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HYDROLOGICAL PROBLEMS IN THE KANDI BELT OF JAMMU REGION

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE - 247 667 (UTTARANCHAL)

PREFACE

The Siwalik foothill region, known as Kandi belt, is spread in the north-western states of Jammu & Kashmir, Himachal Pradesh, Punjab and Haryana. In Uttaranchal, this region is known as Bhabhar belt. Denuded hills, undulating topography, erratic distribution of rainfall in space and time, small land holdings, high soil erosion, coarse textured and infertile soil, and low crop productivity, are typical features of this region.

Agriculture in this region is generally rainfed, except little area irrigated by surface and ground water sources. Although average annual rainfall in the region is relatively high, and a number of streams and rivulets pass through the area, scarcity of water is experienced both for domestic and agricultural purposes. Inadequate storage of the available surplus water, and lack of proper water management, are considered to be responsible for the poor state of natural resources in the Kandi belt.

In a Brain Storming Session, organised by the Western Himalayan Regional Centre of the Institute at Jammu in January, 2000, there was concern on the state of the Kandi belt in Jammu region and the need for systematic scientific studies for the region was expressed. The Jammu Regional Centre has carried out a study on the hydrological problems in the Kandi belt of Jammu region, as part of the work program of the Center for 1999-2000. It was noted that a lot of useful information is available at various sources, both in the government and with individuals. Most of this information was lying scattered in the unpublished records. In the present report, an effort was made for compilation of information on various aspects pertaining to the Kandi belt of Jammu & Kashmir, especially natural resources and relevant socio-economic data. It is expected that the report will be very useful to the planners, development agencies, researchers and technologists in their efforts for development of the region.

This report is prepared by Dr. V. C. Goyal, Scientist 'E', and Dr. S P Rai, Scientist 'B'. Dr Vijay Kumar, Scientist 'C', helped in the preparation of maps using GIS.

(K.S. Ramasastri)

Director

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ABSTRACT

The submontane tract lying in the outer Himalayas of Jammu Division of Jammu & Kashmir is locally termed as **Kandi belt**. This unit is an extension of the Kandi belt in the States of Himachal Pradesh, Punjab, Haryana, and Uttaranchal. The upper portion of Kandi belt consists of low hills covered by shrubs and forest, and the lower terrain has cultivated lands and gully beds. It has undulating topography, steep and irregular slopes, erodible and low water retentive soils and badly dissected terrain by numerous gullies.

Tract further south-southwest of the Kandi belt is generally a modulating land. The topographic gradient is gentle. Boulders and pebbles almost disappear from the surface and their place is taken by finer material. In the tract the groundwater is met with at a shallow depth and supports good agriculture. This tract of undulating land with flowing stream and good agricultural ground presents a green look. This tract is locally known as the **Sirowal Belt**, equivalent of the Tarai Belt in other parts of the Himalayas. Shallow ground water conditions in the Sirowal belt are causing water logging and, at places, soil salinity problems.

Population in the entire Kandi belt suffers from water scarcity. Ground water table is deep. Streams of the area carry huge amount of debris material during rainy season due to fragile geological conditions. Human activities such as cutting of trees and shrubs for domestic purposes and unmanaged agricultural practices have aggravated the denudation rate. The soil loss has affected the agricultural production and hydrological regime to a large extent. Flashy flows of the streams and rivulets in the Kandi belt has denuded most of the top fertile soil, and due to excess runoff of water, the area remains devoid of water except in the monsoon months.

The major land and water management problems being faced in the Siwalik hills and Kandi belt include excessive runoff, soil erosion, land degradation and erratic rainwater distribution in space and time, hampering agricultural production. Too little and too much syndrome is playing havoc in both Kandi and Sirowal belts, respectively. If, through appropriate soil and water conservation measures, rainwater in the Kandi belt can be harvested and conserved, this would result in mitigating the problems being faced in both the Kandi and Sirowal belts. In order to control the spread of the degraded lands in this area and to restore these for productive purposes, a comprehensive strategy for survey, monitoring and planning is required.

This report is a compilation of the status of different natural resources as well as of the problems and constraints being faced in utilizing the scientific techniques for improvement of water and other resources in the Kandi belt. Suitable actions and methods are also recommended to achieve the goal of tackling these problems in the study area.

1.0 INTRODUCTION

The submontane region of the Himalayas fringing the Siwalik hills, termed as Bhabhar or Kandi, is a steeply sloping belt of less than 10 to 30 km width, extending discontinuously from Jammu and Kashmir to Assam. The Kandi (Bhabhar) is steeply sloping and flattens downstream, imperceptibly merging with the Sirowal (Terai) in the south. The tract lying in the outer Himalayas of Jammu Division of Jammu & Kashmir, locally termed as Kandi belt (Figure 1), is an extension of the Kandi belt in the States of Himachal Pradesh, Punjab, Haryana, and Uttaranchal.

Towards south and southeast of the Siwalik range, the soil material becomes finer grading from gravel and sand to silt and clay. This gradation of the material to fine sediment almost marks the southern limit of this tract. Hill torrents contain water only during freshets and run dry for most of the time. Vast stretch of boulders and dry streambeds present a very dry look to this tract. On account of its dry look, the tract is locally known as the **Kandi Belt**.

Tract further south-southwest is generally a modulating land. The topographic gradient is gentle. Boulders and pebbles almost disappear from the surface and their place is taken by finer material. In the tract the groundwater is met with at a shallow depth and supports good agriculture. This tract of undulating land with flowing stream and good agricultural ground presents a green look. This tract is locally known as the **Sirowal Belt**, equivalent of the Tarai Belt in other parts of the Himalayas.

The upper portion of Kandi belt consists of low hills covered by shrubs and forest, and the lower terrain has cultivated lands and gully beds. It has undulating topography, steep and irregular slopes, erodible and low water retentive soils and badly dissected terrain by numerous gullies.

The major land and water management problems being faced in the Siwalik hills and Kandi belt include excessive runoff, soil erosion, land degradation and erratic water distribution in space and time, hampering agricultural production. In order to control the spread of the degraded lands in this area and to restore these for productive purposes, a comprehensive strategy for survey, monitoring and planning is required.

Population in the entire Kandi belt suffers from water scarcity. Ground water table is deep. Streams of the area carry huge amount of debris material during rainy season due to fragile geological conditions. Human activities such as cutting of trees and shrubs for domestic purposes and unmanaged agricultural practices have aggravated the denudation rate. The soil loss has affected the agricultural production and hydrological regime to a large extent.

The major causes of water shortage and soil erosion are deforestation, denudation of the slopes and the rugged topography, The reckless cutting of trees and shrubs for fuel, fodder and wood has led to deforestation. Overgrazing of pastures and common grazing

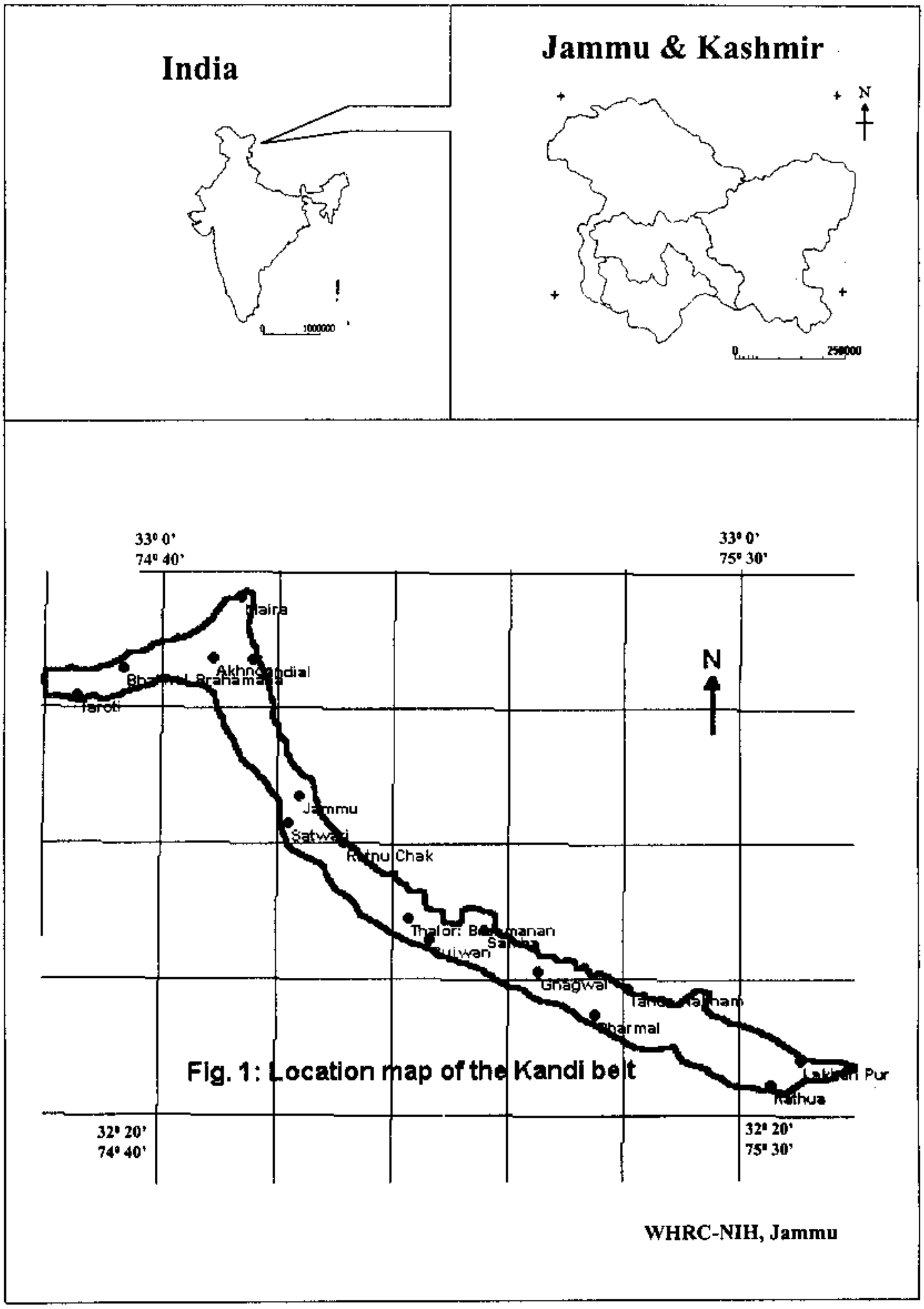


Fig. 1: Location map of the Kandi belt

WHRC-NIH, Jammu

lands has made the whole landscape naked. Agriculture is uneconomic because of poor soils and low moisture content.

2.0 THE STUDY AREA

The Kandi belt is the foothill zone of the Siwalik of Jammu and Kashmir. This belt stretches between longitude 74^0 21' to 75^0 45' E and latitude 32^0 22' to 32^0 55' N, except in the western portion, where it lies between latitude 32^0 50'to 33^0 N. The Kandi belt in J&K is extended between River Ravi in the East and Munawar Tawi on the West within the Jammu and Kathua Districts (Figure 2). The area is covered under the Survey of India toposheet nos. 43L/5, 9, 10, 11, 13, 14, 15 and 43P/2, 3, 6, 7, 11. It lies at the altitude between 300 and 490m above mean sea level. Transition zone of Kandi and Sirowal lies near Jammu Pathankot National Highway, Ranbir canal and then along the Partap canal to the line of actual control on the Munawar Tawi.

Total area of the Kandi belt is estimated to be 811 Km^2, of which the upper and lower Kandi belts constitute 610 Km^2 and 201 Km^2, respectively. The area under Kandi belt is covered in two districts, namely Jammu and Kathua. The Kandi belt is encompassed by only three out of the five tehsils of the Jammu district, and two out of the four tehsils of the Kathua district. The area of Kandi belt falling within each of these tehsils is Jammu (189 Km^2), Akhnoor (147 Km^2) and Samba (163 Km^2) in the Jammu district, and Kathua (158 Km^2) and Hiranagar (155 Km^2) in the Kathua district. Salient socio-economic data pertaining to these two districts is given is shown in Table 1.

2.1 Jammu District

Jammu is the largest populated district in the State of Jammu & Kashmir, with fastest decadal variation in population over the last four decades. It has an area of 3,097 km^2 and has the fastest growing cities such as Jammu. According to 1981 census, the total number of villages in the district are 1,192, out of which 1,054 are inhabitated and 138 uninhabitated, and 9 towns are located in the district. Total population in the district, according to 1981 census, is 9,43,395, and estimated population in 1991 is 12,26,413 with a population density of 390 and a decadal growth rate of about 28%.

The district has the largest livestock population. Out of total livestock population of about 11 lakh, there are 4.6 lakh cattle, 2.6 lakh buffaloes, 1 lakh sheep, 2.5 lakh goats and rest horses, ponies, donkeys/mules, camels and pigs.

2.2 Kathua District

Kathua district is situated in the southeast of Jammu and Kashmir state and is surrounded on the north by Udhampur and Doda districts. Samba tehsil of Jammu district touches it in the northwest while Shakargarh tehsil in Pakistan and district Gurdaspur of Punjab fall on its south and Chamba district of Himachal Pradesh in the east. The

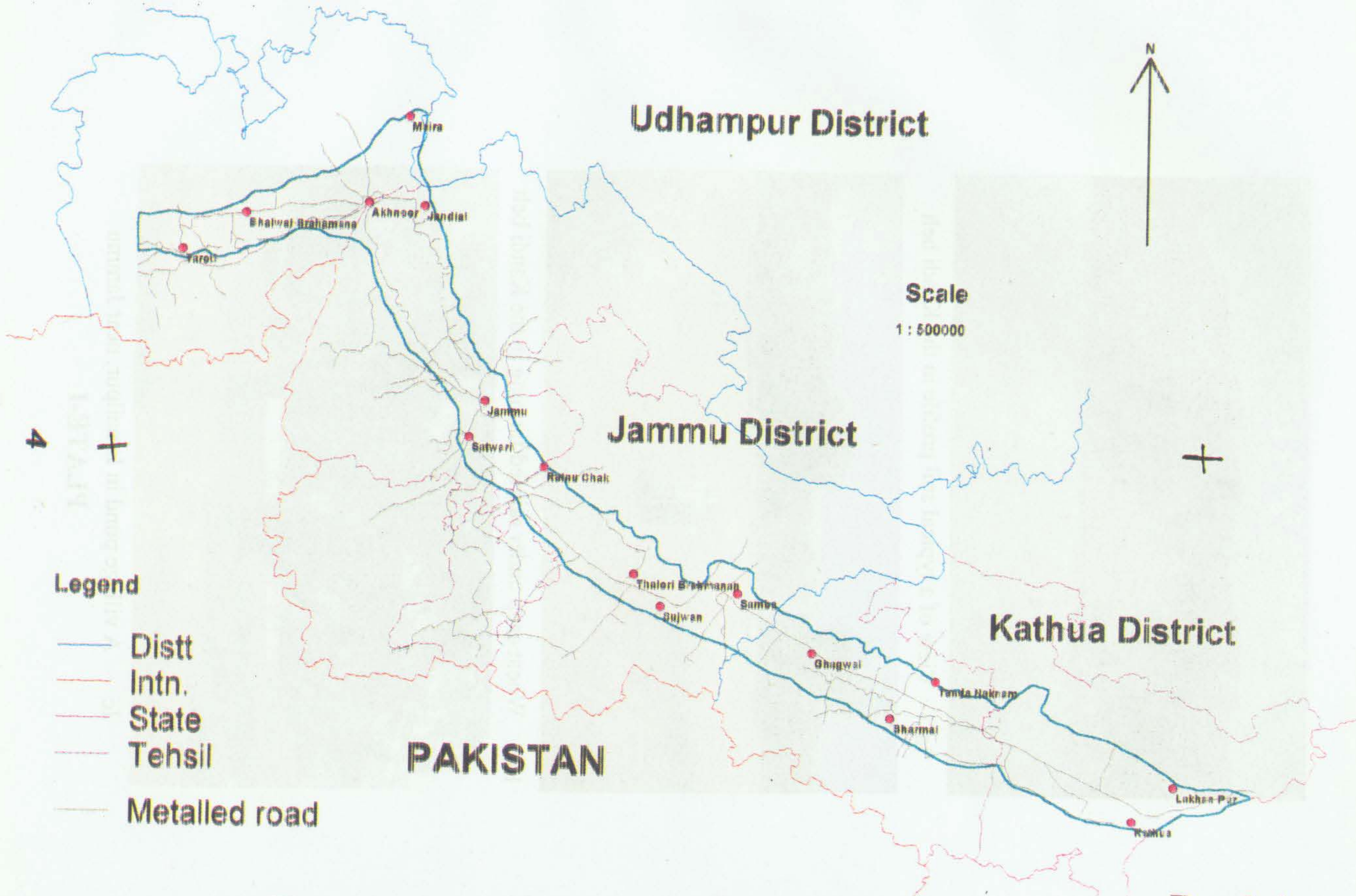
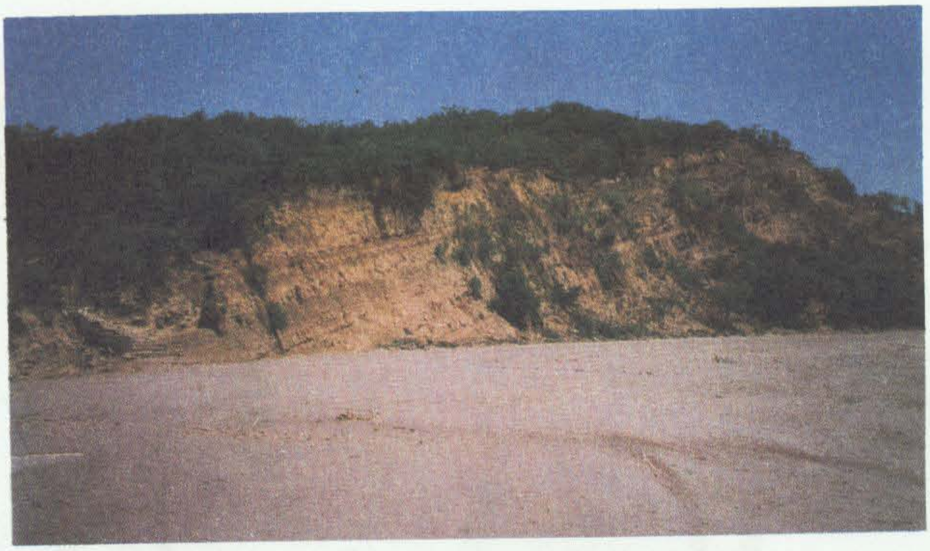
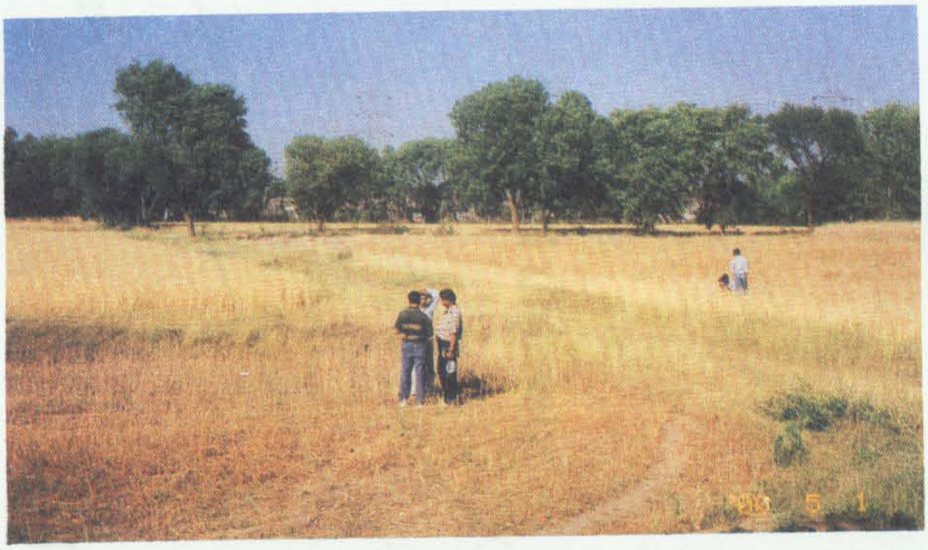


Fig. 2: Base map of the Kandi belt



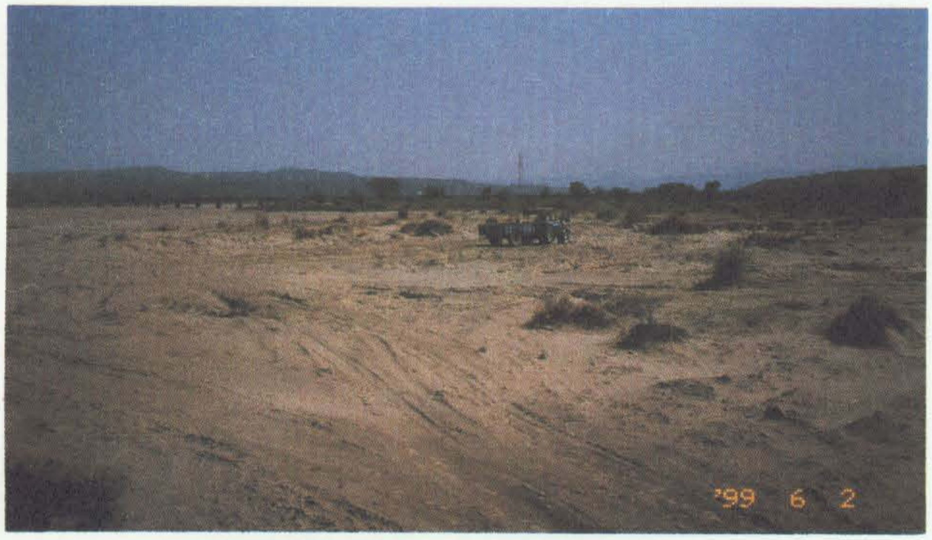
Ia View of a typical soil profile in the Kandi belt



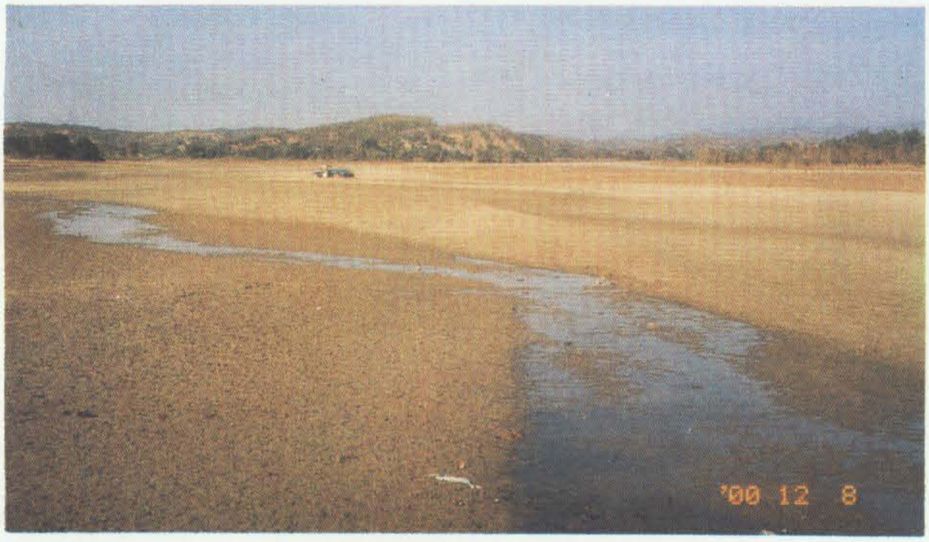
Ib Wheat crop under rainfed farming in the Kandi belt

Ic A village pond in Ismailpur, near Jammu

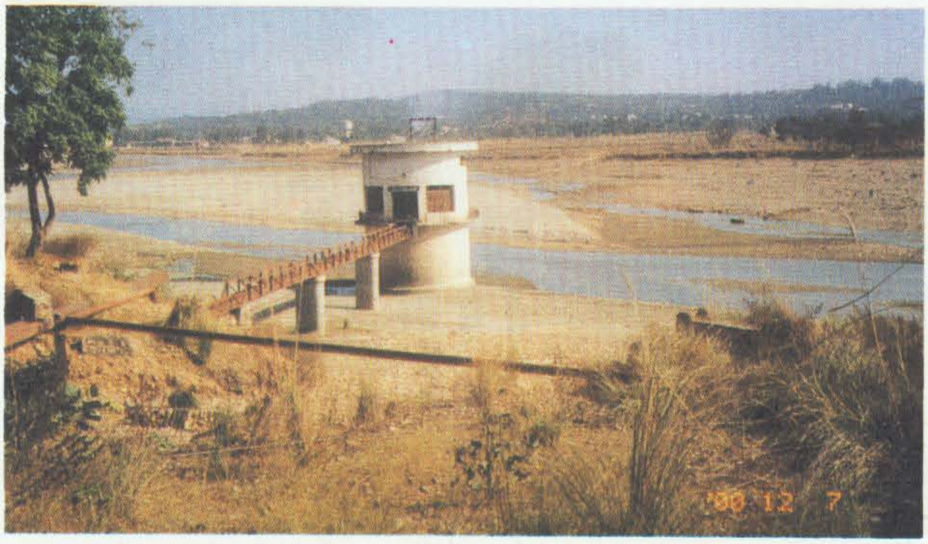
PLATE-I



IIa A view of Devak stream, from a bridge near Vijaypur



IIb A view of Rui stream, from a bridge on Jammu-Mansar road



IIc Pumping station of the Basantar Lift Canal scheme, near Samba

PLATE-II

IIIa Drilling of a tubewell in village Ghagwal

IIIb Spring line manifested as oozing of ground water in a stream bed

IIIc Survey in progress to explore lifting of water from the spring line

PLATE-III

northern part of the district is situated in the foothills of the Himalayas. The southern part is alluvial plain. Ravi river flows in the east of the district.

Table 1. Socio-economic Data Pertaining to Jammu and Kathua Districts

	JAMMU	KATHUA
Geographical Area (Km^2) (& percentage of area falling within Kandi belt)	Jammu: 907 (21%)	Kathua: 570 (28%)
	Akhnoor: 968 (15%)	Hiranagar: 536 (29%)
	Samba: 794 (21%)	
Sub-Total Tehsils (Km^2)	**2669**	**1106**
Total District (Km^2)	**3097**	**2651**
Population Density (Per Km^2)*	390	186
% Urban to Rural Population	29.64	11.38
Population (1981) & Growth Rate (1971-81)	Jammu: 430277 (26%)	Kathua: 115184 (35%)
	Akhnoor: 146802 (35%)	Hiranagar: 113857 (35%)
	Samba: 159027 (37%)	
Livestock Population*	1103000	1000300
Human Population (1991)*	1207996	492288
No. of Inhabited Villages	Jammu: 315	Kathua: 174
	Akhnoor: 206	Hiranagar: 244
	Samba: 277	
Towns (& Population in 1981)	Jammu (MC) (214737) Jammu Cantt (8624)	Lakhanpur (1162) Parole (5397) Kathua (23612)
	Akhnoor (6721)	Hiranagar (4805)
	Samba (7960) Vijaypore (2731) Bari Brahmana (16099)	
% Cultivable to Total Area	Jammu: 43.28	Kathua: 41.62
	Akhnoor: 38.55	Hiranagar: 52.32
	Samba: 53.82	
% Irrigated Area to Total Cultivable Area	Jammu: 35.53	Kathua: 32.89
	Akhnoor: 16.17	Hiranagar: 19.06
	Samba: 3.59	

(Source: District Census Handbooks, 1981. Jammu and Kathua Districts, Dte. of Census Operations, Jammu & Kashmir; * Digest of Statistics (1997-98), Dte. Of Economics & Statistics, Govt. of J&K)

Kathua district has an area of 2,651 km^2. According to 1981 census, the total number of villages in the district are 587, out of which 555 are inhabitated and 32 uninhabitated, and 6 towns are located in the district. Total population in the district, according to 1981 census, is 3,69,123, and estimated population in 1991 is 4,92,288, with a population density of 186 and a decadal growth rate of about 33%.

Out of total livestock population of about 10 lakh, there are 2.1 lakh cattle, 0.8 lakh buffaloes, 3.1 lakh sheep, 3.9 lakh goats and rest horses, ponies, donkeys/mules, camels and pigs.

3.0 LANDUSE

For the state of Jammu & Kashmir, about 90% of the total geographical area (including area illegally held by Pakistan and China) consist of high mountains and only about 3% area is available for cultivation. Actual forest cover of the State is about 9% of geographical area (FSI, 1997). About 30% of the total reported area (24,160 Km^2, according to village papers) is available for cultivation in the State.

The districts of Jammu and Kathua together constitute about 23% of the total cultivated area in the State, and about 10% of the total forest area, that too in the higher reaches most of which lie outside the Kandi belt. The fisheries activities in the districts of Jammu and Kathua together constitute about 10% of the State.

Agriculture is the main occupation of the people living in the Kandi belt. About 70 percent of the population is dependent on land for its living. The majority of farmers have small and marginal holdings (70% ≤ 1Ha in Jammu and 65% in Kathua). Details of various landuses in the tehsils of Jammu and Kathua districts are given in Table 2.

Table 2. Landuse in Jammu and Kathua districts

Tehsil	Total Area (Km^2)	Forest	Cultivated Area (Irrigated)	Cultivated Area (Unirrigated)	Culturable Waste	Area not Available for Cultivation
Jammu District						
Jammu	907	142	139	224	29	372
Akhnoor	968	261	60	240	72	312
Samba	794	119	15	311	101	248
Total	2669	522	214	775	202	932
Kathua District						
Kathua	570	76	78	116	43	257
Hiranagar	536	38	53	212	15	218
Total	1106	114	131	328	58	475

(Source: District Census Handbook, Jammu District, 1981; District Census Handbook, Kathua District, 1981, Dte. Of Census Operations, Jammu & Kashmir)

4.0 CLIMATE

The Kandi belt experiences subtropical climate, where summers are very hot and winters are cold and dry. The summer season usually starts from April and lasts upto

June. June is the hottest month (Average 39°C; highest 46°C, observed in 1995) (Figure 3) and January is the coldest month (Average 7°C; lowest <1°C, observed in 1993) (Figure 4). Temperature rises rapidly after February, and drops rapidly after October. The weather is very hot during summer period, and occasional dust and thunderstorms followed by light rains offer respite from the scorching heat. The months of October and November, although generally dry, are the most pleasant part of the year. The winter season begins from December and ends upto March.

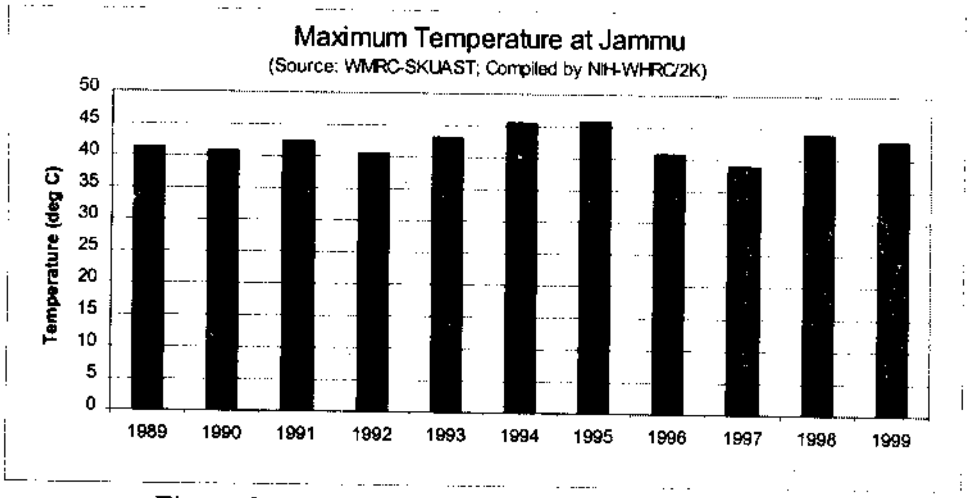


Figure 3. Average maximum temperature at Jammu

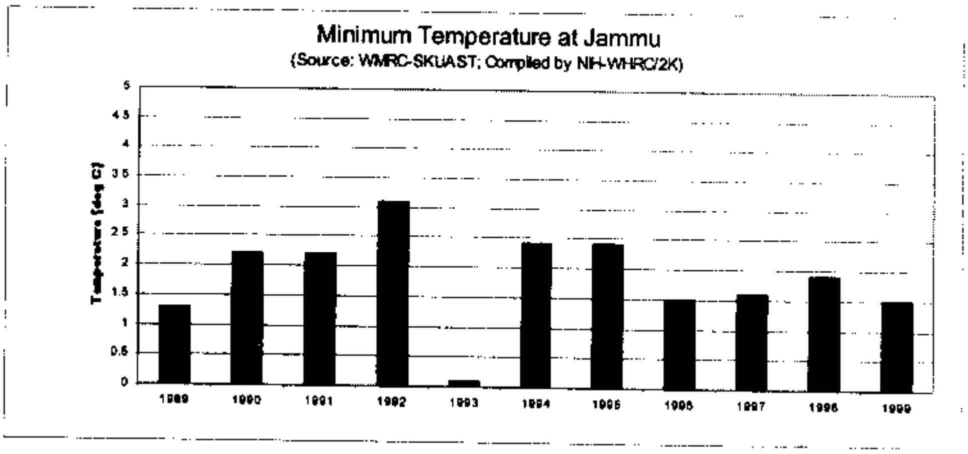


Figure 4. Average minimum temperature at Jammu

The air generally remains dry except during the monsoon season, when the average RH exceeds 70%. The summer months of April to June are the driest with average RH in the morning and evening is 40 to 48% and 23 to 32%, respectively. The high RH during rainy season is very conducive for the growth of crops. Evaporation in the area is generally high. Within a year, pan evaporation typically varies between less than 1mm/day in January to about 9mm/day in June (Figure 5).

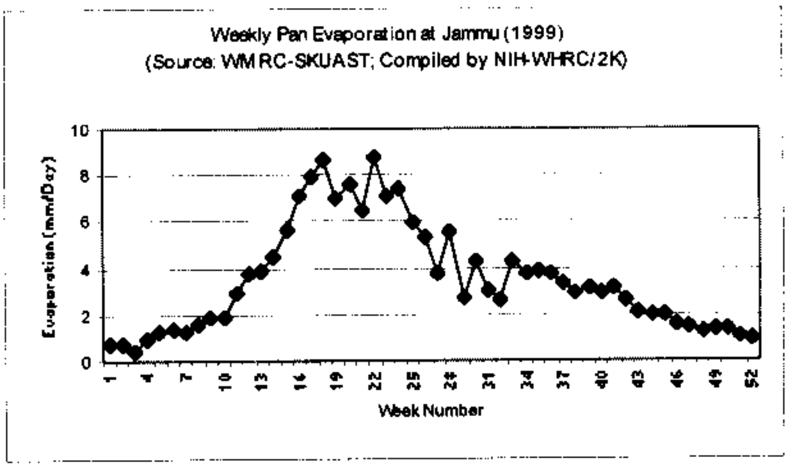


Figure 5. Weekly pan evaporation at Jammu

The first showers of the southwest monsoon usually arrive in the first week of July. The average annual rainfall is about 1400mm, of which more than 70% is received during the monsoon period, i.e. from June to September. Distribution of monthly rainfall at four important rainfall stations in the Kandi belt, namely Jammu, Akhnoor, Samba, Kathua is shown in Figures 6-8.

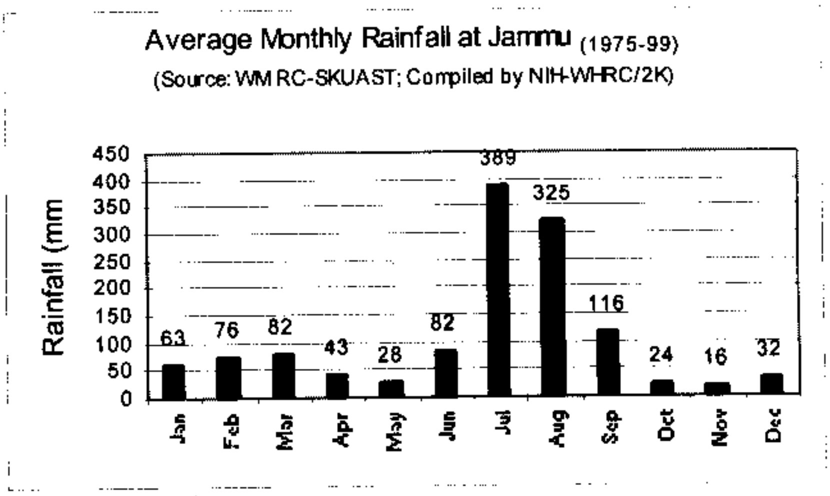


Figure 6. Average monthly rainfall at Jammu

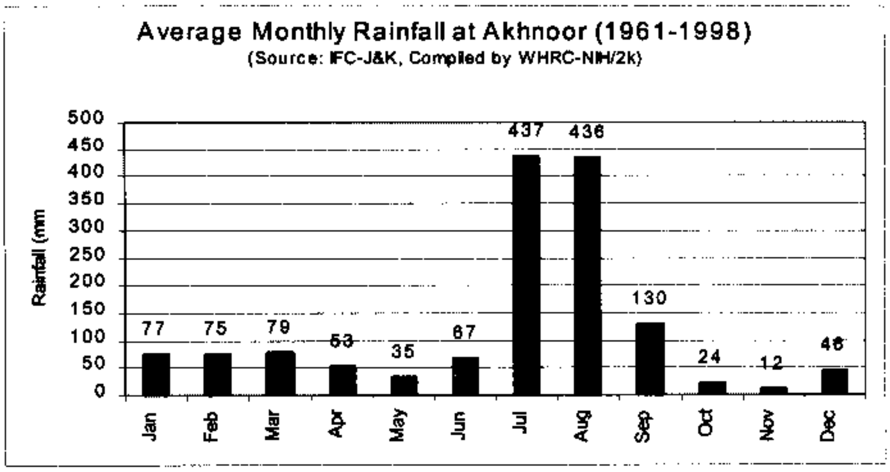


Figure 7. Average monthly rainfall at Akhnoor

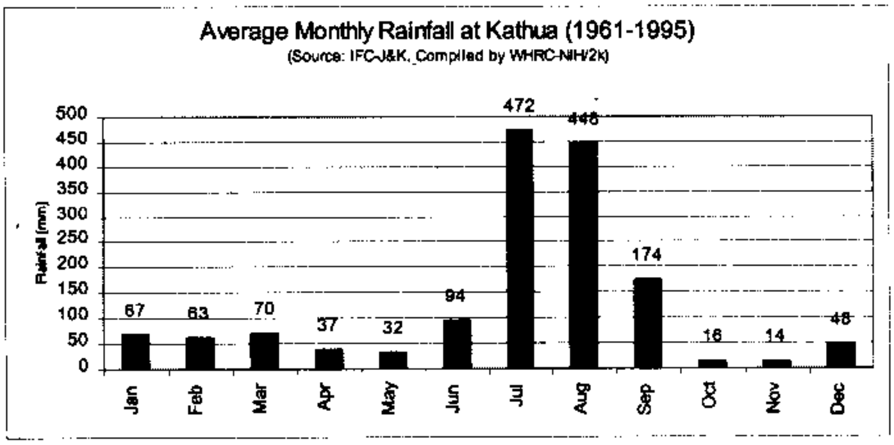


Figure 8. Average monthly rainfall at Kathua

It is observed from the available data that the wet spells less than 12 hours is showing increasing trend during the last three decades, e.g. it has increased from 4mm to 30mm to 8mm to 48mm. This increase in hourly rainfall system and decrease in number of rainy days causes soil creep, mudflows accelerated sheetwash erosion and increase in the anthropogenic activities in the Siwalik landscape.

It has also been observed that rainfall intensities are higher in the monsoon season. A dry spell prevails a week prior to the monsoon, owing to which soils in many parts of Jammu Siwalik are pulverised and loose cohesion. If rainfall of high intensity occurs on such a non-coherent soil, the soil may be beaten into a pasty semi-fluid mass before runoff begins and, therefore, the soil surface becomes protected by surface detention.

5.0 SOILS

Soil is a very important natural resource. The elements present in the soil depend to a large extent on climatic and geologic factors, and determine the type of crops that can be grown in a particular region. The importance of soil lies in its fertility, which varies from place to place.

The soils of the Jammu Siwalik region range from alluvial soil with medium sand to fine loam in texture (Figure 9). The Kandi belt and its adjacent area have loose sandy loam type of soil comprising boulders and gravel with ferruginous clay matrix. Such type of soil is encountered in the Tehsils of Kathua, Hiranagar, Samba and Jammu. In Jammu plains, the soils are mostly alluvial in nature with medium fine and silt loamy texture. In the areas of Upland Dun and Siwalik hills, particularly, Udhampur, Ramnagar, Billawar and Basholi, the soils are of fine sandy loam to loam in texture. The water holding capacity of the soils is very low. Due to excessive permeability, losses of nutrients by leaching are high. These soils are discussed below:

1. **Alluvial Soil:** The alluvial soil with medium sand of Jammu tehsil, mostly located in Marh block, in upper Jammu plain,
2. **Fine Sand:** Moderately deep to moderately shallow near river bed having fine sand texture with no variation down the soil profile is, particularly located in Kathua tehsil in middle Jammu plain,
3. **Sandy Loam:** Moderately shallow with lithic/paralithic contact, sandy loam to loamy sand texture is located in the upper portion of Kathua, Hiranagar, Samba and Jammu tehsil in the Rolling Kandi belt,
4. **Fine Sandy Loam:** These type of soil are located in parts of Udhampur and Billawar tehsils on the Murees and Siwalik hills,
5. **Loam:** The soils are located in Mansar, Ramkot and Surinsar in Siwalik hills and piedmont region at moderate depth. They have loam to silt clay loam texture,
6. **Silt Loam:** These types of soil are associated with fallow and waterlogged areas. They are found at moderately shallow to very deep depths, with silt loam to silt clay loam texture, are mostly located in Hiranagar tehsil in middle Jammu plain,
7. **Clay Loam:** Typic ustochrepts, fine loam, calcareous, shallow to medium depth, are located in Udhampur, Ramnagar and Billawar tehsils and Siwalik hills,
8. **Fine Loam:** Fine loam soils are deep to very deep, non-calcareous typic ustochrepts, are located in the tehsils of R S Pura and Bishnah in lower Jammu plain.

Locally, the soils of the Kandi belt are named as (Bhan et al., 1994): *Gheo Mitti* (clay or silty clay loam in texture with presence of free $CaCO_3$ content in variable amount), *Phull Mitti* (loose in structure and sandy or loamy sand in texture), Mairall Stony and Sandy type (poor in fertility and occur in barani areas), *Gora* (lands which are manured constantly), *Parola* or *Golma* (greyish in colour, loam to clay loam), *Moongi* (brown or pink in colour with heavy texture and sometimes calcareous in nature) and *Bellas* (variable in texture).

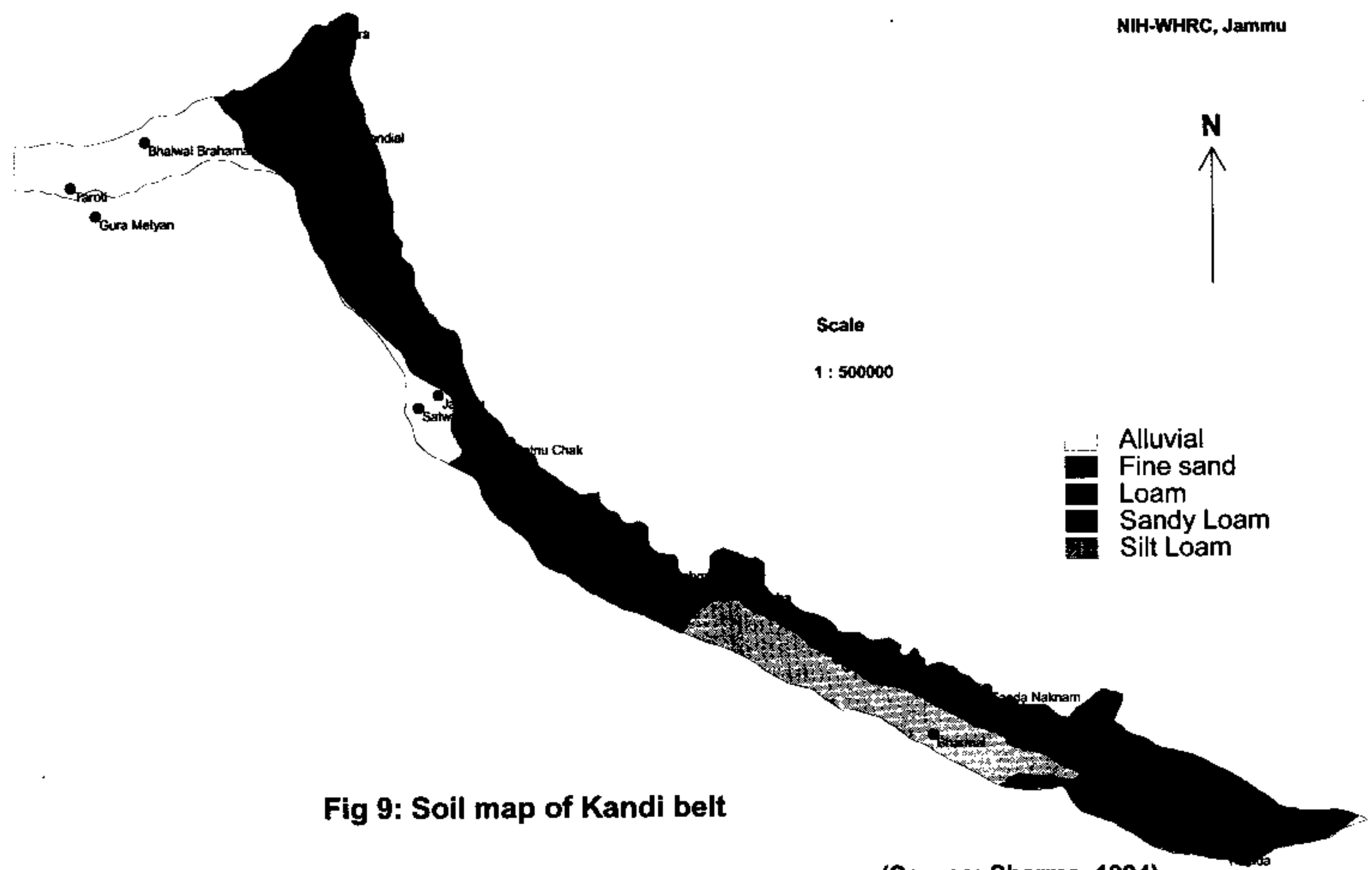


Fig 9: Soil map of Kandi belt

(Source: Sharma, 1994)

The Soil Survey Organisation of the Department of Agriculture of the Jammu & Kashmir state has identified eleven soil series of the entire Kandi belt of Jammu region (Bhan et al., 1994). These are Jandial, Amb, Bansultan, Kotli, Aitham, Smailpur, Aitham Narka, Janakha Tara, Tara, Choha, and Punara. Bhan et al. (1994) reported that the soils in the Kandi belt are, in general, of low fertility due to deficiency in nitrogen, phosphorous, potassium and organic matter.

Gupta et al. (1990) and Sharma (1994a) studied some typical soil profiles in the Jammu Siwaliks, of which the Kandi belt is a part. Salient physico-chemical and hydrologic characteristics of the soils of the Jammu Siwaliks are shown in Table 3 and Table 4, respectively.

Table 3. Physio-chemical Characteristics of Soils of Jammu Siwaliks

Location	Physiography	Depth (cm)	Texture	PH	Organic Carbon (%)	Cation Exchange Capacity (me/100g)	Water Holding Capacity (%)
Patyari	Siwalik Hills	0-30	Sandy Loam	7.3	0.4	7.3	34.4
		30-60	Loam	7.4	0.42	7.1	36.2
		60-80	Sandy Loam	7.8	0.21	6	38
Mahamaya	Siwalik Hills	0-18	Silty Loam	7.6	0.3	6.2	36.3
		18-35	Silty Loam	7.5	0.25	5.8	23.4
		35-66	Silty Loam	7.4	0.15	5.1	21.8
Bahu Fort	Kandi Belt	0-16	Loamy Sand	7.8	0.51	7.8	36.4
		16-36	Sandy Loam	7.9	0.38	8.4	26.4
		36-67	Sandy Loam	7.4	0.32	7.1	25.0
		67-78	Sandy Loam	7.4	0.22	6.4	22.2
Samba (Chichi Mata Temple)	Kandi Belt	0-27	Gravelly Loam	7.7	0.57	9.4	36.4
		27-47	Gravelly Loam	7.9	0.45	10.8	30.1
		47-91	Loam	8.2	0.52	7.7	27.2
Kathua	Plain	0-33	Silt Loam	6.9	0.6	6.6	N.A.
		33-141	Silt Loam	7.2	0.55	6.7	N.A.
Bari Bramhana	Plain	0-15	Silt Loam	8.1	0.49	7.6	N.A.
		15-40	Silt Loam	8.5	0.38	6.8	N.A.
		40-105	Silt Loam	8.3	0.23	6.9	N.A.

(Source: Gupta et al., 1990 and Sharma, 1994a) N.A.-not available

Table 4. Salient Hydrologic Characteristics of Soils of Jammu Siwaliks

S No.	Soil Texture	Predominant Physiography	Location	Soil Moisture Content (% wt) at		
				PWP	FC	AWC
1	Alluvial Soil with medium sand	Upper Jammu Plain	Marh and Gajansoo	1.7	6.8	5.1
2	Fine Sand	Middle Jammu Plain	Kathua tehsil	2.3	8.5	6.2
3	Sandy Loam	Kandi Belt	Upper portion of Kathua, Hiranagar, Samba and Jammu tehsils	3.4	11.3	7.9
4	Fine Sandy Loam	Murree and Siwalik Hills	Part of Udhampur, Ramnagar and Billawar tehsils	4.5	14.7	10.2
5	Loam	Siwalik Hills and Piedmont	Mansar, Ramkot and Surinsar	6.8	18.1	11.3
6	Silt Loam	Middle Jammu Plain	Hiranagar tehsil	7.9	19.8	11.9
7	Clay Loam	Upland Dun and Siwalik Hills	Udhampur, Ramnagar and Billawar tehsils	10.2	21.5	11.3
8	Fine Loam	Jammu Lower Plain	Tehsils of R S Pura and Bishnah	14.7	22.6	7.9

(Modified from Sharma, 1994a)

PWP-Permanent Wilting Point; FC-Field Capacity; AWC-Available Water Capacity

The decrease of cultivable land due to increasing soil loss from the upland areas, has deprived the area from fertile lands. Vegetal cover and landuse are two important factors that control the infiltration rate in the soils. A study of infiltration rates and mean annual soil loss under different landuses (Table 5) corroborates the findings of the Forest Department that deforestation has been responsible for high rates of soil loss from the catchments (Sharma, 1994a).

Table 5. Infiltration Rates and Mean Annual Soil Loss for Different Landuses

Landuse	Location	Average Infiltration Rate (cm/hr)		Slope (degree)	Soil Loss (t/ha/yr)
		Initial	Final		
Agriculture Land	Billawar, Ramkot, Samba	19.6	1.4	4-8	15-35
Bare Land	Hiranagar, Kot-Balwal, Mansar	12.3	1.4	2-6	20-45
Forest Land	Manthal, Surinsar	19.0	1.4	10-15	20-40
Grass Land	Birpur, Jindrah, Kathua, Nagrota	25.7	1.9	5-10	10-30

(Source: Sharma, 1994a)

6.0 GEOLOGY

The area of the Jammu and Kashmir State contains one of the finest developments of the stratigraphic succession right from the oldest Archaean to Recent. The first three geological formations of the stratigraphic sequence, as worked out for the State by the Geological Survey of India, are (1) Alluvium, river terraces, pebble beds of Jammu, etc. of Recent to Sub-recent age, (2) Karewas, terraces of Kargil basin of Upper Pliocene to Pleistocene age, and (3) Siwalik System, comprising Upper Siwaliks of Upper Pliocene to Lower Pleistocene age, Middle Siwaliks of Upper Miocene to Middle Pliocene age, and Lower Siwaliks of Middle to Upper Miocene age.

The Siwalik formations show typical and complete development in Jammu hills where they attain a thickness of about 6,000m with an outcrop width of about 40km as seen along the Chenab section in Reasi-Akhnoor sector and in Ramnagar-Samba sector (GSI, 1977). The Upper Siwaliks, locally known as the Kandi formations, consist of red earthy clays with massive beds of coarse pebbly sandstone, gritty in the lower part, overlain by about a thousand metre thick siliceous bouldary conglomerate. The coarseness of the conglomerate varies from that of a true boulder conglomerate to that of a gravelly conglomerate. The constituent boulders are 15-38cm in diameter, formed of compact siliceous rocks of a wide range of composition, embedded in a loose sandy matrix.

Based on the gradation from coarse to fine, the foothill zone can be further subdivided in two belts, one lying immediate south of Siwalik hills (Kandi belt) and the other lying further south, generally made of fine sediments (Sirowal belt). Among the Recent to Sub-recent deposits, those included are the vast alluvial tracts, flood plains, river terraces and talus and fans deposited by the major rivers and the adjoining *nallahs* in the Jammu region. The local geological setting in the area, as defined by some workers, is in the following chronological order (Pitale, 1969):

Area of Sirowal	Fine sediments comprising} Contemporeneous Gravel sand, silt and clay } sub-recent to recent
Area of Kandi Belt	Course sediments boulders} Cobbles and pebbles } }
Upper Siwalik (Hills on the north)	Boulder bed and sand rocks} Upper Pliestocene

The upper Siwaliks lying immediately north/northeast of the foothill zone comprise boulder beds and sand rocks. Boulder bed is made up of boulders, cobbles and pebbles of white quartzite, ferruginous quartzite and other material from the lower Siwalik horizon, interbedded with buff, yellowish and orange clay bands.

7.0 GEOMORPHOLOGY

Typically the Kandi tract runs in the northwest-southeast direction upto Akhnoor, from where it takes a northeast-southwest turn; the former part running parallel to the strike of the Upper Siwalik formations. The tract is dissected intensely by streams of various sizes and types, gullies of various dimensions, and thus displaying a rolling appearance.

The topography of the area is typical that of the piedment/alluvial deposits. The tract lying immediate south and south west of the Siwalik hills having average width of about six kilometers. It is widest in the proximity of the rivers such as Chenab, Tawi and Ravi. The general gradient is about 10 m\Km (1:100) towards south in the Kandi belt (CGWB, 1986).

The elevation in the area varies between 298m to 491m AMSL (Figure 10). A gradational elevation variation is encountered all along the Kandi belt; except around Akhnoor, which is located at higher elevations of about 375-390m. The highest elevations are found in the eastern part from Lakhanpur to Samba, Garh Mandi to Smailpur and Bantalab to Jandial (east of Akhnoor) in the central part, and Maira to Badgel Kalan in the western part. Relatively high elevated portions in the Lower Kandi Belt are encountered around Kalibari, Ghagwal, and above Bharmal.

The area south and south west of the Kandi belt is gentler because boulders and pebbles almost disappear from the surface and their place is taken by finer material. In this part of the area groundwater occurs at a shallow depth. It is the main reason that area is best suitable for agricultural.

Kandi area is mainly made up of sub-recent to recent sediments deposited by streams operating from the hilly area. A continuous deposition of these sediments has given rise to alluvial cones and fans. The sediments are poorly sorted and comprise boulders, cobbles, pebbles, gravels, sand, silt and clay. Near the Siwalik range, sediments are coarse and range in size from boulder to pebble with varying percentage of silt and clay. Away from the hills, the sediments are fine and the nature of gravel and sand with varying percentage of silt and clay. The deposit shows reworking everywhere by sheet flooding and severe gullying by hill torrents. The contact of coarse with fine sediments is gradational. Springs issue at places along the contact of coarse and fine sediments.

8.0 DRAINAGE PATTERN

Lithology and structure of the various geological units influence the drainage pattern in the area. The trend of the hills in the upper reaches is mostly controlled by the strike of the bedding of the rock formations. These hills display mostly the dendritic pattern with subtrellis to radial patterns at places. The drainage developed on the Lower

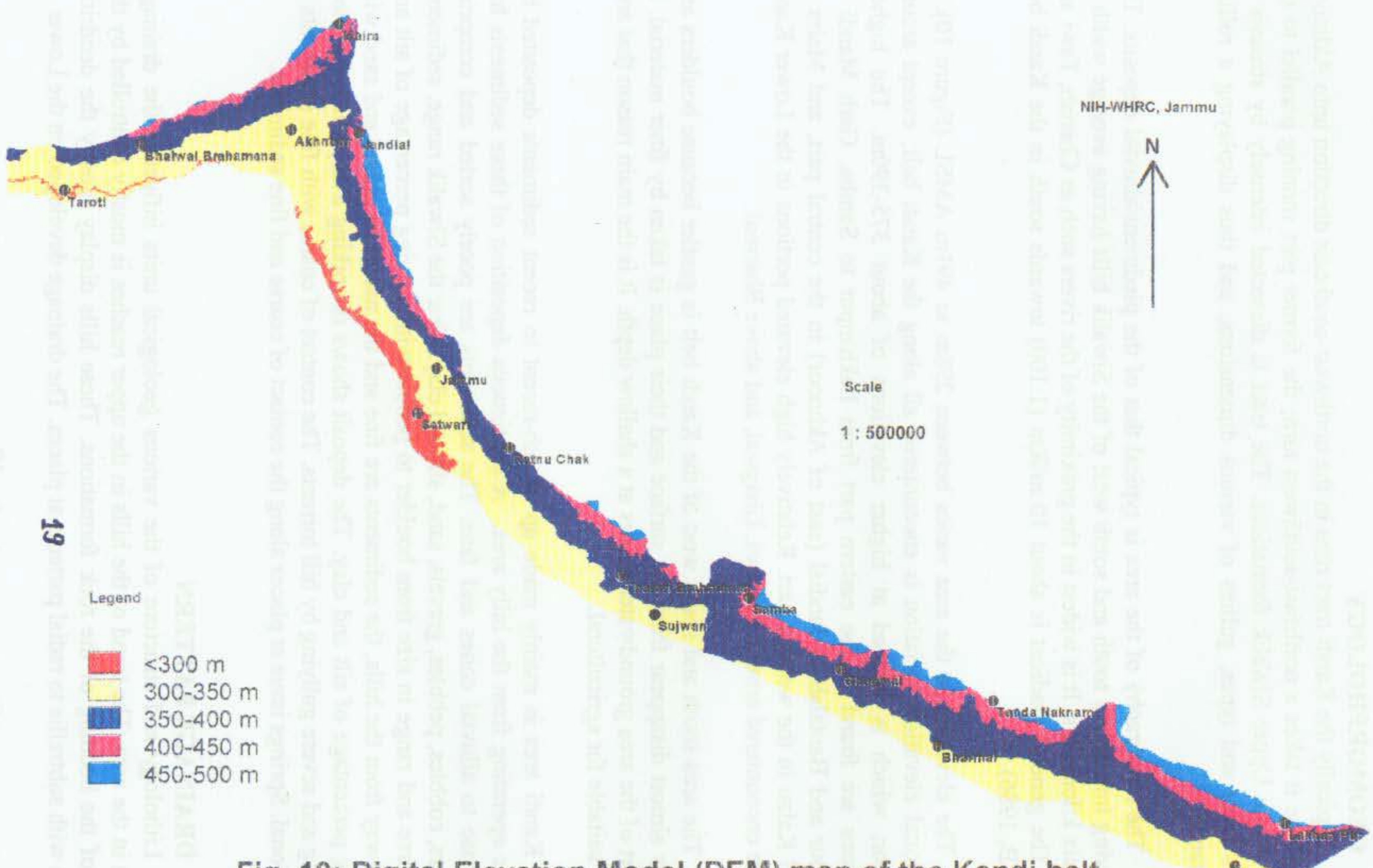


Fig. 10: Digital Elevation Model (DEM) map of the Kandi belt

Siwaliks is medium textured in contrast to fine texture developed on the Middle and Upper Siwaliks. Sharp and straight drainage lines indicate the influence of structural lineaments on the drainage pattern in the area.

The hills in the Kandi belt have developed badland topography due to repeated cycles of erosion and dissection of its lithounits resulting into a networks of gullies and ravines (Figure 11). Streams and gullies cutting across these hills show sub-dendritic to dendritic and sub-parallel to parallel drainage patterns. Sub-parallel ephemeral streams draining the southwestern slopes of the denudational hills follow structural dip. Centrifugal drainage east of Bahu Fort appears to be a manifestation of fault bound basement ridge. A high elevation and coarse drainage density in this area is due to partly internal nature of drainage and porous formations. A radial drainage pattern has been noticed east of Samba (Sharma, 1994b).

The surface of piedmont alluvial plain is dissected by numerous ephemeral streams originating from the Siwalik hills. A number of dry, wide and flat bouldery bottomed drainage lines, known as Khads, traverse the Kandi belt and perennially drain the Sirowal belt downstream across the spring line.

9.0 HYDROGEOLOGY

Based on the geology and aquifer characteristics, the piedmont deposits of older plains of Jammu are classified into the following three hydrogeoelogical sub-units:

1. Recent alluvium,
2. Kandi belt, and
3. Sirowal belt

Recent alluvium are found all along the river courses and occur as terraces and coalesced alluvial fans.

Kandi are fan deposits occurring immediately below the outer most Siwalik hills. Topography is characterised by steep slopes. Because of sudden fall in topographic slope and emergence of spring line, all the dry streams of Kandi become flowing in Sirowal. Lithologically, the Kandi are fan deposits comprising boulders, pebbles, and cobbles, mixed with clay. The sediments are heterogeneous, comprising of boulders to gravels in clayey matrix alternating with sand lenses of variable thickness. These fan deposits are highly porous and are capable of allowing *in-situ* percolation of large quantities of rain water/surface water, but are deprived of the water because of substantial runoff due to steep topographic gradient.

A spring line, roughly following the topographic contours of 300 to 320m AMSL, demarcates the Sirowal belt in the south from the Kandi belt in the north. There is a general decrease in the particle size of sediments in the area as compared to Kandi.

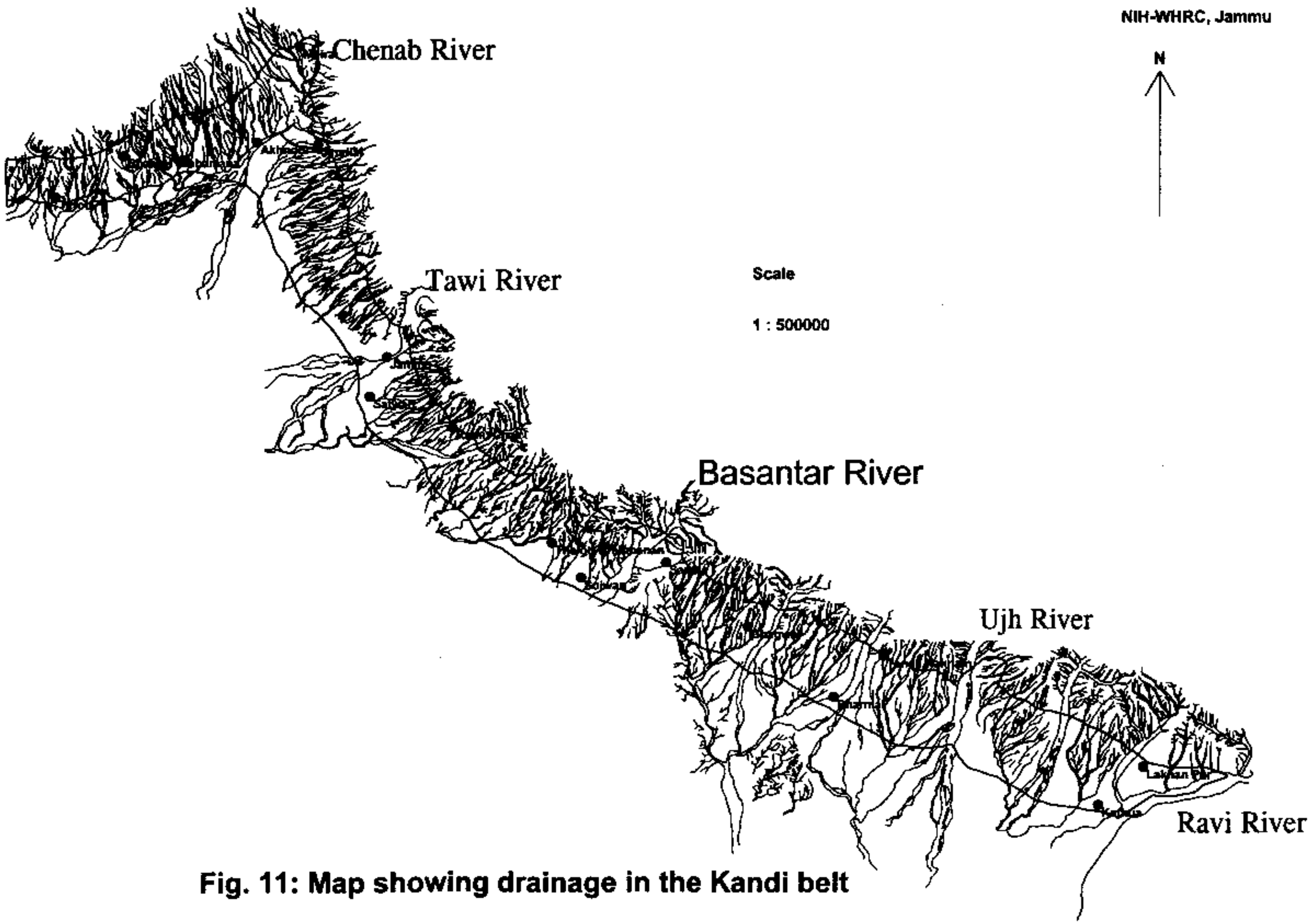


Fig. 11: Map showing drainage in the Kandi belt

Sirowal belt shows persistent clay beds occurring close to the ground surface, resulting in swampy or water logging conditions. At deeper depths, the strata consists of fine to coarse sands with occasional beds of gravels, pebbels, and intervening clayey to silty layers.

Litholog data reveals that area near Jammu is made of conglomerate and boulder gravel, up to a depth of about 120m. Conglomerate and boulder gravel constitute 90 to 98 percent of the total sediments. The conglomerate tapped in the tubewells appears to be sub recent. Towards the southwest, the percentage of boulder gravel decreases (up to 80%) and finer materials increase. In the proximity of the river Tawi, a good amount of sand and gravels are present.

Litholog data between Jammu and Akhnoor reveals that this belt also comprises boulder, gravel and conglomerate. There is not much variation in the nature of sediments from the Chenab to Tawi. Along the old road alignment, conglomerate is found at a depth of 50 to 60m below the ground level. The new road runs parallel to the old one up to a distance of about five km. Tubewells along the new road indicate that sediments down to a depth of about 75m comprise boulder, gravel, conglomerate, sand and clay. The clay percentage is as high as 35 to 50. A comparison of the nature of sediments along these two alignments indicates that the finer fraction in the sediments increases towards the southwest. In Kandi tract between the Chenab and the Munawar Tawi the sediments down to depth of 180m comprise boulder gravel and conglomerate with minor bands of clay.

Pitale (1967) studied the foothill zone lying between the river Tawi (Jammu) in the northwest and Chakki khad (Pathankot) in the northeast for assessing its groundwater potential, and for delineation of Kandi (Bhabar) and Sirowal (Tarai) belts. Sinha (1967) carried out geohydrological reconnaissance in the area between Tawi and Ravi rivers with a view to determine the possibilities of sinking irrigation tubewells. Jha (1972) carried out groundwater investigation around Kathua. Sharma et al. (1971) studied the Kandi and Sirowal belts of Jammu. Sangra (1987) carried out geohydrological and groundwater assessment studies of Jammu and Kathua Districts.

10.0 STATUS OF GROUNDWATER

Groundwater in the Kandi area occurs under water table conditions. The primary source of groundwater in the area is rainfall. A part of the rainwater is lost in evapotranspiration, part as run off and the remainder percolates down to reach the zone of saturation. Due to hot summers, evapotranspiration losses are considerable in this area.

The Kandi sediments being of boulder gravel nature, rain water percolates down to great depth till it meets some obstruction (e.g. an impervious layer) and then starts rising occupying more space of boulder gravel. The nature of sediments and disposition of the Kandi belt make the zone of saturation lie at great depth in the Kandi. Confined conditions have not been met with in the Kandi belt. Groundwater in the Sirowal, however, occurs under both water table and confined conditions. Deeper granular zones in the Sirowal contain water under confined conditions. The overall pattern of water table contours is suggestive of effluent nature of all the three major rivers of the area.

The static water levels in Kandi are very deep. Few exploratory tubewells drilled in the Kandi belt have indicated that potential aquifers capable of yielding water for irrigation occur at depths up to 300m below ground level (CGWB, 1986). Thus, the Kandi belt offers hydrogeologic setup characterized by deep water level, high permeability and occurrence of high rainfall.

The yield of the exploratory wells ranges between 230 to 2550 LPM for moderate drawdowns. Transmissivity values range from 367 m^2/day to as high as 2613 m^2/day. In one or two cases, wells located in Kandi belt, but tapping Siwalik aquifers from deeper depths, encountered free flowing conditions. This phenomena shows that Siwalik aquifers have positive pressure heads (Misra, 1998).

A total of about 150 borewells are available in the Kandi belt (Figure 12). These wells have been drilled by various agencies, both of the state and central governments, including Central Ground Water Board (CGWB), Geological Survey of India (GSI), and J&K Directorate of Geology and Mining (DGM). CGWB has drilled 25 boreholes in this belt, reaching to a maximum depth of 351m bgl (Misra, 1998).

Sharma and Sangra (1972) conducted geohydrological surveys of Jammu and Kathua districts to assess groundwater potential of the area for constructing shallow tubewells. Dulloo (1986) evaluated groundwater resources of Kaluchak-B.K. Bari area of Kandi belt in Jammu district. It has been established by the CGWB that the entire Kandi area of Jammu region is falling in white category in respect of the level of development and utilization of the resource. Only about 1.25% of the total annual resource is being utilized for irrigation. Similarly, for domestic and industrial purposes, the utilization of ground water falls within the provision of 15% of the total available resource (CGWB, 1986), assuming an average annual draft of each tubewell as 50m^3/h/3000 h.

10.1 Depth to Water Table

The depth to water table is influenced by the topography of the area, variation in lithology, proximity to surface water bodies, drainage channels, canals, etc. A hydrograph network of 143 ground water monitoring stations in the Jammu Province is operated by the CGWB. At these stations, ground water level is monitored in the dug wells four times a year, i.e. in the months of January, May, August, and November, and the chemical quality is monitored once (in the month of May) in a year. The depth to water level in these shallow wells in the Kandi belt generally ranges between 3 to 10m bgl and 2 to 7m bgl during pre-monsoon and post-monsoon periods, respectively (Figures 13 and 14).

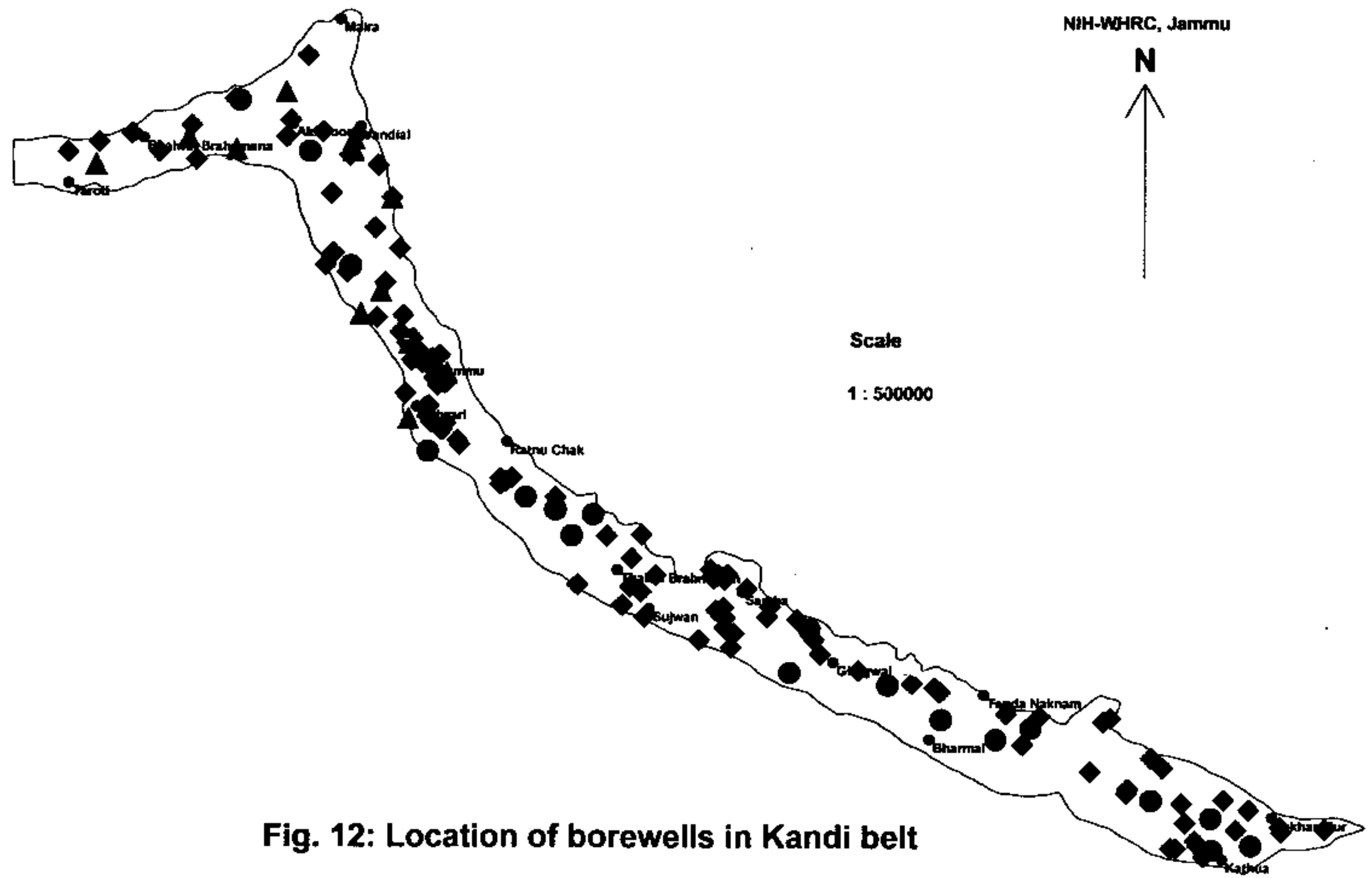


Fig. 12: Location of borewells in Kandi belt

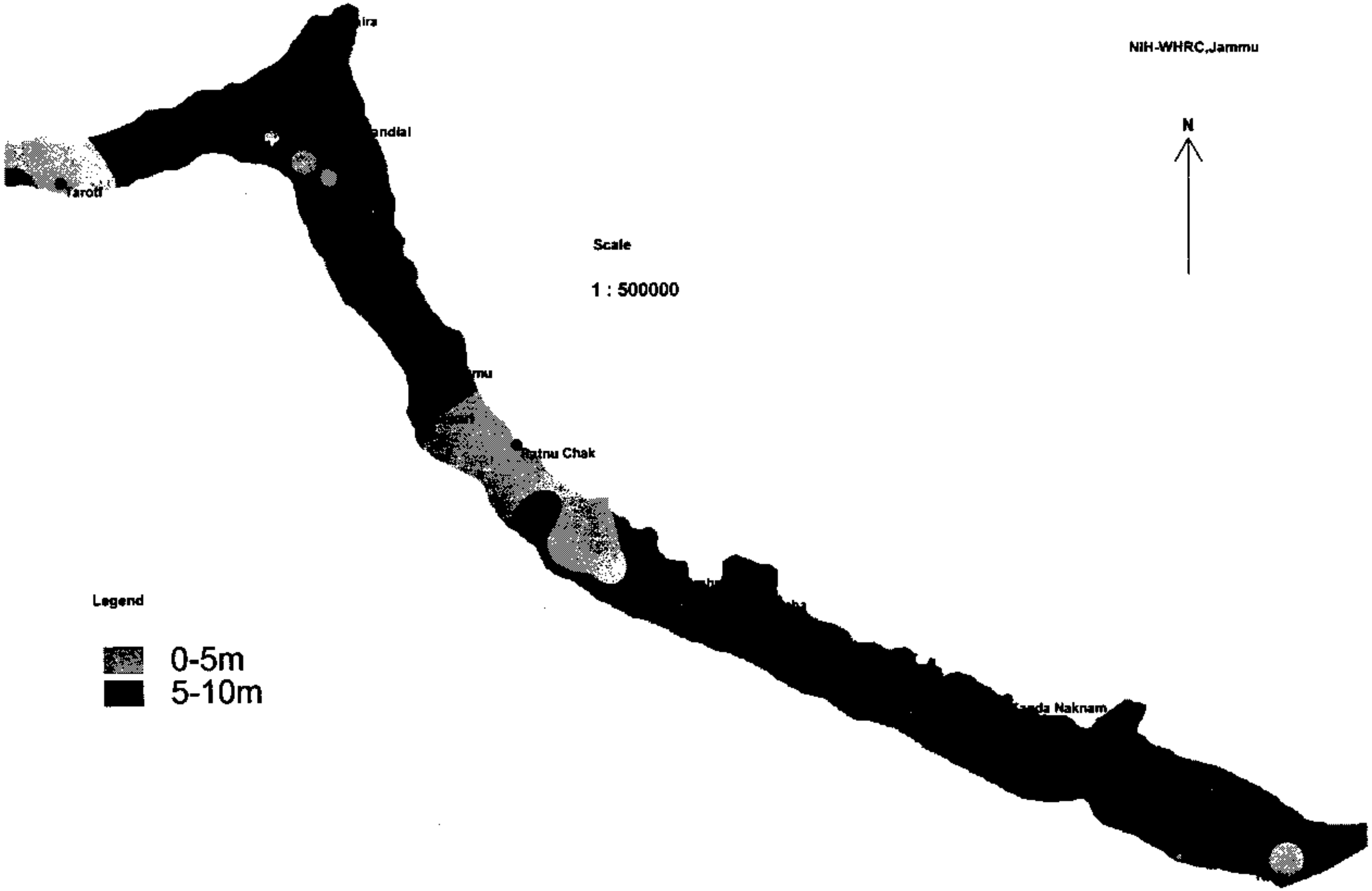


Fig . 13: Ground water levels in the Kandi belt during pre-monsoon

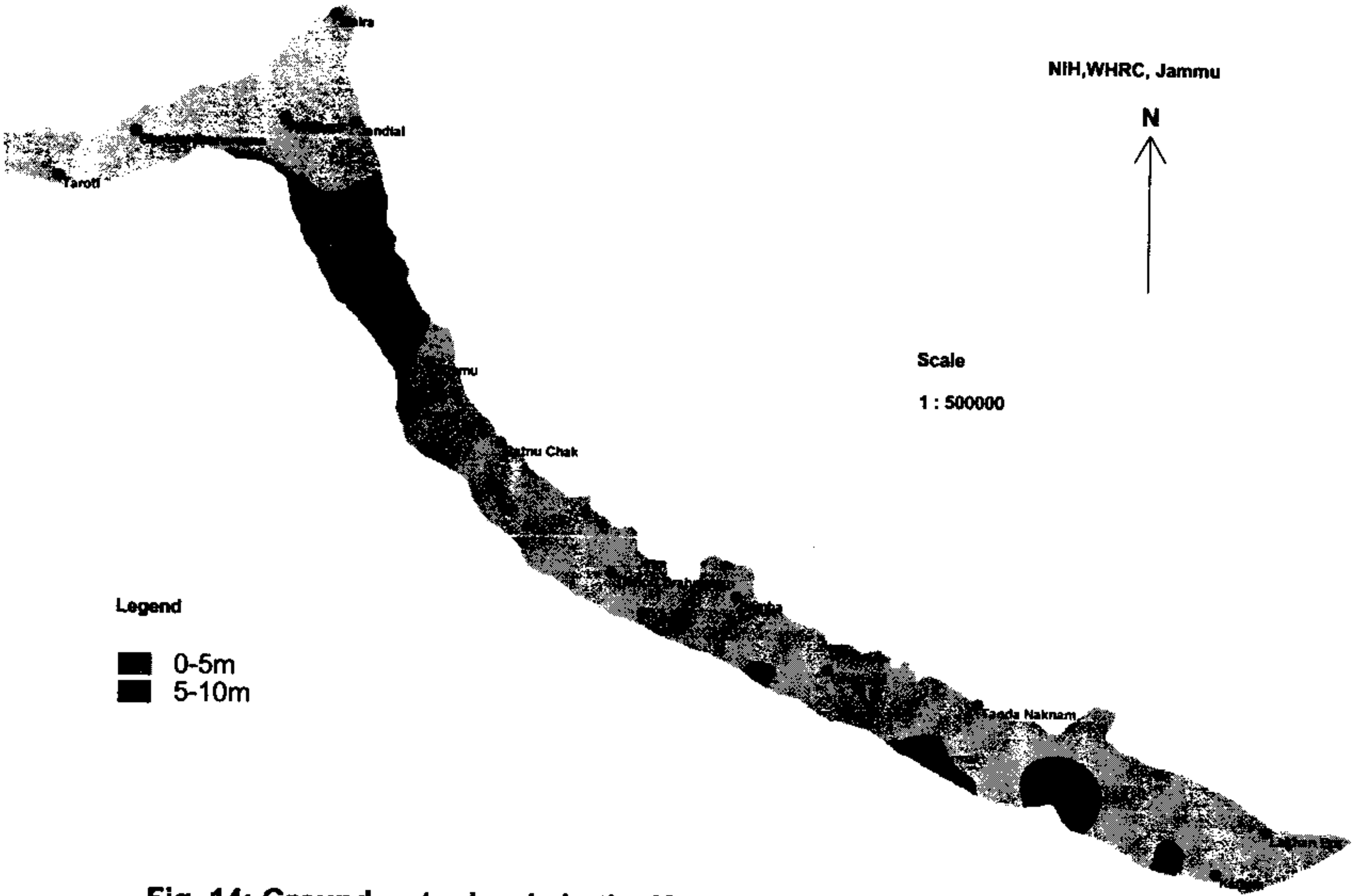


Fig. 14: Ground water levels in the Kandi belt during post-monsoon

Deep water table condition is one of the characteristic features of the Kandi belt. Immediately south/southwest of the Siwalik hills, the static water table is very deep. Values of 100 to 120m below ground level are not uncommon. Slightly away from the hills, depth to the static water table is 30 to 60m below ground level, and further away it becomes shallow, in the general range of 8 to 30m. Depth to static water level ranging from 45 to 84m, 10 to 74m and 0.5 to 5m in the area immediately southwest of Siwalik hills, Kandi and Sirowal belts, respectively, was observed by Pitale (1967). The change in depth to the water level, i.e. very deep in close proximity of hills and shallower further away, reflects a lithological variation, i.e. an increase in finer sediments away from the hills.

The Sirowal is characterised by shallow water table condition. The depth to water level range between 1 and 12m below ground level. Towards the southwest/southern extremity of the belt, the water level is the shallowest. There are few locations in Sirowal where the water table intercepts the land surface to give rise to springs. This spring alignment roughly marks the boundary between Kandi and Sirowal belts. West of the river Chenab, the spring locations are uncommon but wet grounds in the Khud courses and shallow water-table conditions indicate roughly the boundary between the Kandi and Sirowal in this tract. Major khuds in the area maintain flow downstream of the spring locations.

Geoelectrical soundings in Sirowal and Kandi belts were also carried out to explore the potential of aquifers at different depths (Sharma et al. 1984, Wahi et al. 1967; Raja et al., 1988; and Singh et al. 1988).

10.2 Movement of Groundwater

The movement of groundwater is a function of the aquifer material, thickness of aquifer material, transmissibility character of aquifer and various other factors. These variables determine the nature of groundwater movement in the area. The slope of the water table has been studied by Pitale (1969), between Jammu and Akhnoor. In the boulder gravel of Kandi belt the slope is of the order of 5 to 15m/km. However comparative gentle slope is observed around some places in Kandi belt, e.g. in Bhagwan Chak. In the Sirowal, slope of water table is of the order of 1.5 to 4m/km. In general, the form and slope of the water table in the area is typical that of a piedmont alluvial deposit.

Groundwater moves in the direction of maximum hydraulic gradient i.e perpendicular to the water table contours. Immediate south/southwest of the Siwalik hills, the hydraulic gradient is steep indicating a faster downward movement of groundwater in the boulder gravel. Dominant movement of groundwater is from northeast, to south in the tract between Chenab and Munawarwali Tawi. In general the groundwater moves towards topographic depressions along *Khuds*, *choes* and river courses.

Comparatively high rate of ground water movement in the vertical and horizontal planes indicates that the Kandi tract acts as a recharge zone. A general drop in the altitude of water table from the northern to the southern extremity of the Kandi belt is of the order of 40m, as compared to 20m in Sirowals. A general uniformity in the pattern of water table contours in the Kandi belt is indicative of homogeneity of sediments and a fairly uniform rate of groundwater movement.

10.3 Quality of Ground Water

Ground water has been an important source of water for domestic uses in Jammu and Kathua Districts. It is generally believed that the ground water resource in the J & K State is good for drinking purposes. According to State Government statistics, about 30% villages have only protected safe water supply in Jammu and Kathua Districts, which is a poor position indeed (Anonymous, 1987). It indicates that the large chunk of population is still dependent upon the local unprotected sources of water, such as wells (dug and tube wells), hand pumps, springs, rivers, ponds and tanks, etc. Due to increasing urbanisation and industrialisation, ground water is increasingly laced with pollutants from industries, municipal sewers and agricultural fields that are treated with fertilisers and pesticides.

National Institute of Hydrology has undertaken limited ground water quality monitoring and evaluation studies for drinking and irrigation purposes in parts of Jammu region. Higher concentrations of certain water quality parameters have been reported in Jammu and Kathua districts (Table 6). In a recent study, pH values greater than 7 have been observed at all sites, which indicate alkaline nature of ground water in the area. The results have shown about 75% sites belonged to very hard (Total hardness>180mg/l) and remaining mostly under hard category (Total hardness, 121-180mg/l) of ground water. The fluoride concentration has been observed below desirable limit (0.6 mg/l) at about 78% sites (Omkar et al., 1999-2000). Although there is nothing to panic at the moment, there is a need to be watchful on the quality of water available from both the ground water and surface water sources.

Table 6. Chemical Characteristics of Ground Water in Jammu and Kathua Districts

Parameters	Pre-monsoon (June, 1998)	Post-monsoon (Feb, 1999)
PH	8.16	7.8
EC, mhos/cm at 25 ^{0} C	1374	1064
TDS, mg/l	879	681
Alkalinity, mg/l	329	315
Total Hardness as $CaCO_3$, mg/l	270	327
Chloride, mg/l	48	54
Sulphate, mg/l	45	29
Phosphate, mg/l	0.08	0.08
Nitrate, mg/l	5	10
Calcium, mg/l	71	85
Magnesium, mg/l	23	28
Sodium, mg/l	41	37
Potassium, mg/l	19	27
Fluoride, mg/l	-	0.45

11.0 STATUS OF SURFACE WATER

11.1 Rivers and Streams

Kandi belt is dissected intensely by streams of various sizes and types, gullies of various dimensions, and thus displaying a rolling appearance. A majority of these streams have their origin in the hills of Siwaliks. Some rivulets operate within the Kandi belt (Figure 11). Chenab, Tawi, Basantar, Ujh and Ravi rivers perennially drain the area. Many other streams, e.g. Aik, Tarnah, Bein, Devak, are intermittent in the Kandi belt but perennial in the Sirowals. All the drainage east of Devak river are the tributaries of the Ravi river, while those on west join Tawi, which ultimately joins the Chenab river across the Indo-Pakistan international border.

Chenab, and its two tributaries viz. Tawi and Munawar Tawi, drain the area in the western part. Devak, Basantar, Ujh and Ravi are the main rivers in the eastern part. All of these, except Devak, originate in the hilly tract on the north, and are perennial. The Chenab shows extreme variation of flow. The summer flow is about ten times that of winter flow. An increment in flood in summer is indicative of its snowfed nature (due to melting of snow in summer).

Presently, only Chenab and Tawi in the west and Ujh and Ravi in the east are being monitored for their discharge. Central Water Commission is monitoring the streamflow and sediment discharge in the rivers Chenab and Tawi, whereas the State government is monitoring discharge in the Ujh river at a barage station. None of the other numerous streams in the Kandi belt is monitored. In order to tap the vast potential of these streams, it is essential to install hydro-meteorologic stations in the catchments of some selected streams. Monitoring of water quality should also be initiated, at least for streams passing through the urban areas. In the meantime, for planning the water resources projects in the area, discharge of these streams can be estimated based on geomorphological parameters.

Water availability studies are useful to ascertain the success of development projects for long term operation in an area. Water availability of Tawi river flow for different time periods, and its dependability, has been worked out by Patwary and Kumar (1991-92), using rainfall-runoff series method (Table 7). 29 years mean monthly rainfall of four stations and 13 years discharge data was used in computation of the water availability.

Table 7. Dependable Monthly Flows for Tawi River (in Cumec)

S N	Prob. (%)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	60	35	26	21	22	23	102	168	46	17	8	10
2	70	31	18	13	16	20	95	154	35	13	8	6
3	80	21	12	6	11	17	62	128	26	11	7	3
4	90	17	3	2	8	9	52	77	17	7	6	3

Water availability of Ujh river has been computed by Rao and Sharma (1991-92), using conventional rainfall-runoff regression method (Table 8). Rainfall data of three stations and runoff data at the outlet near Kathua has been used to study the water availability study in Ujh River.

Table 8. Dependable Seasonal Flow for Ujh River

S N	% Dependability	Yield ($*10^7$ m^3)	
		Monsoon	Non-monsoon
1	50	76	33
2	60	68	29
3	75	56	22
4	90	39	19
5	95	30	15

11.2 Canals

The Jammu region had a tradition of minor irrigation. *Kuhals* or *Kuhls* (diversion canals) constituted the ancient irrigation system in the region. Kuhls attained a high degree of efficiency because of a well developed system of social management. With the take over of these canals by the government after independence, the system of *Kuhls* has suffered a setback. The major source of irrigation in the State, however, continues to be canals (Table 9).

Table 9. Net Area Irrigated (in Km^2) from Different Sources (1997-98)

District	Canals	Tanks	Wells	Other Sources	Total
Jammu	516.8	0	1.8	19.5	538.10
Kathua	159.4	0	2.6	58.0	220.00

(Source: Digest of Statistics, 1997-98)

There are two major irrigation projects in existence in the Jammu province. These are Ranbir canal, the largest irrigation system in the province, and Ravi-Tawi Irrigation complex (Figure 15). The Ranbir canal, issuing from the Chenab at Akhnoor, drains the area between the Chenab and Tawi. There are numerous distributaries from this canal which feed the area south-west of the Akhnoor-Jammu road. The old Pratap canal, which takes off from the Chenab south of Makhiawala, joins the Chenab at Nawanshahr after draining the tract south of the Akhnoor-Chenab road. New Pratap canal covers the entire area between the Chenab at Akhnoor and discharges in Munwarwali Tawi.

Ujh and Kashmir canals drain the water of the river Ujh and Ravi, respectively, for irrigation in Kathua district. Ravi-Tawi canal, the southern most canal system runs between Tawi and Ravi rivers to irrigate land both in Jammu and Kathua districts. Apart from this there are a number of lift irrigation schemes operating in the Kandi belt of Jammu and Kathua districts (Table 10).

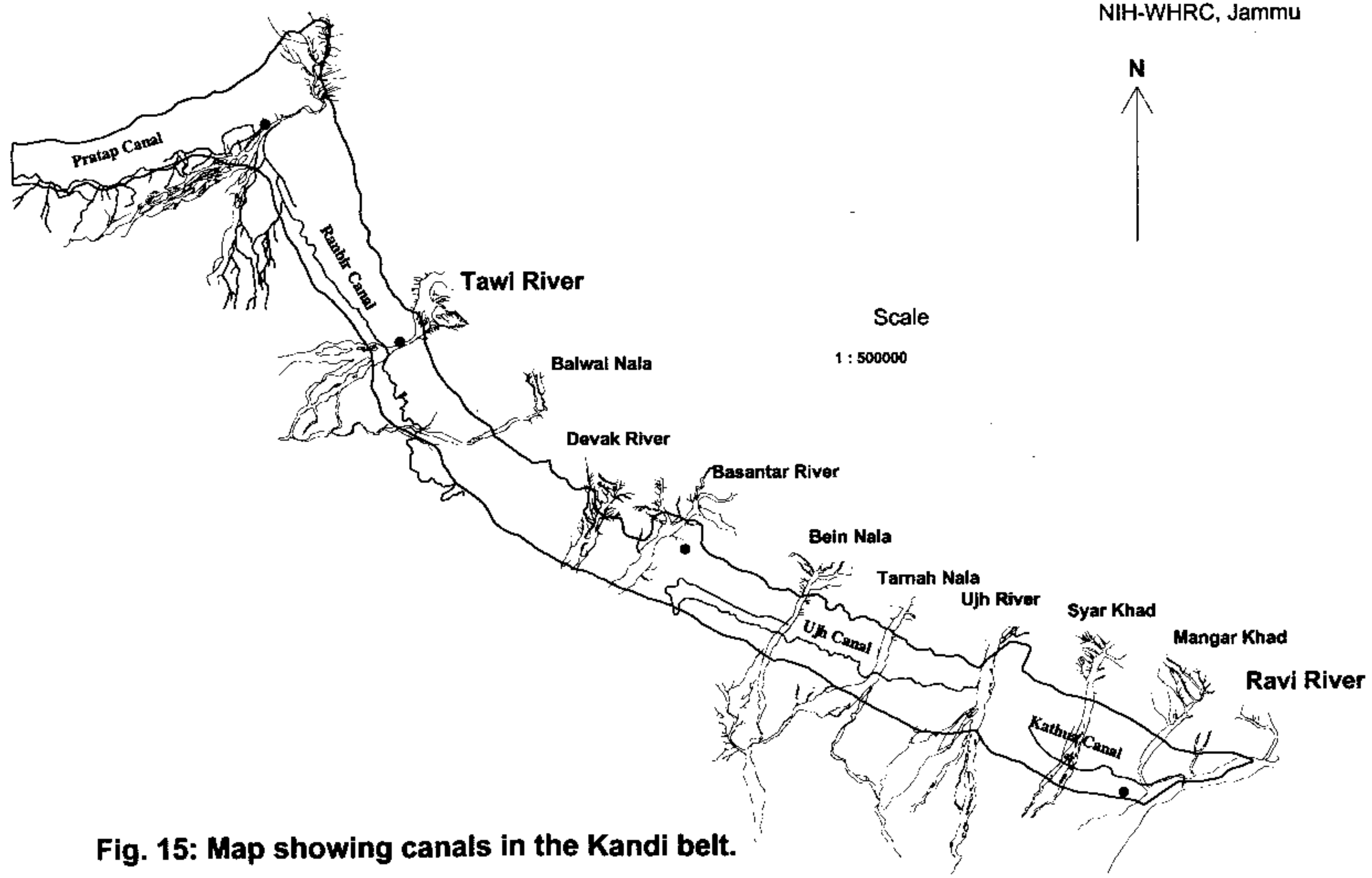


Fig. 15: Map showing canals in the Kandi belt.

Table 10. Irrigation Systems in Jammu & Kathua Districts

SN	Name of Scheme	Year Commissioned	Type of Scheme	Source of water	CCA (Ha)	Design Discharge (cusec)	Potential (Ha)	
							Created	Utilised*
1	Ranbir Canal	1905	Gravity	Chenab	38,623	1000	67,814	65,458
2	Pratap Canal	1961-62	-do-	-do-	9,919	500	14,879	9,225
3	Parwai Canal	1974	-do-	-do-	2429	175	3,644	1,681
4	Ranjan Canal	1994-95	Lift	-do-			3,036	514
5	Kathua Canal	1961-62	-do-	Ravi	11,741	400	17,611	14,128
6	Ravi-Tawi Lift Canal	1978	Lift	Tawi	14,170	300	12,880	6,942
7	Ravi Canal Ph-I	1982-83	Gravity+Lift	Ravi+Ujh	32,185	250	12,000	N.A.

(Source: Prabhakara and Raina, 1997). * As on 1995-96

11.3 Ponds and Tanks

Ponds played a crucial role in the Kandi belt, and were the main source of drinking water till 1960s. The semi-hilly Kandi belt is generally devoid of any springs or *baolis*, which made ponds an important source of water to meet the community needs in the region. Most ponds were so designed that a part of the runoff from adjoining rivulets could be trapped. This helped in reduction of runoff, erosion and downstream floods. Also, the ponds helped in improving the level of ground water in the surrounding area. These ponds were located in forts, near temples, and along highways. Over the years, the design of ponds, stone pitching of their berms, and the role of clay in checking heavy seepage in the highly porous Kandi belt evolved. By the middle of 20^{th} century, piped drinking water supply led to the neglect of these ponds. Pressure on land and a decline in community institutions further speeded their decline.

There are 406 ponds located in the Kandi belt, primarily concentrated in the Jammu and Kathua districts (Figure 16). Udhampur district is predominantly hilly and has fewer ponds. Ponds are found more in the semi-hilly region whereas springs are found in the higher hills. There are three types of ponds in the Jammu region- *chhappris*, big ponds, and *pucca* tanks. *Chhapris* are small shallow ponds with hardly any masonry work. They fill up in a single shower and serve the needs of cattles and graziers, and dry up during the summers. Almost all Kandi villages have one big pond to meet the domestic needs through out the year. These big ponds were constructed with masonry work on three sides, the fourth side left open for the water to flow in. The *pucca* tanks have four-sided enclosures and are often found near temples, forts or highways. Almost all Kandi ponds had *banyan* and *peepal* trees on their banks. These trees provided shelter to travelers and animals, and also served as evaporation retardant.

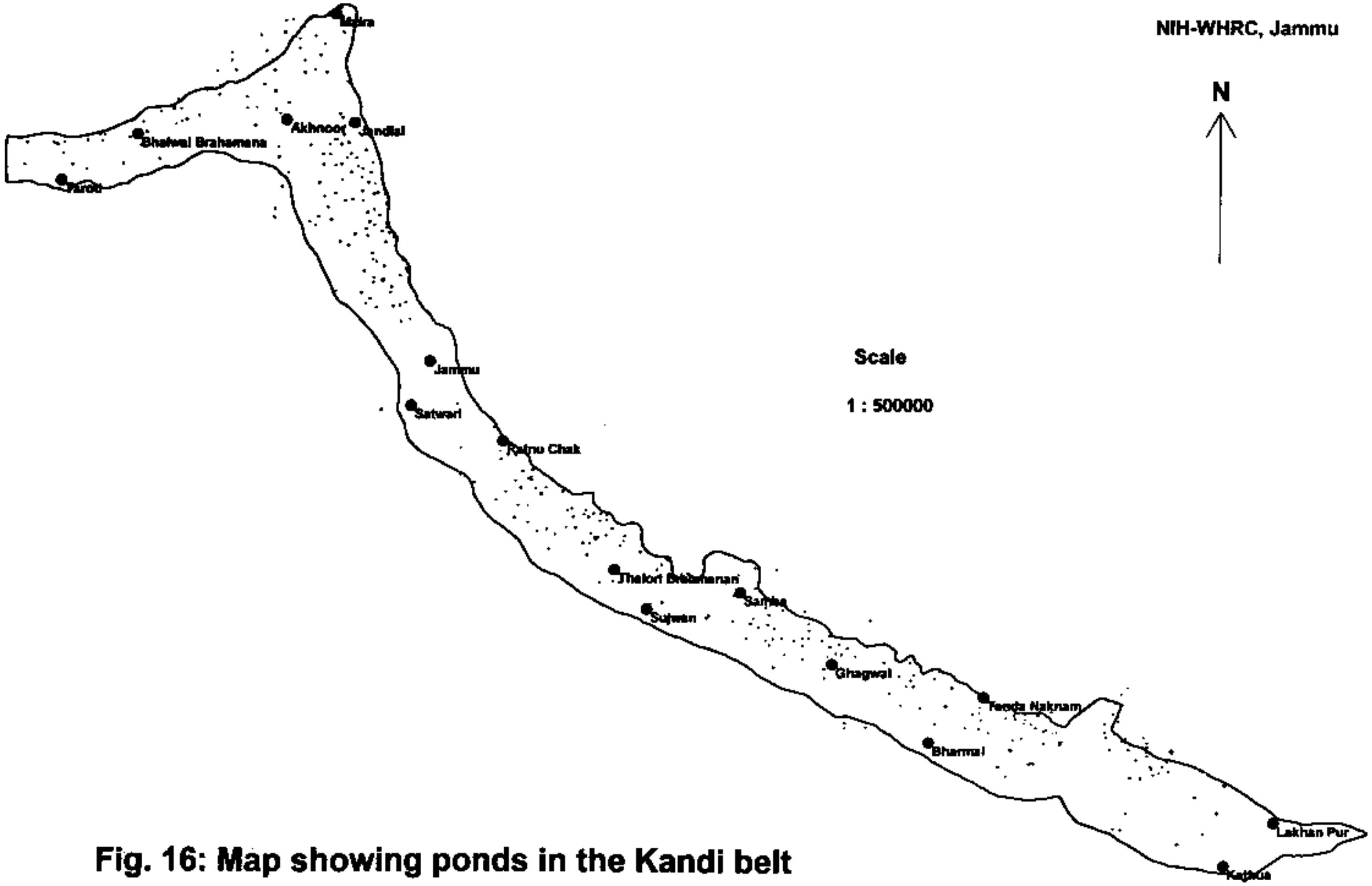


Fig. 16: Map showing ponds in the Kandi belt

Sites for construction of these ponds and tanks were selected very carefully. Unlike ponds in the plains, Kandi ponds were dug adjacent to a seasonal rivulet. During high floods, part of the river water was diverted into these ponds. These ponds were not used for irrigation purposes, crops being largely rainfed. An indigenous system of drip irrigation, however, existed in earlier days (Agrawal and Narain, 1997).

Traditionally, these ponds use to have an elaborate community-based management system. Strict control was exercised for the economic use of water to ensure that it did not get polluted. Community leadership ensured a clean catchment for drinking water requirements. In many villages, there were separate ponds for humans and cattle, and guards were appointed and paid by the community to prevent animals from using the ponds meant for the humans. The construction and regular repairs of ponds were often done through voluntary labour.

12.0 AGRICULTURAL PRODUCTION

Agriculture is the main occupation of about 70% population in the Kandi belt. In this region, *Rabi* crops are sown during October to November and harvested from April to mid May. Similarly, *Kharif* crops are sown during June to end of July, and harvesting takes place during September to October. Cultivation of *Zaid Kharif* and *Zaid Rabi* crops is done between regular *Kharif* and *Rabi* seasons, respectively.

The crops are predominated by millets like *Bajra* and *Jowar*, followed by Maize, Wheat and Barley. Lesser millets, such as *Kodra* and *Kangni* are also grown as mixed crops with maize and *bajra*. Rice is grown in some pockets of the region situated near *khads* by direct sowing. Pulses, like *Moth*, cowpea, *arhar* or pigeon pea, *rajmash*, peas, gram, *mash*, *moong*, lentil, and *kulth* are cultivated to some extent. Among the oilseeds, *til*, *raya*, *toria*, and groundnut are common. The main crop rotations followed in the area are as follows (Gupta et al., 1990):

Table 11. Common Crop Rotations in the Kandi belt

S N	Rotations
1.	Maize-Wheat/Barley
2.	*Bajra*-Wheat
3.	Maize-Wheat+*Raya*
4.	*Bajra*-Gram/Lentil
5.	*Mash/Kulth*-Barley/Wheat
6.	Maize/Bajra-Wheat+Peas
7.	*Mash+Til*-Mustard (or *Toria*)
8.	*Moth*-Wheat
9.	*Kulth/Mash*/Pigeon Pea-Wheat
10.	Groundnut-Mustard (or *Toria*)/Wheat
11.	*Bajra*-Gram/Lentil
12.	Maize+Cowpea-Barley/Wheat
13.	Pigeon Pea-Wheat

The productivity of various food crops in the region is much lower than the all India average, except in the case of Maize (Samra et al., 1999). Kaul et al. (1991) reported the productivity values of wheat and maize in the Kandi belt as 800Kg/ha and 1000Kg/ha, respectively. The productivity of total food grains in the Jammu Province is 1596 Kg/ha. Production levels of important crops are shown in Table 12.

Table 12. Productivity of Important Food Crops

Crop	Productivity (Kg/ha)		
	Jammu Province*	Jammu & Kashmir	All India Average
Rice	1680	1857	1921
Maize	1711	1871	1493
Wheat	1644	1419	2553
Total Cereals		1680	1763
Total Pulses	476	561	609
Total Oilseeds		610	848

*Source: Digest of Statistics (1997-98)

13.0 HORTICULTURAL PRACTICES

The Kandi area is considered to be more suitable for growing of fruit plants. Three main zones recognised for fruit growing in the Jammu region are (Parihar and Singh, 1994): (i) Sub-tropical zone (elevation between 300 to 1350m), (ii) Intermediate (low hill) zone (elevation between 1000 to 1500m), and (iii) Temperate (high-hill) zone (elevation between 1500 to 2500m and above). The area under fruit plantation in different districts of the Region is: Doda (8,500ha), Poonch (7,000ha) Udhampur (7,000ha), Jammu (6,600ha), Rajouri (4,000ha), and Kathua (3,500ha). This constitutes about 1.5% of the total area of Jammu region.

The most important fruit-growing belt of the Jammu region falls under Sub-tropical zone, which comprises the bulk of Jammu district, and parts of Udhampur, Kathua and Rajouri districts. The land in this zone is eminently suitable for cultivation of sub-tropical fruits, like citrus, mango, guava, *ber*, papaya, pomegranate, *karonda*, custard apple, *phalsa* and *lasoda*. Some wild fruit trees are found abundant in the area; these are *Bil (or Bel), Girna, Amla, Daruni, Jaman, Kakaoa, Shahtoot, Ber*, etc.

Among the wild vegetables grown abundantly include *Jangali Kandoli* and *Ban Karela*. Other vegetables grown in the area are *tinda*, bottle gourd, chillies, tomato, onion, radish, turnip, and spinach. Among condiments, which are grown in certain pockets with available water, are turmeric, garlic, mint, and ginger. To some extent, potato is grown as spring or summer crop, which is generally sown from January to February.

14.0 WATER DEMAND

14.1 Domestic

The total rural population in the Kandi belt, residing in the five tehsils of Jammu and Kathua districts, is about 2.11 lakh. Estimated domestic water requirement for this population, based on the standard norms of per capita requirement of 100 LPD, works out to be 21,151m^3/day. Tehsilwise distribution of this water demand is shown in Table 13.

Table 13. Domestic Water Demand in the Kandi belt

Tehsil	Total Population	Population in the Kandi belt	Domestic Water Demand (m^3/day)
Jammu District			
Jammu	206916	64809*	6481
Akhnoor	140081	39125	3913
Samba	132237	38449	3845
Sub-Total (Jammu Dist.)	479234	142383	14239
Kathua District			
Kathua	85013	34215	3422
Hiranagar	109052	34900	3490
Sub-Total (Kathua Dist.)	194065	69115	6912
Total	673299	211498	21151

* Including 2 villages of Bishna tehsil.

14.2 Livestock

The Jammu and Kathua districts have total livestock population of about 11 lakh and 10 lakh, respectively, against human population of 12 lakh and 5 lakh. Assuming a uniform population of livestock in the two districts, an estimate of the livestock population in the Kandi belt under the identified tehsils can be found as the ratio of human population living in the Kandi belt to the total population in the district. Accordingly, estimated livestock population in the Kandi belt under the identified tehsils of the two districts is 1.28 lakh for Jammu and 1.38 lakh for Kathua. Computing on the basis of standard norms of 40 LPD per capita, the water requirement for the livestock works out to be 51.2 lakh LPD (5120m^3/day) for Jammu and 55.2 lakh LPD (5520m^3/day) for Kathua; and a total of 10,640m^3/day for the Kandi belt.

14.3 Agriculture

Total crop water requirement can be computed on the basis of sown area for different crops in the region. Total sown area for the crops grown in the two districts is shown in Table 14a. Tehsilwise distribution of sown area for different crops was not available at the time of preparation of this report. Assuming the same pattern of crop cultivation in the Kandi belt as in the district as a whole, except rice which is grown predominantly in the lower irrigated areas, an estimate of the crop water requirement in unirrigated areas of the Kandi belt is computed as the ratio of cultivated area (unirrigated) in the Kandi belt to the total cultivated area in the district (Table 14b). As shown in the

Table, the total crop water requirement for the important crops grown in the unirrigated areas of the Kandi belt in Jammu and Kathua districts is 70Km³ and 67Km³, respectively.

Table 14a. Total Area Sown (Km^2) Under Different Crops in Jammu and Kathua Districts

District	Rice	Jowar	Bajra	Maize	Wheat	Barley	Millets	Pulses	Sugarcane	Fruits & Vegetables	Other Food Crops	Oilseeds	Fibres	Fodder Crops	Total Area Sown
Jammu	579.4	0.2	83.2	267.7	940.7	3.2	0	84.1	0.6	14.9	0.6	26.2	2.8	125.0	2128.6
Kathua	343.5	0	14.9	158.9	487.2	13.4	0.4	46.3	1.0	2.1	0	58.7	0.8	87.0	1214.2
Total	922.9	0.2	98.1	426.6	1427.9	16.6	0.4	130.4	1.6	17	0.6	84.9	3.6	212	3342.8

Source: Digest of Statistics (1997-98)

Table 14b. Crop Water Requirement (Km^3) for Important Crops in Unirrigated Area of the Kandi belt

	Bajra	Maize	Wheat	Barley	Pulses	Fruits & Vegetables	Oilseeds	Fodder Crops	Total
CWR (mm)*	350	350	420	375	280	650	280	650	
Jammu District									
Sown Area in the District	83.2	267.7	940.7	3.2	84.1	14.9	26.2	125.0	2128.6
Sown Area in Kandi belt	9.1	29.2	102.7	0.3	9.2	1.6	2.9	13.6	232.33
CWR in Kandi belt	3.2	10.2	43.1	0.1	2.6	1.0	0.8	8.8	69.8
Kathua District									
Sown Area in the District	14.9	158.9	487.2	13.4	46.3	2.1	58.7	87.0	1214.2
Sown Area in Kandi belt	1.3	29.2	102.7	0.3	9.2	1.6	2.9	13.6	104.58
CWR in Kandi belt	0.5	10.2	43.1	0.1	2.6	1.0	0.8	8.8	67.1
Total CWR in Kandi belt	3.7	20.4	86.2	0.2	5.2	2.0	1.6	17.6	136.9

*CWR- crop water requirement (Source: CAD, Jammu)

15.0 PROBLEMS

The Kandi belt area has good potential for horticultural production, including agricultural crops, provided scientific land use and water management practices are followed. The diverse problems of the region need to be identified to evolve location specific package of solutions aimed at improving the productivity as well as the natural environment. A major problem in the Kandi belt has been degradation of land due to runoff characteristics of the streams in the region. Water related problems of the Kandi belt broadly comprise of domestic and irrigation requirements. The various water and natural environment related problems of the Kandi belt are listed below and discussed next.

Hydrological Problems in the Kandi Belt of Jammu Region

- Land Degradation
- High Rates of Soil Erosion
- Low Crop Productivity
- Loss of Biodiversity
- Degeneration of Forests
- Poor Water Availability for Crop Production
- Under Utilization of Horticulture Potential
- Water Availability for Domestic Purposes
- Water Pollution
- Low Productivity of Animals
- Lack of Hydro-meteorological Data
- Socio-economic Problems
  - Degeneration of Community based Institutions
  - Lack of Public Awareness on Environmental Issues
- Lack of Coordination among Institutions

15.1 Land Degradation

Undulating topography, combined with deforestation and torrential rains during monsoon season, has severely denuded the once tropical deciduous forests to the present day degraded forests in the Kandi belt.

Majority of land is rainfed, risk prone and has low pay-off. Farmers do not pay adequate attention to land management and follow traditional farming practices which yield high runoff and soil loss. Consequently, the arable land converges towards marginal land through continuous erosion of productive soil layers and washing out of nutrients.

15.2 High Rates of Soil Erosion

Because of undulating terrain, excessive runoff and high erodibility of soils, erosion is major problem. High runoff and soil erosion during rainy season are due to inadequate protective vegetative cover in the upland areas. High erosion diminishes the productivity of arable and non-arable lands, marginalizes the aquatic resources, and causes physical degradation of land. Further, deposition of eroded material in the streambeds reduces the carrying capacity of the streams and causes floods in the down plains besides causing siltation of reservoirs.

The severity of soil erosion can be best seen in Mansar, Surinsar, Bhalwal, and Akhnoor areas, where the surface soil has been completely washed away fully exposing the parent material. The soil productivity is, thus, very low. In Devak watershed, under Ujh catchment of Ravi river basin, soil loss of the order of 25 tons/ha/yr was estimated (Srinivasulu et al., 2000).

15.3 Low Crop Productivity

Traditional cultivation practices coupled with harsh climatological conditions produce low crop yields. The productivity of various food crops in the region is much lower than the all India average, except for Maize. Low fertility of soils, lack of adequate irrigation facilities, and erratic rainfall occurrence in space and time, lead to reduced crop yields. Also, crop varieties suitable for water scarcity areas are not available/developed to withstand the adversities of the soil and climatic conditions.

15.4 Loss of Biodiversity

Due to increasing tendency of producing economical crops, e.g. cash crops, less economical crops have been neglected, narrowing down their gene pool. Neglect of the traditional local varieties of crops, which have low yield potential but possess more resistance to moisture stresses and diseases, has posed a serious threat to sustained food production under the adverse climatic conditions in the region.

15.5 Degeneration of Forests

Forests play an important role in ecosystem development of a region. A gradual decline in the forest area is the result of excessive harvesting of forests for fuel, fodder, timber and other products, and improper burning, lopping and cutting of trees. As a result, many important native plant species are facing acute problem of regeneration.

Stall feeding of animals is primarily done on cut grasses, lopped trees and dried crop residues. The grazing is predominantly unregulated and open access activity. Over grazing of forests has resulted in excessive runoff and soil loss, poor regeneration and low productivity of pasture lands. Demarcated, privately owned or earmarked grasslands, where grazing is restricted, are not maintained in the region.

15.6 Poor Water Availability for Crop Production

This region receives rainfall from the 3rd week of June to middle of September through southwest monsoon. About 74% of the total rain is received in a short span of 4 months during the monsoon season. Winter rains are received during January to March due to western disturbances. Long rainless periods occur even during rainy season, causing water stress to crops. Most of the rainwater goes as surface runoff due to flashy nature of the streams.

The rain in June is erratic and quite uncertain, resulting in delays in the sowing of *Kharif* crops and consequent reduction in crop yields. After continuous rains during July and August, the monsoon recedes by end of August or early September, leading to dry spell, causing stress to the crops. Breaks in rainfall are frequently encountered in the monsoon season and sometimes it either sets in late or withdraws early, resulting in reduction in crop yield.

In winter season, the rains are light and surface runoff is mild. The winter rain is received in an unpredictable manner. Also, often early receding of monsoon causes acute moisture stress at the sowing time of *Rabi* crops. Drought is frequently experienced during *Rabi* crops, i.e. during October to December and March to April. A weekly distribution of rainfall at Jammu at different probabilities is shown in Figure 17.

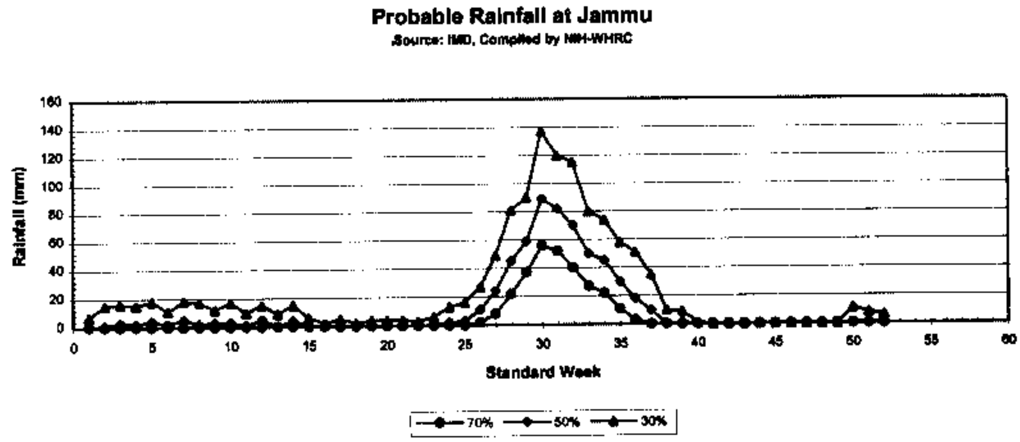


Figure 17. Distribution of weekly rainfall at Jammu at different probabilities

The inherent fertility of the soils of this belt is generally low to medium. These soils are particularly deficient in nitrogen and phosphorous. The yields of rainfed crops are low and unstable, governed mainly by the rainfall pattern. *In situ* moisture conservation and rainwater harvesting and recycling techniques are not popular among farming community.

Irrigation facility through canals is available only in the Lower Kandi areas. The Pratap and Ranbir canals cover the majority of Lower Kandi area between western end of the Kandi belt to Akhnoor, and from Akhnoor to Jammu. Between Jammu and Kathua, only Ravi-Tawi canal network is available.

15.7 Under Utilization of Horticulture Potential

The typical agro-climatic conditions in the Kandi belt provide a conducive environment for growth and development of a variety of horticultural crops. In a water scarcity area with erodible soils, the advantages of growing fruit plants include (1) low water requirement as compared to the agricultural crops, (2) higher economic returns, (3) better soil protection due to less ploughings, (4) suitability of growth on slopes and terraces. Many wild fruits, e.g. *Bel*, *Amla*, *Daruni*, *Jaman*, *Shahtoot*, *Ber*, and vegetables are available in the region. The commonly grown fruits in the area include mango, guava, lemon, lime, and *kinnow*.

The present fruit plantation in the Jammu region covers only about 1.5% of the total land area (Parihar and Singh, 1994). Keeping in view the climate, soils, topography, adequate rainfall, etc, there is no doubt that there is large scope for pushing up fruit cultivation in the Kandi belt of Jammu region.

The orchards in the region are mostly unplanned plantations on rainfed sloping land without proper soil and water conservation measures. This has resulted in low water holding capacity, more leaching and washing of nutrients from the soil, and high incidences of diseases and pests. Lack of irrigation facilities and inadequate knowledge on the suitable varieties, fertilizers, insecticides, pesticides, etc. has hampered the desired development of horticultural activities in the region. Use of the latest techniques of water-efficient irrigation methods is almost non-existent in the area. Improved fruits varieties with characteristics like high productivity, low chilling, disease resistant, longer shelf life, etc. have been tried only to a very limited extent. Absence of adequate infrastructure for marketing of such produce, including food-processing industry, is also a major constraint.

Also, a vast potential for growing of vegetables, flowers and medicinal plants is still untapped in the area. Research is needed to identify suitable sites for cultivation, crop varieties and appropriate technologies for economic cultivation of these crops.

15.8 Water Availability for Domestic Purposes

A number of *Choes* (torrential streams) pass through the Kandi belt, manifesting "too little or too high" syndrome, which is typical of the hilly areas, and are eroding the fertile soils of the area. Extinction of the age-old system of water harvesting through village ponds has resulted into water scarcity during non-monsoon months. Though the area receives a fairly high average annual rainfall of more than 1200 mm, yet harvesting of this water is lacking, which is one of the root-causes for water crisis.

Most villages of the region are claimed to have been covered by installing dugwells in the beds of the rivulets. According to the State Government statistics, almost all villages in the two districts have been covered under drinking water schemes. But, in the so-called covered villages, water is supplied only two to three days a week, and at times only weekly. Water supply is frequently interrupted, especially during summers, due to failure of pumps, etc. Water is also supplied by tankers, but only in villages along the roadside. When demand rises sharply in the summer, villagers very often resort to the ponds for drinking water, which is no longer hygienic in present times. Quite often, the same pond has served as a drinking water source for both humans and cattle. When the ponds dry up in the summer, villagers trek long distances to fetch drinking water.

Water bearing aquifers in the region are deep and, therefore, ground water is inadequate and, thus, economically not feasible. Grain size of the aquifer material in the Kandi belt is very coarse. The cost of drilling of wells also is high because of hydrogeological conditions.

15.9 Water Pollution

Water from the hills is considered pure and safe for drinking due to its natural filtration inside the soil system. However, with the advent of rapid urbanisation, and its consequences, this assumption does not hold good in many cases. Besides the sediment load, other pollutants may enter the water (both stream water and ground water) through sewage and garbage disposals, industrial wastes, fertilizers, insecticides and pesticides. Water flowing through various rocks may also contain different amounts of trace metals and ions.

Entry of pollutants from the major urban areas of Akhnoor, Jammu and its surroundings (including industrial area of Bari Brahmana), Samba, Hiranagar, Kathua, and other towns in the Kandi belt is a risk to the quality of water in the area, and should be watched carefully.

15.10 Low Productivity of Animals

In summers, animals also do not get sufficient water from natural resources as these dry up due to intense heat. Consumption of unhygienic water from contaminated sources leads to various diseases among the livestock. Higher temperature during summers severely decreases the humidity levels and, under such conditions, the xerophytes flourish, while seasonal and perennial grasses, bushes, etc. fade away due to scorching heat. The availability of fodder is thus reduced during this period, affecting production of milk, meat, etc. Improved varieties of high-yielding animals are required. Appropriate technologies to increase production of suitable varieties of fodder are required to improve productivity of the animals. Systematic efforts to promote cold water fisheries along seasonal streams also need encouragement.

15.11 Lack of Hydro-meteorological Data

A reliable hydrological database of sufficient time period is necessary for planning and development of water resources in an area. In the Kandi belt, long term hydrological data is presently available for only two major rivers, viz. Chenab and Tawi. No hydro-meteorological monitoring station is available in the catchments of important streams in the Kandi belt, e.g. Tawi, Devak, Basantar, Ujh, Tarnah, to monitor flow and sediment discharge. A spatio-temporal monitoring of streamflow, water quality, rainfall, temperature, humidity, evaporation, and solar radiation is required from carefully selected sites in the catchments. This data is needed for planning, investigation and execution of future projects in the region.

15.12 Socio-economic Problems

Means of transport and communication are much less developed in the region. Small land holdings, low investment capacity, and illiteracy are the main socio-economic constraints. Natural environmental factors have both direct and indirect influence on the socio-economic status of a region.

15.12.1 Degeneration of Community based Institutions

Although the traditional community based village level activities used to be technically sound and environment friendly, gradual shift towards 'modernisation' has resulted in a situation where the 'urabnising' population neither fully adapted the new technologies nor retained the ageold proven ones. The present state of the system of village ponds and minor irrigation through '*kuhls*' is a glaring example of this offshoot of urbanisation. Increasing dependence on the government schemes has divested the local population from its control on sustainable development of the area. Failures and inefficient functioning of the government-run schemes is the result of lack of participation of the local people in the schemes.

Similarly, increasing tendency of shifting from traditional crops, which suited to the local soil and climatic conditions and whose water demands were mostly met locally, to the cash crops has made the farmers more dependent on the irrigation facilities, predominantly required from government sources. As a consequence, there is a shortage of traditional food crops, e.g. cereals, millets, oilseeds. Proper crop management for a region, which includes selection of suitable crop types, high yielding varieties, use of efficient techniques of cultivation, irrigation, storage, and post-harvest management, can be effectively handled by village level and/or community based institutions, e.g. cooperative societies, which are presently absent in the area.

15.12.2 Lack of Public Awareness on Environmental Issues

Literacy rate in the Kandi belt, as in Himalayan region on the whole, is very low. There is an earnest need to educate the local masses about the environment, and its functioning. They need be told about the things they should do, and the things they should not do, to conserve and improve the environment. Use of various media skills, preferably in the local language, could be employed to transfer the messages to the local population. Women are the backbone of hill agriculture, and participation of women should be especially encouraged in all community-based activities at the local level.

The farmers should be acquainted with the advantages, disadvantages, and limitations of new technologies. To ensure sustainability of efforts, local people should be involved after imparting necessary technical and management skills. A mechanism should be evolved for regular interaction with these local participants through refresher courses, training programmes, discussicns, etc.

15.13 Lack of Coordination Among Institutions

Development of natural resources in an area requires planning, investigation, and implementation of various schemes. A number of organisations are available in the region, both in the government and non-government sectors, who are dealing with different aspects of the natural environment. In the present setup, however, there is lack of effective interaction between the State and Central government organisations. Effective participation of the non-government organisations in the water resources sector is mostly lacking at present.

The State government agencies should come forward with water related problems and seek necessary guidance/help from the concerned Central organisations. Non-governmental organisations and local institutions should also be involved in formulation and implementation of the schemes. In consultation with all involved institutions, a water (or watershed) management policy should be formulated by the State government. A State-level committee could be constituted to periodically review the performance of watershed management schemes in the region. This committee could also provide a platform for better coordination of efforts and for resolution of conflicts among the institutions.

16.0 SOLUTIONS

Water related problems of the Kandi belt broadly comprise of domestic and irrigation requirements. The problems can be tackled by adopting two-tier approach- short-term and long-term. Under the former category, immediate solution of the domestic and, to a limited extent, irrigation water requirements can be handled by providing water from tubewells, ponds, and small reservoirs created with the help of check-dams on seasonal streams and rivulets, wherever feasible. Solution under the latter category would involve measures like watershed management, including hydro-meteorological monitoring in the region. The latter category of solutions would in any case be desirable to improve the regional environment and ecology.

As mentioned earlier, two major physiographic sub-divisions of the Kandi belt are- the Upper Kandi and Lower Kandi. The above mentioned solutions would have to be applied keeping in mind the local conditions. There cannot be a general recommendation, which would suit all areas of the region. In order to achieve sustainability of the efforts, it would be better to have a number of small schemes rather than one or two major schemes. Involvement of the local people and local institutions would assure success of these schemes.

Planning of a scheme for a particular area should consider the natural factors, e.g. water demand of the area, source(s) available in the vicinity, distance between source and users, topographic conditions (e.g. gradient), together with economic aspects to evaluate the viability of the scheme. In the first place, identification of villages and hamlets with deficit water supply from existing sources (e.g. through pipelines) alongwith their water demand is necessary, followed by identification of sources of additional water supply (e.g. springs, streams, ponds, tubewells). The possible sources of water supply for different purposes are shown in Table 15. Evaluation of the feasibility as well as viability of supply from each of the available sources is the next step. A final decision on the scheme(s) to be selected should be based on the economic viability and acceptance/support of the local population.

Table 15. Water Supply Options from Different Sources

Water Requirement	**Source(s) of Water Supply**		
	Surface water	**Ground Water**	**Surface+Ground Water**
Domestic+Small Scale Irrigation (e.g. for horticulture)	(1) Rainwater Harvesting, (2) Streams, (3) Ponds	(1) Tubewells, (2) Lift from springs	(1) Village ponds, (2) lift from streams, (3) lift from tubewells, (4) check dam & reservoirs on streams
Crop Irrigation	Canals	Tubewells	Gravity flow from (1) big ponds, (2) lift from streams, (3) lift from tubewells, (4) check dam & reservoirs on streams

The various options suggested for tackling the water scarcity problems, and the steps recommended for long-term improvement of the natural environment in the Kandi belt are listed below and discussed next.

Hydrological Problems in the Kandi Belt of Jammu Region- Solutions

IMMEDIATE

- Utilization of Irrigation Potential
- Ground Water Development
- Hydrogeological Mapping
- Rejuvenation of Village Ponds
- Water Harvesting in Streams
- Soil and Water Conservation Works in Cultivated Areas
- Earthen Dams Across Gullies at Foothills
- Use of canal water for storage in village ponds
- Water Harvesting Tanks in Cultivated Areas

LONG-TERM

- Ground Water Storage
- Tapping Ephemeral Streams for Irrigation
- Management of Riparian Zones
- Protection of Forests
- Agroforestry Management
- Hydro-meteorological Analysis
- Hydro-meteorological Monitoring
- Watershed Management

16.1 IMMEDIATE SOLUTIONS

16.1.1 Utilization of Irrigation Potential

As long back as early ninteen seventees, it was reported that the Govt. of Jammu & Kashmir has prepared a plan to expand irrigation facilities to the Kandi belt by gravity flow from the river Ravi and its tributaries and by lift irrigation schemes, including lift through the tubewells (Anonymous, 1972). Of these schemes, the Tawi Lift Irrigation scheme from the river Tawi, Kathua canal from the river Ravi, and Ravi canal from the rivers Ravi and Ujh were made operational.

As seen in Table 10, except in the case of Ranbir and Kathua canals, utilization of the created potential is poor. The newly commissioned/partially commissioned schemes (Ranjan and Rajal) can be expected to achieve higher utilization through CAD programmes in the coming years. But an overall utilization of less than 50% of the potential created in the case of Ravi-Tawi canal system needs improvement through CAD programmes, and other suitable measures.

Improvement of the mere 56% utilization of the potential created in the minor irrigation schemes in Jammu region should be the thrust area of research/development in the coming years (Prabhakara and Pandita, 2000). A sound management of the potential irrigation water can help a lot within the command areas and even to the adjacent rainfed regions.

In remote areas where the streams have sufficient gradient, water could be lifted using hydraulic rams, also known as 'hydrams', which operate without any fuel or electricity. Irrigation in limited areas is possible through these devices.

16.1.2 Ground Water Development

Stage of ground water development in Jammu & Kashmir is very low against the vast available irrigation potential. The Jammu district presently has 425 tube wells and 77 dug wells. The Kathua district presently has a total of 460 tube wells 37 dug wells, out of which 27 tube wells and 37 dug wells are being used for drinking water supply. Present stage of ground water development in the Jammu and Kathua districts is only about 5%.

CGWB has drilled 25 boreholes in the Kandi belt, reaching a maximum depth of about 350m bgl. The yield potential of Kandi aquifers is good, and is comparable to that of Sirowals. Average discharge from tube wells in the Kandi and Sirowal belts are estimated to be 4.5 ham and 9 ham, respectively. Steep slope and deep water levels, however, prohibit use of ground water for irrigation in this area. According to CGWB projections, about 10,000 additional ground water structures are feasible in the two districts of Jammu and Kathua (CGWB, 2000).

For determination of aquifer parameters, it is necessary to have observation wells with the test wells at the time of pumping tests. Creation of free flowing condition by way of tapping deep seated Siwalik aquifers in the Kandi belt can prove to be a boon for the region. Owing to the hydrogeological conditions, however, ground water development through tube wells is feasible mostly in the middle and lower reaches of the Kandi belt. The Kandi formations, because of their high permeability, may support high yielding wells. Some of the relevant hydrogeologic parameters for the Kandi zone are given below (CGWB, 1996):

Table 16. Hydrogeologic Parameters in the Kandi Belt

S No	Parameter	Value
1.	Soil Infiltration Rate	20%
2.	Porosity	28-43 %
3.	Specific Yield	0.10
4.	Coefficient of Replenishment	0.12
5.	Area under 17m (or more) Thick Potential Unsaturated Zone	1200 km^2
6.	Water Required to Create Subsurface Storage upto 3m BGL	4320 MCM
7.	Utilizable Ground Water Storage Potential	3600 MCM
8.	Average Depth to Water Level	33.0 m BGL (10-100m)

Ground water exploration in the Kandi belt need be more systematised and efforts should be made to achieve deeper depths. Tapping of deep seated Siwalik aquifers in the Kandi region is suggested to be a means of solving the water crisis in the region (CGWB, 1998). Special combination rig is required to drill in the bouldery formations successfully. Efforts are required to determine aquifer parameters with the help of observation wells.

Also, a spring line demarcates the Sirowal belt in the south from the Kandi belt in the north. This line is manifested in the form of springs and oozing of water in the streambeds in the Sirowal area, whereby dry stream channels become perennial from that location onwards. Free-flowing wells have been located in such areas. Water available from these sites could be lifted, after constructing suitable storage structures, and utilized in the upstream areas in the Kandi belt. Depending upon the demand of water in nearby villages, and considering the economic feasibility based on the topographic conditions for networking of distribution lines, cost of lifting involved, etc., adequate quantity of water can be lifted from such locations. Demarcation of suitable sites for availability of water from springs, and sites (villages) with demand of water on priority basis, is a pre-requisite for this option. This option is feasible for the lower areas of the Kandi belt.

16.1.3 Hydrogeological Mapping

The nature of subsurface formations in the Kandi belt warrants a careful selection of site for location of any structure for water resources management. Coarse textured soils in the area often lead to failure of wells and ponds, if constructed without taking into consideration the subsurface lithology. Also, harnessing of surface water through check dams, etc. would pose a problem if geology of the area is neglected. This necessitates a detailed hydrgeological mapping of the area.

Lithologs (strata chart) of about 200 wells in the region are available with different organisations, viz. Central Ground Water Board, Geological Survey of India, Public Health Engineering (J&K), Directorate of Geology and Mining (J&K). Preparation of fence diagrams along different sections would immensely help in planning soil and water conservation structures in the Kandi belt.

16.1.4 Rejuvenation of Village Ponds

The semi-hilly Kandi belt is generally devoid of any springs or *baolis*, which made ponds an important source of water to meet the community needs in the region. Most ponds were so designed that a part of the runoff from adjoining rivulets could be trapped. Also, the ponds helped in improving the level of ground water in the surrounding area. By the middle of 20th century, piped drinking water supply led to the neglect of these ponds. Pressure on land and a decline in community institutions further speeded their decline.

Most of the ponds in the Kandi belt are today in a state of utter neglect and disuse. Village institutions, which organised annual desilting through voluntary labour and guarded the ponds against pollution, have since collapsed. In some cases, dirty water drains have been diverted into the ponds. High silt deposits have greatly reduced their storage capacity. With the advent of *pucca* houses, a rural women's need for pond silt to mudwash her house has lessened and, as a result, this need driven desilting of ponds is coming to an end.

Water inlet routes of several ponds have been encroached upon by influential persons, resulting into less runoff coming from the catchment area for storage. Although some efforts have been made to construct new ponds in the Kandi belt for irrigation purposes, yet limited success was achieved due to ignoring the importance of selection of suitable sites for this purpose. Water stored after good rainfall seeps out in just a few days (Agrawal and Narain, 1997).

Based on the Survey of India's toposheets, 406 ponds of various sizes have been located in the Kandi belt (Figure 16). A long-term solution to solve the water scarcity problem in the Kandi belt lies in the rejuvenation of these village ponds, with a total surface area of approx. 1.7 Km^2 which, considering an average depth of 2m, would store approx. $17x10^8$ litre of water. This water could be utilized for domestic purposes and, to a limited extent, for irrigation purposes (e.g. in horticulture, agroforestry). These ponds would also help in improving the ground water regime in the region.

A sound scheme for rejuvenation of the village ponds is required, which should use the traditional folk wisdom and the skills of the modern techniques, e.g. inputs from the hydrology, geology and geophysics, soil sciences, remote sensing and GIS. An estimated expenditure of Rs. 2-5 lakh, depending on the local conditions, would be required for rejuvenation of each of these ponds. Specific objectives would be:

(1) selection of suitable sites for location of new ponds,
(2) improving inlets to the ponds, with augmentation of runoff from nearby areas,
(3) necessary desilting of ponds,
(4) deepening of ponds, if required, and improving the side walls/bunds,
(5) lining of ponds with appropriate material to control seepage from the beds,
(6) reduction of evaporation from the ponds through appropriate measures (e.g. through plantation),
(7) constructing separate sections for drinking water, bathing and washing, cattle needs,
(8) networking of ponds, wherever feasible, for domestic and irrigation purposes
(9) recharge of the ponds through dug wells near the stream beds, wherever feasible based on hydrogeology of the area. This is known as the Makowal model, which was successfully implemented in the Kandi areas of Punjab.

The success of this activity would, however, depend on participation of the local people for sustainability of the ponds, e.g. for periodic desilting, preventing from polluting material, maintaining inlet routes. The local people should come forward to revive this age-old system of water harvesting structures, which had successfully served the water requirement of the region since long time.

16.1.5 Water Harvesting in Streams

Areas in the Kandi belt have heavy rainfall during a short period of the year and very little during the rest of the time. It is not uncommon for these areas also to have problems with flooding, which occasionally causes substantial damage to land and vegetation. For regions with sufficient yearly rainfall, the problem can be treated as a mere storage problem. Water from periods with more abundant rainfall has to be collected and stored for later use.

Storage of water flowing in a stream can be done in two ways, depending on the runoff characteristics of the stream. If there is a large runoff with a huge transport of coarse sediments during at least one part of the year, one or several dams filled with such sediments can be used as storage (Figure 18). If there is no large runoff and sediment transport, water can be stored in the riverbed by the construction of subsurface dams (also known as "Trap Dams"). These dams also act as stream flow moderators, consequently helping in flood mitigation. Additional advantage with these dams is their capability to recharge the ground water since some leakage takes place through the bottom and the sides of the dam, depending on the bedrock characteristics.

These dams must be designed and constructed in such a way that erosion will not cause failure of the dam. Every dam site is specific with respect to its geology, size, stream characteristics, etc. Such dams exist along the foothills of the Himalayas, where well confined streams with large intermittent transport capacities and low gradients are abundant (Baume, 1984).

Streams of different sizes, of both ephemeral and more or less perennial character, are equally suitable since there is shortage of water during the summer season. In order to store water and to reduce flooding, a series of dams can be constructed along the course of ephemeral and intermittent streams in the region. These dams should be constructed in such a manner that they would naturally fill with coarse sediments during the rainy season. To achieve this, they should be built in a stepwise manner, where the height of each individual step should be governed by the stream flow characteristics of the particular stream involved, to ensure sedimentation of desired grain sizes. A typical design of such a "trap dam" for remote areas is shown in Figure 19. Depending on the availability of local construction material, the dams could, for example, be made of reinforced concrete, concrete, masonry, etc. (Figure 20).

16.1.6 Soil and Water Conservation Works in Cultivated Areas

The cultivated areas, just below the foothills, have undulating topography, irregular slopes, and very small land holdings. Suitable engineering and non-engineering measures are required for this area. Conventional engineering measures like contour bunding, graded bunding, bench terracing and contour ditching are not viable in this region. A set of measures, including (i) terracing within field boundaries, (ii) land grading to bring down slope between 0.3 to 0.5%, (iii) field bunding, and (iv) outlet structures for draining excess water from field to field, and from field to water ways and grassed water ways, has been found technically viable in the Kandi belt of Punjab (Verma, 1992), and could well be attempted in Jammu and Kashmir.

16.1.7 Earthen Dams Across Gullies at Foothills

There are numerous big gullies and ephemeral streams originating from low hills and flowing down into cultivated fields. They have progressively increasing cross-sectional area toward flow direction in upper portion of the catchments with porous bed. Small earthen dams can be constructed at suitable locations near foothills to store considerable quantity of runoff water. These earthen dams can be constructed using clay (locally available) core wall and simple earthen spillway. Success from these dams can be achieved if these are designed based on sound hydrological data (primarily rainfall and runoff) and analysis.

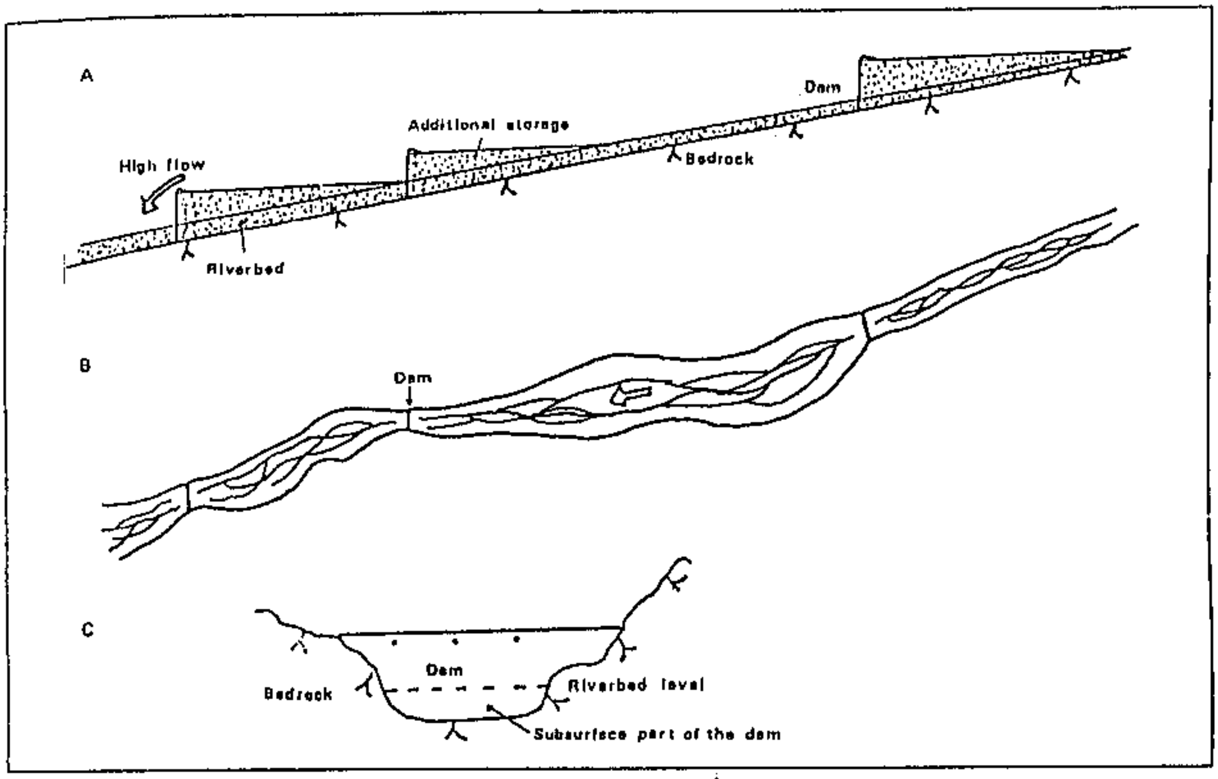


Figure 18. View of a Trap Dam

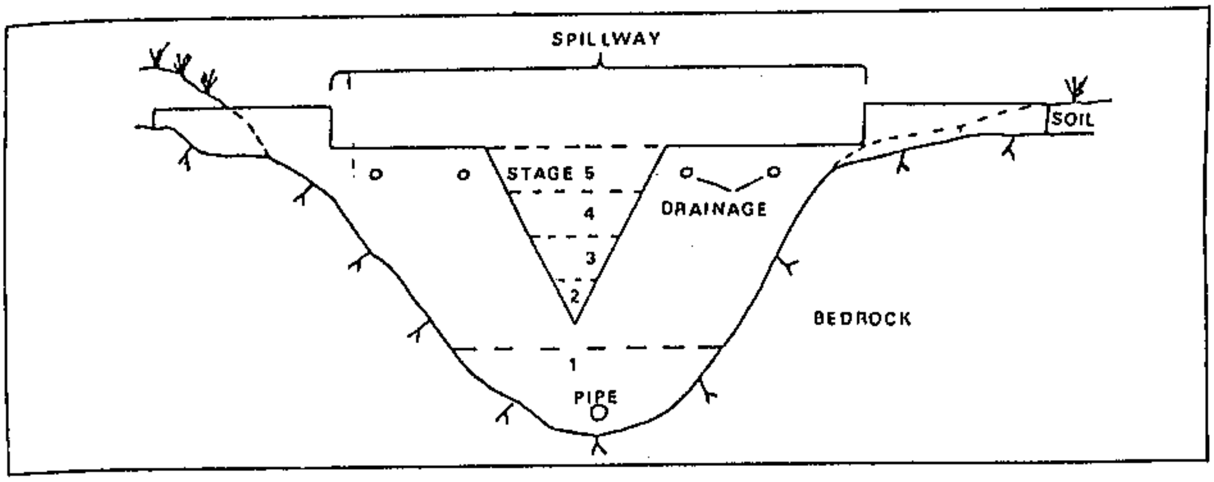


Figure 19. Construction of a Trap Dam with a notch

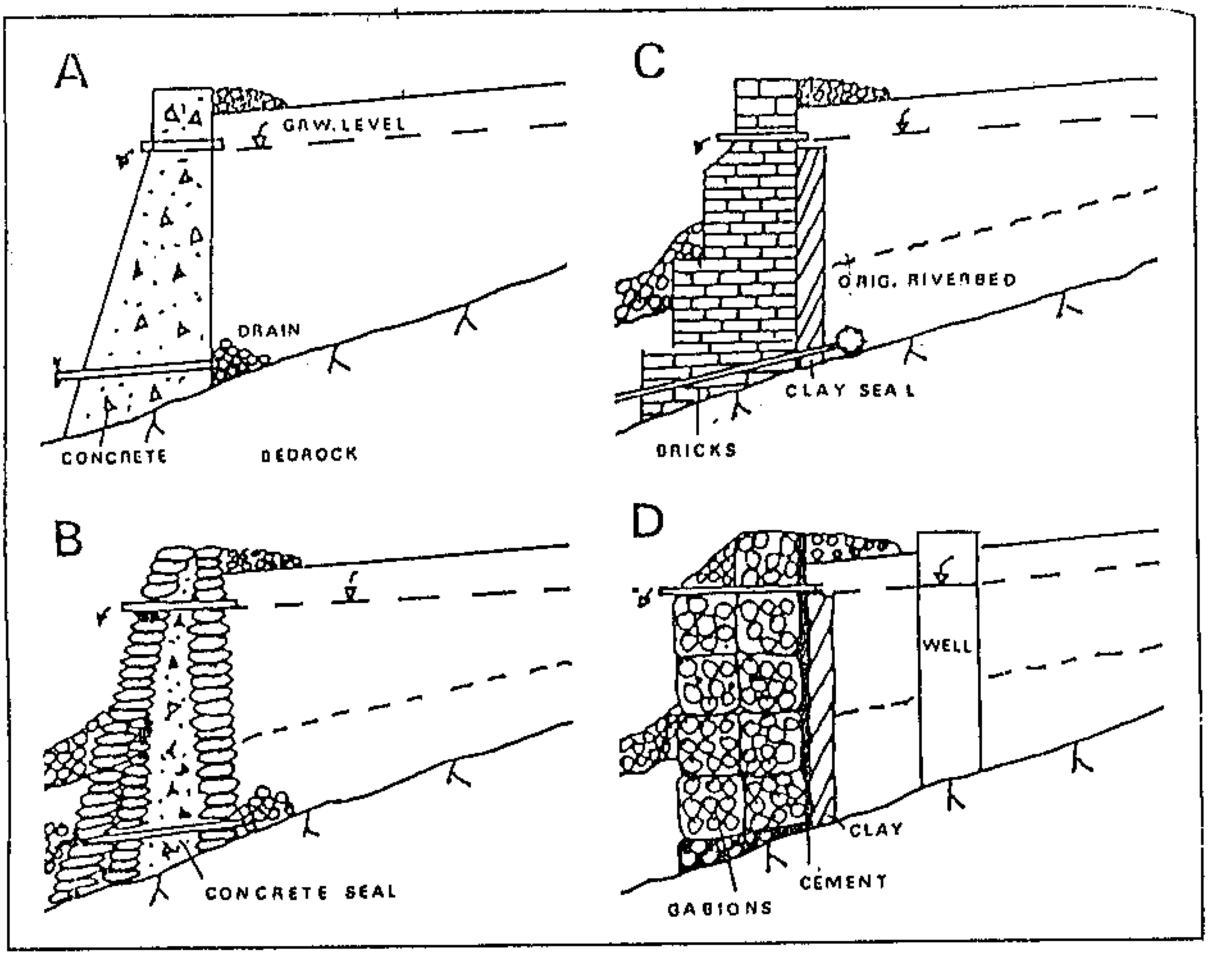


Figure 20. Examples of different ways to construct Trap Dams

The construction of a dam reservoir in gully not only benefits supplemental irrigation to rainfed crops, but is also useful as soil conservation structure, as percolation tank for ground water recharge, and as flood detention dam. Ever increasing damage of cultivable area can be checked, and a portion of the damaged area can be reclaimed, through construction of earthen dams in gullies, especially in the upper Kandi areas. About 115 rainwater harvesting dams of Sukhomajri pattern were reportedly constructed in the Kandi areas of Punjab, Haryana and Himachal Pradesh (Grewal et. al., 1995). The cost of a typical dam of about 16m height, storage capacity of about 60ha-m, and serving a command area of 243ha, is reported to be approx. Rs 35 lakh in 1984. The cost per hectare of command and catchment area for such a project is Rs 11,000 approx. (Arya and Samra, 1995).

16.1.8 Use of Canal Water for Storage in Village Ponds

A network of canals is available in the Kandi belt, drawing water from the rivers Chenab, Tawi, Ujh, Basantar, and Ravi (Figure 15). Although withdrawal of water from Chenab and Tawi is limited by the Indus Water Treaty, the other three eastern rivers are not bound by the Treaty. Even the percent utilization of the minor irrigation potential created in the Jammu province is only about 55% (Prabhakara and Raina, 1997).

The irrigation demand from these canals is more during the months of June and July for Kharif crops and October and November for Rabi crops. Water through these canals during lean demand months could be utilized, where ever feasible, to store in the village ponds, of course taking into consideration the topographic conditions.

16.1.9 Water Harvesting Tanks in Cultivated Areas

The set of engineering soil and water conservation measures, discussed above, cannot conserve all rainwater in-situ due to limited water storage capacity of the soils in the Kandi belt, and runoff is bound to occur. A considerable amount of runoff can be collected in tanks for supplemental irrigation to rainfed crops. Tanks in fields with loamy sand are preferred since runoff from these soils is low which can be easily managed in the field itself. Dug out tanks are most suitable for excess runoff storage in cultivated lands, provided heavy seepage is controlled through suitable methods. The tanks of inverted truncated pyramid shape having square base and 1:1 side slopes and lined with polyethylene sheet of 200 micron were found suitable under the All India Coordinated Research Project on Dryland Agriculture (Verma, 1992).

16.2 LONG-TERM SOLUTIONS

16.2.1 Ground Water Storage

In hilly terrain, steep slopes result in heavy runoff and low infiltration, resulting in less availability of water after the rainy season. In order to check excessive runoff, soil erosion, nutrient loss, and to enhance water storage, the best measure is to conserve rainwater *in-situ* where it falls. Besides surface water storage, it is advisable to augment the ground water reservoir through recharge process. The ground water storage has advantage over surface water storage in that it reduces evaporation losses and helps natural filtration of water besides eliminating the need of large land areas needed in case of surface water reservoirs.

Natural seepage from ponds and reservoirs of the check-dams contribute to the ground water recharge. The type of ground water recharge system that can be developed/expected at any specific site is controlled, to a large extent, by the geologic, hydrologic, and topographic conditions that exist at the site. Availability of water, either on a perennial or intermittent basis, is of prime concern in any recharge operation. The quality of recharge water should be considered to avoid contamination of the ground water.

Success of a recharge project requires that the aquifer to be recharged must underlie the potential recharge site, and the hydrogeology of the site should permit development of a ground water mound underneath. In areas of complex subsurface terrain, e.g. in the Kandi belt, it is not easy to determine aquifer interconnections. Also, the aquifer must have sufficient permeability and thickness to carry away the recharged water.

Owing to the complex hydrogeologic and topographic conditions, suitable sites need be identified carefully for recharging in the Kandi areas, otherwise the benefit of recharging will not be available within the country, and may benefit the areas across the international border. Since ground water in the Kandi belt is flowing under steep gradient, the need is to control, i.e. to delay the movement of ground water, through suitable structures (e.g. subsurface dykes). This way recharging the Kandi deposits in the outer most Siwalik area, and junction of Siwalik and Kandi, would gradually raise the deeper water levels in the piedmont zone. Subsequent to installation of water harvesting structures, e.g. check dams in the Siwaliks, the construction of a battery of tubewells may be taken up along lower Kandi areas, and along the spring line in the Sirowals, to salvage the water recharged (CGWB, 1996).

16.2.2 Tapping Ephemeral Streams for Irrigation

Flash flood is commonly associated with a violent, short-duration, high intensity convective storm that falls on a steep watershed. The climatic and geomorphic characteristics of watersheds in the Kandi belt provide a suitable environment for persistent flash-flood hazards. These floods usually occur only on small headwater streams, minor streams, or inadequately drained areas. The key hydrological factors that control floods, in general, and flash floods in particular, include temporal and spatial aspects of rainfall, landuse, soils, and geomorphological aspects of the watershed.

Ephemeral, or flashy, streams in the Kandi belt discharge onto the plains and during times of severe floods cause great damage by spreading sand deposits on otherwise fertile lands. The ever-increasing demand of water, especially for irrigation purposes, can also be met by tapping ephemeral streams with small reservoirs, water harvesting tanks, diversion weirs, etc. Such works must be designed to accommodate the following characteristics of ephemeral streams (Dhillon and Paul, 1987):

i. their steep slopes,
ii. the short duration, but comparatively high peaks of the flood flows,
iii. the high sediment loads, which reduce the effective life of a reservoir to about 20 years,
iv. the small denuded watersheds generating runoff only in the monsoon season, or as a result of winter storms.

The construction of such small and medium dams, e.g. of 10-40m height, on streams with drainage areas of the order of 10-60km^2 can provide a fairly large storage capacity for irrigation requirements of the Kandi belt. Water harvesting tanks can also be constructed on streams, which do not have good sites for the provision of dams. Wherever gravity flow irrigation is not feasible, solar pumps or diesel generator-operated pumps can be used to lift the water from such tanks. Appropriate measures need to be taken on the embankments, and to reduce the seepage losses from the beds.

Dhillon and Paul (1987) advocated the provision of small-capacity reservoirs, diversion weirs, and water harvesting tanks for harvesting of the ephemeral streams. Under a World Bank aided scheme, namely Kandi Watershed and Area Development Project, the Punjab Government constructed dams/reservoirs and water harvesting tanks. Salient features of a few of such schemes are shown in Table 17.

Table 17. Salient Features of Dam Reservoirs on Ephemeral Streams

Watershed	Year	Dam Specifications	Drainage Basin Area (Km^2)	CCA (Km^2)	Storage Capacity (M m^3)	Cost (in Million Rs)
Dholbaha	1986	38.8m high	56.13	37.0	31.45	94.0
Maili	1986	23m high	17.0	9.1		23.4
Janauri	1987	26m high		5.9		20.6
Mehngerwal		27m high		15.2		29.9
Budki		21.4m high		15.0		16.5
Lalwan		31m high		4.5		33.6

16.2.3 Management of Riparian Zones

A stream is a complex ecosystem in which several biological, physical, and chemical processes interact. Changes in any one characteristic or process have cascading effects throughout the system and result in changes to many aspects of the system (USDA, 1998). Some of the factors that influence and determine the integrity of streams include chemical variables (e.g. nutrients, organics, solubilities, temperature, turbidity, hardness, pH, DO), flow regime (e.g. precipitation, runoff, land use, velocity, ground water), biotic factors, energy source (e.g. sunlight, nutrients), and habitat structure.

Many stream processes are in a delicate balance. For example, stream power, sediment load, and channel roughness must be in balance. Hydrologic changes that increase stream power, if not balanced by greater channel complexity and roughness, result in "hungry" water that erodes banks or the stream bottom. Increases in sediment load beyond the transport capacity of the stream leads to deposition, lateral channel movement into streambeds, and channel widening.

The major categories of chemical pollutants are oxygen depleting substances, such as manure, ammonia, and organic wastes; the nutrients nitrogen and phosphorous; acids, such as from mining or industrial activities; and toxic materials, such as pesticides and salts or metals contained in some drain water.

It is important to recognise that streams and flood plains need to operate as a connected system. Flooding is necessary to maintain the flood plain biological community and to relieve the erosive force of flood discharges by reducing the velocity of the water.

Efforts are needed for restoration and maintenance of streams to a healthy condition. The benefits of healthy streams include improved baseflow, forage, fish, wildlife, reduced flooding downstream, and reduced water pollution. This would provide long term benefits to the population not only living on the banks of the stream but also to all those living in the downstream reaches, within the catchment area of the stream.

16.2.4 Protection of Forests

The forest resources of the Kandi belt in Jammu region have been under mounting pressure owing to increasing human and livestock population. Excessive deforestation has resulted in the depletion, degradation and endangering natural regeneration of the forests which has become a cause of serious concern. The large-scale deforestation is causing significant changes to the high and low flow regimes of rivers, massive soil erosion etc.

The entire philosophy of the role of forests is based on the ability of the forests to prolong the water cycle from its inception as falling precipitation to the final disposal as runoff into streams. The longer the water is retained on the land, the greater is its usefulness in nurturing crops and trees, in maintaining the regular supply of water in streams, and in preventing soil from washing away. Precipitation without forests is rapidly disposed off by surface runoff. In forests, it is retained in the soil and gradually utilised for the growth of trees and crops, and for maintaining a steady and sustained flow of water in the streams.

In general, afforestation is found to reduce runoff volume and peak and soil loss from a watershed. The hydrological consequences of different forest management practices/systems and biotic interference have been studied in a limited extent. Higher infiltration rates are expected under forest soils due to improved structure of soils, and forest soils have been found to have better moisture holding capacity due to its high humus content. The peak rate of runoff could be reduced by 60 to 70% by introduction of proper forest cover and other soil conservation measures in the watersheds.

Forest influences on various hydrological parameters viz. rainfall, interception, infiltration, soil moisture, evapotranspiration, groundwater, water yield, soil loss and floods etc. form an important area of hydrological studies. Studies are also required for effects of forests on water quality in forested catchments. The following studies may be initiated for future research on the subject:

1. Systematic studies to assess the changes in water yield (including regenerated flow) and sediment yield of watersheds, and variations in water quality due to different land uses and vegetative covers, e.g. different tree species and forest types, grasses, shrubs.
2. Experimental and representative catchment studies to cover different vegetation types in the region, and to establish a fully instrumented 'model forest hydrological research watershed', which can serve as a model for understanding the system in a better way and may also be used for training purposes.
3. Systematic studies may be taken up in upper catchments of flood prone areas to examine the effects of forests on rainfall and floods.

16.2.5 Agroforestry Management

Agroforestry is the practice of combining agriculture and forest activities in such a manner that the horizontal and vertical interspaces in forests are utilized by growing suitable and useful plant species on one hand, and growing of trees integrated with other farm operations on the other hand. Agroforestry enhances the overall productivity of the land in terms of food, fuel, fodder and other products. This term can also be synonymously used for multiple cropping system of farming.

Agroforestry has proved to be a successful method for efficient land and water management, especially in areas with small land holdings, poor soil status, and degraded lands. This practice has large potential in marginal areas, such as Kandi belt, where traditional monocultural agriculture or forestry may not be feasible or desirable. A combination of agroforestry systems, agri-horticultural system, and agrisilvipastoral systems, depending on the local conditions and resources, can prove to be beneficial for the local population.

Various research institutes of the Indian Council of Agricultural Research (ICAR), e.g., Central Soil & Water Conservation Research & Training Institute, Dehradun, have evolved technologies suitable for dryland areas (Grewal et al., 1990). Some of the combinations of such practices recommended in the Kandi areas are:

i. Forestry-agronomy
ii. Forestry-horticulture
iii. Forestry-agronomy-animal husbandry
iv. Forestry-agronomy-fishery
v. Forestry-agronomy-animal husbandry-fishery

Though the Kandi belt can support a large number of plant species, the trees having multipurpose uses and depending upon the choice of the local farmers should be preferred. Adoption of agroforestry by the farmers of the area is need of the day. But, the choice of plants/trees should not be thrust upon the local farmers. The identification and utilization of indigenous trees will have advantage of their being in harmony with the local environment. The various tree characteristics and factors important in agroforestry programmes are as follows (Kaul et al., 1991):

A. Tree Characteristics

i. **Nitrogen fixing ability:** In order to conserve nitrogen in the soils, tree species belonging to leguminosae family should be selected as they fix atmospheric nitrogen. Some of such species are Leucaena, Albizia, Acacia, Sesbania. Species belonging to non leguminosae family, which are capable of fixing atmospheric nitrogen into soil, are alders.

ii. **Rapid growth rate:** Fast growing tree species are preferred for better return. Leguminous trees such as *Leucaena* and *Albizia* can attain annual growth rate as much as 2 to 7m in height and 10 to $60m^3ha^{-1}$ (in volume). Other indigenous species found suitable for the region include *Albizia lebbeck, Ailanthus excelsa, Grevillea robusta, Melia azedarach, Bauhinia purpurea, Morus alba.*

iii. **Good coppicing ability:** For efficient management, the species should have good ability for coppicing and vegetative propagation. The trees grown in agricultural lands can be cut and pruned during the cropping period to shun the shading effect and leaves, twigs can be used for fuel, fodder and soil mulching.

iv. **Multipurpose uses:** Suitable species for fodder purpose are Dhaman, Bel, Khirk, Shahtoot, Kachnar, and Sababul; for fuel wood are Kikar, Shisham, Khair, and Albizia; for fruit trees are Mango, citrus, guava, Amla, Ber, Jaman.

B. Factors

i. **Soil:** Suitability of soil in terms of soil depth, moisture regime, stonyness, slope, topography should be considered in selecting the tree species. In areas with good soil depth, species like *Jaman* and poplars can be planted. On slopy, undulating lands, *Khair* is preferred. In stony soils, *Shisham*, *Kachnar* or *Katrer* and *Dhaman* can be grown. In degraded or denuded lands, shrubs like *Girna*, *Santha*, *Bana* and *Branker* have been found useful in checking the soil erosion.

ii. **Climate:** The selected plant species must posses high resistance to the adversities of the climate, e.g. frost, drought.

iii. **Disease resistance:** The selected plant species must be resistant to the attacks of diseases and pests.

iv. **Phenology:** The phenology of the selected plants, their rate of litter fall and its decomposition, must have positive effect upon soil.

v. **Efficient nutrient pumps:** The selected trees must have ability to bring nutrients from lower soil horizons to the surface.

Coordinated efforts should be made to enhance the production of horticultural crops on a sustainable basis. Off-season cultivation of vegetables should be exploited using the latest techniques of irrigation, cultivation, post-harvest management. Establishment of food processing industry in the region would give a boost to the development of such produce. Proper storage and marketing infrastructure should also be developed to enable full commercial exploitation from this activity.

16.2.6 Hydro-meteorological Analysis

Analysis of hydro-meteorological data from various watersheds is important to evaluate the environmental status of a region. This helps in not only evaluating the present status but also in planning for the future based on the present status. Simulation studies can also be carried out

Information on minimum water yield (streamflow) for different return periods and catchments is useful and important in water management projects; telling the planner that in very dry periods, one must plan to get along with only so much flow, or develop storage systems to supply extra water. This data will tell how often to expect these low flows. Flow duration curves should be prepared for better planning and management of the water available in different streams.

Hydrologists need to estimate the probability of occurrence of a given rainfall event, in order to assist planners in determining the likelihood of the success and/or failure of a given project. The main parameters needed to describe rainfall frequency distributions are the duration, intensity, and the return period. The return period is the average period of time in years expected between either high intensity storms, or between very dry periods. Generally, while planning for drains, ditches, etc., an event with a return period of 5 to 10 years is sufficient, whereas, hydrologic plans for urban areas are more commonly concerned with rainfall events that occur only once in 100 years, or even less frequently for large cities.

For projects that are concerned with storm runoff from small to medium sized watersheds (upto 260km^2), planners generally require a storm event with a duration varying from 5 minutes to 24 hours. Larger watersheds may require storm durations or cumulative rainfall amounts for time periods upto one month.

The extreme wet year probabilities are useful in planning reservoir spillway capacities and river flood routing projects. On the lower end of the probability scale, the probabilities of dry years are used to assist in planning volumes of storage reservoirs or the capacity of irrigation systems that may be needed to meet demands during dry years. Low river flow estimates are also needed in determining the quality of sewage discharge that a river can accept without adversely affecting the river ecosystem.

Sometimes, hydrologists need to estimate the probability that a given return period storm will occur at least once within a given number of years, e.g. what is the probability that a 100 year storm will occur at least once during the next ten years? Most hydrologic studies with smaller watersheds require rainfall-frequency data for time periods or durations shorter than one year (e.g. 1 hr, 24 hrs) for various return periods, e.g. 2, 5, 10, 25, 50 and 100 years.

16.2.7 Hydro-meteorological Monitoring

A headwater flood in small rivers and their tributaries resulting from small-area storms is termed a small-area flood. It is distinguished from a large-area flood found in downstream channels where flood-control programmes are wholly of an engineering nature. Headwater floods are typically flash floods of short duration. In smaller headwater areas, variations in climatic and physiographic factors which affect runoff are often more extreme than in larger watersheds. The effects of crops, soil, tillage practices, and conservation measures are more important in headwater areas since the surface condition of the entire area might change completely from season to season and from year to year. The effectiveness of headwater flood-control measures decreases rapidly with distance downstream. Mitigation of such floods, which are largely responsible for the degeneration of the Kandi area, is an important task to improve conditions in the region.

A reliable hydrological database of sufficient time period is necessary for planning and development of water resources in an area. The hydrological observation stations presently maintained in the western Himalayan region operate with limited objectives of monitoring in major river basins, e.g. Chenab and Tawi. However, to have a good water resources database in the Himalayan region, a scheme for monitoring of tributaries of the major rivers is required. Hydro-meteorological monitoring stations are required in the catchments of important streams in the Kandi belt, e.g. Tawi, Devak, Basantar, Ujh, Tarnah, to monitor flow and sediment discharge. A spatio-temporal monitoring of streamflow, water quality, rainfall, temperature, humidity, evaporation, and solar radiation is required from carefully selected sites in the catchments. The data from these stations should be available in a centralised data bank, from where all the important information could be made available. This data will be useful for planning, investigation and execution of future projects in the region.

16.2.8 Watershed Management

Both engineering and non-engineering measures are needed in the watersheds to control the menace of soil erosion and land degradation, and in improving the environmental conditions in the region. Besides ensuring adequate vegetative cover, gully control structures and water harvesting structures are required at appropriate locations for effective management of the water and other natural resources. Various types of structures like jetties or groynes, permeable spurs and other masonry and concrete structures are required for deflecting the flow of water away from the vulnerable points to reduce stream bank erosion (Samra et al., 1999).

In tackling the problem of land degradation, the Govt. of India's approach has gradually moved from mere soil conservation to that of watershed management. Starting from the soil and water conservation programmes, launched in the early fiftees, now the focus is on integrated natural resources management on the basis of watershed, which is considered to be a compact and homogeneous unit. Watershed management has been defined as an integration of technologies within the natural boundaries of a drainage area for optimum development of land, water and plant resources to meet the basic minimum needs of the people in a sustainable manner (Honore, 1999).

In order to achieve sustainable development of natural resources in the Kandi belt, a watershed management approach is necessary to derive long-term benefits. The approach should include water conservation, land development, crop planning and management, agro-forestry measures. The first and foremost task is to delineate and prioritize the watersheds on the basis of the natural factors and local needs. Then, based on the availability of funds and logistics, projects should be initiated in selected watersheds in order of their priority. Involvement of local people right from the planning stage is essential for success and sustainability of a watershed project. Village level "watershed committees" have proved to be a vehicle of success, and are often recommended for this purpose.

The Kandi belt can be divided into small watersheds having denuded hills in the upper part and undulating cultivated fields in the lower portion. It is necessary to develop this area on watershed basis and all engineering and non-engineering measures of rainwater management and soil conservation should be planned and implemented in the watersheds.

While working on watershed projects, it is important to keep in mind the data requirements. Spatial and temporal data are needed for these projects. Special care is needed in dealing with temporal data, which ought to be measured at desired time periods, whereas spatial data can be monitored or compiled at any convenient time. It is advisable to carefully plan and implement the data monitoring programmes whenever a watershed management project is initiated.

17.0 SUMMARY

The Kandi belt area has good potential for agricultural, including horticultural, production provided scientific land use and water management practices are followed. The diverse problems of the region need to be identified to evolve location specific package of solutions aimed at improving the productivity as well as the natural environment. A major problem in the Kandi belt has been degradation of land due to runoff characteristics of the streams in the region. Water related problems of the Kandi belt broadly comprise of domestic and irrigation requirements. The status of hydrological problems and constraints in utilizing the scientific techniques for improvement of water and other resources in the Kandi belt is presented under the following headings:

i. Land Degradation
ii. High Rates of Soil Erosion
iii. Low Crop Productivity
iv. Loss of Biodiversity
v. Degeneration of Forests
vi. Poor Water Availability for Crop Production
vii. Under Utilization of Horticulture Potential
viii. Water Availability for Domestic Purposes
ix. Water Pollution
x. Low Productivity of Animals
xi. Lack of Hydro-meteorological Data
xii. Socio-economic Problems
xiii. Lack of Coordination among Institutions

Water related problems of the Kandi belt can be tackled by adopting a two-tier approach- short-term and long-term. Under the former category, immediate solution of the domestic and, to a limited extent, irrigation water requirements can be handled by providing water from tubewells, ponds, and small reservoirs created with the help of check-dams on seasonal streams and rivulets, wherever feasible. Solution under the latter category would involve measures like watershed management, including hydro-meteorological monitoring in the region. The latter category of solutions would in any case be desirable to improve the regional environment and ecology. Suitable solutions and actions suggested in this report include:

IMMEDIATE

i. Utilization of Irrigation Potential

ii. Ground Water Development

iii. Hydrogeological Mapping

iv. Rejuvenation of Village Ponds

v. Water Harvesting in Streams

vi. Soil and Water Conservation Works in Cultivated Areas

vii. Earthen Dams Across Gullies at Foothills

viii. Use of canal water for storage in village ponds

ix. Water Harvesting Tanks in Cultivated Areas

LONG-TERM

i. Ground Water Storage

ii. Tapping Ephemeral Streams for Irrigation

iii. Management of Riparian Zones

iv. Protection of Forests

v. Agroforestry Management

vi. Hydro-meteorological Analysis

vii. Hydro-meteorological Monitoring

viii. Watershed Management

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STUDY GROUP

DIRECTOR	: Dr. S.M. Seth
CO-ORDINATOR	: Dr. S.K. Jain, Scientist "F"
HEAD	: Dr. V.C. Goyal, Scientist "E"
STUDY GROUP	: Dr. V.C. Goyal, Scientist "E"
	: Dr. S P Rai, Scientist "B"