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# HYDROLOGICAL NETWORK FOR TAWI - J & K

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1992 - 93

# PREFACE

The science of hydrology has taken rapid strides during the last two decades. Hydrological analysis has come a longway from the simple empirical formulae to the present day conceptual and mathematical modelling. These techniques would, however, require extensive and intensive reliable data which is generally not available with the type of network and instrumentation currently in operation in many parts of the country.

Ever since the establishment of the Western Himalayan Regional Centre of the institute at Jammu, the scientists of the centre have been closely interacting with the senior officers of the different departments in the states covered under the region. The Tawi river in the Jammu region of the state of Jammu and Kashmir is blessed with abundant water resources and is also prone to floods in the monsoon season. Though a number of schemes for water resources development have been contemplated, so far no systematic hydrological studies could be carried out for the catchment because of lack of proper hydrometeorological and hydrological data. The Chief Engineer (Ravi and Tawi) J & K requested the centre to carry out studies for recommending a network of hydrometeorological and hydrological stations for the Tawi catchment so that the state irrigation department could execute the plan.

This report has been prepared by Shri K S Ramasastri Scientist F at the Western Himalayan Regional Centre based on the data available within and outside the catchment.

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## ABSTRACT

Planning the development of water resources depends to a large extent on the proper assessment of available water resources and their ditribution in the different river basins. Data of hydrometeorological and hydrological parameters is necessary for developing and managing water resources. Forecasting of flood discharge, study of low flows, operation of reservoirs and hydroelectric projects

A hydrologic network is an organised system for the collection of information of specific kinds, such as precipitation, runoff, water quality and sedminetation. The basic objective of hydrologic network design is to determine the optimum number of stations and their optimum locations so as to yield representative data for the catchment or region. While lack of a generally acceptable methodology often creates difficulties for network design their execution is hampered by the lack of necessary funds.

The Tawi river in the Jammu region of the state of Jammu and Kashmir has abundant water resources for harnessing. However, systematic hydrological studies have not been carried out till to date, due to lack of proper and adequate hydrometeorological and hydrological network. For a catchment of nearly 2000 sq. km there

are only two raingauges at Ramnagar and Udhampur and one I.M.D. observatory at Jammu. There is only one gauge discharge site of the C.W.C. at Jammu. Keeping in view the need for carrying out necessary hydrological studies for the various water resources development schmes being proposed by the state of J & K , the irrigation department has desired that the design of hydrometeorological and hydrological network may be taken up.

In the absence of adequate data base rigorous methods of network design could not be applied. The design had to be based only on WMO and BIS norms and simple empirical methods using the limited precipitation (rainfall and snowfall) data recorded at the three stations within the catchment and another four stations, Samba, Bhadarwah, Rot and Batote outside the catchment.

Based on the study, a network of eleven hydrometeorological stations including raingauges, snow gauges, self recording rain gauges and hydromet observatories and a network of five gauge discharge and sediment sites has been recommended.

## 1.0 INTRODUCTION

Long term hydrological and meteorological data and information about physical characteristics of watersheds , provide the basis for all hydrological studies and for assessing, developing and managing the water resources. Hydrological networks serve an important role in the scientific and rational development and management of water resources

The aim of hydrological network is to provide a density and distribution of stations in a region such that by interpolation between data sets at different stations, it would be possible to determine with sufficient accuracy, the characteristics of meteorological and hydrological elements anywhere in the region.

Hydrological networks are intended to serve one or more of the purposes such as water supply, hydrpower generation, irrigation, flood control etc. The purposes of the data collection and the level of information required changes as the level of development of the region changes. For example the information required for design and construction purposes would be more than that for mere inventory purpose and would be certainly much more for operation and management purposes such as reservoir regulation, flood control and flood forecasting.

The Tawi catchment is blessed with adequate water resources potential. The increasing demand of the development of Tawi river waters for benefitial uses like water, irrigation and power development necessitated systematic hydrologic studies. To

support various hydrological studies, the Tawi catchment is not having adequate raingauge network, sufficient discharge observation sites and sites for monitoring sediment and water quality. The existing network is unsystematic and the available data has many gaps and inconsistencies. Planning a proper network of raingauges, self recording raingauges, hydrometeorological observatories , gauge- discharge and sediment sites is, therefore, a pre- requisite for carrying out systematic hydrological studies.

Realising this need , the irrigation department of the Government of Jammu and Kashmir has requested the Western Himalayan Regional Centre of NIH to assess the present network in Tawi catchment and recommend an adequate network of hydrometeorological observatories and hydrological sites for water resources development and flood forecasting. A study to design the hydrometeorological and hydrological network for Tawi catchment has been accordingly undertaken.

## 2.0 REVIEW

In general considerable effort is directed to improve methods of analysis and prediction than towards advancement of the means for securing the basic hydrological information. Design of hydrological networks is thus a much neglected subject

Due to lack of scientific norms, many network densities are being decided on empirical and subjective considerations. In India also, hydrological and meteorological networks are evolved without any scientific design or planning. The Bureau of Indian Standards (BIS) committee on stream gauging methods has drawn attention to this problem by inquiring as to what methods or techniques could be applied to Indian catchments which will enable us to evolve norms keeping in view the WMO guide lines on network design.

The WMO has prescribed certain norms for hydrological and meteorological networks as follows

| Type of Observation | Type of Network | Flat regions of temperate and tropical zones | Mountainous areas of temperate and tropical zones | Arid Zone |
|---|---|---|---|---|
| | | Representative area per one gauge/site | | |
| Precipitation | Adequate | 600-900 sq km | 100-200 sq km | 1500-10000 |
| | tolerable | 900-3000 .. | 250-1000 .. | - |
| Runoff | Adequate | 1000-2000 sq km | 300-1000 sq km | 5000-10000 |
| | tolerable | 3000-10000 .. | 1000-5000 .. | |

The Bureau of Indian Standards ( Revised version of IS Code 4987-1968) suggested that one raingauge upto 520 sq. km might be sufficient in non orographic regions. In regions of moderate elevation ( upto 1000 m a.s.l ) the network density might be one raingauge for 260 sq. km to 390 sq. km. In predominantly hilly areas and areas of heavy rainfall, the density recommended was one for 130 sq. km

Rao (1979) indicated that during the second half of the 20th century observational sites were set up in the country on large scale. For immediate implementation of network the norms given by the WMO have been modified as below :

(i) Flat areas : One station for $\frac{3000 + 10000}{2}$ or 6500 sq km instead of 2500 sq km

(ii) Hilly areas : One station for $\frac{1000 + 5000}{2}$ or 3000 sq km instead of 1000 sq km

(iii) Arid Zones : One station for 30,000 sq km instead of 20,000 sq km

Using these modified norms and WMO norms, Rao (1979) worked out the number of gauge and discharge stations to be set up under the immediate and ultimate stages for major, medium and minor river basins in India. A committee of the river valley projects of BSI is reviewing these norms to suggest some standards for use in India.

## 2.1 Design of Networks

The study of network and their design is a subject that is common to many sciences. Hydrologists have been mostly concerned in the study of linear networks, particularly for examination of stream systems. There are two basic problems in network design. The first is to determine the optimum number of observation sites required to meet a specific objective and the second is where to locate them. The second question may present some difficulties because the optimum pattern of distribution may be affected by factors that are not always hydrological.

According to Rodda (1969) there are at least three categories of observation stations in a hydrometeorological or hydrological network. They are

(i) primary network stations or base stations
(ii) secondary network stations and
(iii) special network stations

The primary stations also called principal stations, base stations or permanent stations furnish the basis for statistical studies and therefore should be used for observations continuously. A small number of long term primary stations supported by a large number of secondary stations are to be installed so that a statistical relationship can be developed between the primary and secondary stations.

The secondary stations are operated for a limited number of years only. They should function just long enough to establish a good correlation between them and the base stations or with characteristics of the terrain.

Special purpose stations may be required for a specific purpose or they may be established to augment the network of base and secondary stations. The length of operation of the special purpose stations depends on the purpose for which they are installed. In some cases the observations may be confined to one particular aspect or to one season of the year.

Data from the secondary or special stations is generally used for specific purposes such as project planning, forecasting of floods or study of low flows etc.

### 2.1.1 Optimum and saturated networks

In the case of project areas where already some gauges were in operation it may be essential to review the network density to ascertain whether it is optimum, saturated or otherwise.

The optimum network should be one which could provide by interpolation between values of different stations, all the characteristics of precipitation data with sufficient accuracy for practical purposes.

IS code has recommended certain procedures for determining saturated networks so that the unnecessary stations could be

discontinued without sacrificing the accuracy of the estimates. In many areas it may not be possible to install the gauges as per the optimum network designed. In such cases, a minimum network is maintained.

## 2.2 Methods for Design of Networks :

The diversity of terrain and hydrologic problems throughout the world make it impractical to derive one universally satisfactory procedure for the design of networks Moreover, it is generally accepted that any theoretical approach must be supplemented with an element of judgement. This is because, first the network must be made to provide data for purposes not yet apparent and second, the network density and required length of records depend upon areal and time variability of hydrological and meteorological elements.

### 2.2.1 Design of precipitation gauge networks :

The IS code 4987 - 1968 of Bureau of Indian Standards and India Meteorological Department manual on Hydrometeorology (1972) recommended a simple formula based on Rycroft (1949)

$$N = \left( \frac{C_v}{p} \right)^2 \quad \ldots\ldots (1)$$

where N is the number of rain gauges, $C_v$ is the coefficient of variation of the rainfall of the existing raingauges and p is the percentage permissible or desired error of accuracy.

Kagan (1966) suggested a procedure for computing the error in estimation of areal rainfall which could be used as a criteria for detrmining the optimum network density of raingauges.

Based on optimal estimation procedures, O'Connel et al (1979) assessed the accuracy requirements for point and areal rainfall estimates using the data from existing network in the Wessex water authority of Southwest England. Root mean square errors of interpolation were calculated using the estimates of spatial auto correlation of daily and monthly rainfall.

Sreedharan and James (1983) used the spatial correlation technique proposed by Kagan for design of raingauges network in the Chaliyar basin in Kerala.

Seth et al (1985) used the BIS and Kagan's technique for recommending raingauge network for the Rajasthan state. Mehra et al (1986) also used the Kagan's technique for assessing the adequacy of raingauges in the Poorna catchment in the Tapi basin.

Surinder Kaur and Upadhyay (1987) proposed a methodology for the design of raingauge network in mountainous areas. They used the technique for the Beas catchment in Himachal Pradesh.

### 2.2.2 Design of hydrological networks

Studies for determining optimum density of hydrometric stations in general and stream gauging network in particular are

not extensive in many countries including India.

Benson (1965) presented a study based on multiple regression technique to relate the dependent variables ( number of gauging stations ) to independent parameters like demographic, economic and hydrological factors.

Rao et al (1983) have presented a study for network design of stream gauges for water resources assessment in Krishna basin. In this study, the criterion of reliability of interpolation of stream flow data at intermediate locations has been used and the stream gauge network has been evolved for different sets of conditions of variability and relative errors.

## 3.0 PROBLEM DEFINITION

Hydrometeorological networks are generally set up for

(i) climatological or water balance studies

(ii) flood forecasting and

(iii) weather modification evaluation

The networks are seldom planned or designed. The development of hydrometeorological networks, more often than not, has been haphazard and adhoc, generally catering to the immediate local needs of time specific problems. Such networks even though adequate in number may mot meet the requirements of water resources assessment and/or flood forecasting.

Several factors influence design of a network. The criteria used for design of hydrological network must be appropriate to the targets to be achieved by such planning. Problems of network design can be summed up as

(i) number of data acquisition points required

(ii) location of data acquisition points

(iii) duration of data collection from a network

The Tawi catchment is not having adequate meteorological and hydrological network. The existing network is unsystematic and the available data is inconsistent. This led to the results of the studies carried out being inconclusive and often unreliable.

A study to design the hydrometeorological and hydrological network in the Tawi catchment is carried out with the objective of assesiing the present network in the catchment and recommend an adequate network of hydrometeorological and hydrological stations and suggest suitable locations to meet the needs of water resources development and flood forecasting.

## 4.0 DESCRIPTION OF STUDY CATCHMENT

The Tawi river is a tributary of river Chenab in the Indus system of five rivers. The Tawi catchment is contained between 74 35' - 75 45' E longitude and 32 35' and 33 05' N latitude. The catchment area of the river upto Indian border is 2168 sq. km. The length of the river upto Jammu is 182 km and has a catchment area of 1885 sq. km. The catchment covers three districts of Jammu region in the state of J & K. They are parts of Udhampur, parts of Jammu and a small portion of Doda district.

The river is fed by nine important tributaries namely Kali Kundi, Pich, Magri, Chenani, Dhak nalla, Naddal Khud, Calari , Pharos and Gamhi (figure 1). The river is fed by melting snow and Glacial melt from Kali kundi glacier during the spring season in the upper parts of the catchment. The lower parts of the catchment are completely rainfed. An area of approximately 200 sq. km is snowbound through out the year.

### 4.1 Topography :

The upper part of the catchment is characterised by rugged mountainous topography, where as lower catchment consists of low hills and aggradatioal plain. The average height of the catchment is about 2200 m above m.s.l. The catchment elevation varied from 4000 m in the upstream to about 400 m above m.s.l in the plains.

The slope of the basin is from east to west in the upper part and north east to south west in the lower part. From origin

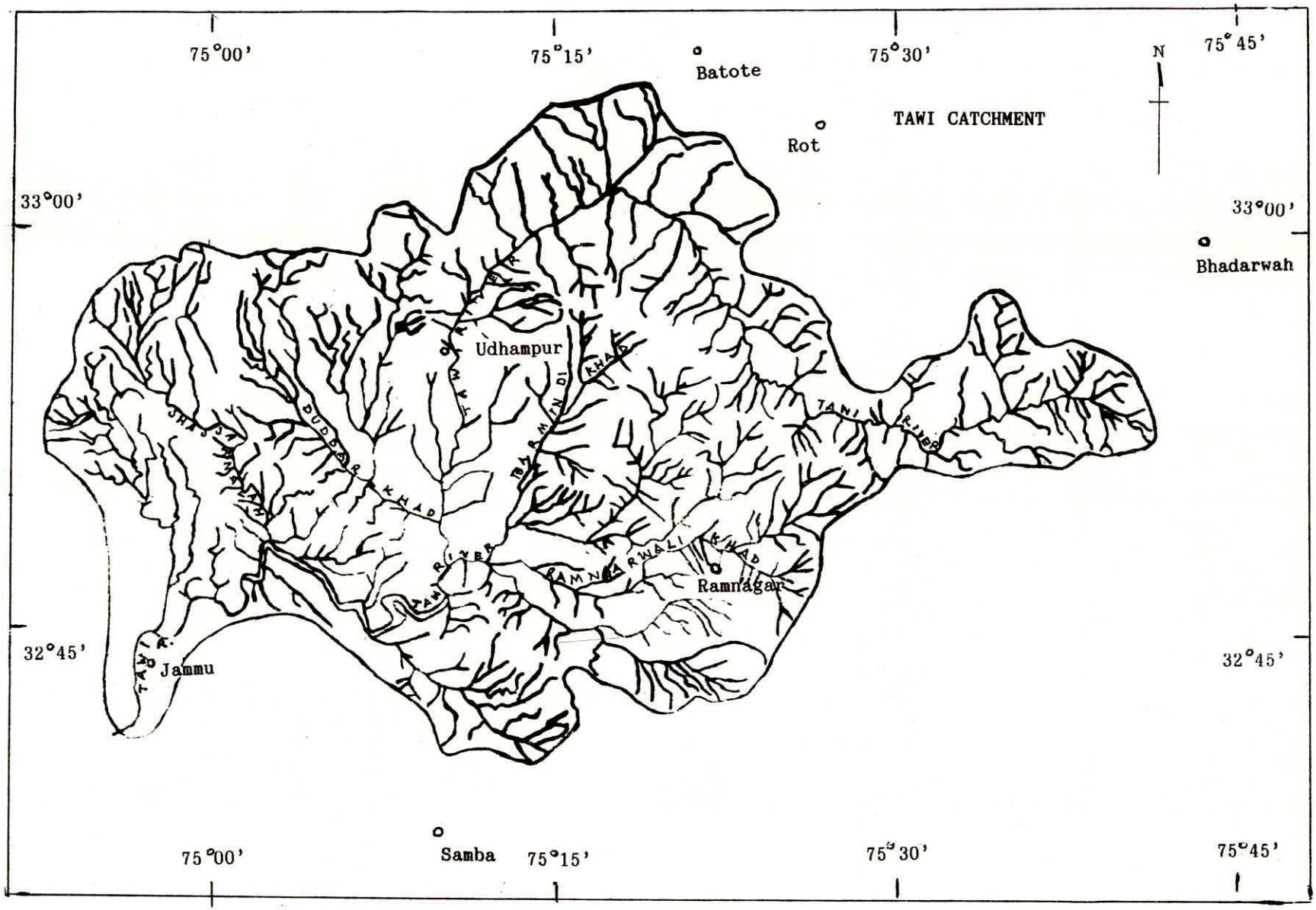


Figure 1 : Catchment map of Tawi river and streams

to outfall the longitudinal section of the river ( figure 2 ) exhibits wide variation. The gradient changes from very steep at upper part to concave and flat in the lower part of the river.

4.2 Land Use :

The land use pattern in the Tawi catchment ( NIH Rept Cs ) is given in Table 1 and is shown in figure3 .

4.3 Climate :

The climate of the catchment is characterised by three distinct features

(1) The north eastern part comprising Bhadarwah and adjoining area where the climate is of the extratropical mountain type. The mountain type climate has wide variation in temperature and rainfall depending on location and direction of land features.

(2) The central part comprising Udhampur district where the climate is mountain type but is influenced by southwest monsoon.

(3) The southwestern part comprising Jammu district where the climate is warm and mainly influenced by monsoon. It could be categorised as the subtropical wet and dry climate.

The southwest monsoon generally reaches the area by 1st July. Rainfall occurs during the southwest monsoon season June - Sept. July and August are the principal rainy months contributing 55 % of annual rainfall. The annual rainfall over Jammu district

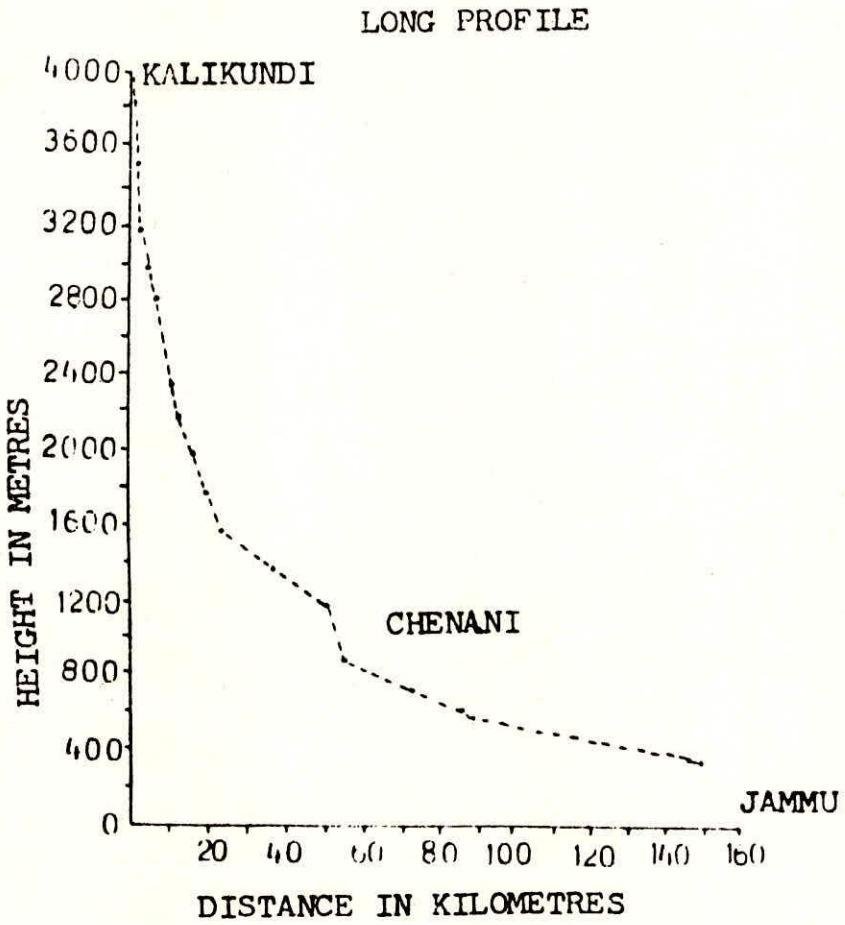


**Fig. 2:** L – SECTION OF THE TAWI RIVER

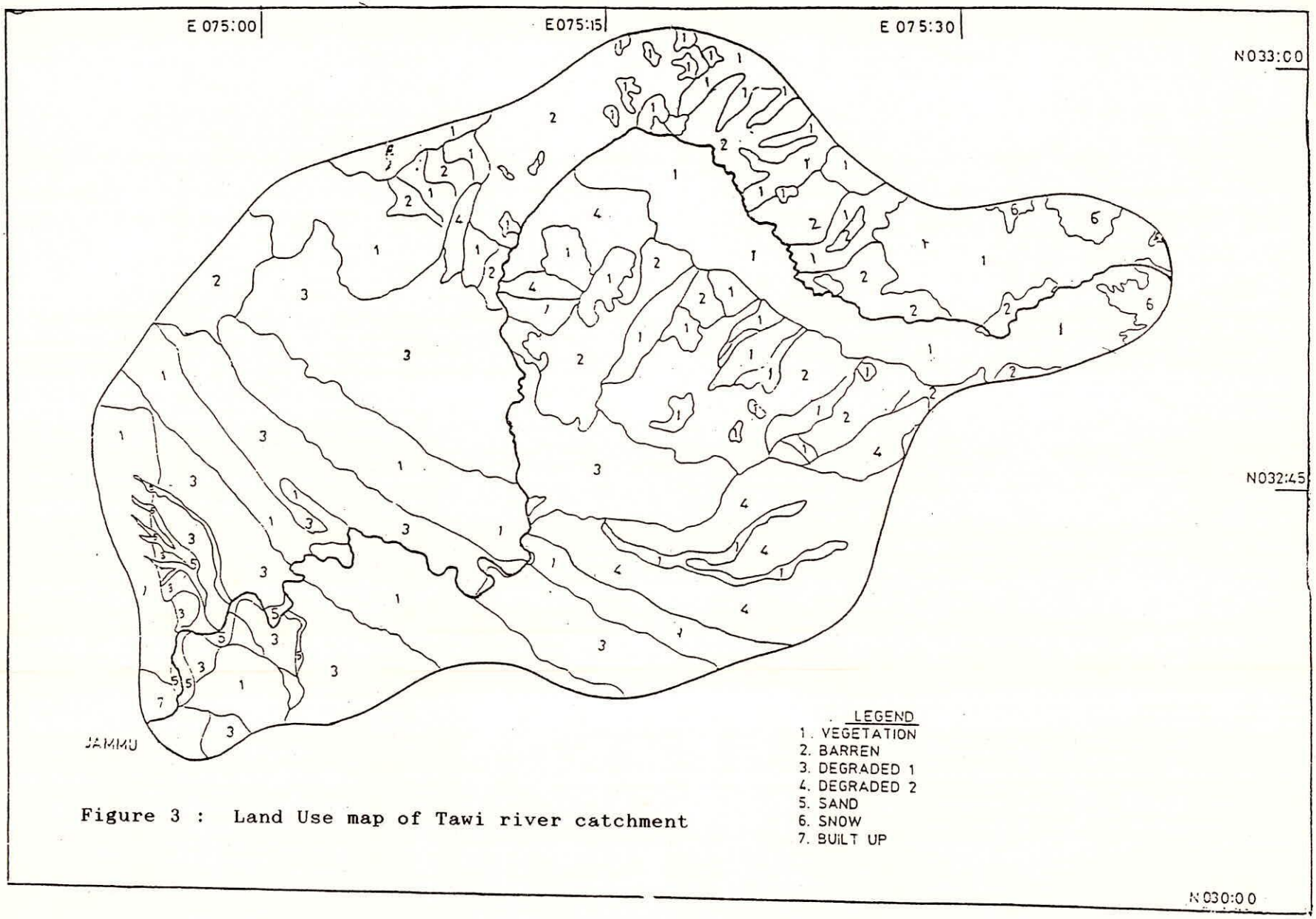


Figure 3 : Land Use map of Tawi river catchment

varies from 90 to 100 cm, over Udhampur district from 140 to 190 cm and over Doda district from 90 to 140 cm. Rainfall in lower parts and snow fall in upper parts of the catchments occur in winter in association with passage of western disturbances and troughs in the westerlies. Snowfall is very heavy in the months December to February. At higher elevations snowfall is experienced even during the month of May. Winter precipitation contributes nearly 45 % of the annual precipitation.

Table 1 : Land Use Classification in Tawi Catchment

| Description of class | Percentage of catchment area under each class | |
|---|---|---|
| | Visual interpretation | Digital processing |
| Vegetation | 44.15 | 23.33 |
| Barren | 16.69 | 14.34 |
| Degraded | 35.71 | 43.93 |
| Sand | 1.39 | 1.47 |
| Snow | 1.20 | 1.02 |
| Built up (Urban) | 0.86 | 1.09 |
| Shadow | - | 14.82 |

Note : Some area which is under shadow has been classified as vegetation in the visual interpretation based on the classification of the adjacent areas

## 5.0 DATA AVAILABILITY

Hydrometeorological data in the catchment is observed by IMD and the J & K state Irrigation and Flood control Department. The available records indicate the following availability of rainfall and other meteorological data.

Table 2 : Availability of Data of Raingauge and Hydromet observatories within Tawi catchment

| S.No | Name of station | District | Raingauge/ observatory | Period of Data availability | Organi-sation |
|---|---|---|---|---|---|
| 1. | Cheneni | Udhampur | Raingauge | 1938 - 1948 | I M D |
| 2. | Cheneni | Udhampur | Raingauge | 1961 - 1975 | Irrig. |
| 3. | Udhampur | Udhampur | Raingauge | 1901 - todate | Irrig. |
| 4. | Ramnagar | Udhampur | Raingauge | 1901 - todate | Irrig. |
| 5. | Kawpota | Udhampur | Raingauge | 1961 - 1970 | Irrig. |
| 6. | Katra | Udhampur | Raingauge | 1961 - 1975 | Irrig. |
| 7. | Barmin | Doda | Raingauge | 1961 - 1973 | Irrig. |
| 8. | Jammu | Jammu | Observatory | 1910 - todate | I M D |
| 9. | Jammu | Jammu | Observatory | 1991 - todate | N I H |
| 10. | Samba | Jammu | Raingauge | 1901 - todate | Irrig. |

I M D : India Meteorological Department
N I H : National Institute of Hydrology
Irrig.: Irrigation and Flood Control Department, Govt of J & K.

In addition to the above the Indian Air Force (IAF) is having observatories at Udhampur and Jammu but data is not available for general use.

Outside the catchment of Tawi, in the Chenab basin the Central Water Commission is having rain gauges and snow gauges at Bhadarwah, Rot and Batote which have influence over the Tawi catchment. Data for these stations is available since 1967 till

to date. The locations of the different raingauges are shown in figure 1. Data for the stations Jammu, Samba, Udhampur and Ramnagar were collected from the records of I & FC Dept and revenue authorities. Data for CWC stations was made available by the office of Superintending Engineer, CWC, Jammu

The Chenab circle under the Central Water Commission is making observations of daily gauge and discharge at the Tawi Bridge in Jammu since 1977 ( Figure 4 ). Also, the Irrigation and Flood Control Department of J & K state observes the gauge at the Tawi bridge in Jammu during the flood season. Daily gauge and discharge data has been collected from the office of S.E , CWC, Jammu.

Information of any other gauge sites on the river upstream of Jammu has not become available inspite of a number of visits and correspondence.

Figure 4: CWC gauge discharge site at Jammu

## 6.0 NETWORK REQUIREMENT

In the absence of long term data from a good network of raingauge stations and observatories or gauge discharge sites rigorous statistical techniques could not be applied for determining the network. The number of stations in the network have been worked out based on the WMO and BIS recommendations. The locations have been recommended keeping in view the existing network and the feasibility of installation and operation of the instruments at the various sites.

### 6.1 Hydrometeorological Network

The hydrometeorological network for the Tawi catchment is worked out using the recommendations of WMO and the methodology suggested in the IS code. For this purpose the data of three raingauge stations within the Tawi catchment namely Ramnagar, Udhampur and Jammu and three stations in the Chenab basin namely Bhadarwah, Rot and Batote and one station in the Basantar catchment, Samba have been used. Since the data of Bhadarwah, Rot and Batote is available only for the period 1967 to 1989 the data of the other stations has also been considered only for the period 1967 to 1989 for the purpose of computing the average rainfall. In the case of Samba the data are not available for the period 1974 to 1978 and for Ramnagar the data are not available from 1986 to 1989. However, instead of ignoring the data altogether it was considered advisable to compute the averages

Table 3 : Monthly and Annual Average Precipitation ( Cm ) of Gauges in and around Tawi Catchment
( Period 1967 - 89 )

| S.No | Rain/snow gauge | Lat | Long | Elev | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Jammu | 32 44' | 74 55' | 366 m | 5.9 | 5.8 | 7.7 | 3.5 | 4.6 | 8.8 | 35.3 | 22.6 | 10.7 | 2.0 | 1.7 | 3.4 | 112.1 |
| 2. | Samba | 32 34' | 75 07' | | 6.5 | 6.2 | 6.3 | 3.9 | 3.1 | 11.3 | 35.9 | 30.8 | 12.7 | 2.1 | 1.0 | 3.2 | 123.0 |
| 3. | Udhampur | 32 55' | 75 08' | 655 m | 9.2 | 10.0 | 19.1 | 5.5 | 4.0 | 11.5 | 39.5 | 36.5 | 14.7 | 2.2 | 2.2 | 4.6 | 159.0 |
| 4. | Ramnagar | 32 48' | 75 19' | 792 m | 10.8 | 10.4 | 10.1 | 6.3 | 5.0 | 11.8 | 41.5 | 30.1 | 11.1 | 2.2 | 1.9 | 7.7 | 148.9 |
| 5. | Bhadarwah | 32 59' | 75 43' | 1830 m | 12.8 | 12.5 | 17.8 | 10.4 | 9.3 | 5.9 | 14.8 | 13.9 | 6.2 | 3.7 | 3.2 | 7.5 | 118.1 |
| 6. | Rot | 33 02' | 75 27' | 1375 m | 13.4 | 15.7 | 20.5 | 12.2 | 9.7 | 7.0 | 14.9 | 12.3 | 7.5 | 3.6 | 3.2 | 7.6 | 127.7 |
| 7. | Batote | 33 07' | 75 19' | 1570 m | 15.6 | 18.4 | 23.4 | 11.0 | 10.4 | 6.9 | 16.2 | 10.8 | 7.8 | 3.7 | 4.2 | 9.4 | 143.7 |

Note : (i) Data of Bhadarwah, Rot and Batote include snow.
(ii) Data of Samba missing from 1974 to 1978
(iii) Data of Ramnagar missing from 1986 to 1989
(iv) Data of Batote missing from Sept 1982 to December 1984

using data for what ever years it is available. The computed averages are given in Table 3.

Based on the WMO criteria and the criteria as recommended by IS code on the basis of area the catchment of Tawi which is a mountainous area would require atleast 10 raingauges ; eight to cover the 1200 sq km mountainous area at the rate of one gauge for every 150 sq. km and two gauges for the plain areas at the rate of one gauge for every 500 sq.km

Using the data of average monsoon ( Jun - Sept) rainfall at the seven stations in and around the catchment it would require 13 raingauges worked out on the basis of 10 % error criteria in the formula at equation (1). It may, however, be noted that all the stations whose data is used are located below 2000 m elevation while the catchment has a considerable area with elevation above 2000 m.

Table 4 : Recommended Network of Raingauges, Snow Gauges and Hydromet Observatories in Tawi Catchment

| S.No | Name of Location | Lat N | Long E | Elev. | Type of Observatory |
|---|---|---|---|---|---|
| 1. | Padra | 32 53' | 75 27' | 3000 m | Raingauge/snowgauge |
| 2. | Sarah | 32 57' | 75 20' | 3200 m | Raingauge/snowgauge |
| 3. | Rasein | 32 54' | 75 19' | 2200 m | Raingauge/SRRG |
| 4. | Ramnagar | 32 48' | 75 19' | 792 m | Hydromet Obsy. |
| 5. | Kud | 33 05' | 75 18' | 1250 m | Raingauge |
| 6. | Katra | 32 59' | 74 55' | 1200 m | Raingauge/SRRG |
| 7. | Udhampur | 32 55' | 75 08' | 655 m | Hydromet Obsy. |
| 8. | Mansar | 32 42' | 75 06' | 1000 m | Raingauge/SRRG |
| 9. | Suruinsar | 32 47' | 75 03' | 800 m | Raingauge |
| 10. | Kawpota | 32 51' | 75 04' | 600 m | Raingauge |
| 11. | Jammu * | 32 44' | 74 55' | 366 m | Hydromet Obsy. |

* existing

The requirement of raingauges, self recording raingauges, snow gauges and observatories is indicated in Table 4 and their locations are shown in figure 5. The snow gauge stations need to be equipped with facilities for measuring rainfall and temperature ( maximum and minimum). In the case of Self Recording Raingauge (SRRG) stations they need to be equipped with a non recording raingauge also. The Hydromet observatories are to be established as per the IMD norms. The observatories should be equipped to measure the following hydrometeorological parameters.

(i) Temperature ( maximum and minimum )

(ii) Precipitation ( rainfall/snowfall amount and intensity )

(iii) Humidity ( Dry and wet bulb temperature)

(iv) Wind speed and direction

(v) Pan evaporation

The lay out of a typical hydrometeorological observatory is shown in figure 6.

6.2 Hydrological Network

As mentioned earlier, the river Tawi is gauged only at the Jammu bridge by Central Water Commission. Other than this no other data is available for any scientific design of hydrological network for the catchment. The recommendations for the gauge sites have, therefore, been made by examining the river morphology ( stream network).

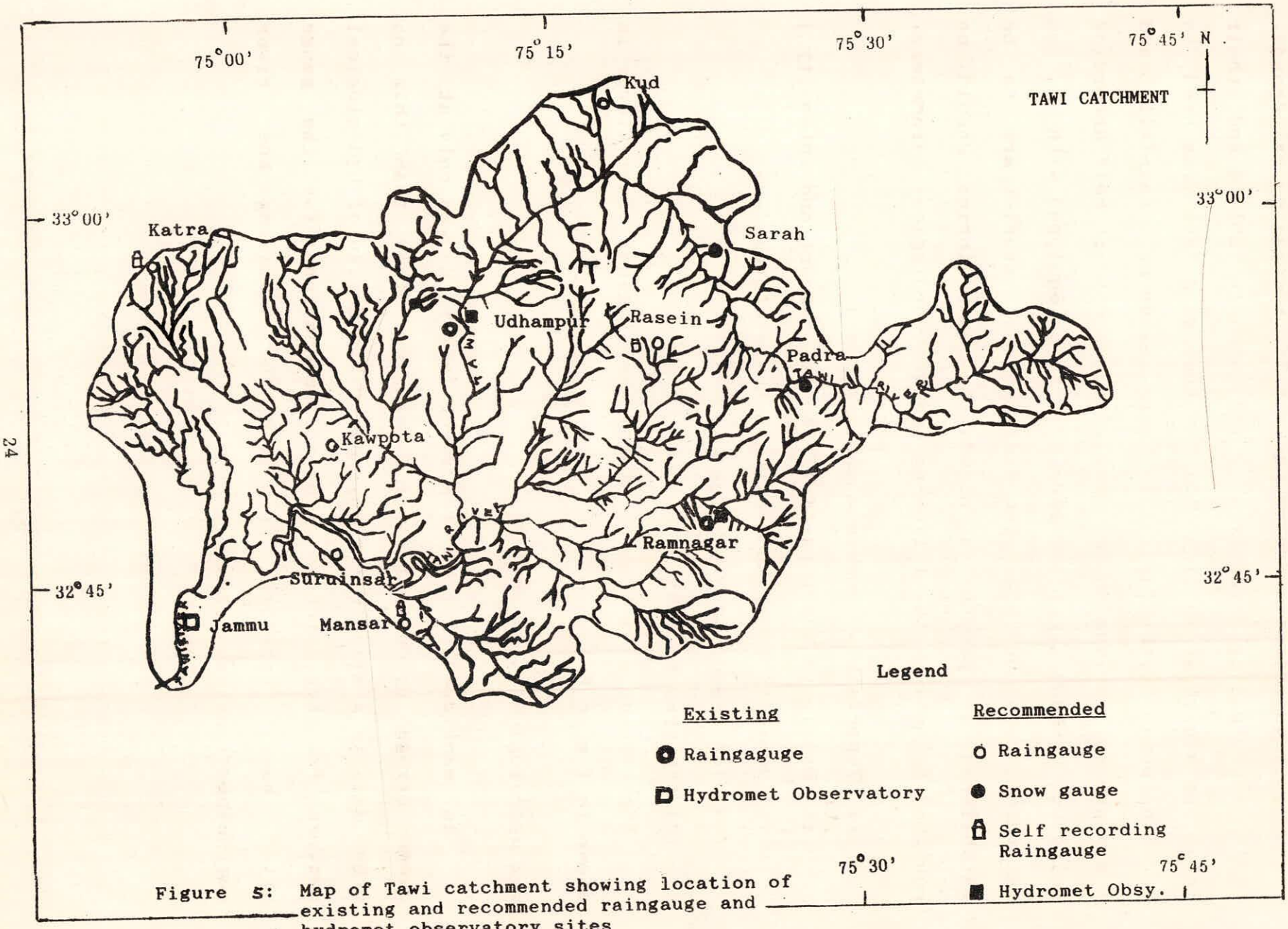


Figure 5: Map of Tawi catchment showing location of existing and recommended raingauge and hydromet observatory sites

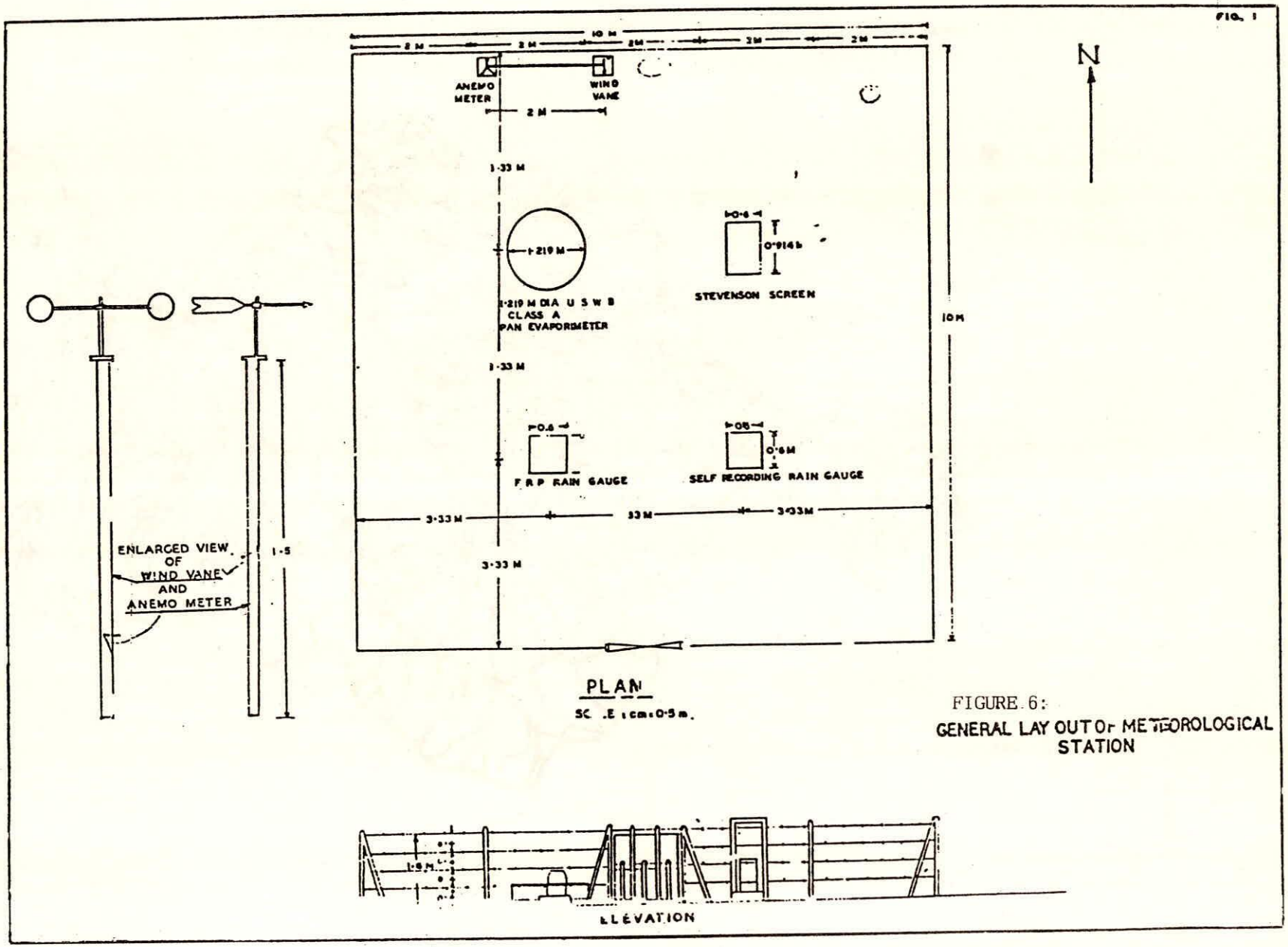


FIGURE 6:
GENERAL LAY OUT OF METEOROLOGICAL STATION

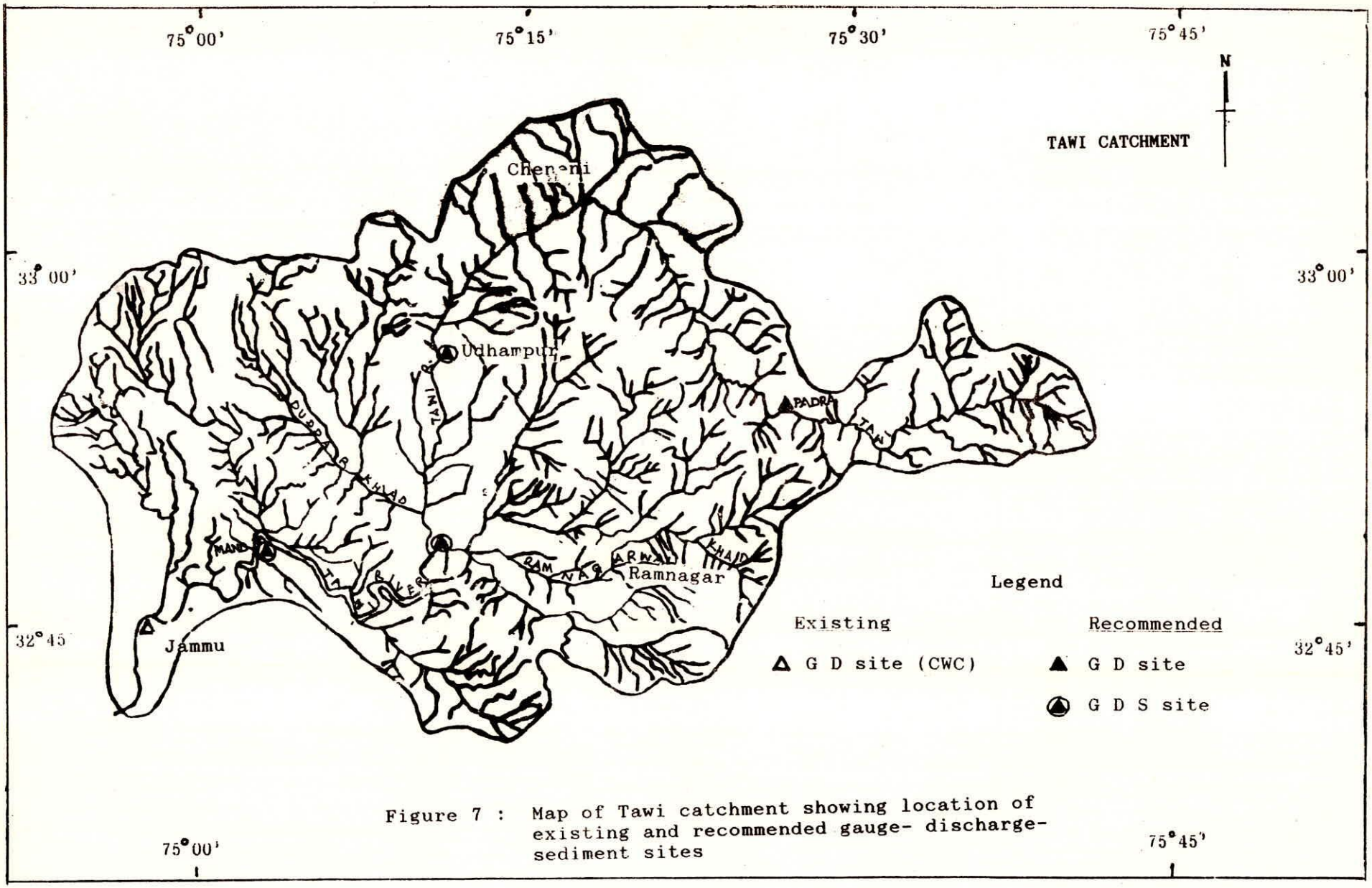


Figure 7 : Map of Tawi catchment showing location of existing and recommended gauge- discharge-sediment sites

Based on the WMO criteria, the catchment would need two to three gauge discharge sites. However, since the upper part of the catchment is snow bound and glaciers are present there is need for monitoring the contribution of snow and glacial melt also. Similarly the soil in the catchment is prone to erosion. There is, therefore, need for sediment monitoring sites. Based on these considerations, the following network is recommended for the catchment.

Table 5 : Recommended Network of G-D and G-D-S sites in Tawi catchment

| S.No | Description of location | Type of observation |
|---|---|---|
| 1. | At Padra on Tawi | Gauge - discharge |
| 2. | At Udhampur on Tawi | Gauge-discharge-sediment |
| 3. | On Ramnagarwali Khud before confluence with Tawi | Gauge-discharge-sediment |
| 4. | Near Mand on Tawi | Gauge-discharge-sediment |
| 5. | Jammu Bridge * | Gauge - discharge |

* Existing C W C site.

The locations of the sites are shown in figure 7

## 7.0 CONCLUDING REMARKS

Considering the importance of water resources development in the Tawi catchment the hydrometeorological and hydrological network has been recommended. The network recommended is the optimum and needs to be developed within a period of one or two years. The length of the period for which this network needs to be operated depends on the quality of the data collected and the variability of the various hydrometeoroloigical and hydrological parameters. The adequacy or otherwise of the network can be reviewed after necessary data base is built up. The network also needs to be supported by field experiments on infiltration and water quality.

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