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STATUS REPORT ON SNOW SURVEYS

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PREFACE

Accumulation and ablation of snow depends upon the climatic conditions and topography of the basin. In general December to March is considered accumulation period while April to June/July is considered ablation period in the Himalayan region. The information on snow water equivalent,snow depth and snow density in a watershed is considered an important tool for snowmelt forecasting. For this purpose snow courses are established in the basin and measurements are taken in different parts which are representative of the basin. This report deals broadly with the selection of snow courses ,instruments used in snow surveys, sampling procedures, documentaion formats and requirements of the field party. The instruments have been discussed in detail. A status of snow surveys in India is presented in this report. This report has been prepared by Dr Pratap singh, Scientist'B', National Institute of Hydrology, Roorkee.

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1.0 INTRODUCTION

Snowfall in India is controlled by the winter weather system caused by movement of western distrubances. The snow that accumulates in a draiange basin is a natural storage reservoir. The normal snowfall season in India is considered form middle of December to April, but there are some fluctuations in the snowfall season. In the summer season the snow melting starts and melt water significantly affect the hydro-electric power production, irrigation, water supply and flood control.

Unlike rainfall, snow being solid precipitation does not result into total processes of runoff immediately after it falls on the ground. It's density varies with time. It is observed minimum at the time of occurence and then gradually increases when it becomes older and get compressed. Consequently, mere measurement of depth of fresh snowfall does not help in quantitative estimate of snowmelt runoff.

The importance of assessing snow accumulation is quite obvious where a great part of the annual precipitation is falling in solid form. The water equivalent of the accumulated snow helps in assessing water resources potential of the deposited snow. Hydrological models used for prediction of generated runoff essentially include either total precipitation or the water equivalent of snow cover.

The most simple and reliable standard method of obtaining snow water content is by gravimetric measurement using snow tube to obtain a sample core. This method serves the basis for field snow surveys described below.

2.0 SNOW SURVEYS

Snow Surveys are made at regular intervals at snow courses throughout the snow accumulation and ablation periods to determine the depth, vertically integrated density and water equivalent. An estimate of the mean snow cover water equivalent over an area is obtained by this technique. Variability of the water equivalent is also assessed by snow survey network in a watershed.

2.1 Snow Course

A conventional snow course is defined as a permanently selected line of marked sampling points and length in snow accumulation area along which snow depth, density and water equivalent measurements are made each year. Few general rules for establishing ideal snow courses are listed below.

2.2 Selection of Snow Course

Snow courses must be carefully selected, so that measurements of water equivalents will provide a reliable index of the water in snow storage over the entire basin.

2.3 Representativeness of Watershed

Since the purpose of a snow course is to provide a representative sample of the snow in a watershed, the elevation, aspect and other conditions of the course should represent the area that produces the water. An elevation must be selected where there is a minimum of preseason melting. The course should not be so high that the area sampled is too small to represent a major water-producing elevation zone. An area-elevation map of the basin aids materially in determining this point. A snow course of an elevation and aspect that is usually bare of snow when the information is needed for forecasting is of little value.

A snow course must be located in an area free of ponded water resulting from poor drainage. A gently sloping terrain is preferred to a flat area or a steep slope. Individual sampling points should be located remote from ground irregularities such as boulders, fallen logs or shrubs. Areas affected by snow removal operations should be avoided.

2.4 Measurement Points

In the hilly terrain the length of conventional snow course generally ranges from 120 to 270 m in length along which observations are taken 20 to 40 m apart. In plain regions, the distance between points of snow sampling with density measurements should be 100 to 500 m and measurement made at about five equally spaced points. More samples will be required in large open area where snow will tend to drift owing to wind action. Since sufficient knowledge of the tendency of the snow to drift is lacking initially, it is expedient ot provide for an extensive survey having long traverses and a large number of measurements. For a new snow course in an area for which adequate information about snowcover is not available the best practice is to over sample i.e. use long lines and a high sampling density. On reappraisal of the data collected for 5 to 10 years, the length of the course and the number of sampling points may be reduced suitably to minimum, depending on the accepted level of acuuracy. Usually ten sampling points in hilly and five in the plain regions are selected for a permanent snow course, once the prevailing length and direction of the snow drifts have been ascertained.

The length of a snow course, the number of sampling points and the distance between them may vary from one course to another depending upon the local site conditions and the unformity of the snowcover. Any large obstruction on or near the line may require increasing or decreasing the interval for one or more sampling points. Also, the course may take a shape other than a straight line. Some typical shapes of snow courses are illustrated in Fig.1.

In most countries the stratified sampling procedure is at present only used by researchers in special surveys designed to obtain an absolute estimate of snow water equivalent. Agencies operating snow courses for the purpose of runoff prediction usally operate a standard snow course survey of 5 to 10 points; the same numbers of depth and density samples are taken. Since the sampling points are at fixed locations, repeatability and compatilibity of successive samples are possible.

For conceptual hydrological modelling, the snow course water equivalents should be as close as possible to the average actual water equivalent of the snow cover over the basin. Before establishing a snow course it is to be decided whether an index or an absolute estimate of snow water equivalent is required. When data are used as an index then it is important that equipment, procedures and siting of the course remain consistent over time. If absolute snow water equivalent values are required, the representativeness of the terrain and landscape is an important factor in network design since it affects the

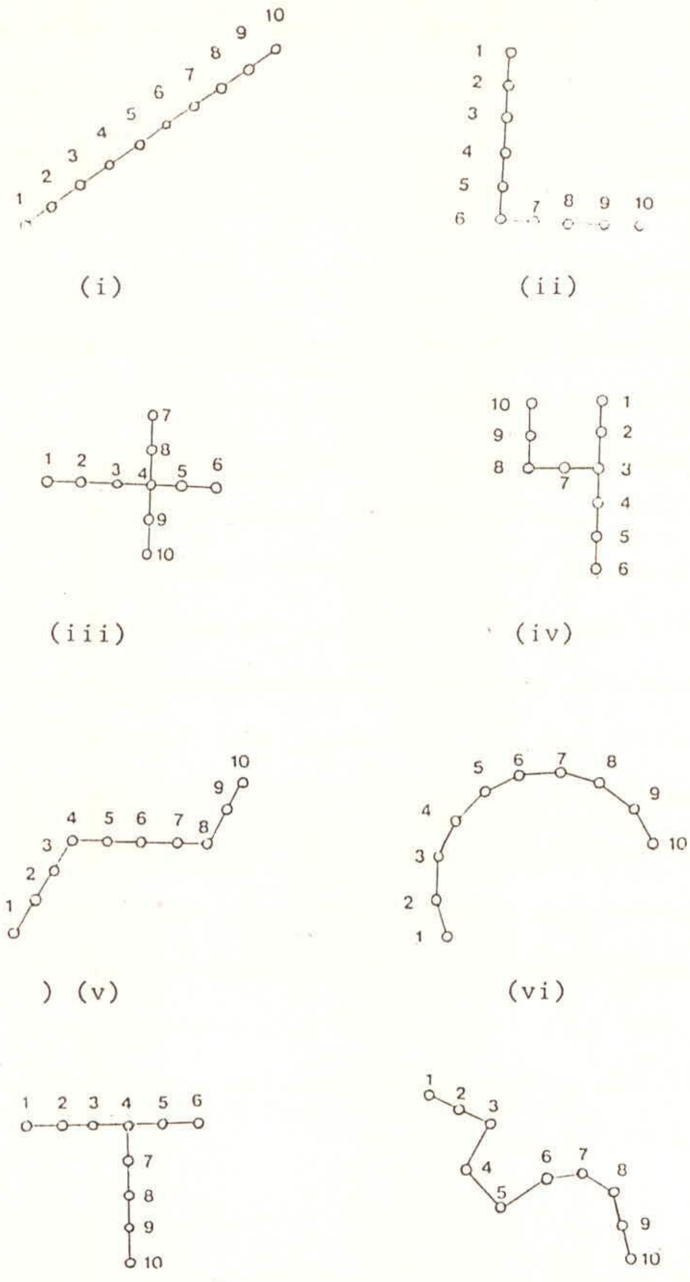


Fig.1 Some typical shapes of snow courses

representativeness of the snowcover. Because the data are to provide an index for predicting a volume of runoff, it would appear that the more data available, the more accurate the forecast will be done. But there is a practical limit to the data that can be gathered because of physical, financial and other limitations.

2.5 Accessibility

Each watershed has its peculiar forecast requirements and problems. In most places the best snow courses for forecasting purposes are the most difficult to reach because most of the snow zone is not readily accessible. It is also observed that in most cases precipitation increases with elevation. The rate of increase in most cases appears to be linear with elevation with the amount of scatter depending on the aspect, slopes and windiness of the area. The increase with elevation cannot, of course, the extended upwards indefinitely. The course at the higher elevation, therefore, is usually the best because it usually correlates seasonal snowmelt runoff better than one at medium or lower elevation, but is of no value unless it can be measured on schedule. Accessibility, therefore, is an essential criterion in snow course selection. The site should be accessible by foot, skis or vehicle.

2.6 Aspect

The direction which a watershed or sub-basin faces will affect the amount of additional lift to the air, thus increasing the cooling process and the condensation rate, and hence the amount of precipitation. To illustrate, if winds are from the east, an east facing slope will create more lift to the air than one facing southeast and hence will recieve more precipitation. Similarly a north-facing slope provides the maximum accumulation of snow because winter melt is minimal. Southern or western slopes, except at the highest elevation should be avoided as well as areas on the lee side of a hill where large amounts of snow may accumulate from drifting. Orographic effect from massive topographical features must, therefore, be kept in mind while establishing a snow course.

2.7 Slope

The degress of steepness of the general terrain will likewise affect the amount of precipitation. Steep slope should be avoided as the movement of the snowcover destroys the integrity of the masurements. Sampling difficulty increases with slope.

2.8 Canopy Cover

The amount and kind of forest cover directly influences the amount of snow that accumulates at a given site. Snow courses above timberline generally are not satisfactory because of wind. Experience and research have shown that snow courses located in snow protected mountain meadows have a minimum of drifting and are generally ideal sites. Dense forest cover should be avoided. Large cones that form around trees may give unrepresentative measure of snow depth and water equivalent.

2.9 Others

Another factor in slecting a site is security. A snow course should not be placed in a good stand of marketable timber that may be cut. Any major change in ground cover or timber stands due to fire or logging operations will change the snow course measurements and negate the historical records, and should be avoided. The site should be selected so as to yield consistent results over time. The permanency of site and the continuity of record are key factors in site selection.

3.0 SNOW COURSE NETWORK DESIGN CRITERIA

Until new techniques for measuring areal precipitation are fully developed and yield accurate result on testing, point measurements will remain the primary source of data. These point measurements may provide reliable estimates of the spatial distribution of precipitation. Therefore emphasis must also br given for network design, that is, the number and spacing of the measuring points.

Snow data from a network of snow courses or from a special snowcover survey provide estimates of the mean depth, density and water equivalent over a selected area. The accuracy of these estimates depends on the representativeness of the sample, whose determination requires a minimum number of observations which varies for each survey.

The general criteria for an efficient snow course network are similar as that of an efficient precipitation network. It requires answers to the following primary questions.

- What is lthe cbjective(s) of the study ? For what purpose are the data to be used.
- What data are required to achieve the objective ? What time resolution and accuracy are required ?
- What is the most suitable aids available to provide the required data ? How accurate are the point measurements
- What financial and manpower resources are available ?

The answers to these primary questions vary from basin to basin and region to region. The design of a regional network varies with the scope and purpose of the individual study, and depends greatly on the regional physiography. In those regions where snow is an important climatological variable,network planning, development and operation is difficult. More areas have common problems, such as, difficult access, severe climate. Less than ideal siting conditions (meteorological and topographical features), high cost of operation. Because of these problems, some compromise is to be made. For example, mountainous regions stations are usually located at accessible valley locations, even though most of the land and snowfall is at higher elevations.

Accurate estimate of basin snowcover depth, density and water equivalent can be obtained from a snow course network specially designed to represent local landscape characteristics. In a region where rapid temporal and spatial changes in the snow cover are common, a snow course with fixed sampling points provide regular, compatible, and repeatable measurements throughout the winter. Sampling of only one type of land use results in a biased estimate useful only as an index of the basin snowcover. If the aim is to develope accurate and physically meaningful hydrological models, the use of indices and optimized parameters must be minimized.

4.0 SNOW SURVEYING INSTRUMENTS

The basic snow surveying equipment commonly consist of a graduated tube with a snow cutter fixed at its lower end, and a spring or lever balance for determining the weight of the tube and its contents. The balance readings are directly in snow water equivalent units. Besides the spring balance, accessories include a wire cradle for supporting the tube while it is being weighed, a driving wrench or turning handle, and spanner wrenches for operating the snow sampler. Most snow tubes are made of aluminium, other are fibreglass or plastic. A large diameter shallow snowcover samplers are a single tube; the smaller diameter for deeper snowpacks are in sections for easier portability.

4.1 Cutter

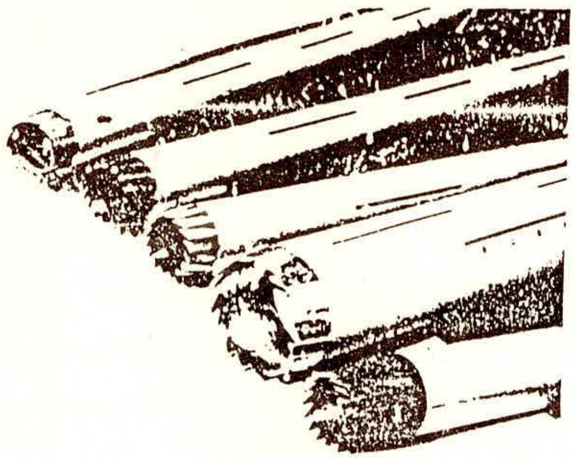
The cutter is designed to penetrate the various types of snow, through crusted and icy layers, and in some cases solid ice layers of appreciable thickness which may form near the surface. The cutter must not compact the snow to avoid an excessive amount of snow to be accepted by the interior of the cutter. It is designed so that it may seize the core base with sufficient adhesion to prevent the core from falling out when the sampler is withdrawn. Small diameter cutters retain the sample much better than large cutters, but larger samples increase the accuracy in weighing. A large number of teeth provide a smooth cut and keep the cutter free of large chunks of ice. The Mount Roise Sampler, widely used in North America, utilizes a steel cutter with 16 teeth and an inside diameter of 3.77 cm. Cutter of this size gives satisfactory results if the snow depth is greater than 1 m (WMO, 1981). A set of snow surveying instruments is shown in Fig.2.

4.2 Sampling Tube

In snow sampler's tube, the inside diameter of the driving tube is larger than the inside diameter of the cutter. The core, therefore, is able to proceed up the tube with a minimum of interference from friction on the wall. In normal snow, the core will tend to move over and rub on the side walls of the driving tube. The wall, therefore, should be as smooth as possible so that the core may proceed upward without undue friction. The practice of waxing and polishing both the inside and outside of the tube helps to minimize friction between the snow core and the inner wall of tube and to present the ltube from sticking in snow, however, recent tests have shown that baked silicone coating on the tubes is more effective and durable than wax for these purposes. The snow tubes made of plastic, fibreglass, or heavy gauge aluminium have sticking problems since they do not conduct heat as readily under conditions with marked differences in air and snow temperatures.

4.3 Weighing Apparatus

The standard way to measure the water equivalent of snow samples is to weigh the snow core taken up by the sampler. The core is retained in the sampler and sampler with core is weighed. The weight of sampler is known. The spring balance is the most practical approach as it may be easily set-up and read even under windy conditions. The scale balances, potentially more accurate, are very difficult to use specially in wind.



Snow Cutters

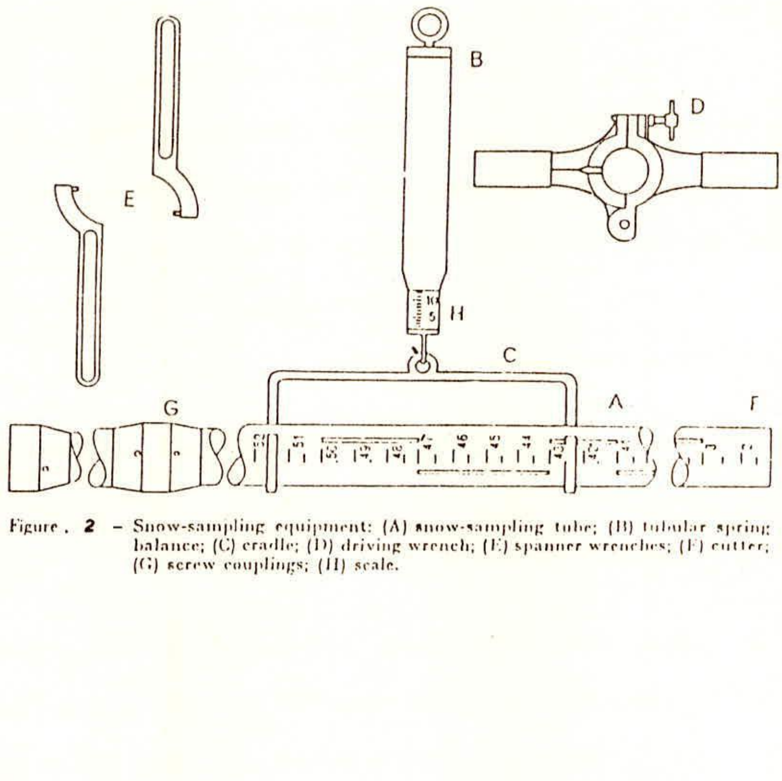


Figure . 2 – Snow-sampling equipment: (A) snow-sampling tube; (B) tubular spring balance; (C) cradle; (D) driving wrench; (E) spanner wrenches; (F) cutter; (G) screw couplings; (H) scale.

5.0 SNOW SAMPLING PROCEDURES

Sampling points should be located by measuring from a reference mark as indicated on the map of the snow course. Missing one of these points by more than a few metres may result in an error.

To cut the core, the sampler, cutter end first, is forced vertically downward into the snowpack with a stready thrust until it reaches the ground. A small amount of turning in a right-hand direction aids in driving the sampler tube and cutting thin ice layers; however, considerable force and twisting of the sampler with the driving wrench may be required to penetrate hard layers of ground ice.

With the cutter at or slightly below ground level and the sampler standing vertically, the reading on the scale that corresponds to the top of the snow is observed. When the depth of sampler has penetrated beyond the bottom of the snow cover is ascertained and deducted from this reading, the result is recorded. This is an important reading, since it is used in computing the snow density.

To prevent loss of core through the cutter end while the sampler is withdrawn from the snow, sufficient soil is gathered in the cutter to serve as a plug.

The length of snow core obtained is observed through the tube slots and read on the scale on the outside of the sampler. After this reading is corrected for any foreign matter picked up in the cutter end, it is recorded.

When a good snow core is obtained, the sampler with core is weighed and the combined weight in water equivalent units is read directly with the spring balance, The tare weight of the tube is subtracted to obtain the snow water equivalent.

The density of the snow is computed by dividing the water equivalent of the snow by the depth of snow. A large deviation from the average usually indicates an error in measurement at an individual point.

When the snow water content is less than 5 cm of water, it is generally difficult to read the weighing scale accurately for single sampling points. To sample these shallow snows the following procedures can be used.

Take a sample at the sampling point. Empty the core into a bucket or any container that can be tied to the weight scale. If the emply container used is not heavy enough to record an empty weight on the scale, additional weights must be added. Record the depth of snow and length of core on notes. Then repeat the procedure at all the remaining sampling points of the snow course. Finally weigh the container when all the sample cores have been accumulated. Find the weight of the container without core but with additional weights, if added. The difference of these two weights will be the water content of the bulk sampled. To obtain average water content on the snow course, divide total water content by total number of sampling points.

When sampling deep snow, drive the sampler rapidly. Try to keep it moving continuously until soil is reached. The following steps will help to meet this difficulty.

Two snow surveyors jointly with a hand over hand motion should drive the sampling tube vertically down at the sampling point. Keep the sampler in motion and grab the handle of the driving wrench and push down. If the tube stops, one man steps on the handles and drive if down to the soil with his body weight and a pumping action of the knees while balancing himself against his partner's shoulders.

Table-2 illustrates a convenient format for recording snow survey information in the field. Sucha form also provides for the documentation of any problems encountered while surveying thaυ may affect the accuracy of the survey and interpreation of the results.

Snow course data may be used for preparing quantitative streamflow forecasts and for calculating indices of snow cover depth and water equivalent. The accuracy of other snowcover measurement techniques, both ground based and with remote sensors, are commonly judged against snow sampler measurements which are still regarded as the best approximation of the true snow water equivalent.

Despite careful observation by the observer, error does creep in the results. It is important, therefore, to know the type of equipment used and the error associated with measurements from different samplers.

The accuracy of measurements of snow depth or the water content of snowcover, at separate points of the snow course, employing the most widely used instruments, depends on the graduations of the scales in question and on instrumental and subjective random errors.

The decrease of the errors for snow depth or water content can be achieved by taking the mean of measurements at each separate point. Reports on tests carried out by various agencies to assess the relative performance of different samplers under difficult sampling conditions and to determine their accuracy and consistency in sampling suggest that a snow sampler with sharp cutter can provide reasonable accurate sampling. A snowpack consisting of light snow and depth hoar can be sampled with a reasonable degree of accuracy with conventional equipment. There is apparently no loss or gain of snow core through the slots of the conventional samplers. Also, the experienced snow surveyors can closely read the tabular scales more consistently than inexperienced surveyors. For shallow snowcovers, a larger diameter sampler is recommended to obtain a larger core to reduce the measurement error.

6.0 DOCUMENTATION

Once a satisfactory site has been found, the snow course and trail to it should be marked, mapped and documented to make them easy to locate under adverse winter conditions and deep snow.

Each sampling point should be located by measuring its distance from a reference point marked on a map at the snow course. Individual points are often marked with numbered metal tags nailed to trees near the sampling point or to wood or metal poles set at the points. Stakes set high enough to extend above the deepest snow and be placed as standard makrers opposite each point where snow samples are to be taken. If course meanders through timber and if small openings are used as places of sampling, each point may be located in respect of two or three marked trees, as necessary to minimise possible error in locating the sampling point. End points and angle points should be marked with a steel pipe of about 40 mm diameter set in concrete. Standard snow course markers should be bolted securely to the top of the pipes and the pipes painted organge or red and yellow. This method ensures accurate location of sampling points and is convenient for surveyors.

Tables 1 & 2 show examples of the standard snow course markers, and maps, respectively, most widely in use. All maps should have the standard map heading and title block. Pertinent data are recorded on a snow course biography form as illustrated in Table -1. Documentation of snow course should be updated from time to time.

Table 1 : DOCUMENTATION OF SNOW COURSE INFORMATION

Snow Course No. ________

GENERAL

Region: ____________________

Drainage: ____________________

Maps: ____________________

Climate Station: ____________________

Stream Gauging Station: ____________________

Mountain Range: ____________________

Range Faces: ____________________

AT SNOW COURSE SITE

Elevation: ________ Latitude: ________ Longitude: ________

Reference Markers: ____________________

Exposure Aspect: ____________________

Canopy Cover: ____________________

Ground Slope: ____________________

Tree Types: ____________________

Undergrowth Density: ____________________

OTHER INFORMATION

Access: ____________________

Cabins: None ____________________

Co-operator: ____________________

Sampler: ____________________

Address: ____________________

____________________ Phone No. ________

Date Established: ________ By: ____________

Remarks: ____________________

Table 2 : FORMAT FOR RECORDING SNOW SURVEY INFORMATION

Snow Course No. ______________
Name : ______________________
Sampler ______________ Date ________________

Station No.	Snow Depth (cm)	Weight tube & Core	Wt. Tube only before Sampling	Water equivalent (cm)	Core length (cm)
Total					
Average					

Checked______________________________ Date______________________________

SNOW SAMPLING: Began__________ a.m. p.m. Ended __________ a.m. p.m.

Sampling Conditions

(Please check items descriptive of present conditions)

Weather at time of sampling. Temp.____________oC

______Clear ________Snowing
______Partly Cloudy ________Blowing
______Overcast ________Freezing
______Raining ________Thawing

Snow Conditions at Snow Course

__________Crusted-supports man on skis/snowshoes
__________Breakable crust-breaks under man on skis/snowshoes.
__________Snow soft and powdery-non sticky.
__________Snow soft and wet-sticky.
__________Snow samples obtained easily.
__________Snow samples obtained with moderate dificulty.
__________Snow samples obtained with extreme dificulty.
__________Ice layer on ground. How thick? ________cm.
__________Ground frozen under snow.
__________Ground not frozen under snow.
__________Ground dry under snow.
__________Ground damp under snow.
__________Ground Ground wet (saturated) under snow.

General Snow Conditions

What elevation is snow-line generally? __________
Is snow melting on north and east slopes? __________
Is snow melting on south and west slopes? __________
How many centimetres of fresh snow at snow course?__________
Is there evidence of snow-slides? __________
Weather conditions of past month
__________generally overcast and stormy.
__________generally clear and cold.
__________generally clear and melting.

REMARKS: ____

7.0 CARE OF SAMPLING EQUIPMENT

Taking good care of sampling equipment can make the difference between a good survey and a poor one. Here are some basic rules which one must follow:

- Handle the equipment carefulluy to prevent damage.
- Do not cling to the sampling tubes while sampling on steep slopes.
- Keep the sampler tub covered inside and out with a thin coating of wax or a waxing compound.
- Ice and rock feel and sound similar when struck. Before one exerts pressure, be sure for ice striking.
- Keep lthe cutter sharp and orifice true to its original diameter.

8.0 CHECKING EQUIPMENT OTHER FIELD REQUIREMENT

Before Leaving headquarters on a snow survey trip, the following items should be checked:

- Sampling tubes properly waxed
- Spannner wrenches
- Thread protector
- Driving wrench
- Field data notebook
- Snow course map
- Pencil
- Weighing scale and cradle
- Measuring tape
- Snow survey safety guide
- First aid kit
- Snow survey sampling guide.
- Goggles
- Snowshoes-varnish coating, webbinb, bindings
- Skis-running surface, bindings, poles, climbers
- Oversnow vehicles-fule and oil
- Check your clothing and that of your companions.

It is much easier to check these items at headquarters where replacements are available than at the snow course site.

9.0 CLOTHING & PERSONAL EQUIPMENT

All clothing of the snow surveyors should help to retain body heat as well as allow freedom of movement so that the blood can circulate without restriction. Loose fitting, lightweight warm clothing (preferably woolen) in several layers is the best dress for outdoor work in cold weather. Several layers with air space between fibres and layers are effective insulation to retain body heat.

To protect you from wind and snow, your outer garment should be tightly woven, water repellent (not waterproof), have a parka hood. A full-length front zipper is preferably. Wear a hood full enough to protect most of your face. One should be able to cover mouth to provide warm breathing and protect your lungs from very cold air.

Similarly a snow surveyor should have two or three pairs of thermal socks, water-repellent thermal trouser having elastic holddowns to go under the arch of the foot to hold trouser leg in shoe. He should have leather-palmed canvas mitten and large soft rubber-rimmed goggles with dark smoke-coloured plastic lenses etc.

For use in emergency, a snow surveyor must carry in pockets the following essential articles.

- Wooden matches (waterproof), Butane lighter is good substitute
- Pocketknife (Boy scout type)
- Compass, not too small
- Trail food-nuts, raisins, gum, fruit drops, sugar cubes
- Large kerchief
- Ointment-for lips or burns
- Flashlight
- Face mask or scarf

The snow survey team should have a walkie-talkie set for link with the cap site in case of emergency.

10.0 WORK AND TRAVEL GUIDELINES

All the surveying team members must undergo a physical examination before the beginning of the travel season as a safety measure.

Designate a member of the snow survey party as leader usually the one most fimiliar with the terrain to be travelled.

Employees making snow surveys should always work in parties of not less than three men to avoid personal hazard.

When working in severe cold weather, move and act slowly. Avoid windy areas. The orderly collection of basic data over wide areas and cover long periods of time is the fundamental task of the major meteorological and hydrological services in the world. The results from studies conducted by various agencies involved in snow data observations sugggest that accuracy of data depends somewhat on the experience of the observer and type of instruments used. The persons having long practical experience of the observer and type of instruments used. The persons having long practical experience and skilled in these works could produce more accurate data with the same equipment than others. Thus maintaining consistency in data observation is the basic requirement. Those who must work with the practical aspects of snow surveys should stimulate interest in it.

The accuracy and reliability of snow survey measurements depend equally on the integrity, and training of the individual snow surveyor. Although the measurement of snow and other variables is not a complex procedure when operations go well, the snow surveyor must know how such measurements are obtained. He must also understand what to do when situations are unusual.

Experience shows that regardless of the skill of the individual in other fields, the best snow surveyors are those who are trained specifically in snow surveying both in classroom (theory) and in the snow (practical). Of equal importance is the safety of the snow surveyor. Field snow survey involves personal hazard, avoid calculated risk.

11.0 STATUS OF SNOW SURVEYS IN INDIA

A meeting was held in August 1946 between the Central Waterways Irrigation and Navigation Commission (the predecessor of Central Water Commission) and the India Meteorological Department to consider and lay down a general policy for collection of hydrological data in which snow surveying was discussed. It was decided to invite Dr. J.E. Church, the then Meteorologist, Agricultural Experiment Station Reno, Nevada, U.S.A. and later President of the International Commission on Snow and Glaciers, to visit India and initiate snow surveys and stream flow forecasting in the Himalayas and also to impart necessary training to Indian personnel in this science. Accordingly, a formal invitation was sent by CWINC to Dr. Church in December, 1946 to visit India. Dr. Church had initially proposed the Satluj river basin to layout a system of snow surveys but as there was no past precipitation and river flow data available for any site above snowline in that basin, it was decided that the first snow surveys might be started in the Kosi and the Tista basins. Dr. Church arrived in India in March 1947.

For the purpose of snow surveying some equipment were pruchased from U.S.A. which included a snow mobile and snow samplers. Procurement of sufficient quantities of blankets, overcoats, ground sheets sleeping bags, mittens, marching boots, raincoats, water proof bags and sheets, duffle bags, tinned food, sugar, cereals and kerosence oil, etc. were made locally.

Two snow survey parties were made under the overall guidance of Dr. Church, one for snow surveys in the Tamur catchment, a tributary of the Sapt Kosi and the other for the Tista catchment. Darjeeling was fixed up as a base camp for both the parties. Dr. Church himself was in the second reconnaissance expedition which traversed East, North and South Sikkim in Tista catchment. The reconnaissance teams comprised of Indian officers dealing with irrigation, engineering, hydroelectric engineering, geography, geology, meteorology, botany, forestry and soil conservation etc.

The first reconnaissance party was led by Sh. J.Banerji, I.F.S. and included besides a representative of the Govt. of Napal, 3 other members. The area was surveyed from 17.3.47 to 28.4.47. The team started their trip from Darjeeling (3064 m.) and reached upto Khangla Deorali (5582 m) origin of the Yangma Khola, a tributary of the Tamur. The team tentatively selected 4 snow courses in the Tamur Valley and made snow measurement.

In the second team there were 23 members including a singal unit of 4 wireless operators, one mechanic and an officer in-charge. The team was led by Dr. Church. As mentioned earlier, this team made three reconnaissance expeiditions to cover the Tista basin. The first trip comprising East Sikkim Route was made from 3.4.47 to 9.4.47 in Sikkim upto Natu La (4298 m) through Gangtok. The team slected tentatively the following three snow course.

(i) In the compound of Chhangu Bungalow (3749 m)
(ii) On the slope of the hill opposite Chhangu Bungalow.
(iii) At Natu La (4298 m)

There was not enough snow to be sampled as it had melted by the time of the year.

The party made its second trip to North Sikkim along the Tista river upto Himalayan Club Hut (4572 m.) on the Jha Chu, a tributary of the Tista, from 10.4.47 to 25.4.47. They conducted snow surveys south of Club-hut at various spots, but only 4 observations were considered worth retaining.

The third and last trip, this party made from Darjeeling was upto Romo near Chiya Bhanjyan (3292 m) along the ridge between Sikkim and East Nepal border during the period 3.5.47 to 14.5.47. By this time there was no snow but the party provisionally selected the following 15 snow course.

(i) Two at Chiya Bhanjyang (3292 m)
(ii) Three along route from Phalut down to Rangeert Valley (3353 m)
(iii) Two between Phalut and Sandakphu (3353 to 3658 m)
(iv) Seven between Sandakphu to Tanglu (2957 to 3292 m)
(v) One at Tanglu Bungalow (3063 m.)

During the expedition Dr. Church gave a practical demonstration of how to lay out a snow course sample snow at various points and record observations, use of fushine dye to study the metling of snow and the manner of systematised surveys. However, the party was somewhat late in reaching the desired spots for snow survey observations and the snow had melted away leaving fast melting patches. The details of covered area and route are given by Dhir and Singh (1956).

The reconnaisance cum snow survey teams left Darjeeling on 16th May 1947 and reached back to Delhi on 23rd May 1947 via Calcutta.

With the partition of the country in Aug.1947, Tista Project was dropped as the benefits from it were going to then East Pakistan. Snow surveys were therefore, confined to Tamur catchment only. In Nov.-Dec.1947, snow courses were marked in this catchment at heights between about 4000 to 4700 m . Lower down the discharge sites were fixed. Regular snow measurements were started early in 1948. Since little or no snow could be found at the snow courses, the snow surveyors went higher up. Even at the altitude of about 5300m , the average depth of snow was about one foot, and it was fast melting. In view of the above it was decided to take more set of measurements before arriving at any conclusion . During the next year, i.e. 1949, measurements were, however, restricted to only two sub-basins of the Tamur catchment. Snow Surveyors left their base camp in Feb.1949 and were at the snow courses by 1the due date i.e. 1 March,1949. They went as high as about 5700 m but the results obtained even during this year were not encouraging. It was difficult to go above the height 5700 m. Therefore, relatively deeper snow would have been small, and its the area covered by it would have been small, and its contribution to river run-off could not, therefore, be very significant. Snow surveys thus seemed to be failing at least in this region.

Thereafter no regular efforts continued for snow surveys. In March-April, 1981 snow surveys were conducted by a team including IMD and BBMB participants to understand the physical characteristics of seasonal snowcover and its variation with time and space in the Beas basin. These results were used to estimate the total volume of water accumulated in the form of seasonal snow and evaluation of theoretical snowmelt run-off in the upper Beas catchment.

Since 1984 snow surveys are also being carried out by CWC in an experimental Sundli Nallah watershed at Jubbal (H.P.). The demonstration has been given by CWC surveyors to the participants from IMD, UPIRI,NIH,SOI under activities of Snow & Ice Panel of INCOH activities.

12.0 REMARKS

Snow surveys are made to obtain fairly accurate observation of seasonal snowcover, its water equivalent and density in the fixed snow courses. Various "Snow courses" representative of various aspects, terrain characteristics and elevations are to be established and studied. Snow courses should be carefully selected so that measurements of water equivalent may provide a reliable index of the water in snow storage over the entire basin. The review of literature reveals that very limited snow surveys have been carried out in our country. The very rugged topography of the Himalaya may be one of the reason for it. Such topography make accessibility very difficult to the sites in the Himalayas.

The accuracy of snow sampler is largely determined by the ability of the sampler to cut and retain the snow core. The tests have shown that Sharp Federal sampler is found suitable for use in all type and depths of snow cover. It contains a 76.2 cm aluminium tube and its cutter has 3.77 cm internal diameter with 8 teeth. It can easily sample the snowcover having depth more than 5 m.

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