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HYDROLOGICAL ASPECTS OF THE RIVER TAWI

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PREFACE

Since setting up of regional centre of National Institute of Hydrology at Jammu in 1990, on the request of Govt. of J & K, the Scientists of the Institute started interacting with various state & central govt. departments of region and collecting data / informations to initiate hydrologic studies for river basins and sub-basins in the area. In Jammu it was seen that since last two decades attention of the Engineers have been engaged to utilise the vast water resources of river Tawi , flowing through heart of Jammu city, and many developmental schemes came up. Many more schemes were thought of, but for want of hydrologic studies, the planning process could not be completed. Therefore, to begin with, the Institute collected lots of hydrometeorological informations from various state and central agencies for Tawi to understand its hydrologic scenario for specific studies to follow. Based on these informations different hydrological aspects of the river sub-basin, shortfalls & bottlenecks have been discussed in the report and it will be useful in carrying out future studies to formulate Water Resources Development projects on Tawi.

To support various hydrologic studies, the Tawi river basin is lacking an adequate rainfall network, sufficient discharge observation sites and observatories to monitor other hydrologic parameters. Data available are scattered and unsystematic which took much more time to collect, compile and analyze delaying the publication of this report in the process.

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ABSTRACT

The river Tawi originating from Kali Kundi Glacier at an elevation of 4000 m. traversing a distance of about 141 km to outfall at the river chenab in Pakistan, is an Western Himalayan river. The river basin consisting of 2168 sq. km. is characterised by rugged moutainous topography, low hills and aggradational plain like many Western Himalayan rivers. On Tawi and its tributaries very few hydrological studies have since been made. The river is mostly in boulders stage, carrying maximum discharge of about 4.3 lakh cusecs. Since last few decades, number of water resources projects for irrigation, hydropower and domestic water supply schemes have come up. Some more projects on the river Tawi were earlier formulated but due to inadequate data and informations the projects could not be taken up. After the recent flood of Sept. 1988, which surpassed all the earlier recorded discharges, most of the hydrological aspects of project works on Tawi need review. The increasing demand for development of Tawi water for beneficial uses of about 18 lakh population of three districts of Jammu, Udhampur and Doda, calls for immediate and systematic hydrologic studies for the river for effective planning of such schemes. This report attempts to review the various hydrometeorologic studies, works already done or proposed by various state and central agencies, essentially required as an initial input to project planning for water resources development.

1.0 INTRODUCTION

The river Tawi, which passes through the heart of the Jammu city, is one of the major left bank tributaries of the river Chenab. It originates from the Himalayan glacier at Kalikundi and adjoining area nearly 4000 m high and located on the southwest of Bhaderwah in the Doda district of J & K state. Initially after flowing about 16 km in the western direction it traverses 27 km in North-West direction upto Sudh Mahadev, 5 km in westerly direction upto Chenani and then in south-westerly direction upto Udhampur. It flows further 24 km in south direction and is joined by some small streams and nallas. The river then flows 8 km towards south and 12 km towards North-west when it is joined by Jaggar nalla at its right bank. Then the river flows about 24km towards south-west upto Jammu city beyond which it flows in the same direction for about 25 km in braided pattern before entering into Pakistan to outfall at the river chenab. Just below the bridge at Jammu Ranbir canal also crosses the river. Immediately below the canal crossing, the river divides into two channels. These two channels are termed as "NIKKI TAWI" which flows towards left and "WADDI TAWI" flows towards right.

Total length of the river is 141 km. Excepting the lower reach of about 35 km the river generally flows through steep hills on both sides. The width of the river Tawi at Jammu is approximately 300 m at bridge site. It has nine tributaries carrying mostly monsoon discharge. The maximum discharge of the river Tawi was 4.3 lakh cusecs on 25th. and 26th. Sept., 1988 and minimum discharge was about 300-400 cusecs. Normal annual rainfall at Jammu is 111.6 cm and that at Udhampur is 150 cm as worked out from monthly rainfall records for 41 years and 50 years respectively.

The Tawi river basin is contained between, 74° 35'-75° 45' east longitudes and 32° 35' -33° 5' North latitude. The catchment area of the river upto Indian border is 2168 sq.km. The river caters for the needs of irrigation, hydropower, domestic water and agriculture to vast sections of 18 lakh population of Jammu, Udhampur & Doda districts in the state of Jammu and Kashmir. There is ample scope for water resources development in the river basin. For maximum exploitation of available water resources an attempt has been made in this report to review the availability of resources in the Indian part of Tawi catchment as an initial input to such research.

2.0 DESCRIPTION OF BASIN

2.1 AREA AND PHYSICAL FEATURES

The Tawi river basin is a small part of Western Himalayas. At its upper part the basin is narrow and elongated while it broadens down along lower part (Fig. 1). The upper portion of the basin is characterised by rugged mountainous topography, whereas lower basin consists of low hills and aggradational plain. The average height of the Basin is about 2200 m above mean sea level. The Basin ground elevation varies from 4000 m to 400 m above m.s.l. The slope of basin is from East to West in the upper part, while north - east to south-west in the lower part. The river at it its upper reaches is fed by melting of snow and ice of Kali-Kundi Glacier at its origin and by rain. In the lower catchment it is predominantly rained. a small area of about 200 sq. km. is snowbound.

The Tawi river basin of about 2168 sq. km. falls mostly within the districts of Jammu, Udhampur and a small portion of Doda district.

2.1.1 THE TRIBUTARIES OF THE RIVER TAWI

Nine predominant tributaries of the river Tawi have been identified (Fig. 2) as follows:-

Kali Kundi : About 4 kms long this tributary has a long profile, concave in nature. Its level varies from 4000 m to 3200 m.

Pich : It is 2.0 km long and predominantly degrading in nature. Its level varies from 3600 m to 3200 m.

Magri : The stream profile indicates two breaks; first at 3200 m and second on 2600 m elevation. It is 9.5 km long and elevation varies from 3600 m to 2000 m.

Chenani : This left bank tributary flows between altitude of 1100 m to 1700 m and is 7.5 km long.

Dhak Nalla : The profile of this river also shows steepness varying from 900 m to 800 m. R.L. Its length is about 2.5 Km.

Naddal Khud : The profile represents small breaks due to the tectonic structure of the area. Its R.L. varies from 1200 m to 700 m and is about 5.8 km long.

Calari : The profile of this Sewalik stream shows a straight line with out any break. The aggradational process is predominant in the basin of Calari because of the absence of high slope. It is about 15 km long and R.L. is from 900m to 700 m.

Pharos : Its profile presents a steep gradient with high degradational processes. The 5.25 km long river course is between elevation 3600 m to 2400 m.

Gamhi : The course of river is generally straight with small breaks at places. Its length is about 19 km while elevation varies from 700 m to 400 m.

2.1.2 SOIL

Comprehensive soil survey for Tawi basin has not yet been done. However informations collected after reviewing literatures are summerised below (8).

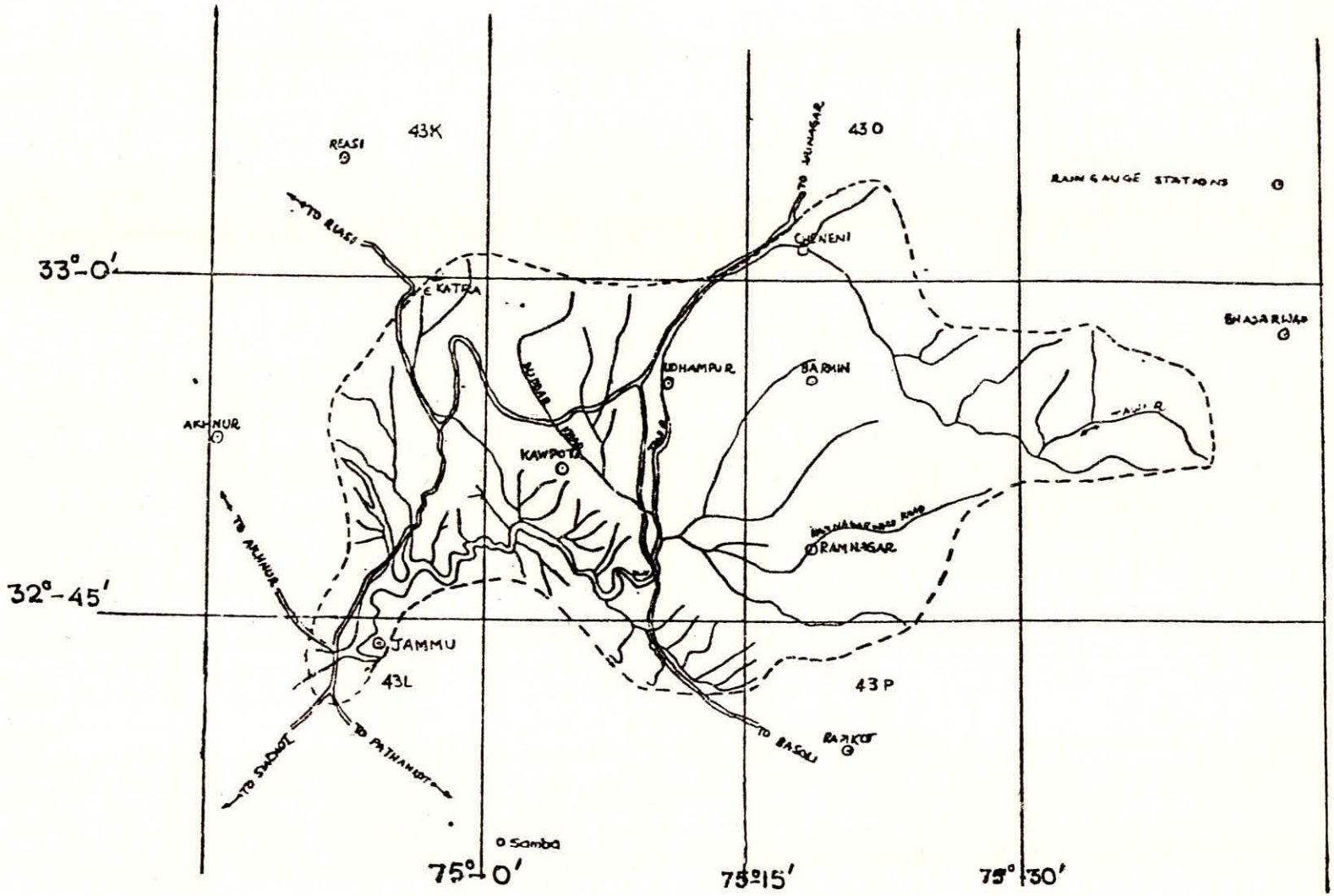


Fig. 1 : TAWI BASIN MAP

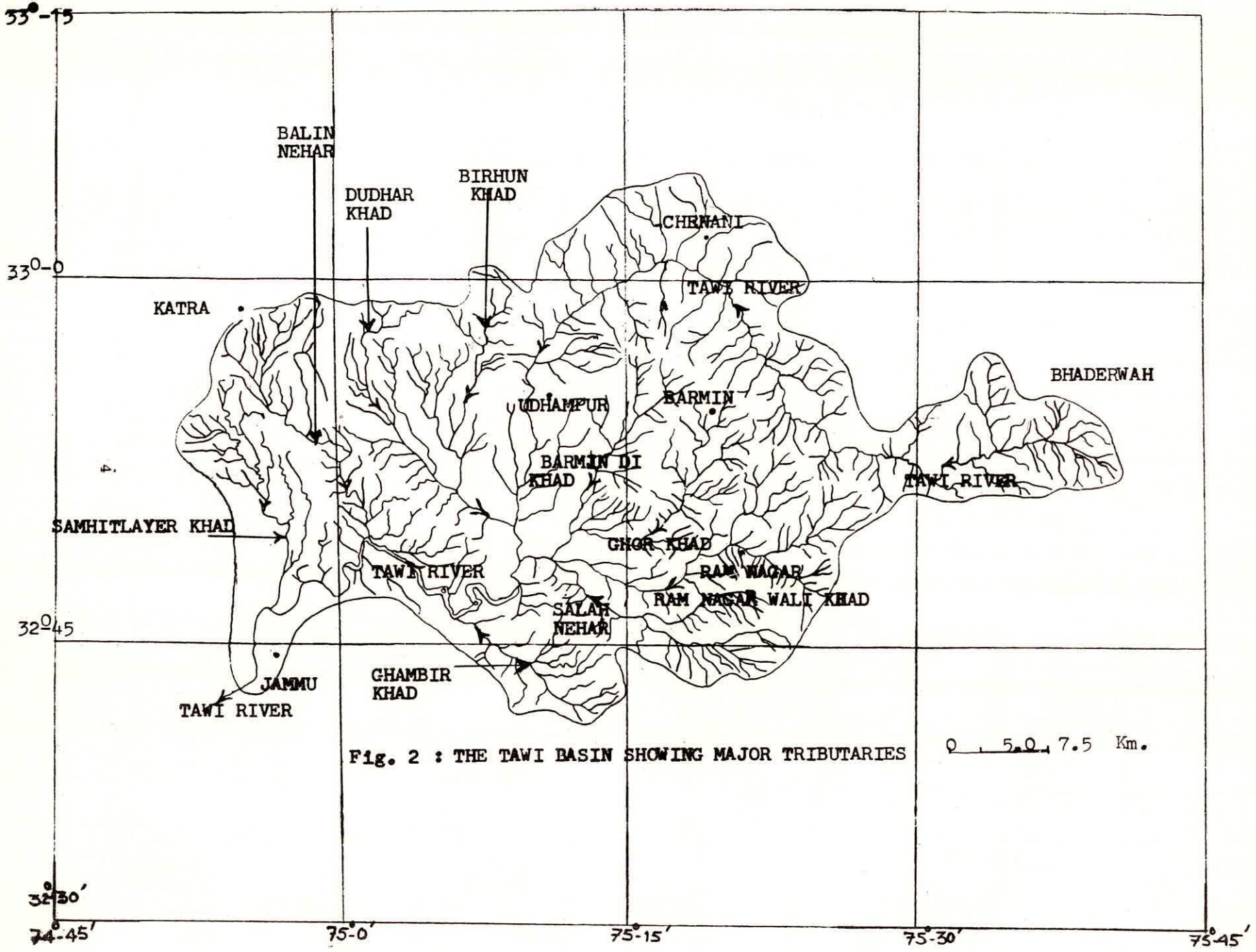


Fig. 2 : THE TAWI BASIN SHOWING MAJOR TRIBUTARIES

The soil classification of Tawi basin exhibits zonal properties as follows:

In Doda district, of which, a very small portion is lying within the basin, the soils are mainly alluvial in nature. Whereas in the mid lands or foot hills, the process of colluviation seems predominant. Generally the silt or other material brought down from above by the action of water gets deposited at the foot hill and gives rise to soil formation. The texture, in general varies from sandy loam to silty clay loam.

In Udhampur part, the soil are moderately deep to deep on the mid hills and plateaus whereas deep to very deep at the foothills. The texture in general is coarse to medium.

Soil of district Jammu are alluvial subtropical having a texture varying between sandy loam to silty clay loam. The lower part is recent alluvium whereas the outer plains are pleistocene. The foothills of Sewaliks are moderately deep to deep soils with coarse texture having stoney face in general and due to lack of irrigation, these are left as uncultivated fallows.

2.1.3 IRRIGATION

Alluvial mountainous tracts of Jammu bounded by the rivers Ravi , Chenab and foothills of lower Sewaliks are identified as major irrigation land. An area of about 44,000 hectares between Ravi and Tawi has been considered, irrigable form the river Tawi.

The present status of irrigations & agriculture in the three districts of the river Tawi basin is shown in Table 1.

Table No. 1

Extent of Area Irrigated in Tawi basin Year 1985-86.

Area in Hectare

S.No.	Name of district	Area sown Gross	net	Area Irrigated gross	net	% of area irrigated to area sown gross	net
1.	Jamme	209926	109872	96462	51285	49.95	46.68
2.	Udhampur	105506	65601	6873	5869	6.51	8.95
3.	Doda	69234	59679	7797	7130	11.26	11.96

Source : Directorate of Economics & Statistics, J & K.

2.1.4 PROJECTS

The basin is also endowed with power potential which have been utilised or being utilised by various power projects described in 3.1

2.1.5. LANDUSE PATTERN

The landuse pattern in the three districts of Jammu, Udhampur and Doda is given in Table No. 2. Out of the total area of 1162000 ha. in these three districts, forest comprises of about 31% and rest are barren, fallow grazing lands or cultivable waste etc.

2.1.6 GROUND WATER

In the Tawi basin, exploitation of ground water is practically confined within Jammu district only. Central Ground Water Board has been carrying out the requisite survey work for the same. Since a long-time, C.G.W.B. has also carried out the studies only in jammu district and for Udhampur & Doda the studies are in progress.

According to C.G.W.B. report (4) ground water resources potential and balance for Jammu (worked as per G.W.E.C. methodology, 1984) is as given below:-

1. Geographical Area: 3165 (Sq. km.)
2. Area worthy of G.W. Development : 2000 (Sq. km.)
3. Annual Average Recharge (MCM) : 1145.60
4. Potential Resources (MCM) : 289.0
5. Total Resources (MCM) : 1434.60
6. Utilisation Resources (MCM) : 1219.41
7. G.W.Draft 1983 (MCM) : 42.0
8. Projected G.W. Draft 1985 (MCM) : 43.34
9. Projected G.W. Draft 1990 (MCM) : 46.80
10. Ground Water Balance

1983	1985	1990
MCM	MCM	MCM
1177.41	1176.07	1172.61

11. Stage of G.W. Development (MCM)

1983	1984	1985
3.44	2.55	3.85

2.2 GEOLOGY

Western Himalaya is geologically described as lying within moving belt of earth's crest. Like other parts Tawi basin mainly consists of Sewaliks, Murree and Granite intrusions. Tawi basin has three Meso geomorphic regions:

(1) Kalplas Granite Zone from Kaplas range to Panjal Thrust Kaplas granite associated with Bhaderwah state, Sewa para gneiss etc. are the main features of the area. Maximum elevation of Kaplas range is 4000 m.

(2) Thrust Zone from Panjal Thrust to Udhampur Thrust having same tectonic structures like Panjal thrust. The height of this region is from 700 m to 1900 m.

(3) Sewalik Zone : Lying between Udhampur Thrust and Jammu. Most of the region

TABLE NO. 2

Landuse pattern in Tawi basin area in (1000 ha)

Sl. No.	Place	Reporting area	Area under forest	Area not available for cultivation		permanent pastures & other grazing lands	land under misc. trees crop grown etc	culturable waste	fallow land	current fallow	distance sown
				For non-agriculture use	barren land						
1.	Jammu	320	40	33	52	11	1	42	1	30	110
2.	Udhampur	431	192	83	26	11	19	20	1	12	65
3.	Doda	411	219	25	44	8	25	23	1	6	60

(Source: Directorate of Economics & Statistics, Govt. of J & K year 1985-86)

consists of hilly as well as plain areas.

2.3 RIVER PROFILE

From origin to outfall the long section of Tawi river exhibits wide degree of variations. The variation (Fig. 3) in slopes along different river reaches are as follows:

R.L. 4000 m - 1600 m = steep gradient of 1:10.42
R.L. 1600 m - 900 m = slight change in slope.
Below 800 m = slope is decreasing

However, variation is not linear. The gradient changes from very steep at upper part to concave and flat in the lower courses. The reasons behind it may be there is degradational process in the upper stage and aggradational process in the lower stages. During field investigations it has been reported that flood plains, meander, meander core and other depositional land forms are formed at the lower course of the river. These are all indicative

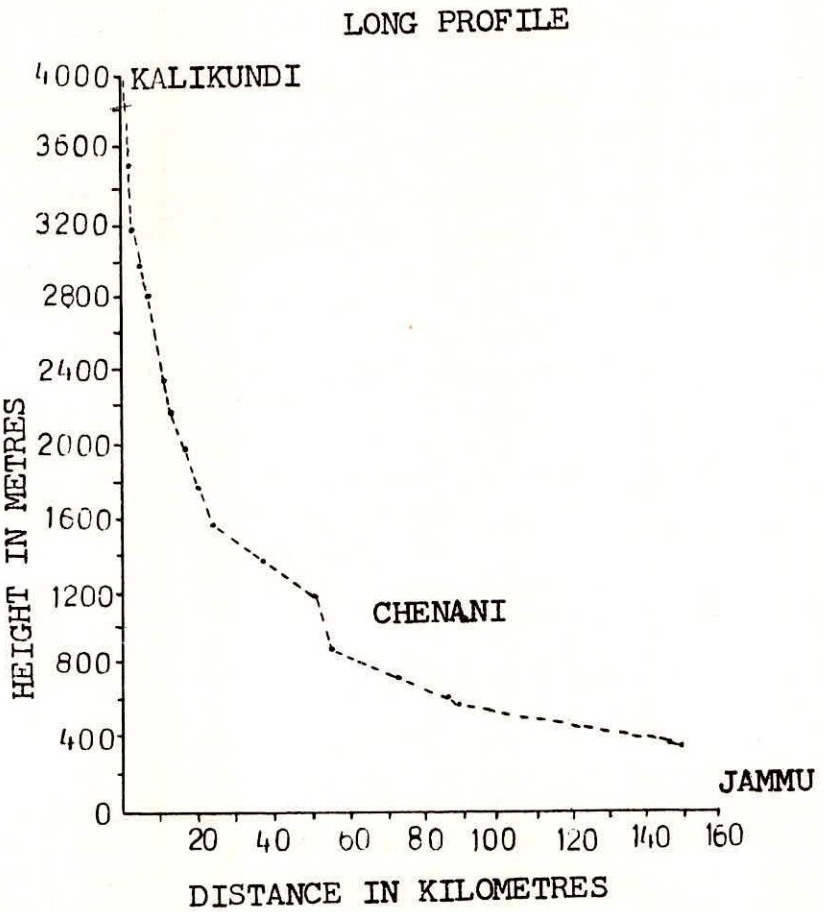


Fig. 3 : L - SECTION OF THE TAWI RIVER

3.0 WATER RESOURCES DEVELOPMENT

Since last few decades various state Govt. Deptts. have attempted to formulate and execute numbers of power, irrigation and domestic water supply projects of which few have seen lights, some are under execution, some are under investigation and few have been shelved due to inadequacy of data or other technical reasons. Details of these projects are described here. The status of irrigation and agriculture is given in Table No. 3.

3.1 POWER PROJECTS

3.1.1. CHENANI POWER PROJECT

The river Tawi at Chenani flows in a steep gradient. In order to utilize its natural fall for power generation, a cascade system of power projects in five stages was proposed. The system envisages construction of power houses in three stages named as Chenani Hydel Project State - 1, C.H.P. stage -2 and C.H.P. stage -3. Beyond stage 3, two more stages named as C.H.P. stage 4 and C.H.P. stage 5 are being envisaged. The existing C.H.P. stage 1 is located in Udhampur district on river Tawi.

First three units each of 4.66 MW were commissioned in 1971. The balance two units of 4.66 MWs each were commissioned in 1975. 200 cusecs of water has been diverted near Bani-Sang by constructing a 68.58 m long weir across river Tawi. The total head available for power generation is 366 m; Two penstocks of 1.5 m and 1.22 m dia to carry 7.84 cumecs of discharge have been installed for feeding the water to turbines of power house.

Table No. 3
Net area irrigated from different sources (000 ha)
1985-86

Place	Canals	tanks	Wells	other sources	Total
Jammu	49.09	-	1.71	0.48	51.28
Udhampur	6.68	-	-	1.19	5.87
Doda	3.75	0.01	0.01	3.37	7.14

To utilize the tail race discharge of the power house (stage I), it has been proposed to construct two more power stations down-stream nearing C.H.P., stage II & III. The net head available for power generation in stage II is 32 m. The water will be fed to the turbines by means of a steel penstock having a dia of 2.6 m. The installed capacity of chanani hydel project No. II will be 2.1 MW. The work of construction of stage - I has been taken up in hand and is proposed to be commissioned in 1991.

The third stage i.e. C.H.P. III will have installed capacity of 4 MWs in phase I and additional 2 MW in phase II. The water conductor system of statge III will be designed for discharge of 11-12 cumecs. The tentative head available for power generation will be 66.3 m.

The tail race waters of stage III will be discharged back into river Tawi and will be again picked up for the power generation in stage IV & V. The head available for generation of 9.00 MWs is 110 m in stage IV and head available for generation of 8 MWs will be 65 m in stage V. These two schemes are under investigation.

3.2 CANALS

Canals form the most important system of irrigation in Jammu region. Where the soil is soft and alluvial and canals can be easily dug. Aslo lift irrigation by pumping water to a higher level and then carrying it to the fields through canals has to begin in recent past.

3.2.1 TAWI LIFT IRRIGATION CANAL

This projects envisage construction of a lift channel for minimum capacity of 300 cusecs from river Tawi with its pumping station located on the left bank of river Tawi, below Bahu fort, opposite Jammu city. The canal covering a length of 28.8 km. from Bahu to Devak nallah, commands enroute an area of 35,000 acres (CCA). The canal starts with a command level of R.L.: 1082.0 ft. above MSL and terminates at a level of R.L.: 1045.0 ft above MSL. The maximum discharge is being lifted through a gross head of 32.31 m by means of five nos. (plus one stand by) electrically driven vertical turbine pumps each of 60 cusecs capacity. The distribution system comprises 11 distributaries with 28 minors and subminors having a length of 172 km. The work on the construction of this project, costing Rs. 747.6 lakh was started during 1969-70 and completed in all respects in the year 1977-78. Tawi canal is designed to irrigate 4,757 hectare in Kharif and 8,279 hectare in Rabi, thereby generating a total irrigation potential of 13,036 hectare in 125 villages of district Jammu. The utilisation of potential upto last year was 8379 hectares.

3.2.2. THE UDHAMPUR CANAL

It flows near Udhampur and about 26.5 kms. long. This canal irrigates about 2400 acres of land. Now it is also used for generating electricity upto 8000 KW. It was built at a cost of 6.11 lacs.

3.2.3 TAWI BARRAGE PROJECT

The Tawi project conceived in the year 1964 envisaged construction of a barrage across the Tawi river in the vicinity of Sidra village about 15 Kms. U/S of Jammu, for diverting 500 cusecs discharge into canal on the left bank to irrigate about 36000 acres. It was proposed to located the barrage on left side of this channel on high ground such that during the construction season, the main channel on right bank would be available for the diversion of the river. The barrage would have been tied to the banks by embankments. Guide banks were proposed on the U/S of the barrage for ensuring normal approach and exit of flows. The max. designed flood as recommended by H&S Directorate of CWC was 5.14 lacs cusecs for water way design and 5.92 lacs cusecs for design of foundation of barrage.

However, it is gathered that the project did not see light due to insufficient informations required for design planning of the proposal.

3.2.4 SUBSIDIARY LIFT SCHEME ON TAWI CANAL AT RAYA

A subsidiary lift scheme to irrigate 1100 ha. of FERTILE tract of land : uphill of Tawi canal in village Raya has been envisaged. The project caters for Rabi season only in the first instance but after completion of these dam (Shahpur Kandi barrage), when full share of Ravi water shall be available , it shall cater to 50% of the area under kharif crops as well. The water for Rabi crop is available in tawi canal at present. The work on the same is in progress.

Upto end of 7th Plan, out of total length of 8 kms. of main water conductor and 6 nos distributaries the work on 5 kms of conductor and 2 nos. distributaries is in advance stage of completion.

The original estimated cost based on March 1980 rates was Rs. 315 lacs. The revised estimated cost may be of the order of Rs. 690 lacs. The scheme shall be completed in the 8th five year plan subject to availability of funds.

3.3 DRINKING WATER SUPPLY SCHEME

Tawi basin as reported earlier consists of Jammu, Udhampur and a small part of Doda districts. The drinking water supply of the region prior to independence used to be mainly met from the local Kacha and Pacca tanks, rivulets and springs in mountainous area.

To meet the demand of drinking water supply a master Plan for augmentation and improvement of water supply to Greater Jammu under long term basis to the areas falling within its limits were formulated in 1976. This project was revised in 1987 and final revised project is envisaged to cover the total requirements of a designed population of 7.16 lacs by 1991.

The designed demand or projected population of 1991 at 50 gallons/day/head works out to 35.84 MGD. The supply level before start of the project in 1979 stood at 11.45 MGD and covering of gap of 24.38 MGD is envisaged in the project. The gap of 24.38 MGD has been propsoed to be covered by tapping of river Tawi at Sitlee located at 8 km. u/s of Jammu and sinking of 66 tubewells in different subzones of the Master plan along the outer boundaries of city. The gap covered by river Tawi at Sitlee has been proposed as 8.4 MGD.

4.0 HYDROMETEOROLOGY

Hydrologic studies in a river basin basically involve evaluation and establishing correlation between precipitation and runoff for efficient project planning with predictions to desired degree of accuracy to the happenings of project proposals. This requires a clear picture of Hydrometeorology of a basin. Long range data like discharge, silt , rainfall, snowfall, groundwater and other climatic elements like temperature, humidity, evaporation are of prime importance for the purpose.

4.1 HYDROMETEOROLOGICAL NETWORK

There is no separate network for Tawi basin. The basin is enveloped within the network of Chenab basin. On appreciation of the proposal of irrigation and hydropower development in Chenab basin and in course of investigation for different projects , C.W.C. started hydrometeorological observation works in the basin since early sixties. Gradually the same has been developed into a systematic network for river gauging and recording the various hydrometeorological data such as silt, snowfall, rainfall etc. According to W.M.O. norms for tolerable network, there should be one rain/snow gauge station per 900 to 1300 sq. km. and 250 to 1000 sq. km. for flat and mountainous region respectively. Keeping in view, that more than 10,000 sq. km. of total catchment of chenab in India remains permanently above snowline, the existing number of rain/snow gauge in the catchment appear to be adequate. Most of these stations have been installed in the last 10 years and data length is not enough for dependability analysis. However daily discharge data for G & D sites are fairly long ranging from 12 years to 20 years.

4.2 CLIMATE

The climate of Tawi river basin is characterized with three distinct features : (1) The north eastern catchment area comprising of Bhaderwah and adjoining area where climate is extratropical moutain type. The mountain type climate has wide variation in temperature and rainfall depending upon the location and the direction of land features. In this area winter is very severe and influence of south west monsoon is negligible. (2) Central territory consisting of Udhampur district where also climate is to mountain type but having sufficient influence of monsoon (3) The south western zone consisting of Jammu district where climate is warm with strong monsoon influence and can be described as tropical rainy during certain part of the year. The details of climatic parameters are described below:

4.2.1 RAINFALL

Records of rainfall in the area comprising of the districts of Jammu, Udhampur and Doda show that monsoon occurs with the storm depressions in Bay of Bengal. Rainfall occurs with the southwest monsoon during the summer and also during winter due to western disturbances which are low pressure systems. South west monsoon is pronounced in July and August and lasts from June to September. Tawi experiences heavy floods in July and August monsoon starts from 1st July with heavy thunder showers and last upto mid September.

The annual rainfall over Jammu district varies from 90 to 100 cm. for Udhampur district from 140 to 190 cm. While for Doda variation is from 90 to 140 cm. As shown in the report (8) the normal annual rainfall at Jammu based on 41 years data is 111.5 cm. with 51.8 nos. of rainy days and that for Udhampur based on 50 years data is 149.97 cm. with 64.8 rainy days.

In the Tawi basin July and August are generally the wettest months with about 55% rainfall and Nov. is the least rainy month with about 2-3 percent of the total rainfall.

Seasonwise distribution of rainfall over the three district during four seasons is summarised in Table No. 4 which is the percentage of annual normal rainfall.

Table 4: percentage of annual rainfall

District	Dec. - Feb.	March - May	June - Sept.	Oct. - Nov.
Jammu	13 to 15	9 to 12	73 to 75	1 to 2
Udhampur	16 to 36	11 to 36	30 to 71	2 to 7
Doda	32 to 37	25 to 34	27 to 35	4 to 6

Average monthly rainfall in Jammu as worked out (8) is furnished in table 5.

The rainfall data for Tawi basin has been collected from State I & F C department and status of data is shown in table 7.

TABLE NO.5
The average monthly rainfall in Tawi
(rainfall in mm)

Month/place	Ramnager	Udhampur	Jammu
January	11.0	10.0	5.8
February	11.8	10.7	6.1
March	12.3	8.8	5.1
April	6.1	4.9	3.3
May	4.4	3.6	2.4
June	11.3	9.6	7.1
July	44.1	38.0	32.5
August	46.9	39.0	30.0
September	14.7	13.6	8.9
October	2.4	2.3	1.9
November	1.2	1.0	0.7
December	5.8	4.8	3.1
	171.8	146.3	106.9

4.2.2 SNOWFALL

The river Tawi is snowfed at its origin from the Kalikundi glacier. The Kalikundi and Seoj dhar start experiencing snowfall in November. Snowfall is very heavy in January & February. In high elevations, snowfall is very deep and continues till May. Measurements of snowfall and snowfall data are not yet available for which contributions of snowmelt could not be ascertained. A small area of about 200 sq km of the basin is snowfed.

is snowfed.

4.2.3 DISCHARGE

The river Tawi is fed by melting of snow and ice of Kalikundi glacier. Low water is experienced during the month of Oct., Nov. and December. (Fig. 4). But there is rise of water in March during the early summer snow melting in Kalikundi valley, Kaplas and Seoj ranges.

The maximum rise in water in the Tawi occurs during July and August. The monsoon rainfall with storms causes flood problem for the Jammu city and adjoining area during these two months.

The water rise in March is a result to early snowmelting in the Upper catchment area of the Tawi. The second rise during the monsoon season occurs in July and August because of max. rainfall in the basin during these months.

At Jammu, the max. theoretical flood discharge is 2.30 lacs cusecs and max. flood discharge observed on 16th and 22nd July, 1988 was 2.23 lac cusecs. Again the max. discharge observed on 25th and 26th sept., 1988 was found to be 4.3 lac cusec which is not yet surpassed.

At the Jammu city bridge site two gauges are being maintained - one by the state flood control deptt. slightly u/s of the bridge and the other by the CWC on the pillar of the bridge itself. The gauge maintained by the state Govt. records hourly gauge readings during monsoon and daily gauge reading during nonmonsoon period. River cross- section was also measured after September 1988 flood, on the basis of which one rating curve has been developed (Fig. 5). In this site gauge reading from 1973 upto date are available. The gauge maintained by CWC records hourly gauges during monsoon, four hourly gauges during nonmonsoon, six monthly river cross-section , float velocity, water temperature, silt sampling and daily air temperature etc. The gauge is maintained since 1979 onwards.

From the discharge site at Jammu the water availability of Tawi assessed by CWC based on three years discharge data are as follows:

Dependability	50%	75%	90%
Discharge (M^3)	2052	1408	1245

Monsoon and non monsoon yields of the river Tawi has been reported as follows:

Dependability	50%	75%	90%
Monsoon(M^3)	1097	927	830
non monsoon(M^3)	814	458	388

The daily discharge of different dependabilities based on three years are furnished in table no. 6.

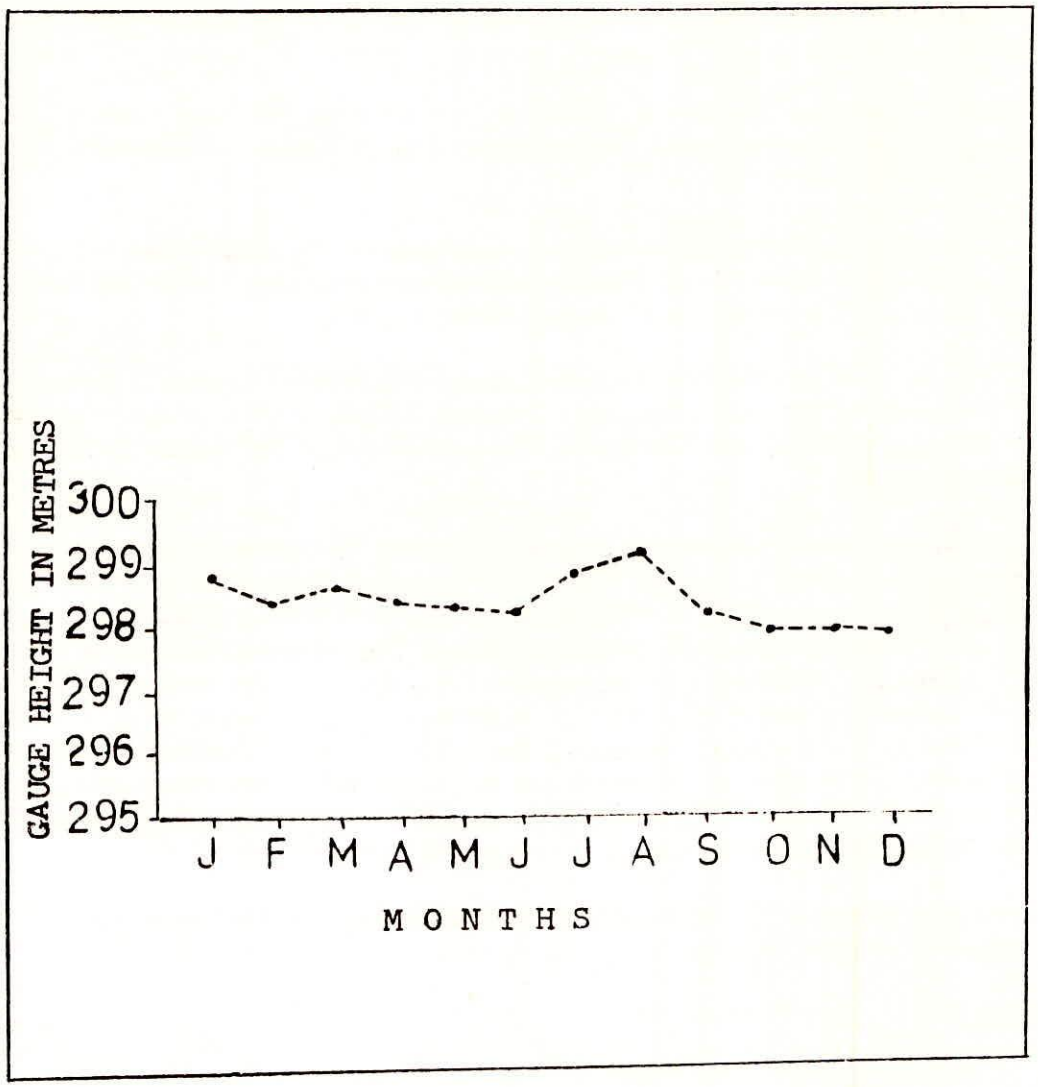


Fig. 4 : THE TAWI RIVER WATER LEVEL

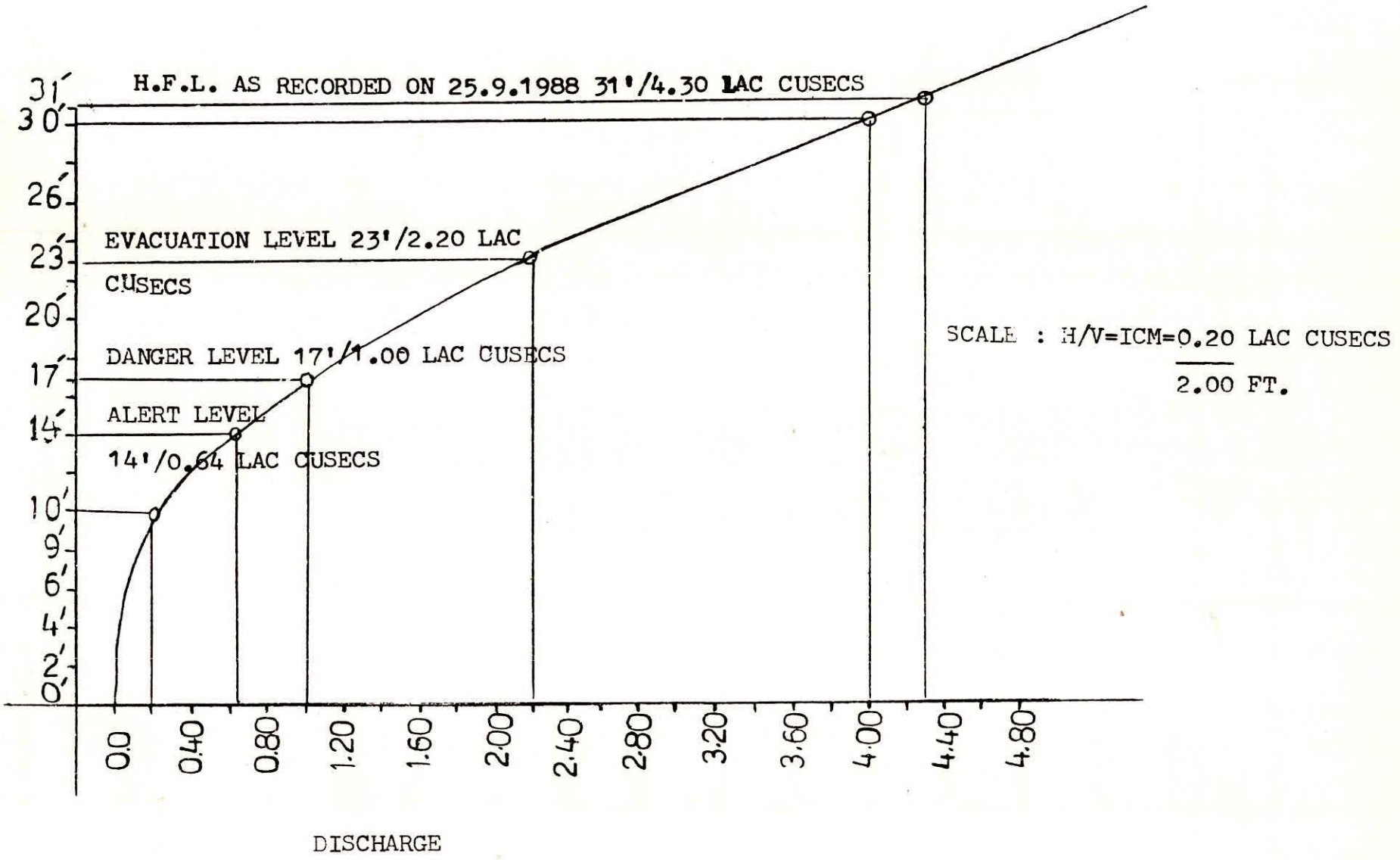


Fig. 5 : GAUGE RATING CURVE OF TAWI
AT JAMMU CITY BRIDGE SITE

TABLE NO. 6

Ten Daily Discharge of Different Dependabilities Jammu G&D Site

Month	Date	50%	75%	90%
January	1-10	120	94	60
	11-20	120	108	91
	21-31	260	160	112
February	1-10	212	161	141
	11-20	391	207	182
	21-28	262	242	132
March	1-10	803	209	144
	11-20	843	252	152
	21-31	403	215	136
April	1-10	274	212	192
	11-20	313	207	168
	21-30	321	194	155
May	1-10	250	208	136
	11-20	231	171	121
	21-31	201	152	52
June	1-10	141	84	28
	11-20	204	98	84
	21-30	245	180	79
July	1-10	449	239	150
	11-20	2311	515	369
	21-31	1901	839	590
August	1-10	3313	2058	576
	11-20	1265	797	578
	21-31	783	515	449
September	1-10	352	209	161
	11-20	470	227	136
	21-30	240	136	80
October	1-10	161	79	49
	11-20	166	60	47
	21-31	125	61	46
November	1-10	99	60	49
	11-20	101	47	47
	21-30	96	71	46
December	1-10	80	56	46
	11-20	97	50	29
	21-31	206	57	44

TABLE - 7

Status of Data for the Tawi Basin

Data	Period of available	Source/ Agency	Remark
A: Rainfall :-			
Annual	1979-85	Digest of statistics	Name of sites in App. I
	1956-90 (Except 59,60)	I & F C, Satwari	---- do -----
Monthly	1956-90 (Except 59,60)	------do--------	---- do -----
Daily	------do----	------do------	------do------
B: G & D DATA:-			
Daily (Gauge)	1973-90 (July - Sept)	I & F C, Satwari	The data has some gaps
	1976-90	CWC, Jammu	
Hourly	1974-88	I & F C, Satwari	
C: TEMPERATURE DATA :-			
Mean Max. & Mean Min.	1978-85	Digest of Statistics (1985-86)	Site Jammu
Normals Temp.	1962-69	Geomorphology of Himalayan Rivers (A.C.S. of Tawi basin)	Sites Jammu & Banihal
Max. & Min. Temp.	1985-90	W.M.R.C. Ponichak Jammu	Site in Ponichak
	1984-90	IMD,Jammu	
D RELATIVE HUMIDITY:			
Rel. Hum. (%)	1985-90	W.M.R.C., Ponichak	Site in Ponichak
Normal of	1955-65	Ponichak, Panjal Geomorphology of Himalayan river (A.C.S. of Tawi Basin)	Site in Jammu & Banihal

The G & D data vailable for the river Tawi have been collected from state and central agencies like I&FC, CWC etc. and the status of these data is furnished in table 7.

4.2.4. RELATIVE HUMDITY

During summer months from April to June the relative humidity at Jammu region is about 70%. The mean max. R.H. recorded at WMRC, Ponichak in the first week of Jan. 1990 was 88.75% and mean minimum in the Ist & IInd week of June was 39.3%. The weekly variation mean relative humidity (1989-1990) collected from WMRC Ponichak

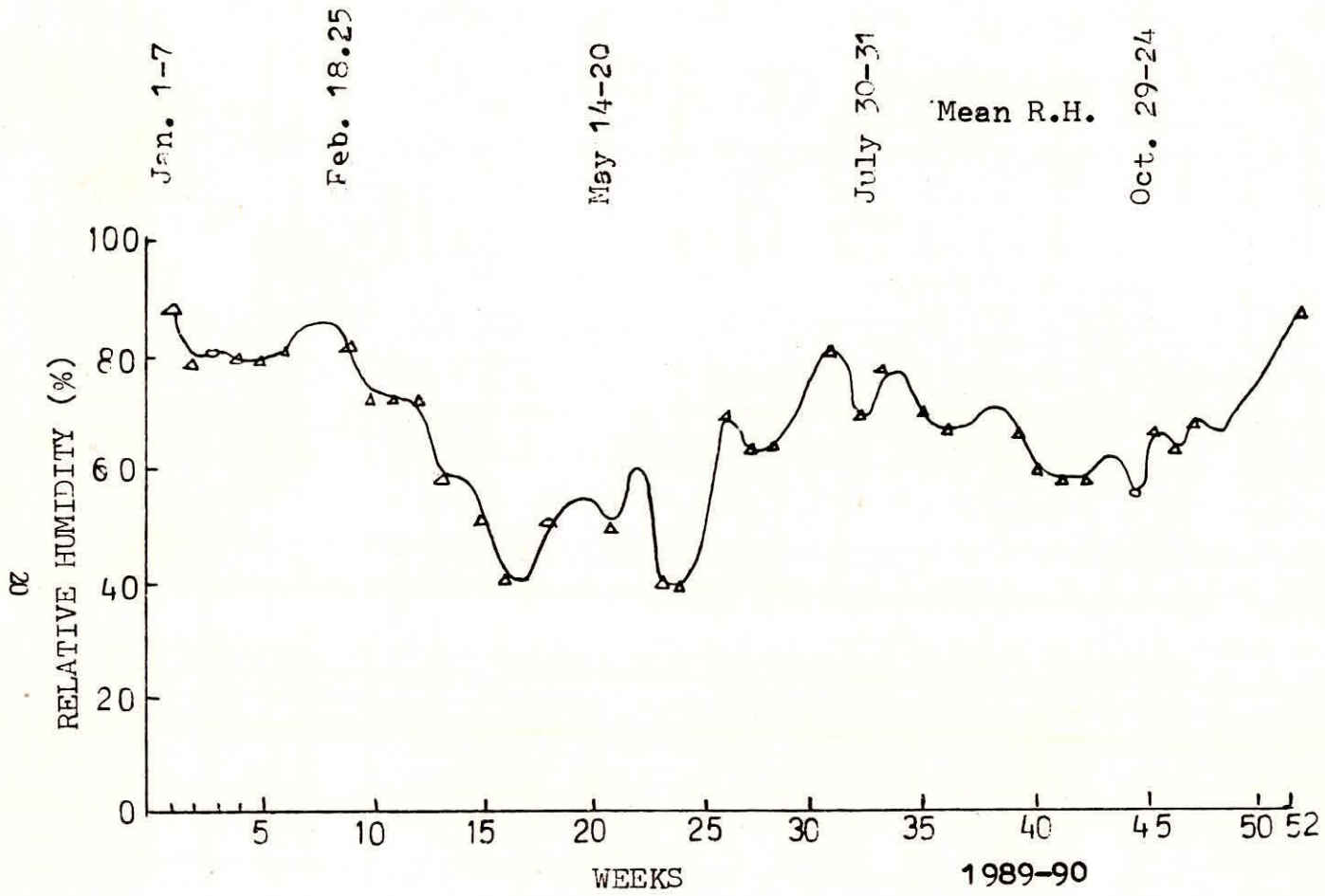


Fig. 6 : WEEKLY VARIATION OF MEAN RELATIVE HUMIDITY

for its demonstration farm is presented in Fig. 6.

4.2.5 EVAPORATION

The details of evaporation is not available for the river basin as a whole. However, some results are available from the demonstration farm of water management Research Centre Ponichak, Jammu under Sher-e-Kashmir University of Agriculture Science & Technology. It reports during the year 1989-90, that total evaporation was 143.3 cm. The peak pan evaporation range from 40 mm per week in the mid April to 62.4 mm per week in mid June. After third week of July Pan evaporation was 36 mm per week. Then from first week of December to second week of Feb. , it was 5 and 10 mm per week. The weekly variation of evaporation (1989-90) collected from WMRC Ponichak for its demonstration farms is presented in fig. 7.

4.2.6 CLOUDS

Clouds cover of about 5/8th of the sky during monsoon month of July and August is reported at Jammu and Udhampur areas. On an average about 10 days in a month the sky remain overcast in this period. Clear sky is visible in October and November. From December to March sky becomes overcast 5 to 10 days in a month at lower part and 10 to 15 days at higher lands. Generally in the lower region cloud decreases towards afternoon but oppoosite is true during winter. Clouds at high altitudes increase in the afternoon when lifted moisture from the valleys due to day temperature gets accumulated. In the Tawi basin a demonstration farm of WMRC, Ponichk Jammu under Sher-e-Kashmir University is being maintained . It is having 5 years experimental data in respect of rainfall, evaporation, temperature and relative humidity etc. which are partially representative to the Tawi command of Jammu region. The experimental results of this farm are presented from Fig. 6 to 9.

Fig. 8 : RAINFALL PROBABILITY AT PONCHAK, JAMMU

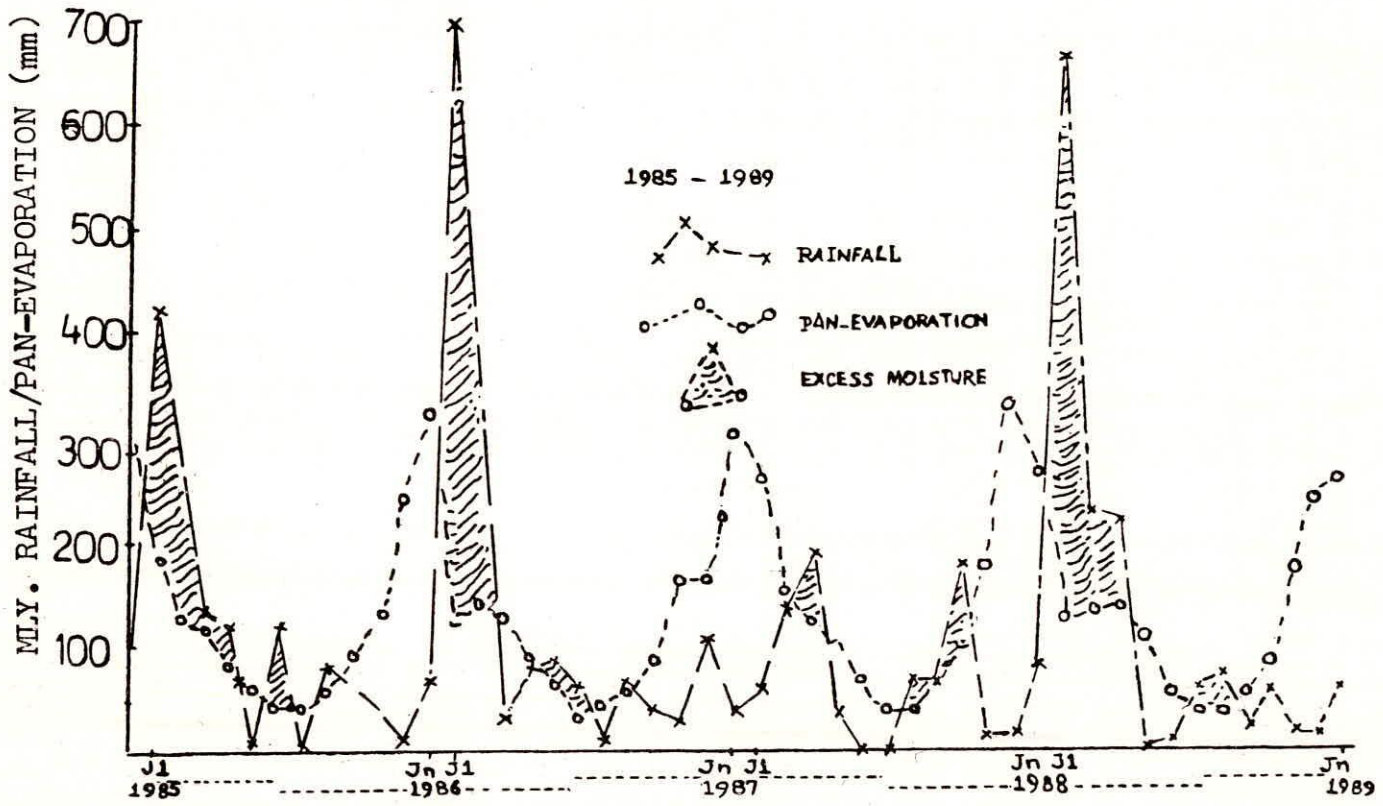
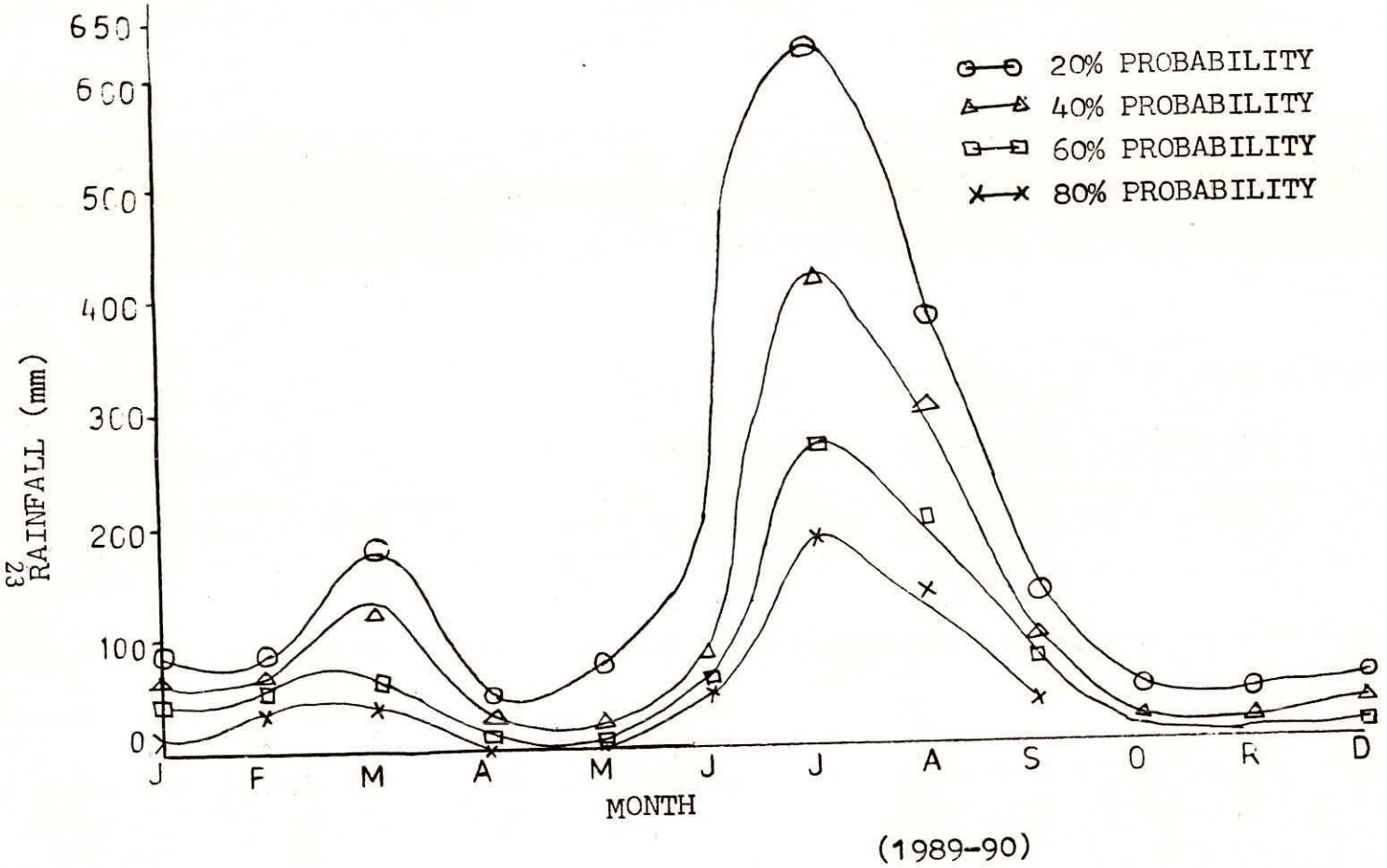
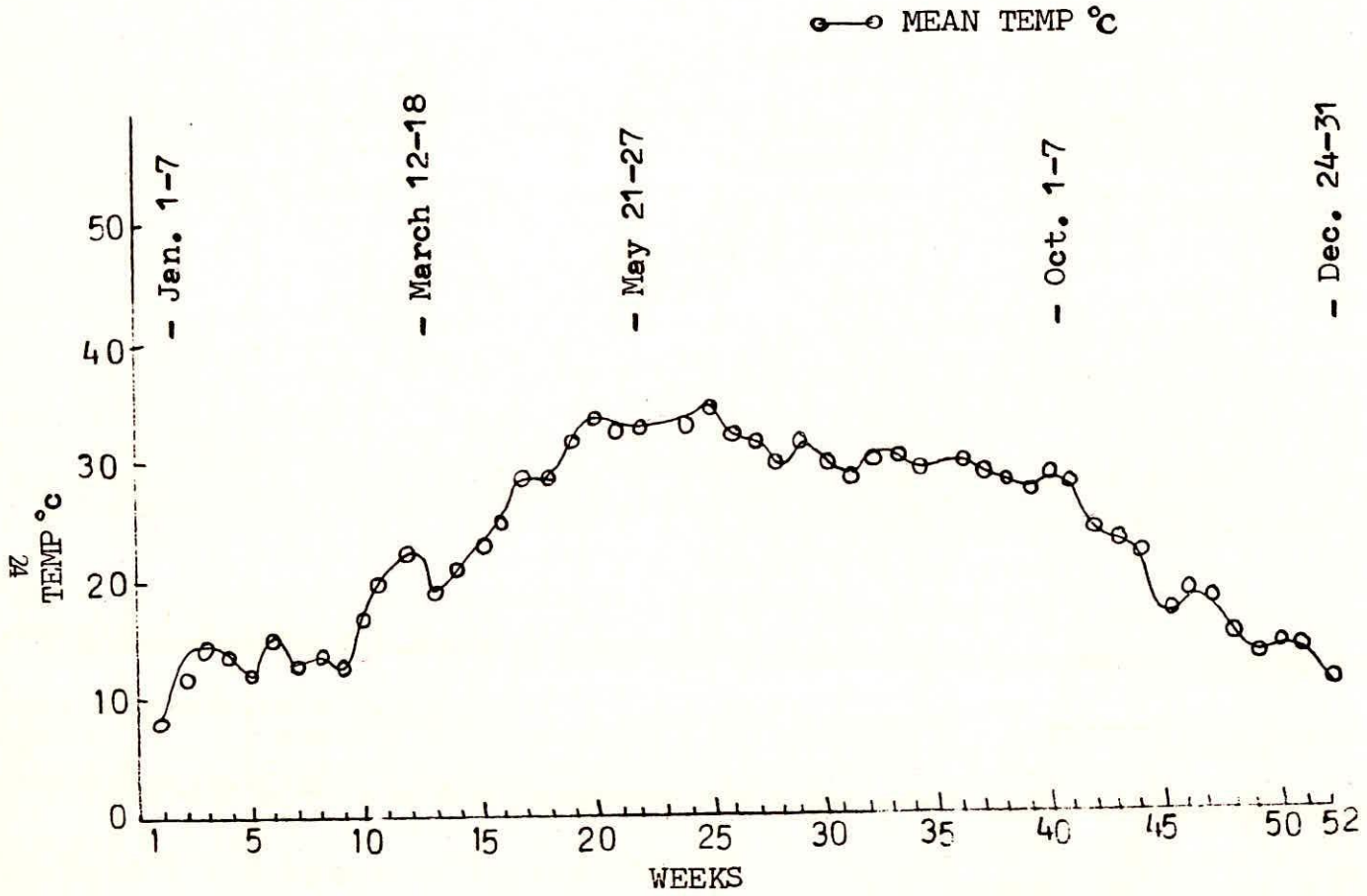


Fig. 7 : MONTHLY RAINFALL & PAN EVAPORATION AT PONICHAK, JAMMU

Fig. 9 : WEEKLY VARIATION OF MEAN TEMPERATURE




MEAN TEMP °C
- Jan. 1-7
- March 12-18
- May 21-27
- Oct. 1-7
- Dec. 24-31
TEMP °c
0
10
20
30
40
50
1
5
10
15
20
25
30
35
40
45
50
52
WEEKS

5.0 EARLIER HYDROLOGICAL STUDIES

In connection of propsoed Tawi Barrage Project near Sidra village, about 10 kms. upstream of Jammu city, hydrological studies of the river were made by the then C.W. & P.C. in early sixties, on the basis of inadequate and incomplete data.

During the period there were only three rain gauge stations viz. Udhampur, Ramnagar and Chenani with in the Tawi catchment. Since these few stations alone could not represent the entire catchment data from nearby stations viz. Jammu, Bhaderwah, Reasi, Akhnoor, Ramban, Jasmergarh, Ramkote, Bhaddu, Gajra Nagrota and Mandli were also made use of in the studies. C.W. & P.C. however suggested installation of rain gauges at some more places - Maruthi, Dudu, Kawpota, Satialta, Katra, Surmin and Biskar.

Regarding Gauge and Discharge data , it was available from May 1955 to October 1962 at Jammu site, then being maintained by Punjab Irrigation Deptt. Length of Discharge data being not enough for frequency analysis for design flood, it was attempted to work out design flood by applying design storm of specific frequencies to the unit hydrograph. Because of the hilly catchment sixty year storm data from 1901 to 1961 were used for Depth - Duration analysis. Then max. one day and two days rainfall series were subjected to frequency analysis. The values of one and two days storms to 60 and 150 years return periods were given as follows:

	one day storm	two day stomr
60 year return period	6.68" (16.83 cm.)	10.5"(26.46 cm.)
150 year return period	7.6"(19.15 cm)	11.95"(30.11 cm)

To develop a unit hydrograph, rating curve for Tawi bridge site was done on the basis of available discharge records. Then with the help of these rating curves hourly gauge records from 1955 to 1962 were converted into discharges. From these generated discharge flood hydrographs were drawn and used to derive unit hydrographs. The mean unit hydrograph derived from four individual unit hydrographs showed a peak 1.1 lakh cusecs with peaking time of 9 hours and base period of 27 hours. Then design unit hydrograph was developed increasing the peak by 15% to take of hydraulic efficiency of the structure in the event of impingement of design flood. The design unit hydrograph with a peak discharge of 1,33,000 cusecs, peaking time 8 hours, base period of 26 hours and duration of 2 hours (as verified from S-curves) is shown in Fig. 10.

The following asumption have been made to arrive at the break up of two day storm values for shorter periods.

1. Two days storm occurs in 36 hours.
2. 80% of two day storm occurs in 24 hours.
3. 60% of 24 hours storm occurs in 6 hours.
4. 45% of 24 hours storm occurs in 3 hours.

Depth - Duration curves are shown in Fig. 11. Two hourly rainfall increments as obtained from 60 years and 150 years storms have been obtained from these curves. Rainfall increments have been converted into run-off by assuming 0.04 inches per hour for first 12 hours, 0.03 inches for next 12hours and 0.02 inches per hour thereafter.

To arrive at the design flood two hourly estimated run-off values were arranged in sequence with reference to the unit hydrograph ordinates and estimated design flood at Sidra and Bahu fort sites were found to be 5.14 lakh cusecs corresponding to 60 years storm and

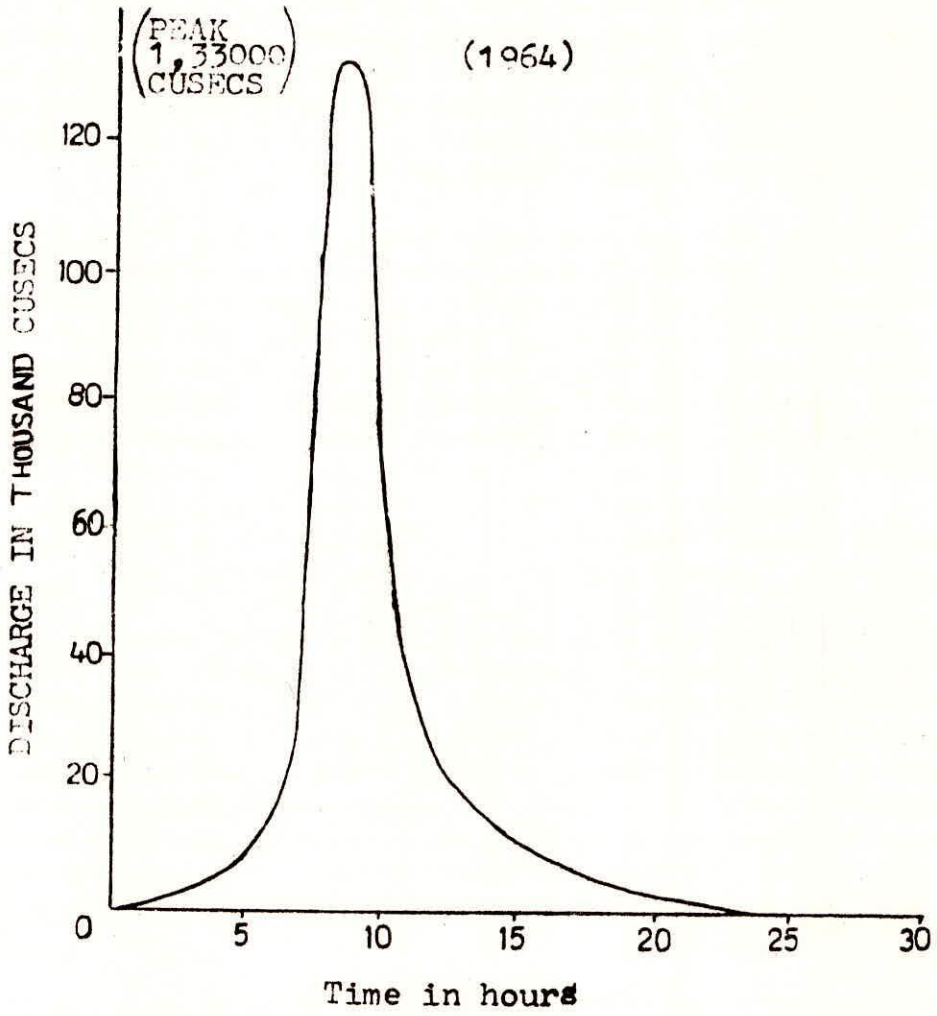


Fig. 10 : UNIT HYDROGRAPH OF
TAWI RIVER AT JAMMU CITY BRIDGE

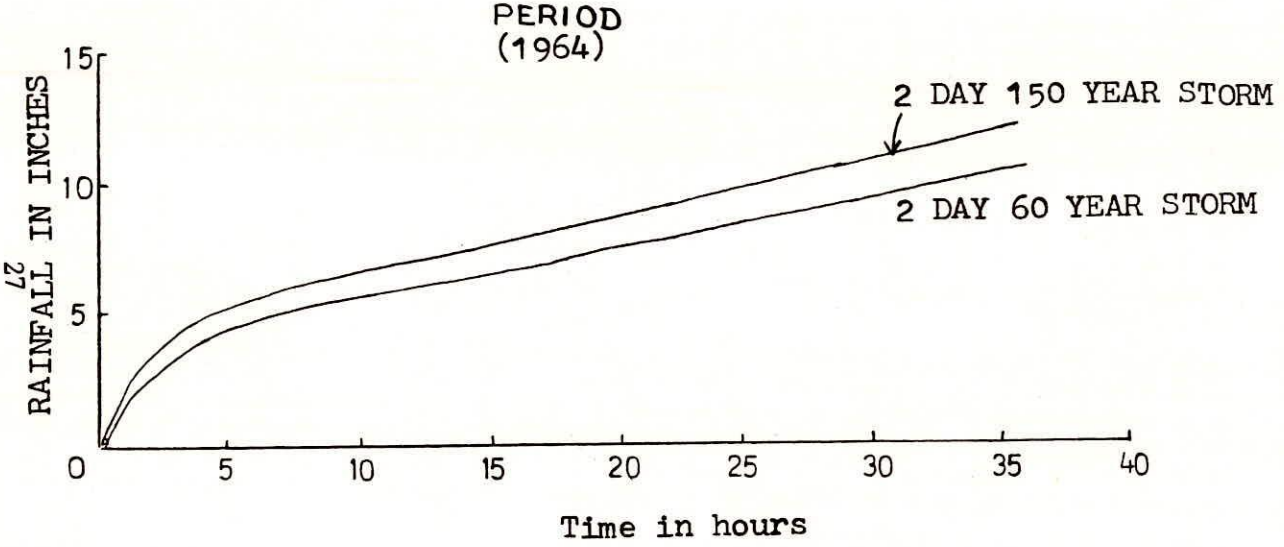


Fig. 11 : DEPTH DURATION CURVE FOR TWO DAYS STORM OF 60 AND 150 YEARS RETURNS PERIOD

5.92 lakh cusecs corresponding to 150 years respectively.

These floods give a coefficient of 3320 and 3825 in the Dicken's formula. Applying these coefficient for a catchment area of 760 sq. miles at Kuppar, the corresponding design flood values at Kuppar site come to 4.8, and 5.55 lakh cusecs.

Since gauge observation were not available at the adjacent barrage site at Sidra, a synthetic curve was developed (Fig. 12) correlating the gauge data available at Tawi bridge site. The correlation equation obtained was $Y = 1.7337 + 0.8269 x$. Then gauge heights at Sidra were worked out and corresponding discharge calculated assuming same discharge as that in Tawi bridge site would have been passing through Sidra site as well. The reasonability of this gauge discharge curve at Sidra was also checked by computing discharges at Sidra by Manning's equation with the suggested value of 'N' as 0.04. The value of coeff. N calculated from the observed discharges at Tawi bridge site was reported to be from 0.0695 to 0.0336.

The variation of results from both the approaches was about 17%. Fig. 13 gives the mean gauge discharge curve for tawi river at Sidra site, showing also two limit curves which afford only 17% change for the actual value to lie beyond either of them. The results worked out on the basis of inadequate data were deemed to be tentative and could be useful for project feasibility study only. It was felt that the results could have been revised on the basis of continuous observed Gauge and Discharge data (Seasonal, monthly , daily and hourly) for atleast four more subsequent years.

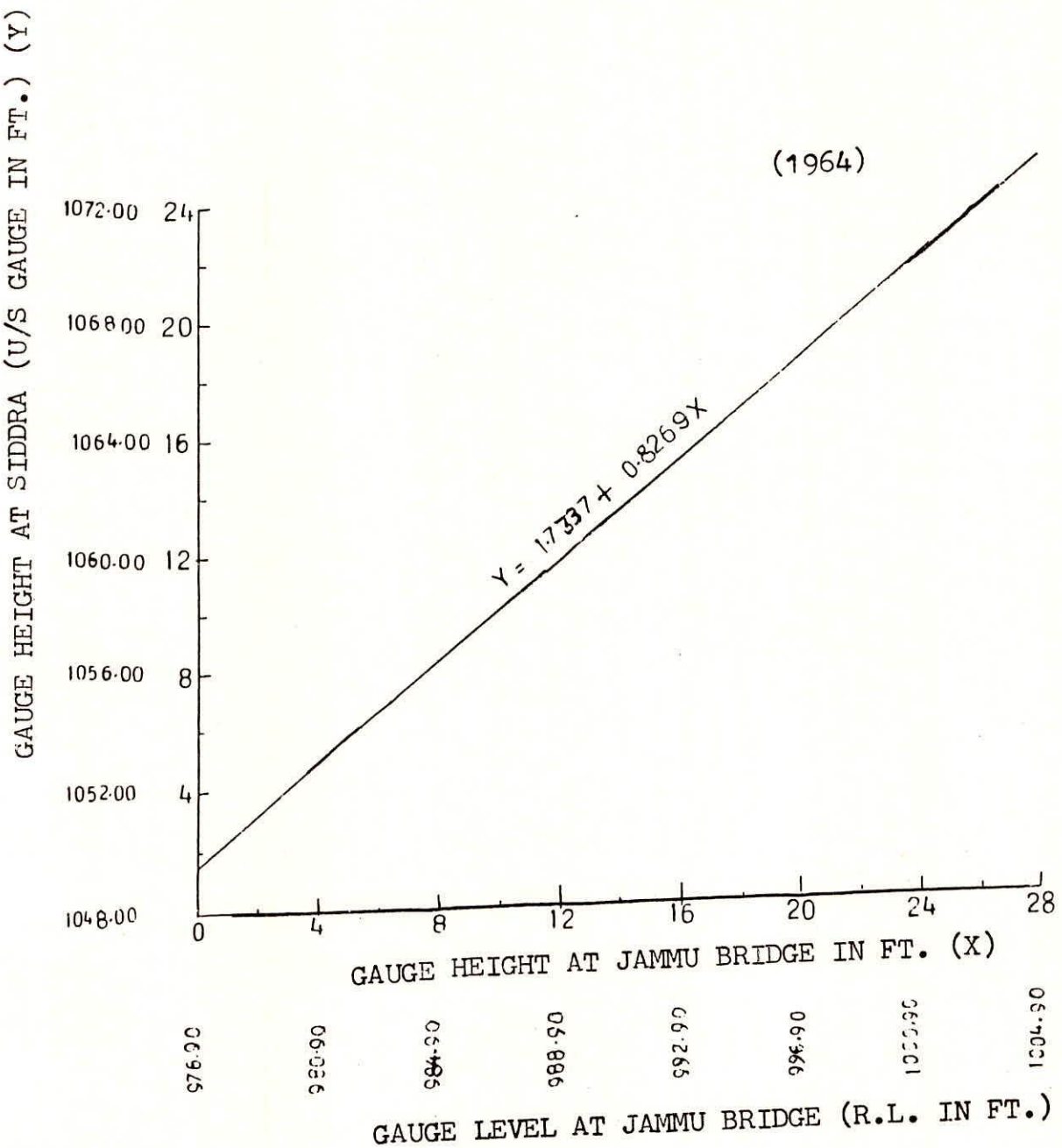


Fig. 12 : GAUGE CORRELATION BETWEEN JAMMU CITY BRIDGE AND SIDDRA SITES

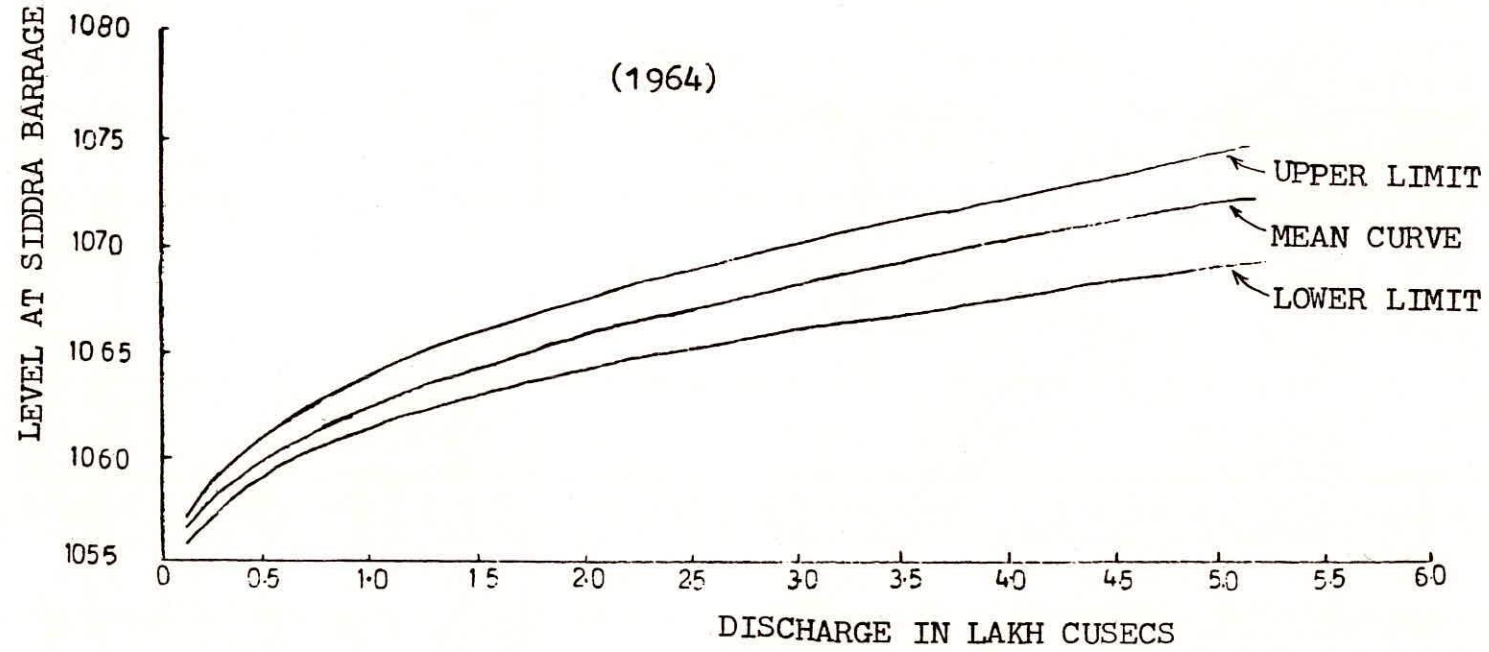


Fig. 13 : MEAN GAUGE DISCHARGE CURVE FOR TAWI RIVER AT SIDDRA WITH POSSIBLE VARIATIONS IN LOWER AND UPPER LIMITS

6.0 CONCLUSIONS

The river Tawi has its source in high altitude in Himalayas and has hilly catchment. The catchment is steep and mostly devoid of vegetation, with the result that the run-off is swift. During the monsoon season, however, highfloods of 80,000 to 100,000 cusecs are frequently experienced. Part of the catchment is snowy, as a result of which the river carries a perennial discharge of 300 to 400 cusecs. However in September, 1988 the river was visited by an all time high flood. During this flood most of the works executed on the river like syphon d/ s of Tawi bridge at Jammu and flood protection works suffered extensive damages. The proposals on Tawi were based on a designed discharge of 2.3 lac cusecs. But a flood discharge of about 4.3 lac cusecs was experienced on 25th & 26th Sep. 1988 which is much higher than the designed discharge. This caused large scale devastation to the flood control works. A substantial area of Jammu city was also inundated on both banks of Tawi causing lots of distress to people living in the low lying areas. The unprecedented discharge of 1988 floods calls for review of the design of existing works on Tawi.

In J & K state, two districts Udhampur and Doda which are classified as drought prone areas partially fall under the Tawi catchment. Central Water commission has prepared a report on identification of drought prone area in J & K state.

The two districts which have been identified as drought prone by the irrigation commission (1972), reportedly (3) have less than 30% of irrigated area and are vulnerable to drought due to lack of irrigation facilities. In order to examine the problem of drought in all its aspects, the various contributing factors, such as temperature, climate, soil conditions, landuse pattern, surface and ground water resources, pollution etc. in the region, have been taken into account in addition to the rainfall and its erratic distribution.

There is large variation in sediment yield. Climate, vegetation cover, lithology and relief are most important controlling factors in Tawi basin. The rate of transport of debris by natural flows into river system is then controlled bysurface slope, rainfall and run-off magnitude. It is reported that early snow melting and retreating monsoon during March and Sept. respectively casue increase in sediment yield and run-off.

It is found that there is direct correlation between sediment yield and run-off. During rainy days of July and August sedimentation is maximum causing large scale erosion in the catchment area. With the increase of run-off in this period the velocity as well as silt carrying capacity are also increased and coarse materials get transported downstream along the river bed. At the same time gullies, rills and joints are activated with the rush of water to trigger the erosion process. The average sediment yield is reported to be of the order of 6503300 MT per year. Change in the landuse pattern, deforestation and low growth rate of vegetation, construction ofnew roads and bridges are causing ecological imbalance in the catchment area due to which sedimentation is found to be predominant almost everywhere. This calls for watershed management through land treatment and artificial vegetation. Regarding change in land use pattern, a study is being made separately with the help of remote sensing technique.

In the Tawi basin there is need to improve the existing raingauge network specially with installation of adequate number of SRRG stations. The data for the raingauge stations of Ramnagar, Udhampur, Chenani and Jammu located inside the catchment is available. These stations do not adequately represent the catchment, particularly the upper hilly portion.

While conceiving the Tawi barrage project at Sidra prepared by the then C.W. & P.C.

outside the catchment but close to it. In the absence of gauge and discharge data for the Tawi river at barrage site synthetic gauge and discharge curve was developed by C.W. & P.C.

The correlation study establishes relation between gauge at Sidra and Jammu (Tawi bridge) statistically as follows:

$$Y = 1.7337 + 0.826X$$

However with the availability of other techniques the discharge at barrage site could be generated.

Further due to inadequate length of discharge data at Jammu bridge site, flood frequency analysis could not be carried out to ascertain design flood. Therefore, it was attempted to obtain the magnitude of the design flood by applying design storm of specific frequencies to the unit hydrograph.

Large gaps on in the available data inadequate observation network, inconsistency in the historical records do not permit detailed hydrologic studies. However there is scope that with the expertise and techniques available with NIH some of the difficulties could be overcome.

Detailed hydrological studies for Tawi like design discharge, water availability, network design, sedimentation study etc. have been engaging the attention of state engineers and systematic studies are to be carried out for the betterment of the large population of this area.

REFERENCE

(1) Annual progress report (1989-90), Water Management Research Centre, Sher-e-Kashmir University of Agriculture Science & Technology, Ponichak, Jammu.

(2) Bhagirath, Oct.-Nov., 1989 J&K Special.

(3) CWC report " Drought area studies and investigation".

(4) C.G.W.B. report on estimation of ground water resources potential for J & K.

(5) Digest of Statistics (1985-86), Directorate of evaluation and statistics, Planning and Development.

(6) Digest of statistics (1987), Forest Deptt., J & K

(7) Data Records of I & FC, Satwary, Jammu

(8) Outline plan for irrigation development chenab basin, (Mach, 1988), Northern Investigation Circle, Jammu.

(9) Project report, Chenani Hydel Project, P.D.D., J & K, Jammu

(10) Project report, TAWI Barrage Project, Jammu

(11) Raina, A.N., (1987), " Geography of J & K" Radha Krishan Anand & Co., Jammu.

(12) Singh Nater, (1990) " Geomorphology of Himalayan rivers", A Case study of Tawi basin.

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