# AUTOMATED SNOW MONITORING SYSTEM FOR THE HIMALAYAS

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## ABSTRACT

Snow and glacial melt contribute significant proportions of spring season flow in the Himalayan rivers. Precipitation during the winter months is 40 to 50 percent of annual precipitation in the Western Himalayas. Monitoring of depth and water equivalent of snow received during the winter months is, therefore, of crucial importance for estimating the spring season flows. There are in all about 115 snow monitoring stations in the Himalayas. All these are located in the Western Himalayas. Except for a few stations of SASE and CWC, data of snow depth and water equivalent are measured manually. Also, the density of snow observatory network is satisfactory only in the Chenab and Sutlej basins. It is proposed to set up around 160 automated weather stations with snow sensors in different river basins located in the Western Himalayas and Eastern Himalayas. The weather stations would be linked to an Indian satellite and the data transmitted through the satellite would be received at a central data receiving centre where the data would be processed and stored.

## 1. INTRODUCTION

Out of a total geographical area of 328 million hectares in India, about 93.06 million hectares are mountainous. The Himalayas are the predominant mountain ranges of the subcontinent with 14 mountain peaks of heights more than 8000 m (a.s.1) and hundred over 7000 m (a.s.l).

The Himalayas run in almost three parallel ranges interspersed with valleys and plateaus. The mountain system is divided into three parallel zones which have marked geographic features. These are the greater Himalayas (between 1500 to 3500m) and the outer Himalayas or Shivalika (greater than 3500m), the lesser or middle Himalayas (between 1000 to 1500m). The Himalayas have about 6 lakh sq. km of snow bound area. A number of rivers fed by melting snow and glaciers originate in the Himalayas. It has been observed that the rivers discharge of Himalayan snow fed rivers of a unit area is roughly twice that of peninsular rivers. This is mainly due to the perennial contributions from snow melt and glacial melt. The Himalayan range and catchments of Himalayan rivers are shown in figure 1. The rivers and the Himalayan area included in the catchments is given in Table 1.

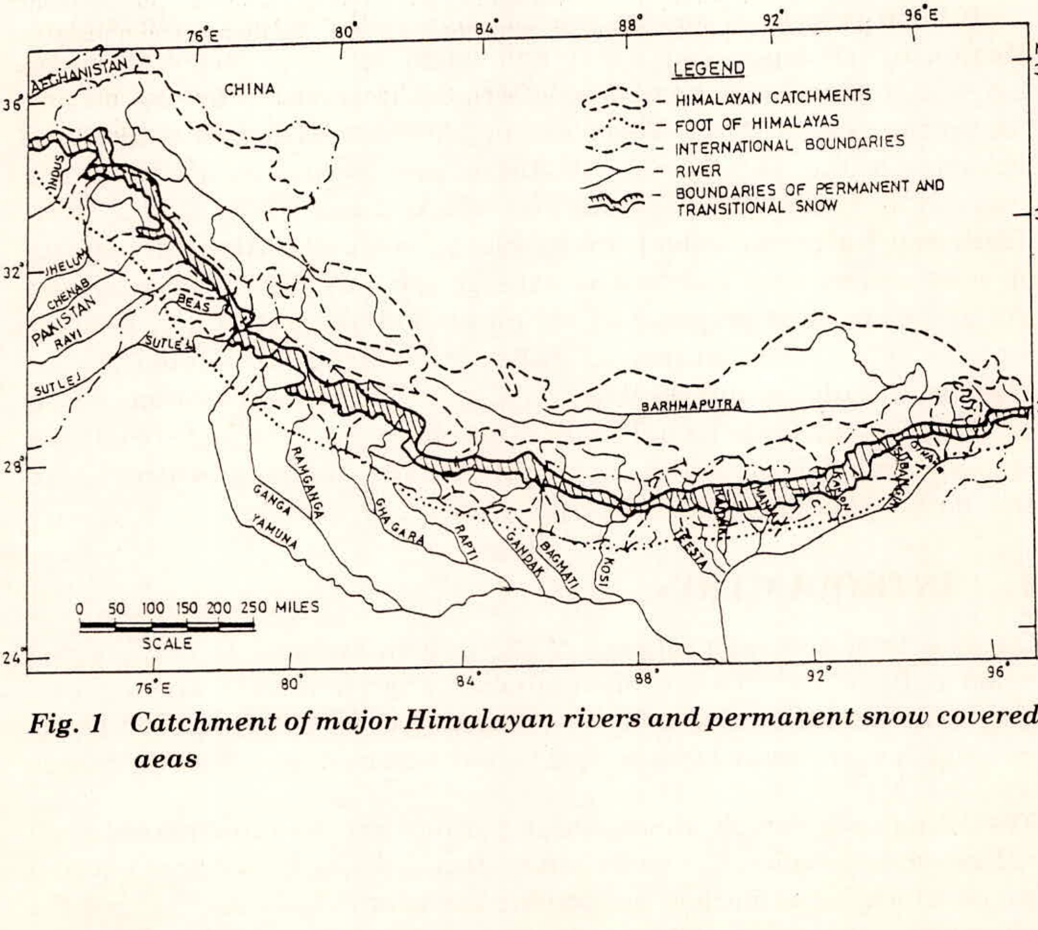


***Fig. 1*** ***Catchment of major Himalayan rivers and permanent snow covered aeas***

*Table 1: Himalayan Catchment Area of Different River Systems*

| S.N0. | River | Approximate catchment area under Himalayas in sq. km. |
|---|---|---|
| 1. | Indus | 2,65,730 |
| 2. | Jhelum | 33,280 |
| 3. | Chenab | 26,880 |
| 4. | Ravi | 7,940 |
| 5. | Beas | 14,336 |
| 6. | Sutlej | 47,360 |
| 7. | Ganga | 22,780 |
| 8. | Yamuna | 11,520 |
| 9. | Ramganga | 6,660 |
| 10. | Karnali | 52,740 |
| 11. | Kali | 16,130 |
| 12. | Rapti | 7,680 |
| 13. | Gandak | 37,380 |
| 14. | Kosi | 61,180 |
| 15. | Bagmati | 3,840 |
| 16. | Teesta | 12,290 |
| 17. | Subansiri | 17,920 |
| 18. | Brahmaputra | 2,53,930 |
| 19. | Manas | 30,720 |
| 20. | Raidak | 26,110 |
| 21. | Luhit | 20,480 |
| 22. | Dibang | 12,800 |

The hydrometeorological characterisitcs of the Himalayan environment are unique and arise from its very high altitude. The type of precipitation i.e. rainfall or snow would depend on the temperatures prevailing at a location. The southwest monsoon affects the major portion of the Himalayas from west to east in the months of July and August. Precipitation which occurs mostly in the form of rain during this period is very heavy in the Eastern Himalayas. In the north eastern Himalayas covering the Teesta and Brahmaputra basins nearly 90 percent of rainfall occurs during June to September. Only 3 percent of precipitation is received during winter (Jan.–Feb.).

Winter precipitation in the Himalayas which is mostly in the form of snow is caused by the passage of western or extra tropical disturbances moving from west to east during the period November to April. At elevations above 3000m snowfall is reported to occur in the months of May and June also. Winter precipitation lasts longer in the Western Himalayas and the accumulation reaches to a maximum by March and April. In some years the snowmelt is abnormally heavy especially over the Western Himalayas and snow accumulation exceeds the loss of snowcover due to melting. The snow depth in the Himalayas may vary from a few centimeters to a few meters within a short distance. Similarly the density of snow also varies from as low as 0.01 to as high as 0.15.

Precipitation during winter is highly influenced by geographical features. Windward slopes of Pir Panjal receive maximum precipitation. The amount increases northward and eastward on the lee side of the range but shows a maximum on the windward side of the Greater Himalayas. The average maximum depth over the windward slopes of the Greater Himalayas was observed to be around 3m.

Winter and summer snow line in the Himalayas is at higher elevations as compared to other parts of the world owing to the relatively higher temperatures for corresponding elevations in India. The snow line experiences considerable fluctuations in altitudes, day to day and season to season. The average altitude of the snow line is about 2500m a.s.l ranging from 2500m in February to 4500m in July. The lowest position of snowline is at about 2200m in the Kashmir Himalayas and about 3000m in other regions of the Himalayas.

**Table 2: Snowmelt Contribution of the Himalayan Tributaries of Ganga Basin**

| S.No. | River | Gauge site | Proportion of annual snowmelt volume over the runoff in percentage |
|---|---|---|---|
| 1. | Alakananda | Rudraprayag | 11.05 |
| 2. | Bhagirathi | Uttarkashi | 9.63 |
| 3. | Bhagirathi | Tehri | 7.97 |
| 4. | Bhagirathi | Deoprayag | 8.37 |
| 5. | Ganga | Joshimath | 14.43 |
| 6. | Ganga | Raiwala | 6.22 |
| 7. | Yamuna | Lakhwar | 7.27 |
| 8. | Yamuna | Tajewala | 5.30 |
| 9. | Sarada | Banbasa | 16.92 |
| 10. | Ghagara | Katariaghat | 17.27 |
| 11. | Gandak | Tribeni | 19.54 |
| 12. | Kosi | Barakshetra | 8.77 |

Source : GBWRO, Central Water Commission

Snowmelt and glacial melt contribute significantly to the spring season flows in the Himalayan rivers. In the Ganga basin for example, snowmelt is reported to contribute 5 to 20 percent of total annual runoff in different rivers (Table 2). A study by the National Institute of Hydrology has shown the contribution due to snow and glacial melt in the Ganga at Devprayag to be of the order of 35 percent. Estimation of volume of snowmelt runoff is, therefore, of vital importance for water resources planning and management.

The total water equivalent of snow cover depends on:

i) surface area of snow cover

ii) snow depth

iii) average density

Satellite imagery and other remote sensing techniques provide a real extent of snow cover over the catchment periodically. Snow depth observations are made by using snow stakes or by Gamma ray and ultrasonic depth monitors. Estimation of snow water equivalent, however, needs the use of gauges or other sensors which could provide estimates of density or weight of snow.

Water equivalent of snow is defined as the depth of water obtained by melting the whole snow cover over an area assuming there are no losses due to evaporation, infiltration and runoff.

In India, as in other parts of the world it has been the practice to observe snow depth using snow poles and snow stakes and use an average value of snow density to obtain the water equivalent of snow. However, in reality, snow density of freshly fallen snow varies with region, with individual storm events and often within the duration of a storm itself. It would, therefore, be necessary to measure the water equivalent of snow by determining the snow density to obtain precise information on water equivalent of snow.

A major problem in the Himalayas as in other regions of the world is the sparseness of data from higher elevations. It is generally noted that the stations are concentrated in valley locations. Thus relatively large amounts of precipitation which falls at higher elevations goes unobserved and is often underestimated.

Modern electronics have led to rapid advances in the development of telemetry systems suited for remote operations in harsh environments. Continuing development of new communication techniques permits access to precipitation and other meteorological data from remote stations on a real or near real time basis.

India has also made some efforts in this direction by setting up such a real time data acquisition system under the Yamuna flood forecasting system. The Indian Meteorological Department has set up a number of Data Collection Platforms (DCP) for data collection and transmission through satellite. However, very little effort has gone into using this technology for obtaining information on snow and other related data from remote and higher elevations in the different Himalayan river basins.

In the present paper an automated snow monitoring data acquisition, transmission and storage system for the Himalayan basins is proposed.

## 2. EARLIER STUDIES AND WORK CARRIED OUT IN INDIA

The importance of snowfall and seasonal snow cover over the Himalayan mountains during the winter months was recognised in the early nineteenth century. The beginnings of the study of snow cover and glaciers of the Himalayas could be traced to the observations of the snow line in the 1840's by some British geologists and surveyors (Vohra, 1981). Qualitative information was being collected monthly from officers incharge of mountain passes, travellers, etc. Their reports usually contained information on the number of days on which snow fell and a rough estimate of the quantity of snowfall during a month, thickness of snow cover on certain passes and stations at the end of a month, the lowest altitude to which the snow-fall reached during the month and a qualitative comparison of the snowfall in the month with that of a normal year. The data supplied were in the nature of estimates and often incomplete because the persons who supplied the information as well as those who recorded them were not trained for the purpose (Dhir and Harbhajan Singh, 1956). The decades following this were marked by some intermittent and incidental observations on the fluctuations of the Pindari glacier and the glaciers of the Karakorams.

In India snow surveys were conducted for the first time in the mid-forties. In 1947 two snow surveys were conducted under the guidance of Dr. J.E. Church from the Agricultural Experimental Station, Reno, Nevada, USA. Snow surveys were conducted in the Tamur and Teesta catchments. The report (Dhir and Harbhajan Singh, 1956) brought out after the survey contained information on precipitation and temperature measurements. Methods of forecasting streamflow from snow melt were also discussed.

After that there was a long gap in the snow monitoring activity in India. The Indian Meteorological Department has started measurements of snow water equivalent using a standard snow gauge since the sixties. The snow gauge receiver is made of copper 60cm deep with a diameter of 203mm. The gauge is protected by a nipher type wind shield and is generally mounted on a stand so that the rim of the receiver is at a height of 11.5m.

In areas where the precipitation is very heavy, snow depth is measured with the help of a snow pole. A square platform 2m x 2m and 75mm thick is made at the ground level in a place where drifting due to wind is the least. A 50 mm square wooden scale projecting 3m above ground level of the platform is grouted (IS: 4986).

The Snow and Avalanche Study Establishment under the Defence Research and Development Organisation started snow observations in the western Himalayan region from 1969 onwards. The daily observations of snow density and snow depth are transmitted to the SASE by wireless system from remote observatories for identifying avalanche formation zones and forecasting avalanches.

As a result of the network of high altitude observatories set up by SASE in the Western Himalayas, a fairly reliable data base regarding snow cover, snow precipitation, and its water equivalent and other meteorological parameters for the last 10 to 15 years is now available.

In 1983-84 the Central Water Commission under the Yamuna flood forecasting system installed a few electrically heated tipping bucket raingauges which act as precipitation sensors of the melted snow. The data is transmitted through VHF transmission and repeater stations to the master control facility at Sewa Bhawan, R.K. Puram, New Delhi, where the data is fed into a HP 1000 computer and used for flood forecasting of the river stage at the Delhi railway bridge. In 1986 a snow hydrology division was established at Shimla. The division has taken a small catchment at Sundli Nallah in the Yamuna basin for experimental studies. Here snow water equivalent is measured using a snow pillow and snow depth is measured using snow stakes. Also snow density is measured with the help of snow samplers at different locations in the catchment through snow surveys along predetermined snow courses.

The Bhakra Beas Management Board has started observations of snow water equivalent in the Sutlej from 1976 onwards and snow depth observations from 1983.

Snow cover mapping using satellite imagery has been attempted by a number of workers in India (Jeyaram and Bagchi, 1982, Dhanju, 1982 and Ramamoorthi, 1984). A review of the snow cover estimation using remotely sensed data was presented by Bhar and Ramasastri (1989). The satellite imagery received from IRS 1A and 1B are being used by the National Remote Sensing Agency (NRSA) to issue forecasts of spring season inflows into the Bhakra reservoir every year.

The first National Symposium on seasonal snow cover was held in New Delhi in April 1983 which brought together 100 delegates from different disciplines. Among the important recommendations, those relevant to snow monitoring and data acquisition were:

i) Concerted action is required to expand the network of observatories and data collection centres in the Himalayas for which both the central and state governments should extend help.

ii) Greater efforts and studies have to be put in by establishing many more observatories and using modern techniques and equipment with closer collaboration, and as an inter-disciplinary activity.

iii) A system be evolved to ensure better coordination and elimination of duplication and dissemination of data collected to all agencies.

With the assistance of USAID, a workshop and training session on snow hydrology was organised by CWC at Manali in 1988. Six experts from the USA, Canada and Switzerland participated in the workshop as resource persons. This workshop covered in a practical manner problems of instrumentation, network design, models for forecasting snow and glacial melt and also the applications of remote sensing for modelling. Use of operational models HYMET (Wendel Tangborn, USA) UBC (Michael Quick, Canada) and PRMS (George Leavsley, USA) was demonstrated. Though a number of recommendations were made, not much has been achieved by way of follow-up.

In spite of several organisations working in the area of snow and glaciers, an adequate network of observatories at higher elevations still does not exist and a clear picture of the total snow covered area and total volume of water which could be obtained from this important resource is not available.

## 3. EXISTING NETWORK OF SNOW MONITORING STATIONS IN THE INDIAN HIMALAYAS

Monitoring of snow in the Indian part of the Himalayas at present is essentially being done by the Indian Meteorological Department (IMD), Snow and Avalanche Study Establishment (SASE) of the Defence Research and Development Organisation (DRDO), Central Water Commission (CWC), and Bhakra Beas Management Board (BBMB). The forest department of Himachal Pradesh is also monitoring the snow. All these are, however, located only in the Western Himalayas covering the mountainous areas in the states of Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh. There is, however, no snow monitoring network in the eastern Himalayas covering the mountainous areas in Sikkim and Arunachal Pradesh.

The IMD has one snow gauge at Gulmarg in the State of Jammu and Kashmir, 13 snow gauges in Himachal Pradesh and nine in Uttar Pradesh. At eight locations in Jammu and Kashmir snow is monitored through eye observation. At two places in Uttar Pradesh snow depth is measured with the help of snow poles.

The SASE has snow monitoring locations at 31 stations in the western Himalayas out of which at 26 places snow density and snow depth is measured manually with the help of snow samplers and snow poles respectively. At five locations in the Beas basin snow density is measured with the help of IMD type snow gauges and snow pillows. At all these places other meteorological parameters like temperature humidity and wind are also measured. The SASE also has a few automated weather stations for real time data acquisition.

The CWC has 33 gauges in the Chenab basin where snow water equivalent is measured using IMD type snow gauges. In the Yamuna basin electrically heated tipping bucket snow and rain gauge is used at four locations and snow pillow at two locations near Jubbal for measuring snow density. Snow stakes are used for measuring snow depth. At all these locations other meteorological parameters are also monitored.

The BBMB has 21 snow monitoring stations in the Sutlej basin above Rampur upstream of the Bhakra Dam. At four places snow water equivalent, snow depth and other meteorological parameters are measured manually and at four places only snow water equivalent, snow depth and maximum and minimum temperatures are measured. At the other 13 places snow depth and snow water equivalent are measured using snow gauges and snow poles.

Details of snow measurement method used by the forest department of Himachal Pradesh are not known but it is reported that snow depth is measured by using a measuring scale.

## 4. NEED FOR NATIONAL SNOW MONITORING NETWORK

One of the most important parameters for hydrologic forecasting and research studies is the water equivalent of snow. Measurements of snow depth and snow water equivalent are required not only for obtaining general information about the winter part of precipitation but also for other purposes such as snow melt runoff forecasting, avalanche research and others.

The contribution of snowmelt and glacial melt to the snowfed rivers of India is well recognised. Though snowmelt may not form a large part of water resources as a percentage of total annual flow, its availability is timely as it starts in the spring season when the demand for water is more. In years of bad monsoons the subsequent spring season flows become all the more vital. A number of simulation models are available for simulation of snow melt and forecasting stream flows. These models require data of snow water equivalent, maximum and minimum temperatures and other data on a daily basis.

Though the network of observatory stations in the country and in the sub mountainous regions of the Himalayas is satisfactory, there is lack of sufficient data concerning the snow cover from the higher mountainous regions. It is well known that large amounts of snow reserves accumulate in the mountainous regions year after year. Although some manual and automated snow gauge stations are functioning in the Himalayas, the installation of the snow gauges has been guided by the availability of observers, site access and requirements of the concerned organisation. The result has been inadequate density and uneven distribution. Considering the variation in the amount and distribution of precipitation at different elevations in the Himalayas, there is need for installing more snow monitoring stations in the remote areas to ensure more reliable data about the snow depth and the snow water equivalent.

In the past, basic data of this parameter was obtained mainly by means of portable tubes used to measure periodically the depth and weight of cores of the snow pack at points along snow survey courses. In the past two decades notable progress has been made in the development of sensors to record *in situ* or measure and transmit data of snow pack water equivalent at an observation point. Depending on the system used, hydrometeorological information from remote areas can be transmitted at a time varying from a few seconds to a few hours after the observations are made. Such equipment permits extension of the snow monitoring network into remote areas and particularly to higher elevations of the mountainous catchments which were hitherto inaccessible for observations through snow surveys.

An integrated multipurpose national snow monitoring network is, therefore, proposed for observing data from high elevations in the Himalayas through modern electronic sensors and data acquisition systems and transmit the data in near real time to a central location for storage, processing and analysis.

## 5. THE PROPOSED SYSTEM

The objective is to:

i) design a national snow monitoring network for the western and eastern Himalayas

ii) to procure and instal automated weather stations for monitoring data of precipitation and other meteorological parameters and transmit the data through satallite

iii) to establish a centralised data receiving station for receiving precipitation and other meteorological data from the automated weather stations through the satellite

iv) to create a national centre for storage and processing of snow and related meteorological data and its dissemination to users.

### 5.1 Proposed Snow Monitoring Network

The existing snow monitoring network in the country is proposed to be strengthened with the installation of Automated Weather Stations (AWS) equipped with snow and radiation sensors at different high altitute elevations and remote locations. The basin wise distribution of the proposed AWS locations is given in Table 3.

## 5.2 Automated Weather Station (AWS)

The AWS is meant for remote areas where manual observations at frequent intervals are not possible due to inaccessibility and other logistic reasons. These stations are to be equipped with sensors having electrical output, a microprocessor and communication equipment. The programmed microprocessor controls the station functions and at preset intervals scans the sensors, compiles the data and transmits to a centralised location for storage and processing. Also to avoid loss of data due to transmission, on site data loggers with sufficient memory are provided. A typical AWS is shown in Figure 2.

*Fig. 2 A Typical AWS*

### Precipitation Sensor

Precipitation is measured either with an electrically heated gauge or snow pillow. The electrically heated gauge is fitted with a heater in conjunction with a thermostat whose cutoff temperature is set at two degrees Celsius to make the heater operational as soon as the ambient temperature falls below the set temperature. This gauge would, however, require power supply through batteries or mains.

The snow pillow sensor used for measurement of weight (water equivalent) of snow consists of four stainless steel thick scale tanks of size $120 \times 150 \times 1.27$ cu.cm. These pillows are connected to each other through a 1.27 cm diameter copper pipe. The snow pillows are filled with antifreeze solution of about 225 litres made from 50 percent methyl alcohol and 50 percent water. The pressure exerted on the pillows by the fallen snow is converted to an analogue signal by a pressure transducer. The pressure transducer consists of the transducer and signal conditioning circuit and is connected to the copper pipe coming from the pillows through a reducer. The signal conditioner conditions the electrical output for transmission to the feeding recorder.

### Temperature

The measurement of a ambient temperature is carried out through a probe consisting of a semi conductor which produces current in micro amperes in proportion to temperature.

### Humidity

A transducer is used for relative humidity sensor which produces an electrical output.

### Wind

A dual channel anemometer is used for recording wind speed and direction. Optoelectronic type anemometer and variable resistance contact type wind are used.

### Radiation

Measurement of shortwave radiation is done through a pyranometer and net (short wave +/–long wave) is measured with a net radio meter.

The sensing element consists of blackened thermopile covered with polyethylene wind shield domes. The electrical output can be used for transmission of data.

### Data Acquisition System

The data acquisition is done through microprocessors attached to the AWS which processes the data for visual digital display as well as storage on solid state memory which can last for several days. The processed data is also transmitted through an antenna which is hooked up to the satellite.

### Power Supply

Since power supply through mains or batteries is difficult in mountainous and remote areas the AWS would be operated through solar powered batteries.

## 5.3 Data Transmission

Though VHF transmission is reliable and economical, in view of the large areas and the distances involved and also problems of line of sight which is difficult to obtain in mountainous terrain, satellite communication through an Indian satellite is contemplated.

## 5.4 Satellite Link Equipment

Downlink equipment would be required to receive data from the satellite through a satellite earth station. These equipment would be located at the central data receiving station.

## 5.5 Infrastructural Facilities

The infrastructural facilities required include the following:

i) building at the central data storage and processing station

ii) insulated huts at the field stations for scientific teams visiting the stations for checking and maintenance

iii) mini computer facility at the central data storage station for receiving data, processing and analysis

iv) personal computers for data analysis, preparation of summaries and data dissemination

v) electrical equipment like uniterrupted power supply, voltage stabilisers, diesel generator

### 5.6 Manpower Requirements

Since all the snow monitoring stations would be automated, no manpower would be required in the field. However, an officer at the middle level has to be stationed in each region for periodical inspection of the field stations and reporting their condition. At the central data storage station, scientists and engineers trained in data processing and analysis would be needed for receiving the data, processing and storing it.

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**Table 3 : Basinwise Proposed Network of Automated Weather Stations for Monitoring Snow**

| Station | Elev. | State |
|---|---|---|
| **Indus** | | |
| 1. Dras | 3066 m | Jammu and Kashmir |
| 2. Kargil | 2682 m | Jammu and Kashmir |
| 3. Leh | 3514 m | Jammu and Kashmir |
| 4. Rhumtse | 4260 m | Jammu and Kashmir |
| 5. Chumar | 4500 m | Jammu and Kashmir |
| **Jhelum** | | |
| 1. Hansraj | 3970 m | Jammu and Kashmir |
| 2. North Portal | 2200 m | Jammu and Kashmir |
| 3. Verinag | 1850 m | Jammu and Kashmir |
| 4. Qazigund | 1739 m | Jammu and Kashmir |
| 5. Kokernag | 1920 m | Jammu and Kashmir |
| 6. Dachigam Forest | 2800 m | Jammu and Kashmir |
| 7. Pahalgam | 2110 m | Jammu and Kashmir |
| 8. Satur | 3100 m | Jammu and Kashmir |
| 9. Chandanwari | 3500 m | Jammu and Kashmir |
| 10. Aru | 2400 m | Jammu and Kashmir |
| 11. Bhairoghati Pass | 4800 m | Jammu and Kashmir |
| 12. Sonamarg | 2745 m | Jammu and Kashmir |
| ]3. Gangbal | 4800 m | Jammu and Kashmir |
| 14. Astanbal | 3853 m | Jammu and Kashmir |
| 15. Gurez | 2417 m | Jammu and Kashmir |
| 16. Gulmarg | 2655 m | Jammu and Kashmir |
| **Chenab** | | |
| 1. Chhoma Chhumkhor | 5000 m | Jammu and Kashmir |
| 2. Tilput Got | | Jammu and Kashmir |
| 3. Matsal | 4325 m | Jammu and Kashmir |
| 4. Mau | | Jammu and Kashmir |
| 5. Ratigot | | Jammu and Kashmir |
| 6. Davigol | 2450 m | Jammu and Kashmir |
| 7. Dusadudha | 2440 m | Jammu and Kashmir |
| 8. Bunnecha | 2600 m | Jammu and Kashmir |
| 9. Bhadarwah | 1830 m | Jammu and Kashmir |
| 10. Kishtwar | 1615 m | Jammu and Kashmir |
| 11. Hawal | 2745 m | Jammu and Kashmir |
| 12. Tillai | 2130 m | Jammu and Kashmir |
| 13. Sinthan Pass | | Jammu and Kashmir |
| 14. Wakbal | 4835 m | Jammu and Kashmir |

Contd. ...

| | | | |
|---|---|---|---|
| 15. | Tashipura | | Jammu and Kashmir |
| 16. | Shupkanjan | | Jammu and Kashmir |
| 17. | Sarkund | 2350 m | Jammu and Kashmir |
| 18. | Inshan | 2440 m | Jammu and Kashmir |
| 19. | Rikhiniwas | 3660 m | Jammu and Kashmir |
| 20. | Patnitop | 2300 m | Jammu and Kashmir |
| 21. | Ramban | 2000 m | Jammu and Kashmir |
| 22. | Gohala | 2400 m | Jammu and Kashmir |
| 23. | Banihal | 1625 m | Jammu and Kashmir |
| 24. | Mohim | 2440 m | Jammu and Kashmir |
| 25. | Sain | 2240 m | Jammu and Kashmir |
| 26. | Baralachala | 4890 m | Himachal Pradesh |
| 27. | Milang | | Himachal Pradesh |
| 28. | Chandratal | 4300 m | Himachal Pradesh |
| 29. | Batal | | Himachal Pradesh |
| 30. | Chatru | 4300 m | Himachal Pradesh |
| 31. | Koksar | 3615 m | Himachal Pradesh |
| 32. | Gondla | 3144 m | Himachal Pradesh |
| 33. | Keylong | 3500 m | Himachal Pradesh |
| 34. | Patsuo | 3800 m | Himachal Pradesh |
| 35. | Ramjak | | Himachal Pradesh |
| 36. | Khanjar | | Himachal Pradesh |
| 37. | Udaipur | 2600 m | Himachal Pradesh |
| 38. | Killar | | Himachal Pradesh |
| 39. | Phalphu | | Himachal Pradesh |
| **Ravi** | | | |
| 1. | Bara Bhangal | | Himachal Pradesh |
| 2. | Mani Mahesh | 4267 m | Himachal Pradesh |
| 3. | Bharmour | 1981 m | Himachal Pradesh |
| 4. | Kugti Pass | | Himachal Pradesh |
| 5. | Sutkar | | Himachal Pradesh |
| 6. | Triund | 2827 m | Himachal Pradesh |
| 7. | Khajjiar | 1951 m | Himachal Pradesh |
| 8. | Dalhousie | 1957 m | Himachal Pradesh |
| 9. | Kalatope | 2440 m | Himachal Pradesh |
| 10. | Subhash Baoli | 2085 m | Himachal Pradesh |
| 11. | Dainkund | 2745 m | Himachal Pradesh |
| 12. | Jandhri Ghat | 2036 m | Himachal Pradesh |
| 13. | Bakrota | 2085 m | Himachal Pradesh |
| 14. | Dhankad | 4300 m | Himachal Pradesh |
| 15. | Kalicha Pass | 5000 m | Himachal Pradesh |

Contd. ...

| | | | |
|---|---|---|---|
| 16. | Bhangar | 2500 m | Himachal Pradesh |
| 17. | Tissa | 2570 m | Himachal Pradesh |
| 18. | Alwas | 3000 m | Himachal Pradesh |
| 19. | Satdhara | 2827 m | Himachal Pradesh |
| **Beas** | | | |
| 1. | Hamta Pass | | Himachal Pradesh |
| 2. | Sara Umga Pass | | Himachal Pradesh |
| 3. | Chanderkhani Pass | | Himachal Pradesh |
| 4. | Chhorang | | Himachal Pradesh |
| 5. | Manikaran | 2000 m | Himachal Pradesh |
| 6. | Beli | 4000 m | Himachal Pradesh |
| 7. | Khalan | 3000 m | Himachal Pradesh |
| 8. | Gushaini | 2500 m | Himachal Pradesh |
| 9. | Banjar | 2000 m | Himachal Pradesh |
| 10. | Charkera Thatch | 3500 m | Himachal Pradesh |
| 11. | Bashelo Pass | 3500 m | Himachal Pradesh |
| 12. | Jalori Pass | 3300 m | Himachal Pradesh |
| 13. | Chauri Khas | | Himachal Pradesh |
| **Sutlej** | | | |
| 1. | Hansa | 3975 m | Himachal Pradesh |
| 2. | Lossar | 4079 m | Himachal Pradesh |
| 3. | Kaza | 3639 m | Himachal Pradesh |
| 4. | Tabo | 3260 m | Himachal Pradesh |
| 5. | Malling Dogri | 3811 m | Himachal Pradesh |
| 6. | Namgia | 2910 m | Himachal Pradesh |
| 7. | Pooh | 2835 m | Himachal Pradesh |
| 8. | Sumdo | 3232 m | Himachal Pradesh |
| 9. | Kalpa | 2439 m | Himachal Pradesh |
| 10. | Rachkcham | 3130 m | Himachal Pradesh |
| 11. | Chitkul | 3841 m | Himachal Pradesh |
| 12. | Narkanda | 2774 m | Himachal Pradesh |
| 13. | Shillaroo | 2600 m | Himachal Pradesh |
| 14. | Shimla | 2202 m | Himachal Pradesh |
| 15. | Chail | 2250 m | Himachal Pradesh |
| 16. | Kasauli | 1927 m | Himachal Pradesh |
| 17. | Naldhera | 2044 m | Himachal Pradesh |
| 18. | Kufri | 2622 m | Himachal Pradesh |
| **Upper Yamuna** | | | |
| 1. | Theo | 2500 m | Himachal Pradesh |
| 2. | Kothkhai | | Himachal Pradesh |
| 3. | Rohru | 2500 m | Himachal Pradesh |
| 4. | Chaopal | 2000 m | Himachal Pradesh |

Contd. ...

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|---|---|---|---|
| 5. | Chithwari | 3000 m | Himachal Pradesh |
| 6. | Purola | 2000 m | Himachal Pradesh |
| 7. | Kharsali | 2591 m | Uttar Pradesh |
| 8. | Rana | 2147 m | Uttar Pradesh |
| 9. | Yamuna Chetty | 1595 m | Uttar Pradesh |
| 10. | Chakrata | | Uttar Pradesh |
| 11. | Mussoree | 2042 m | Uttar Pradesh |
| **Upper Ganga** | | | |
| 1. | Bairanghati | 2865 m | Uttar Pradesh |
| 2. | Rishikund | 1900 m | Uttar Pradesh |
| 3. | Uttarkashi | 1800 m | Uttar Pradesh |
| 4. | Badrinath | 3000 m | Uttar Pradesh |
| 5. | Kedarnath | 3000 m | Uttar Pradesh |
| 6. | Gangotri | 3200 m | Uttar Pradesh |
| 7. | Gaurikund | | Uttar Pradesh |
| 8. | Mana | 3200 m | Uttar Pradesh |
| 9. | Harsil | | Uttar Pradesh |
| 10. | Niti Pass | | Uttar Pradesh |
| 11. | Malari | 3000 m | Uttar Pradesh |
| 12. | Joshimath | 1875 m | Uttar Pradesh |
| 13. | Ghangaria | 3077 m | Uttar Pradesh |
| **Ramganga** | | | |
| 1. | Ranikhet | 1876 m | Uttar Pradesh |
| 2. | Garur | 1900 m | Uttar Pradesh |
| 3. | Nainital | 1953 m | Uttar Pradesh |
| 4. | Mukteshwar | 2311 m | Uttar Pradesh |
| **Upper Sharda (Sarayu, Kali and Dhauliganga)** | | | |
| 1. | Munsiyari | 3414 m | Uttar Pradesh |
| 2. | Bageswar | 2000 m | Uttar Pradesh |
| 3. | Tijjim | | Uttar Pradesh |
| **Teesta** | | | |
| 1. | Muguthang | 4500 m | Sikkim |
| 2. | Donkong | 5000 m | Sikkim |
| 3. | Umthang | 3500 m | Sikkim |
| 4. | Chholomo | 5000 m | Sikkim |
| 5. | Thanggu | 4500 m | Sikkim |
| 6. | Lachen | 4500 m | Sikkim |
| 7. | Chungthong | 3800 m | Sikkim |
| 8. | Pentong | 3500 m | Sikkim |
| 9. | 15th mile on Nathula Road | 3200 m | Sikkim |

Contd. ...

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| **Brahmaputra** | | |
| 1. Tewang | 2914 m | Arunachal Pradesh |
| 2. Bomdila | 2484 m | Arunachal Pradesh |
| 3. Sebba | 2200 m | Arunachal Pradesh |
| 4. Zaro | 3000 m | Arunachal Pradesh |
| 5. Anini | 3580 m | Arunachal Pradesh |
| 6. Tezu | 3400 m | Arunachal Pradesh |