CASE STUDY

FOR OFFICIAL USE ONLY
CS (AR) 160

HYDROLOGICAL STUDY ON DOKRIANI GLACIER IN GARHWAL HIMALAYA (PART II)

आपो हिष्ठा मयोभुवः

NATIONAL INSTITUTE OF HYDROLOGY
JALVIGYAN BHAWAN
ROORKEE - 247 667 (INDIA)

1994-95

Preface

It is well known that snow and glacier melt runoff is substantial in most of the Himalayan rivers. Inspite of significant role of glaciers in the Indian water resources, very limited hydrological studies of the glaciers are taken up in our country. Inaccessibility to the glaciated region due to very rugged terrain, high altitude and harsh weather conditions have restricted such studies in India. Any data collected by any organisation in such environment is considered very important for Himalayan hydrology. National Institute is participating in the Dokriani glacier expeditions since 1992 with an objective of hydrological study of the glacier.

Air and water temperature, discharge and suspended sediment data have been collected at the gauging site of the Dokriani glacier in the Garhwal Himalayas in 1994. Relatively data period for this year was more than other years and water yield for July and August could be ascertained. It is found that for this year maximum water yield was obtained in the month of July. More or less, daily rainfall has been observed in this area.

Scientists from the Mountain Hydrology Division of this Institute are carrying out hydrological investigations on the Himalayan glaciers. Inspite of harsh weather conditions and several difficulties of the field, detailed investigations are being made by the NIH scientists on the Dokriani glacier. In this report investigations carried out for the year 1994 are reported. This work was carried out by Dr Pratap Singh, Scientist C, Shri Naresh Kumar, Senior Research Assistant, Shri S K Dhariwal, Research Assistant and Shri Dhanpal Tech-III.

(S M Seth)
Director

CONTENTS

LIST OF FIGURES

LIST OF TABLES

Abstract

Discharge, suspended sediment, air temperature and water temperature data have been collected at the gauging site established by NIH on the Dokriani glacier melt stream in the Garhwal Himalayan region. Water yield has been determined for different summer months and maximum yield is computed to be in the month of July for this year. More or less daily rainfall was observed in this region which has also contributed in both runoff as well transport of suspended sediment. Maximum temperature for atmosphere as well as stream water is attained in the month of June. After that both the temperatures have shown a decreasing trend. Variability in atmospheric temperature is very high as compared to the water temperature. Attempts also have been made for regression analysis of discharge (Q), atmospheric temperature (T) and rainfall (P). The moisture content in the soil collected from the glacier base camp has been found to be high which helps in clouds formation through evaporation.

1.0 INTRODUCTION

The glacier melt runoff contribution in the rivers originating from Himalaya starts in the month of June/July when seasonal snowcover is ablated. This flow continues till October/November depending upon the climatic conditions in that region. Snowmelt runoff and glacier melt runoff make these rivers perennial in nature. As such very limited detailed hydrological studies have been carried out for the Himalayan glaciers (Singh, 1991, 1992; Singh et al., 1993). Consequently, data base for hydrological studies is very poor for all the Indian glaciers. There is an urgent need to strengthen this hydrological data base. However, glacier melt modelling studies require data on radiation, temperature, precipitation, humidity, wind velocity and direction, discharge etc., but basic data on temperature, precipitation and discharge is also not available for any glacier for a long period. The estimation of the melt rate of the glacier and total volume of water expected in the melt season is of vital use for water resources planning and management including flood forecasting, reservoir operation and design of hydraulic structure etc. In the regions where monsoon rain penetrates the high altitude valleys comprising glaciers and coincide with glacier melt run-off, the flow in the rivers is augmented suddenly that may cause havoc in the down stream. The hydrological data collected during 1994 expedition to the Dokriani glacier has been analysed and presented in this report.

The problems associated with higher rate of suspended sediment, their constitution and structure are of immediate concern in this region. There is a Tiloth Hydropower station at Uttarkashi having capacity of 3x30 MW and was commissioned in 1984. A diversion dam is constructed at Maneri Bhali on the Bhagirathi river to divert water to a hydropower scheme through 8 km long tunnel. There is a peculiar problem of runners damage due to quartz sediment particles. At present only sediment particles having size <0.3mm and concentration not more than 1200 ppm are allowed. In the monsoon period concentration increases substantially and sometimes reaches about 10000 ppm. Therefore, every year during monsoon season hydropower plant is shut down until concentration lowers down to the permissible value of 1200 ppm. The runners are repaired/replaced every year and sufficient spares parts are kept in store so that runners may be replaced at any time, if required. A major expenditure is incurred towards maintenance of this hydropower plant.

2.0 SALIENT FEATURES OF DOKRIANI GLACIER

There is about 25 km long foot trek to approach the Dokriani glacier. This trek starts from a Bhukki village and passes through thick and dense forest cover. The trek is very difficult one and under rainy conditions it becomes very slippery and risky as well. In general, one night halt is made in between to reach the glacier base camp. The snout of the glacier is about 1 km from the base camp.

The Dokriani glacier is a valley type glacier located in Garhwal region of Himalayas. This glacier lies between latitudes 31°49′ to 31°52′ N and Longitudes 78°47′ to 78°51′ E. It is situated about 30 km ENE of Bhukki. It originates in the vicinity of Janoli (6633m) and Draupadi ka Danda (5716m) peaks. The melt stream originating from Dokriani glacier is known as Din Gad. It follows a narrow valley and meets Bhagirathi river at Bhukki. Total drainage area of this glacier is about 23 km^2 out of which about 10.3 km^2 is glaciated.

The elevation of glacier varies from about 3950-5800 m. The length of this glacier is about 5.5 km whereas its width varies from 0.1-2.0 km from snout to accumulation zone. The area-elevation curve of this glacier is given in Figure 1. The middle part of the glacier is highly fractured and consists of crevasses, moulins, glacier table and ground moraines. The crevasses are found mainly transverse type which are wide and long. Sometimes longitudinal crevasses are also seen along the sides of the glacier.

The snout of glacier is situated at an elevation of about 4000 m and covered by huge boulders and debris. The lower portion of the glacier is almost covered by debris. The material of these moraines has been derived from the side of valley mainly by frosting. This glacier is bounded by two large lateral moraines which are about 200 m in height. Besides the above two lateral moraines, there are several other lateral moraines observed at different altitude. These different levels of moraines indicate

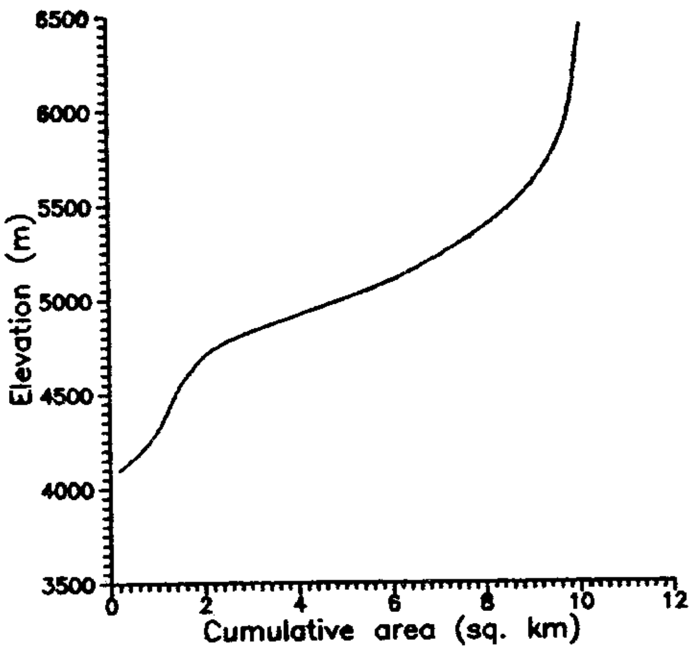

Figure 1: Area–elevation curve of the Dokriani glacier

the past extension of the glacier. The remnants of terminal moraines can be observed up to 2 km downstream of Gujar hut. These are partly covered by grass.

3.0 ESTABLISHMENT OF GAUGING SITE AT GLACIER MELT STREAM AND MEASUREMENT OF STREAMFLOW

The hydrological observations were made at the site which was established by NIH in 1992. During the 1994 expedition, a survey of the melt stream starting from snout to about 2 km downstream was made and finally the same site was selected. The gauging site selected was about 800m downstream to snout. The flow was not very much turbulent at this site and most of the boulders were removed from the channel. The site was about 1 km upstream of the confluence of the several small nallahs joining the main stream from the southern side.

A temporary wooden bridge was erected over the glacier melt stream (Figure 2). The cross-section area of the channel was determined with the help of this bridge. A straight channel reach more than 6 m could not be available at the gauging site. A graduated staff gauge was also installed at the left bank of the stream for observations of water level fluctuations in the melt stream.

Velocity-area method was used to estimate flow in the melt stream. Wooden floats were used to compute the velocity of flow and time travelled by the floats was determined with the help of stop watch. In order to obtain accuracy, velocity, observations were repeated at least three times and an average value was adopted for further computations.

A stage-discharge relationship was established for the gauging site. Later this relationship was used for determining flow only by stage data. The stage-discharge relationship is shown in Figure 3. However, velocity was also measured time to time for verification of flow computed using established relationship. Mean daily flow is given in Figure 4.

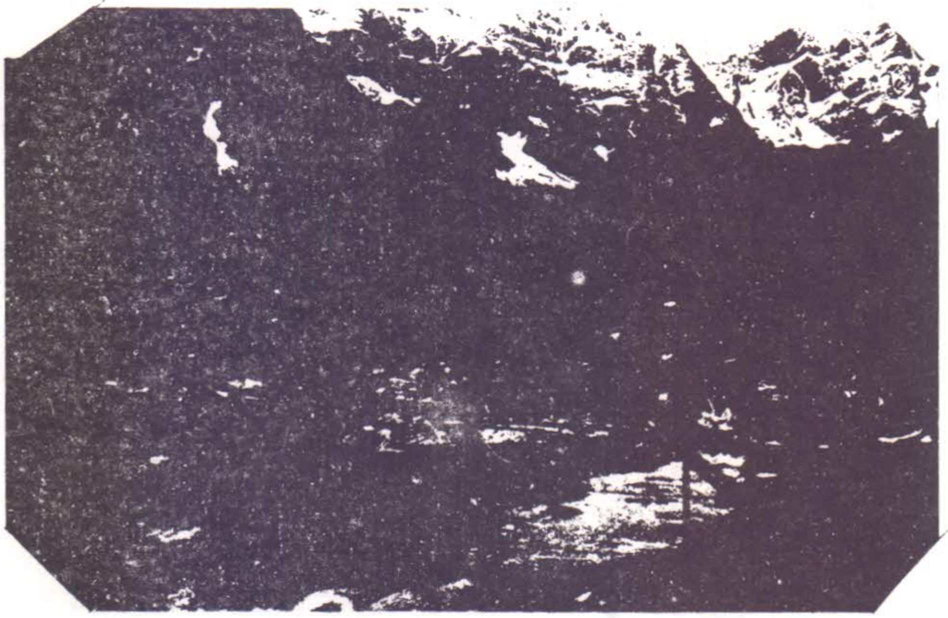

Figure 2 : A view of the gauging site established by NIH on the Dokriani glacier melt stream (1994)

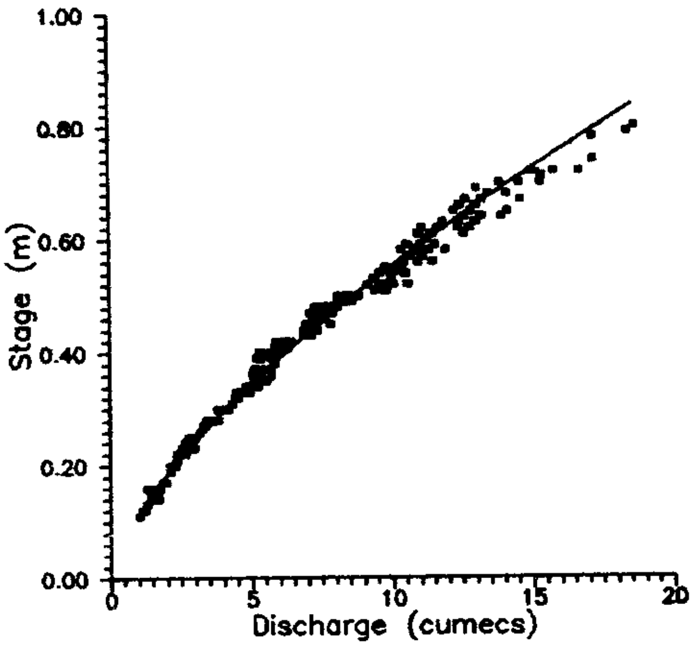

Figure 3: Stage–discharge relationship for gauging site on the Dokriani glacier melt stream for 1994.

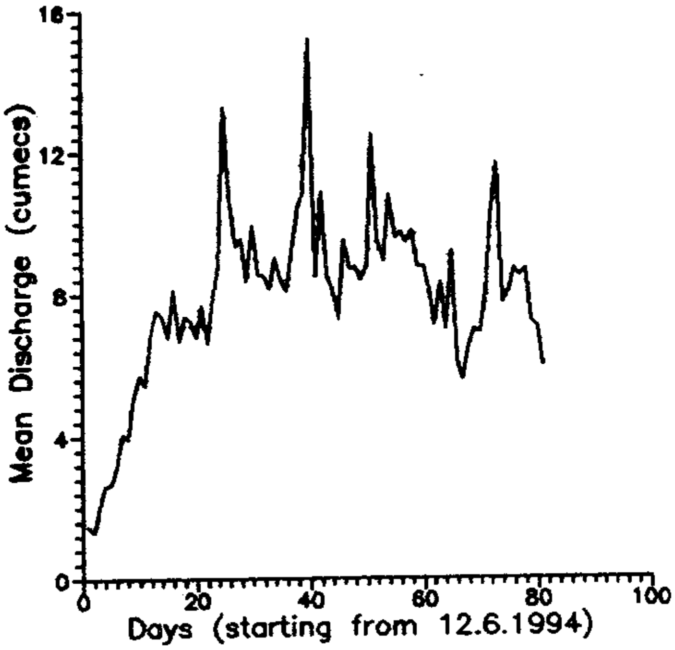

Figure 4: Observed streamflow at the gauging site in 1994.

4.0 RAINFALL, ATMOSPHERIC AND MELT WATER TEMPERATURE

Daily rainfall observed at the base camp is shown in Figure 5. It is clear that there was rain almost everyday.

Hourly observations of air temperature and melt stream water temperature were made at the gauging site. The data were collected during the day time and mean daily values were computed using this data. The mean daily values of these records are shown in Figure 6. It is evident that maximum temperature for both air as well as stream water is attained in the month of June. After that both temperatures have shown a decreasing trend. Variability in air temperature is very high as compared to the water temperature.

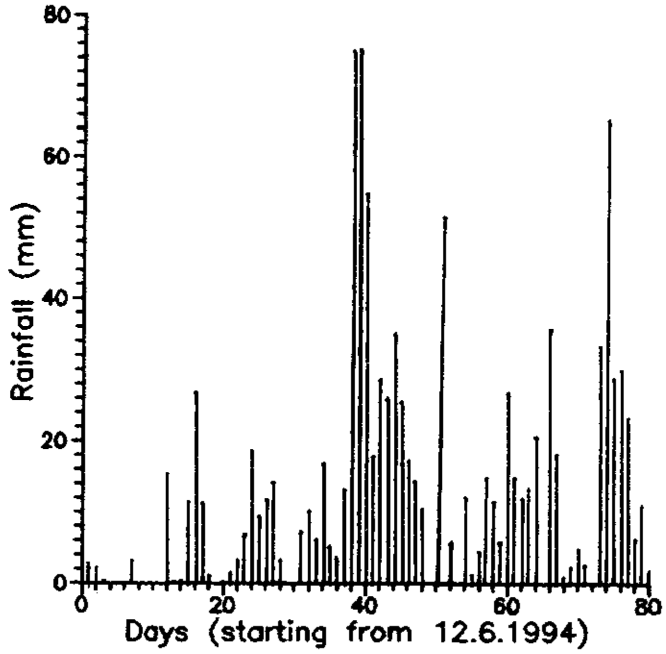

Figure 5: Observed rainfall at the glacier base camp in 1994.

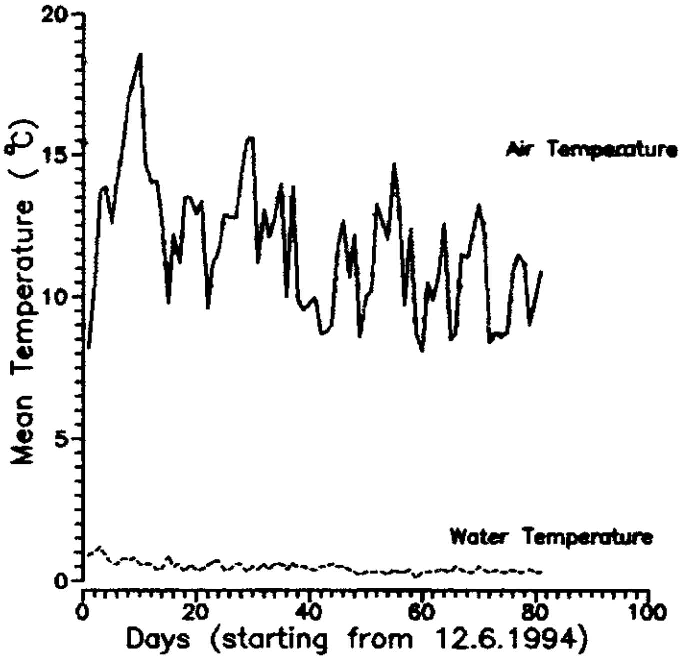

Figure 6: Observed air and water temperature at the gauging site in 1994.

5.0 SUSPENDED SEDIMENTS

Every day, two to three samples were collected and at the same time flow was measured. A known volume of water (500 ml) was scooped from the stream and filtered using Whatman-40 ashless filter paper at the site. The filtered samples were properly packed in polyethylene bags marked with details of samples such as date and time of the sample collection etc.

The samples were analyzed in the NIH Laboratory at Roorkee. Firstly, empty silica crucibles were brought to their constant weight by heating and cooling. The samples were placed in those crucibles and placed in the oven for the period more than 24 hrs. The temperature of the oven was maintained to 200 C during this period. The ashless filter paper was burnt completely in the high temperature. The crucibles were again weighed with samples of sediment. The net weight of sediment was determined by subtracting the weight of empty crucible from the total weight. Because the amount of sediment was very little, therefore, a balancing machine was used for weighing purpose. The suspended sediment load along with flow in the channel at that time is shown in Figure 7.

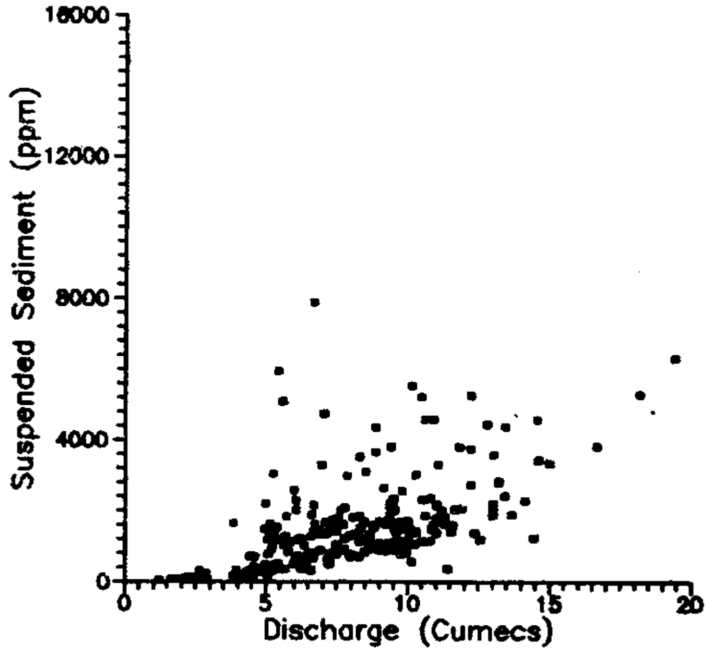

Figure 7 : Observed suspended sediment and streamflow at gauging site in 1994

6.0 SOIL MOISTURE

As discussed above, typical characteristics of rainfall has been observed in this region in terms of rainfall occurrence. Rainfall is observed more or less daily. It is expected that availability of sufficient soil moisture and solar radiation, provide suitable conditions to evaporation from this region. High altitude and content of moisture in the atmosphere produce suitable environment to form clouds immediately after the sunshine. These clouds are generally observed in the afternoon and produce rain. Keeping in view this aspect, soil moisture conditions are studied near the glacier. The soil moisture content observed at different periods is shown in Table 1. It is seen that soil has higher content of moisture (>70%) through out the summer season.

The grain size distribution of the soil samples collected near the base camp was studied and results are presented in Figure 8. The silt forms maximum percentage in the constitution of soil. The soil is classified as silt loam. Details are given in Table 2.

Table 1: Moisture content of the soil collected near the glacier base camp in 1994.

Date	Soil moisture content (by weight)
30.7.1994	74%
07.8.1994	73%
17.8.1994	80%
25.8.1994	76%

Table 2: Textural classification of soil collected near the glacier base camp (1994)

Clay	6.4%
Silt	59.2%
Sand	34.2%
Gravel	0.2%

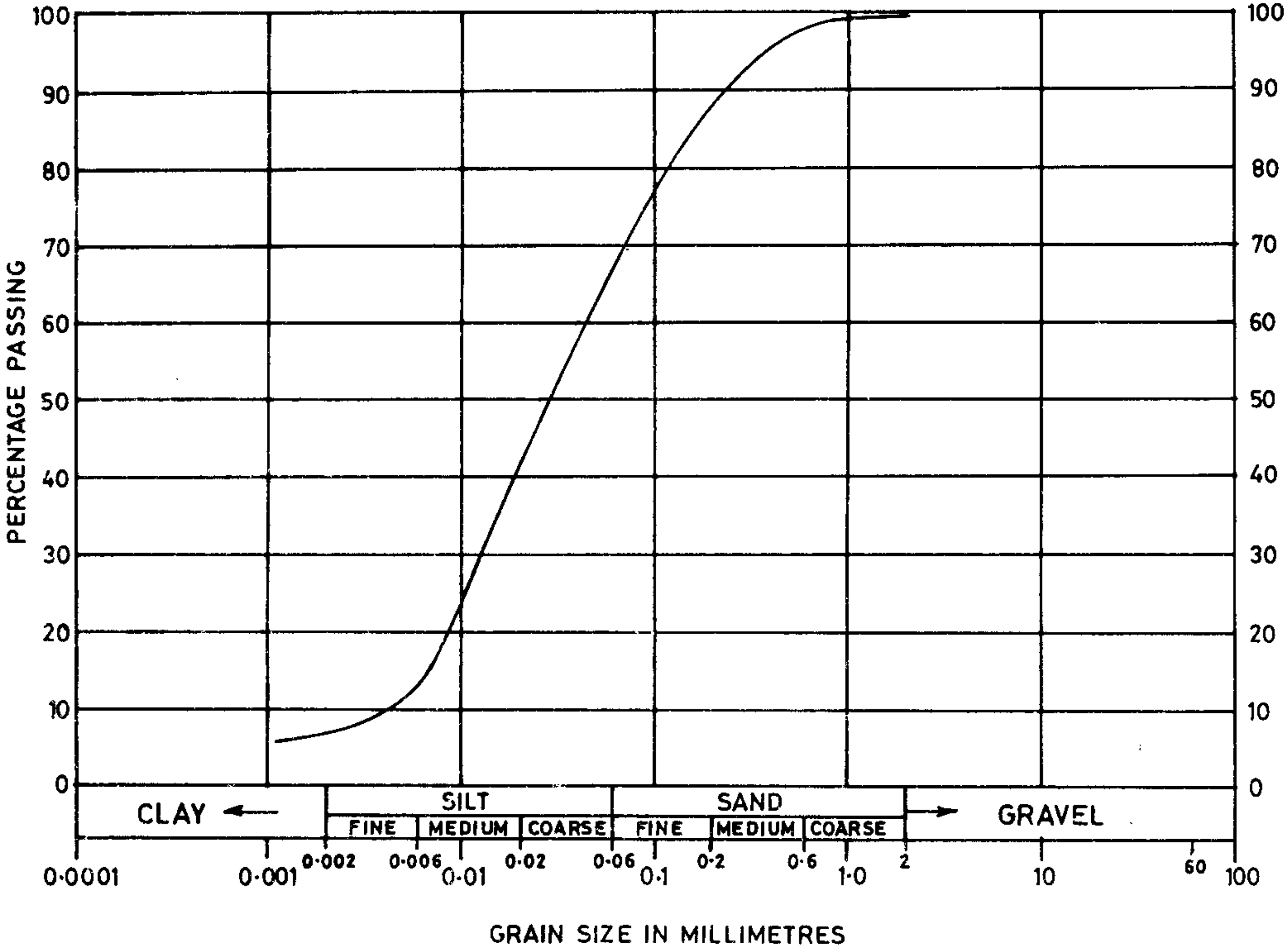

FIG. 8–CHART FOR RECORDING GRAIN SIZE DISTRIBUTION

7.0 RESULTS AND DISCUSSIONS

As mentioned above, the hydrological data collected for the months of June, July and August in 1994 made it possible to compute and compare water yield for different months for the Dokriani glacier (Table 3). From Figure 4 and Table 3, it can be noticed that a major part of the glacier melt runoff is received in the months of July and August. The water yield in the month of July has been observed on slightly higher side. It is possible

Table 3: Observed monthly water yield and rainfall during 1994 Dokriani glacier expedition

Month	Monthly Yield (million cubic meter)	Monthly Rain (mm)
June, 1994 (19 days from 12.6.1994)	8.29	74
July, 1994	23.9	510
August, 1994	22.11	476

because of higher rain and temperature in July in comparison to August (Figure 6 and Table 3). From the present study it is found that maximum water yield from this glacier is in the month of July followed by the flows in the month of August.

It may also be mentioned that in this region, although, maximum air temperature has been recorded in the month of June, maximum flow is observed in the month of July. It can be explained by the extent of snow covered area of the glacier. In the month of June most of the glacier area is covered with snow and by virtue of higher albedo of snow, most of the radiation falling on the glacier surface is reflected back into the atmosphere and ultimately very less energy is used to generate the runoff. As the season advances, snowline moves up because snow over the glacier body melts away. Gradually snow cover area of the glacier decreases and glacier ice is exposed at the places where accumulated snow has completely melted. In other words, ablation area of the glacier increases and accumulation area decreases as the snowline goes up and vice-versa. The glacier ice has lower albedo and absorbs more energy in comparison to the snow surface. Obviously in the month of July and August temperature are lower but glacier physical conditions are more suitable to provide higher quantity of runoff. Temperature follows a decreasing trend due to initiation of cold climate in the region and melt rate of the glacier is also reduced which results in less flow in the melt stream.

A regression analysis has been attempted among discharge (Q), mean daily temperature (T) and precipitation (P), considering P and T as independent variables and Q as a dependent variable. In this region rainfall has been found to be significant in the months of July and August when maximum runoff is drained from the glacier. A close observation of rainfall and streamflow data indicates that most of the peaks in the streamflows are because of the rainfall. The delay characteristics of the rainfall contribution from the accumulation zone in comparison to the ablation zone make such regression analysis complex. It is expected that if Q, T and P data is available for two to three years or more, glacier melt runoff modelling studies may be carried out for this glacier more accurately. Such studies will consider melting processes and its transformation to the runoff using appropriate methodology. Keeping in view these aspects, NIH is planning to make intensive observations of all the hydrological parameters for this glacier during 1995.

The pattern of variation of suspended sediment with flows is shown in Figure 7. No relationship is noticed between streamflow and suspended sediment for this gauging site. It is true that magnitude of rainfall affects the magnitude of suspended sediment at such places. Landslide also contribute in sediment concentration and magnitude in these streams.

The collection of any data on the glacier or on the glacier melt stream is a cumbersome job. It is suggested that use of automated instruments at this altitude and environment should be attempted. Keeping in view the importance of glacier hydrological investigations, a broader data base should be established for the glacier in the different sectors of Himalayas.

8.) CONCLUSIONS

In this report hydrological investigations carried out on the Dokriani glacier are presented. The results are based on the data collected for the months of June, July and August in 1994 are presented. The following conclusions can be drawn from this study:

1. Maximum water yield from this glacier is observed in the month of July followed by the month of August. However, maximum air temperature has been recorded in the month of June.

2. A significant rainfall is observed in the months of July and August when maximum runoff is drained from the glacier. A close observation of rainfall and streamflow data indicates that most of the peaks in the streamflows are because of the rainfall.

3. No relationship is noticed between streamflow and suspended sediment for this gauging site. Magnitude of rainfall affects the magnitude of suspended sediment at such places. Landslide also contribute in sediment concentration and magnitude in these streams.

4. After collecting Q, T and P data for two to three years or more, it is proposed to carry out glacier melt runoff modelling studies for this glacier. NIH is planning to make intensive observations of all the hydrological parameters for this glacier during 1995 and 1996.

5. Collection of any data on the glacier or on the glacier melt stream is a cumbersome job. It is suggested that use of automated instruments at this altitude and environment should be attempted. Keeping in view the importance of glacier hydrological investigations, a broader data base should be established for the glacier in the different sectors of Himalayas.

Acknowledgements

Authors are very grateful to the Director, National Institute of Hydrology, Roorkee for permitting to participate in Dokriani glacier expedition, 1994. Authors are also thankful to Wadia Institute of Himalayan Geology, Dehradun and Department of Science and Technology, New Delhi for organising the expedition and financial support to the expedition, respectively. The rainfall data supplied by India Meteorological Department is also thankfully acknowledged.

References

Singh, P. (1991), Hydrological investigations on Chhota Shigri glacier (H.P.), TR-106, National Institute of Hydrology, Roorkee.

Singh, P., U. K. Singh and M. K. Sharma (1992), Hydrological studies on Dokriani glacier in Garhwal Himalayas. TR-170, National Institute of Hydrology, Roorkee.

Singh, P. (1993), Hydrological characteristics of a Himalayan glacier and problems associated with measurements in the glacier melt streams, Hydrology Journal of IAH, Vol.16, No.3/4, pp.30-51.

Director	Dr S M Seth
Divisional Head	Dr K S Ramasastri Scientist F

STUDY GROUP

Dr Pratap Singh	Scientist C
Shri Naresh Kumar	SRA
Shri S K Dhariwal	RA