari river basin

The study reveals that the city population growth is imposing a burden on the nature of the natural resources. Urban population of main cities of khari river basin is shown in table no. 6.1

Table no. 6.1

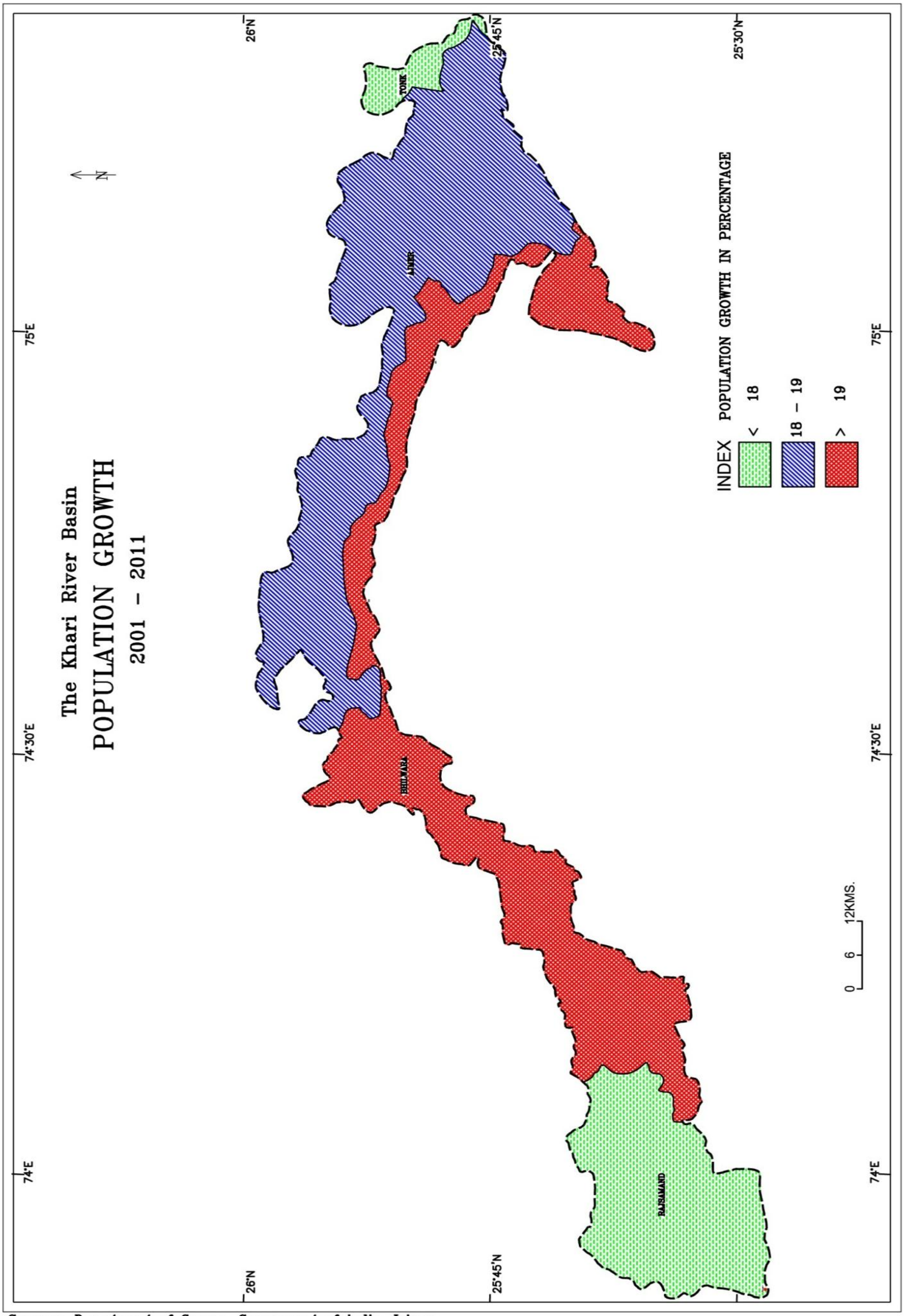
Urban population of khari river basin

Cities of Khari river basin	Urban population (2011)
Beawar	151152
Kekri	41890
Devgarh	17604
Shahpura	30,320
Asind	16,611

Source – District census handbook 2015.

Beawar urban population growth in the decade was 22.13%. This compares to a growth figure of 15.96% for the previous decade. Kekri, Devgarh, Shahpura, Asind also have growth figure then the previous decade. In 1941 Kekri urban population was only 8245. Now it is 41890 in 2011.

This growth does not cope with sanitation, hygiene and civic amenities and pollute or degrade the urban environment. Urbanization can affect the physical process of river growth, modify stream structure and further influence the functions of river system. Urban population growth in decades of different tehsils of Khari river basin is shown in table no. 6.2 . Population growth of Khari river basin is presented in map no. - 19



Source:- Department of Census, Government of india, Jaipur.

Table no. 6.2

URBAN POPULATION GROWTH IN DECADES (%) 2011

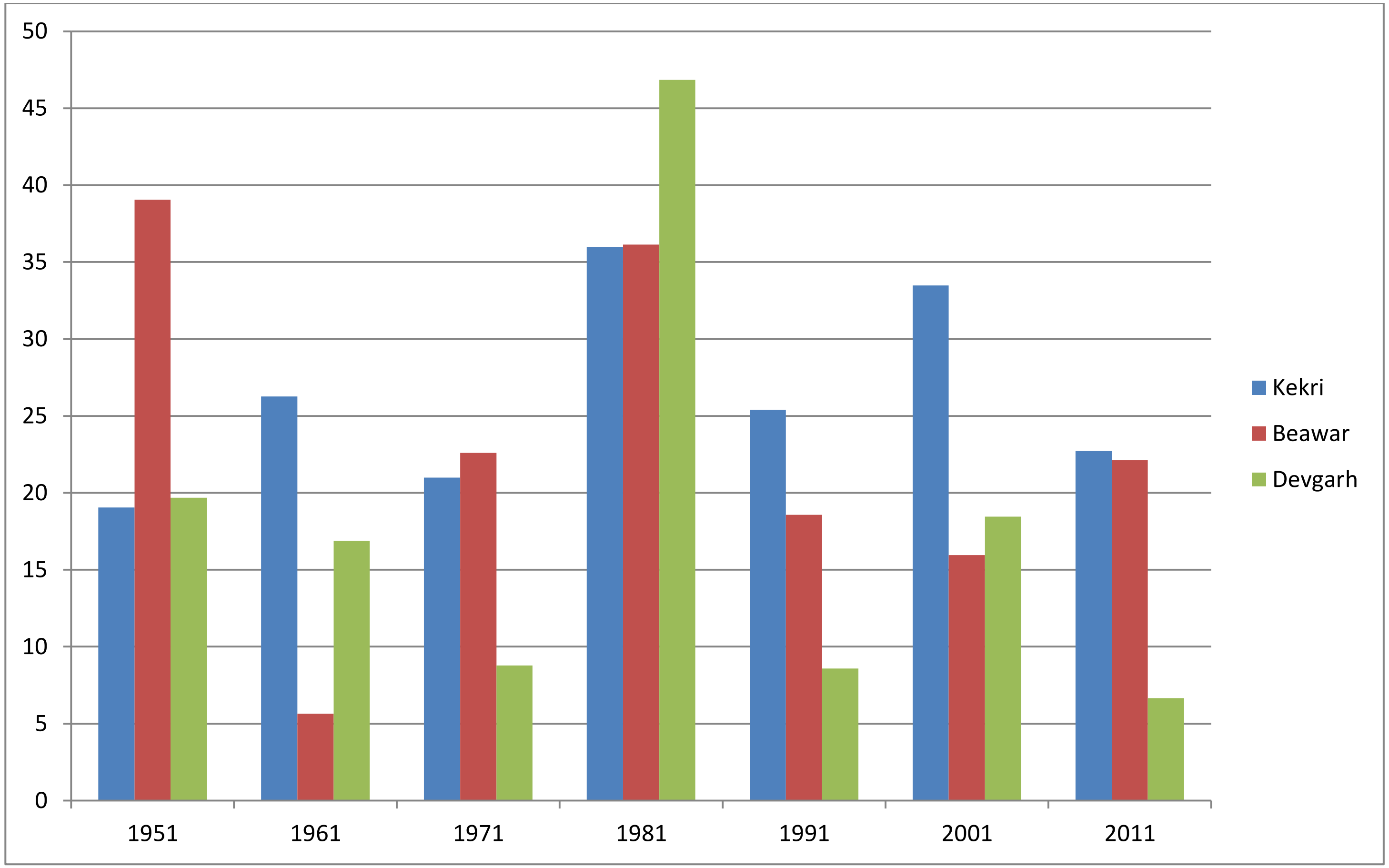
Year	**Kekri**	**Beawar**	**Devgarh**
1951	19.05(+)	39.04(+)	19.68(+)
1961	26.26(+)	5.64(+)	16.88(+)
1971	21.00(+)	22.59(+)	8.79(+)
1981	35.98(+)	36.13(+)	46.84(+)
1991	25.40(+)	18.58(+)	8.59(+)
2001	33.48(+)	15.96(+)	18.46(+)
2011	22.71(+)	22.13(+)	6.65(+)

Source – District census handbook 2015.

Urban population growth in decades is presented in fig. 13

Fig.13

Urban Population Growth in Decades (%)



IV- Agriculture development and degradation:

The impact of agriculture on the environment is often discussed merely in terms of pollution due to leaching of agrochemicals or to erosion of contaminated soil particles. As a matter of fact, however, more important environment problems are due to the imbalance or the lack of closure of nutrient cycles and to the wrong choice made to this purpose.

Some of the environment. issues that are related to agriculture are deforestation, irrigation problems, pollutants, soil degradation and waste.

- **Deforestation –** One of the causes of deforestation is to clear land for crops. When Trees are removed from forests, the Soil tend to dry out because there is no longer shade and there are not enough trees to assist in the water cycle by returning water vapor back to the environment. The removal of trees also causes extremes fluctuations in temperature.
- **Irrigation-** Irrigation can lead to number of problems. Among some of these problems is the depletion of underground aquifers through over drafting. Soil can be over irrigated because of poor distribution uniformity or management, wastes water, chemicals may lead to water pollution. Over irrigation can cause deep drainage from rising water tables that can lead to problems of irrigation salinity requiring water table control by some form of subsurface land drainage. Irrigation with saline or high sodium water may damage soil structure owing to the formation of alkaline soil.
- **Pollutants-** A wide range of agriculture chemicals are used and some became pollutants through use, misuse or ignorance. Pesticide can leach through the soil and enter the ground water as well as linger in food products and result in death in human. Pesticide can also kill non-target plants, birds, fish and other wildlife.
- **Soil degradation-** Soil degradation is the decline in soil quality that can be a result of many factors, especially from agriculture. Common attributes of Soil degradation can be salting, waterlogging, compaction, pesticide contamination, loss of fertility, changes in soil acidity, alkalinity, salinity and erosion.

Agriculture development and degradation in Khari river basin

There are two types of indicators of environmental impact of agriculture: "means based," which is based on the farmer's production methods, and "effect based", Which is the impact that farming methods have on the farming system or on emissions to the environment.

Study reveals that khari river basin area has a semi-arid climate due to which rain only, is not sufficient to make it suitable for agriculture resulting farmers have to use artificial sources for agriculture. Due to these artificial sources land is getting degraded.

It we look at the data, in Bhim Tehsil 4490 hectare, in Devgarh tehsil 5917, hectare, in Beawar tehsil 5654 hectare and in kekri tehsil 24290 hectare area is irrigated. These are irrigated through well, ponds, tubewell and other artificial sources. Irrigated area of Khari river basin is shown in table no. 6.3

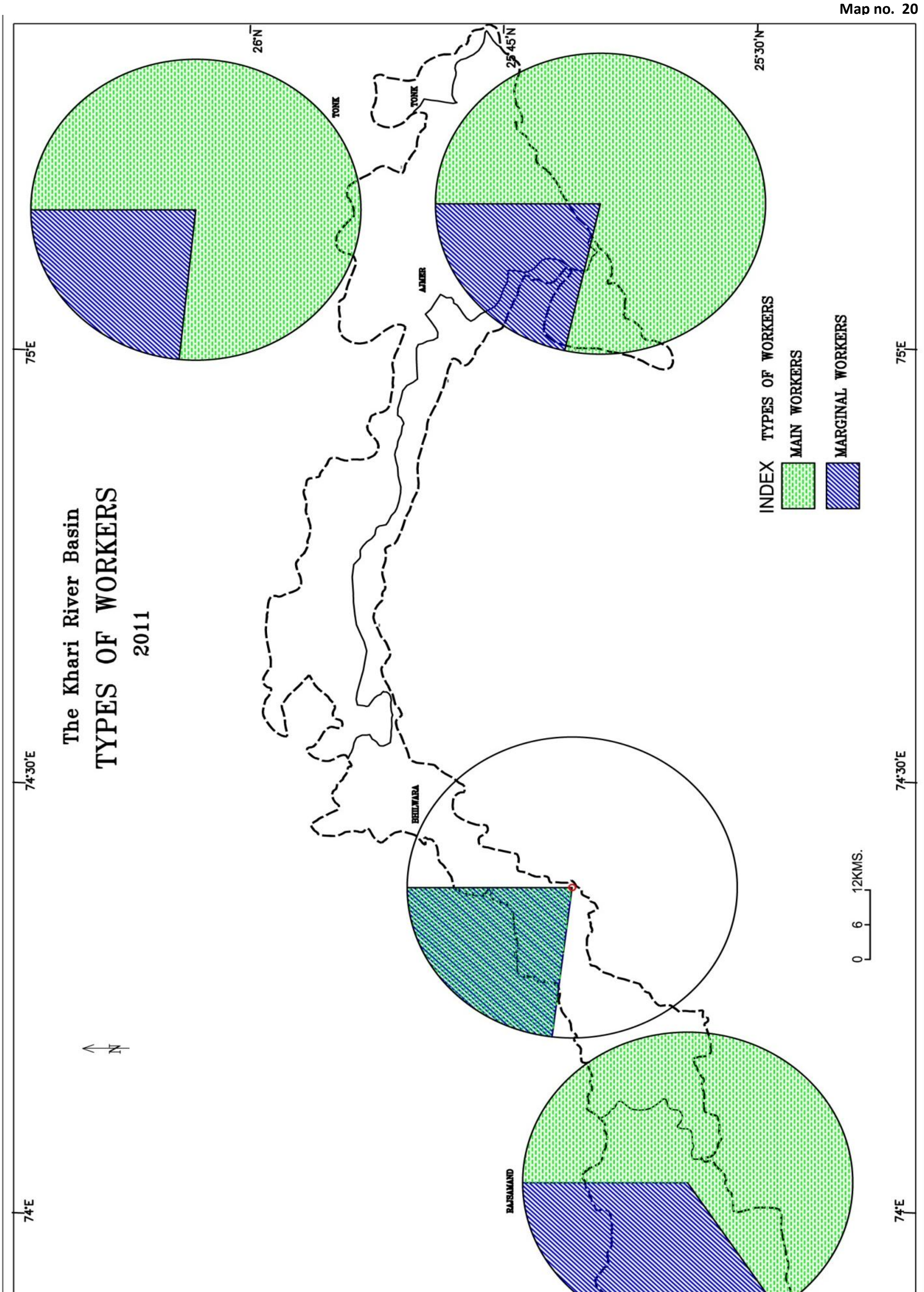
Table no. 6.3

Irrigated area of Khari river basin (2015)

Tehsil	**Irrigated area (Hectare)**
Bhim	4490
Devgarh	5917
Beawar	5654
Kekri	24290
Asind	13065
Hurda	15536
Mandal	7651
Banera	7811

Source – District census handbook 2015.

Map no. 20



Source:- Department of Census, Government of india, Jaipur.

With the development of agriculture, land use is also changing in the area which is affecting the environment. If we look at the data of land use in khari river basin area these are also changing with time. In Rajsamand district barren land which was 2.80% in 2008-09 has become 26.44% in 2013-14.

Forest land in being used for agriculture purpose resulting in degradation of environment. In Bhilwara district only 7.8% land is left as forest area while on 63.220% land is used for Agriculture purpose. Land use data of Khari River basin is shown in table no.6.4 and presented in map no.-21

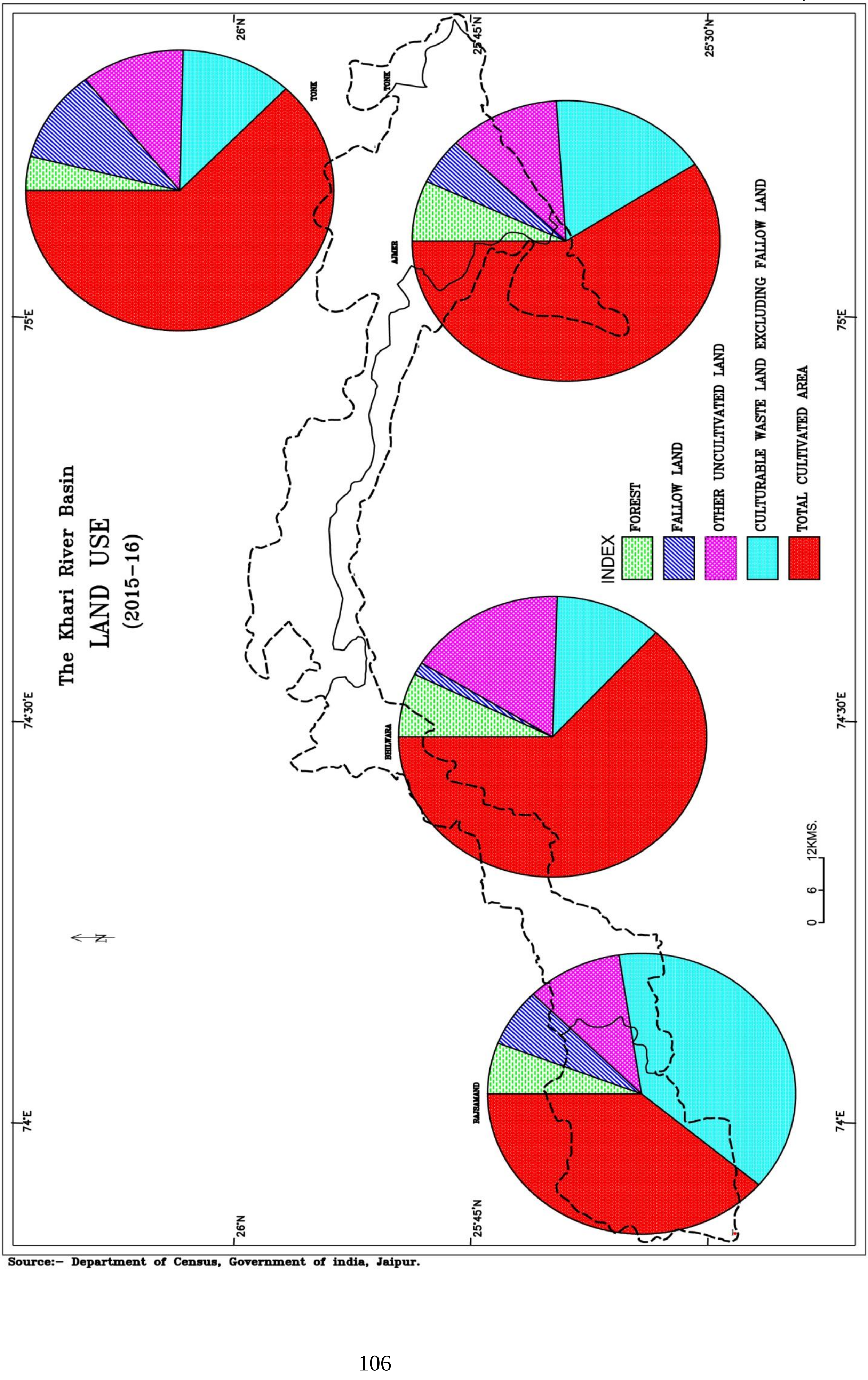
Table No.-6.4

Land-use data (2015-16)

	Rajsamand	**Ajmer**	**Bhilwara**	**Tonk**
Forest	5.79	6.85	7.18	3.76
Follow	6.86	5.34	1.36	10.72
Other uncultivated land	9.84	11.77	17.03	10.89
Culturable waste land excluding follow land	38.79	17.26	11.50	11.84
Cultivated area	39.10	59.33	63.20	62.97

Source – District census handbook 2015.

Map no. 21



Source:- Department of Census, Government of india, Jaipur.

Measures to control environment degradation

Rainfall in the study area is the main source of ground water recharge. Due to less rainfall and increased ground water withdrawals, ground water levels are declining in some parts of the study area. Increasing urbanization and change in lifestyle have led to increased demand of water. So precious ground water resources have to be conserved for sustainable availability. There is need to reduce/avoid wastage of water in various uses. Ground water should be used judiciously taking into account modern agriculture, water management techniques by cultivating crops needing less watering and use of sprinkler system and drip irrigation should be encouraged. Increasing number of ground water structures should not be encouraged and artificial ground water recharge schemes like check dams, bunds, anicut etc., should be constructed at appropriate hydrogeological locations. Surface water reservoirs like ponds/tanks etc. should be constructed, which would serve dual purpose of supply of water during lean period and recharge to the ground water body.

Rain water harvesting should be practiced to reduce the ground water pollution and water scarcity. It is necessary for environmental protection that air, water and noise pollution caused by industrial development should be controlled properly. Air pollution can be reduced by selection of proper fuel and fitting smoke stacke to factories with electrostatics precipitators. Noise pollution can be reduced by efficient machines producing less or no sound. Noise absorbing may also be used to avoid agricultural pollution, use of pesticides and chemical fertilizers should be minimized.

The environment protection Act was passed in 1986 in India. Its objective was to check deterioration in the quality of environment. The legislative measure should be strictly enforced.

Table No.-6.5

Degraded and wasteland statistics of Khari river basin

District	Degraded and waste land classes (Area in ‘000 hactare)					
	Exclusively water erosion (>10Tonnes/ha/yr)	Water erosion under open forrest	Exclusively wind erosion	Saline and sodic soil	Other	Total
Ajmer	275	0	1	10	559	845
Bhilwara	552	19	0	6	466	1043
Tonk	390	0	0	0	327	717
Rajsamand	275	13	0	0	98	386

Source : NBBS and LUP, Udaipur (Rajasthan)

Plate – 22

Vegetation along Khari river basin

(Ramthala village)

Chapter - VII

SUMMARY AND CONCLUSION

SUMMARY

Geomorphology has been defined as the study of terrestrial geomorphology and the forms and features that result from it (peel 1967). Geo-scientists treat it as a bridge between geology and geography. As a matter of fact it harmonises the basic concepts which constitute the philosophical and methodological bases of these sister disciplines and offers a convincing and logically sustainable interpretation of geomorphic process, forms and associated features.

The importance of geomorphology can very well be realized as a resource denominator, evolutionary indicator and surficial viewer. The experiences of geomorphic appraisals in planning project reveals that a drainage basin is the most ideal and fundamental unit for any regional planning. The present study is an attempt in the same direction. The main aim of the study is to understand and illustrate the physiographic character of the river basin and to evaluate environment change and evolve a strategy for combating the geo-environment of the region under study the work has been taken in hand.

The research work is based mainly on field observations. The entire basin area covers ten toposheets of survey of India on the scale of 1:50000. The toposheets used for the study were 45k/5, 45k/9, 45k/13, 45O/1, 45O/5, 45G/14, 45k/2, 45k/14, 45O/2. With the help of these sheets various morphometric technique have been applied to the river basin. The drainage basin area, stream frequency, village map, relief, contour map etc. were prepared. various climatological, geological, geomorphic and land use data was collected from different government and non-government agencies and analysed with the help of different geographical tools such as maps and graphs.

The study area of research work is Khari river basin. Khari river is a left bank tributary of Banas river. Khari river originates from hills of bijral village near Devgarh tehsil in Rajsamand district. The basin is situated in south- east part of Rajasthan state and spreads over in Devgarh and Bhim tehsil of Rajsamand, Beawar and Kekri tehsil of Ajmer district, Asind, Hurda, Mandal, Banera, Shahpura tehsils of

bhilwara. The basin stretches between $25^0$27' North to $26^0$7'30'' North and $73^0$5' to $75^0$7'30" east covering an area of 6,133 Square km. The length of the basin from north to south 65.9 km and width from east to west is 152 km. In the Khari river basin area, there are two seasonal rivers, the Khari and Mansi. The Khari river as well as tributaries are ephemeral and flow only in response to heavy precipitation. A complex ground slope direction pattern is shown by the Khari sub basin where in the middle part of the basin, the directions very from westerly to easterly and southerly to northerly.

The geology of the study area shows that it can be categorized in Proterozoic age rocks. Geologically speaking the study area comprises of Bhilwara super group (3200-2500 m.y.) Aravalli super group (2500-2000 m.y) Delhi super group (2000-800 m.y) Vindhyan super group (700-600 m.y.)

Bhilwara district has predominant geological formations. In this area rock types belonging to Bhilwara super group, Aravalli and Vindhyan super group. In Rajsamand rocks are belonging to Bhilwara super group, Aravalli super group and Delhi super group and alluvial deposits along the channels of river Banas, Khari and other rivers in the form of valley fills. The oldest formations exposed in the area belongs to Bhim super group of archaean age. The northern, central and western part of the area are occupied by the younger formations of Aravalli super group and Delhi super group of Proterozoic age. Quaternary and recent alluvium overlies most of the formations in isolated pockets, along river courses and in shallow depressions. River basin area of Tonk district is underlain by rocks of Bhilwara super group comprising mainly of mica, schist, gneisses phyllites and quartzites having small intrusive granite. These hard rocks are overlain by the alluvium of recent to sub-recent age. Consisting mainly of clay, sand, and silt, Ajmer district has predominant geological formations. Comprising mainly of schist, alluvium and gnesis. Climatically the Khari river basin is part of the semi-arid climatic region of Rajasthan where there are extremes of temperature, low rainfall, greater evaporation and evapotranspiration and scarcity of natural vegetation. The highest temperature in summer season is 41.8^0C the lowest is 25.8^0C. May is the warmest month in this area. In winters maximum temperature is 24.8^0C and minimum temperature is 8.9^0C. December and January are the coldest months. Rainy season starts when the summer condition reach their peak and scorching heat during the day time almost unbearable. Most of the normal annual rainfall is received during the months of July and August. Average annual rainfall in this area is 600mm. The south west monsoon starts retreating from the area by the end of September or early October. The mean monthly temperature recorded in this area during the months of October and November are 25.6^{0}C Respectively.

The relative humidity is lowest in April-May period around 25%, it increases to about 75%. During the peak monsoon activity in August. Skies are generally moderately to heavily clouded during the south west monsoon season. During rest of the year, skies are normally clear to lightly clouded. The predominant wind direction in this area are W, NW, N, NE and East. Mean monthly wind speeds are generally high throughout January to October. Reaching a max in June and may. November and December are relatively less windy.

The soils of the khari river basin have been classified as Red and yellow soil, Red gravelly soil, older alluvial soil, Brown soil. Red-yellow soil is found mostly north and central part of basin. Due to higher degree of hydration of ferric oxide the soil has acquired yellow colour. Brown soil found in different tehsils of Bhilwara. Brown soil are sandy 10am to clay 10am in texture. Older alluvial soil found higher up in the plains at river terraces away from rivers. Mainly found in the different part of Tonk district. Red gravelly soil is found in the western part of basin. Mostly in the different tehsils of Bhilwara and Rajsamand.

Geomorphic environment mainly deals with the geomorphology of the area and geomorphic process, which are responsible for the creation of new land form as well as new geomorphic units. The study area lies in the districts of Ajmer, Bhilwara, Tonk and Rajsamand. Aravallis are present in the western part of the study area. This part is in a shape, which can be technically called as environmentally degraded. All the geomorphic units present in the study region have been divided in main divisions like denudational land forms, depositional fluvial land forms. Geomorphologically there are structural hills, Pediment, buried Pediment, denudation plains, valley fills, flood plains etc.

The land scape in the Khari river basin in indeed resultant feature of structure and processes found in the area through the stages. The region mostly has a gentle slope less then 2^0, the most of the basin area is plain. Maximum slope is found around Devgarh Tehsil and mandwar village and hamela ki Ber in Bhim tehsil of Rajsamand district that is more than 8^0. Generally the slope decreases from west to east. The region is hilly in the western part of the basin. khari river flows from west to east. The hills of bijral village are found in Devgarh tehsil from where this river originates. The eastern part of the basin belongs to lowland where the height is below belong 375mt. The central and western uplands are also almost flat and cover half area of the basin.

Contour map prepared by taking 1:50000 toposheets and drawn the contours at 20mt. interval.

Fluvial morphometry includes the consideration of linear, areal and relief aspects of a fluvially originated drainage basin. To understand the aspect of fluvial morphology like stream frequency, stream ordering, Bi-furcation ratio, Sinuosity index, drainage pattern, the basin area was demarcated by finding out water divides and using spot heights and contours of the area. With the help of toposheets drainage basin area, stream frequency, village map, relief, contour map etc. were prepared and various morphometric techniques have been applied to the river basin. Total range of the stream frequency calculated has been divided into five categories low stream frequency, less moderate, moderate, high and highest. Which varies from low frequency < 4 to highest frequency > 16. Bifurcation ratio is calculated which is a ratio of the number of streams of a given order to the number of streams of the next higher order. The researcher adopted the strahler's method to stream ordering and result shows that Khari river is a 3rd order stream. Simuosity index analysis of river indicates that Khari river is a non-meandering river. The drainage map of Khari river basin shows that it is a subsequent river and has a two type of drainage patterns, dendritic and rectangular.

Environment degradation results due to erosion and decline of the quality of the natural environment. Environment Degradation can completely destroy the various aspects of the environment such as bio-diversity, ecosystem natural resources and habitats. Study reveals that problem of environment degradation in Khari river basin has increased in last few year. Pollution, deforestation, soil erosion, human interference, climate change, urbanization, industrial development, agriculture development are the main causes behind this problem. City population growth is imposing a burden on the nature of the natural resources. Most of the cities of Khari river basin like Beawar, Kekri, Devgarh, Shahpura, Asind have grown in population from previous decade. In 1941 Kekri Urban population was only 8245 now it is 41890 in 2011. Other than this many industries, mining activities are happening in this area, which are responsible for environment degradation.

Conclusion

The result of the study contained on this report pertains to the analysis and Synthesis of multiple parameters and their various components of a geomorphic study of Khari river basin. The principal conclusions are as follows:-

(1) Several hydro-geomorphologic units have been identified and mapped, using toposheets and field survey. The most extensive geomorphic units are pediment, denudational plains, flood plain, structural hills. Hill ranges surround the basin in NW and eastern part of the Bhilwara town. In Rajsamand geomorphological unit show linearity specially the structural hills which are aligned in the direction of Aravalli (NE-SW). Some denudational hills are developed in Devgarh and Bhim Tehsils in Rajsamand district. The pediments are mainly present along the hills in Devgarh and Bhim Tehsils, and eastern and western part of Bhilwara.

(2) The ground slope is an important aspect in geomorphological studies varies from $< 2^0$ to $> 8^0$ while the slope direction is generally from west to east, towards the master river, the Banās.

(3) The principal lithologies of the geologic formations are gneiss, schists, qartzites that have low to medium, primary porosity and permeability. However, structural features such as faults, fractures and joints have produced secondary porosity and transmissibility.

(4) The soil developed in different geomorphic terrains vary in their basic attributes such as thickness, texture, carbonate content and salinity. Based on these, 4 types have been differentiated in different geomorphic terrains. Which is Red-yellow, older alluvial, Brown, Red-gravelly soil.

(5) The study area is a 3rd order strahler’s drainage basin. There is a spatial difference in the relative development of streams of different orders and also in the drainage frequency of the stream network which is due to lithologic and structural in homogeneities of the area.

(6) A choropleth map for measuring local relief indicates that in the study area relief varies from < 300 mt to > 700mt. The region is hilly in the western part of basin. Only 9% area has height which is more than 700mt. Other than this 45% area is covered by height of 300-400mt.

(7) Various fluvial morphometric analysis of the study area indicates quantitative study of the area. Stream frequency indicating the number of stream segments per-unit area. Which varies from low frequency < 4 to highest frequency > 16. Sinuosity index analysis of river indicates that Khari river is a non meandering river.

(8) The drainage map of river basin exhibits that dendritic drainage pattern is most common pattern in this area.

(9) Study area is in a shape which can be technically called as environmentaly degraded. It can be said that agriculture development, urbanization and industrial development in this area are the major cause of environment degradation. These factors are affecting badly long term health of the animals, humans and plants. So there is a need that we come up with a long term plan for the sustainable development of Khari river basin.

(10) The basin area used to have enough surface water resources and underground water resources to sustain thick vegetation cover and maintain rich bio-diversity but at present the basin is drying up. If the present trend continues it may be forecasted that the whole area will be arid and desertified. To protect the basin from being totally dry area must be protected from further environment deterioration.

(11) The population of the basin which shows steady increase should be brought under control as population increase is causing undue stress on the already weak ecology.

(12) Proper water resource management and dry land agriculture techniques like sprinkler irrigation, drip irrigation, soil moisture conservation etc. should be taught to farmers and implements can be subsidized.

(13) Sustainable development should be the main aim of the development as it entails development in such a way that development occurs but the environment and resource should be able to sustain the development of future generations. Thus the prevailing trend of putting more and more land to agriculture in the basin is not right, the stress should be on increasing yield from existing farmland without causing environmental pollution.

(14) The damage to the environment hurts people both today and will do so in the future it provides additional grounds for rethinking of measurement of development. No doubt health, education and nutrition have improved by economic growth but the environment is sometimes damaged by the growth. So development and environment policies must be based on a comparison of costs benefit analysis. This will lead to strengthening of environmental protection measures and consequently lead to rising and sustainable levels of welfare.

Thus today we have to re-think over the man-nature relationship and it is essential to educate the people about environment, to get us out of the present ecological crisis.

Annexure

Village wise list of Khari river basin

District - Ajmer

S. No.	Name of village
1.	Hanutiya
2.	Khejari
3.	Kaniya
4.	Digsingh ka kheda
5.	Sathana
6.	Mokhampura
7.	Kesharpura
8.	Jaliya
9.	Bari
10.	Sutikhera
11.	Bijaynagar
12.	Shikharani
13.	Barali
14.	Ganbera
15.	Lamgarh
16.	Deolia

17.	Bagrai
18.	Gurha Kalan
19.	Sunpa
20.	Prarhera
21.	Ugankhera
22.	Shahipura
23.	Kacharia
24.	Kadera
25.	Dermand
26.	Piplaj
27.	Nahaesaga Khai
28.	Bisundi
29.	Ghoram
30.	Aloli
31.	Khawas
32.	Meharun Kalan (Nayagaon)
33.	Para
34.	Gulgaavn
35.	Kadera

36.	Rajpura
37.	Mundi
38.	Tankwas
39.	Dhundri
40.	Bajita
41.	Khera
42.	Nadi
43.	Kalera
44.	Chosla

District – Rajsamand

S. No.	Name of village
45.	Mandawar
46.	Khajwana
47.	Hamela ki vera
48.	Lakha ka gurha
49.	Kachhwari
50.	Siror
51.	Bagar
52.	Pipli
53.	Sangwas
54.	Kundeli
55.	Bijral
56.	Dolpura
57.	Anjana
58.	Ghati
59.	Lasani
60.	Thiksrwas khurd

61.	Thikarwas kalan
62.	Shangarh
63.	Tal
64.	Kakrod
65.	Miala
66.	Sopari

District – Bhilwara

S. No.	Name of village
67.	Dhapura
68.	Pipliys ks Bsriya
69.	Gyan Garth
70.	Mata ka khera
71.	Khuma ka khera
72.	Dhula
73.	Gopal Sagar
74.	Keriyakhera
75.	Ghitamba
76.	Kangea ka Boriya
77.	Ruppura
78.	Dhaqriya ka bariya
79.	Chansin
80.	Khokhla ka Bariya
81.	Bhaneri
82.	Bital ka Bariya

83.	Jhalra
84.	Raghanatpura
85.	Phokoliya
86.	Sangni
87.	Bamni
88.	Sabdaral
89.	Khgtola
90.	Sulwara
91.	Bharatpura
92.	Govinpura
93.	Asind
94.	Bheunkhera
95.	Daravat
96.	Parasoli
97.	Devpura
98.	Jogpura
99.	Khorchi
100.	Jwar
101.	Jainagar

102.	Gajsinghpura
103.	Shambhugarh
104.	Barni
105.	Tantra
106.	Sangramgarth
107.	Gangdhanagar
108.	Genpura
109.	Rampura
110.	Sapola
111.	Jalkhera
112.	Antali
113.	Songar
114.	Gulabpura
115.	Hurara
116.	Kotri
117.	Kothiyan
118.	Ranjitpura
119.	Bawari
120.	Dhanop

121.	Daulatopura
122.	Rampura
123.	Phulliya
124.	Alambu
125.	Motipura
126.	Bachhkhera
127.	Lasariya
128.	Dabla Chanda
129.	Baland

District – Tonk

S. No.	Name of village
130.	Bijawr
131.	Mansugar
132.	Barla
133.	Ramthala
134.	Maera
135.	Nekdia

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