SNOW SURVEY TECHNIQUES IN THE WAITAKI CATCHMENT, SOUTH CANTERBURY

T. J. H. Chinn*

ABSTRACT

A brief outline is given of observations being made on seasonal snow at snow courses in the Waitaki catchment, and of glacial snow on the Tasman Glacier. Mention is made of measuring equipment used, and the accuracy of readings is discussed.

Sampling difficulties are often caused by ice layers and high-density snow; melting of ice layers also creates difficulties in interpreting summer samples. To overcome this problem without digging pits, a circular shaft, constructed of corrugated iron, has been installed on the Tasman Glacier. This enables snow layers to be marked and sampled at any depth within the shaft.

Loss of records has often occurred because sampling-site marker poles have been overtopped or broken by strong winds; poles consisting of lengths of PVC piping supported by one guy wire have been found partially successful in preventing this.

INTRODUCTION

Experience in snow-measuring techniques and the use of snow samplers has been steadily accumulating since the first Ministry of Works Hydrological Survey snow course was established for the winter of 1963 at the Devils Elbow catchment. Subsequent courses to study seasonal snowpack variations were established at Round Hill (1965) and Ohau (1967), and glacial snow observations commenced on the Tasman Glacier in 1965. Because of unfavourable topography, the Devils Elbow course was closed after the winter of 1965.

The overall objectives of this snow and ice work are as follows:

(1) Collection of data for a water balance and for water resource requirements.

(2) The determination of glacier variations (for water-balance and IHD purposes and as an aid in determining climatic changes).

(3) The collection of data for multipurpose forecasting procedures, including hydro-electric power design.

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* Water and Soil Division, Ministry of Works, Timaru.

FIELD METHODS

Seasonal Snow

The problem of setting out a net of snow-sampling points is similar to the problem of establishing a network of representative rain gauges within a catchment. To sample the complete snow cover of a catchment, samples should ideally be taken on a grid pattern over the whole basin, but in practice this is quite unfeasible. More viable arrangements are usually made by sampling along section lines or courses, usually across the basin following a contour line. The figures for this type of survey give an index of catchment snow cover which may be used for run-off or comparative snow studies.

To simplify field work the present courses have been arranged in the form of sampling points, marked by permanent poles, arranged in a straight line up the centre of the catchment. The Round Hill area has an additional traverse along the crest of the catchment. From this sampling-point arrangement, snow variations resulting from morphology of both wind-swept areas and areas of excess accumulation are sampled, but the averages for any one survey give a good index of the catchment snowpack. This enables comparisons of snow depths at various altitudes to be made. Normally one sample only is taken at each pole after a number of soundings have been made to ascertain a mean snow depth.

All the earlier surveys were made with the Italian C.N.I. sampler and steelyard, weighing directly in grams. In 1967 the Federal or Leupold and Stevens "Mt Rose" sampler was tested, and this instrument is now used on all the surveys. It has a 3.77-cm inside diameter, compared with 7 cm for the C.N.I. instrument, and is favoured because of the easier use of the spring weighing scales which read directly in water equivalents, and because it can penetrate to greater depths in the higher-density glacier snow.

Accuracy of Readings

Direct field weighing of snow cores in the tubes is influenced by even moderate winds, which may increase the readings by 2 cm to 4 cm of water equivalent. On an average seasonal snowpack core of, say, 25 cm water equivalent, wind can cause an error of +8% to +16%.

Snow depths are often difficult to determine, especially when the snow is supported by tall tussock, or covers uneven rocky ground. The sampling tube penetrates to the ground surface, and any air gaps under the snow, or crevices between rocks, cannot be detected. To eliminate this problem, 4 ft × 4 ft white plywood plates have been manufactured for laying at the poles of the Ohau course. Errors of this nature give increased snow-depth readings of from 1 cm to 10 cm. On a 60-cm snow-depth core sample, with a density of 25%, the error in the density calculations would be in the order of −0.5% to −3.5%. (Note that there is no error in the water-equivalent values, as these are read directly off the spring balance.) Snow-depth readings are taken from the graduated scale on the corer tube and are read to the nearest 1 cm, while water-equivalent readings on the spring balance are graduated for each 2 cm and are read to the nearest 1 cm. For various snow densities a family of curves may be drawn which give the magnitude of the error for the snow depth measured, as illustrated in Fig. 1. It can be seen that either very accurate readings, or longer samples taken horizontally, should be made where snow depths are less than 20 cm (i.e., in the range of snow-density error of 0.04 g/cm^3, and greater).

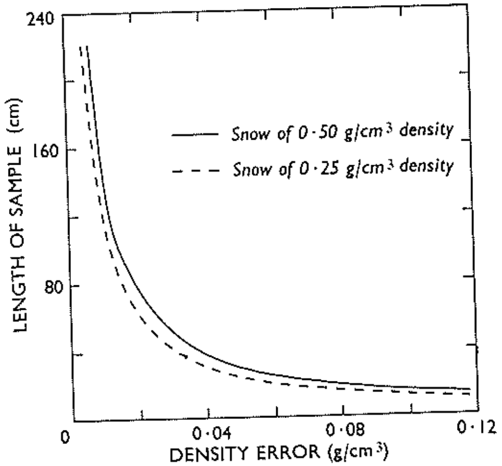

FIG. 1 — Error in density values. Showing the accuracy obtainable when both the sample length and the water equivalent are read to the nearest ±0.5 cm.

From a limited comparison of results from both the C.N.I. sampler and the Mt Rose sampler, made on the same survey, no significant differences were detected. Again, when the Mt Rose sampler was compared with a 500-cm^3 snow tube, values for fresh snow on the Tasman Glacier gave a general agreement to within 2 percent for the snow densities. Work *et al.* (1965) have shown that most snow samplers tend to overmeasure the water equivalent of snow. With the Mt Rose sampler, this error ranges from about +7% in a light shallow snow, to about +10% and over, in deep snow of higher density.

To obtain data to within 10 percent accuracy therefore requires careful field work, especially when working conditions are unfavourable.

Under favourable conditions, when snow depths are read to the nearest 1 cm and water-equivalent values also to the nearest 1 cm, the snow-density figures can be given only to the nearest

±0.01 g/cm³ for samples taken over 50 cm depth, and to ±0.05 g/cm³ for samples that are under 20 cm snow depth.

Glacial Snow

The techniques used for the actual sampling of glacial snow are similar to those employed on seasonal snow courses, but many additional methods have to be employed to mark the base of the snowpack and the sampling site.

On a glacier there is a definite line, the 'equilibrium line', above which the net result of winter snowfalls and summer melt is a positive accumulation of snow over one glacial year. Below this line there is a net loss comprising the winter snowpack plus some ice which has been transported by flow from higher altitudes. Glacial studies should aim at providing the volumes in cubic metres of the net gain and the net loss over both of these areas. The difference between these two values is then the mass balance of the glacier. In addition, the winter balance, or maximum accumulation of winter snow, and the summer balance, or the total loss by summer ablation, may be measured.

On the Tasman Glacier, because of its larger size (approximately 29 km long and 3.5 km wide in the névé area) only partial balance studies are being made. The Geological Survey of the Department of Scientific and Industrial Research have carried out ablation studies over two years in the area below the equilibrium line, together with localized snow studies in the firn area (I. C. McKellar, pers. comm.). Because the size of the firn area is too large to be covered adequately by sampling points, and as there is no contoured map of the region yet available, the results of snow studies cannot be given in terms of volumes. Instead, a series of sampling points on one section line, approximately along the centre of the glacier, has been established. From these sites balance studies of water-equivalent depths or specific water-equivalent values are made, and these give an index of the behaviour of the glacier. Owing to lack of suitable equipment and available staff, summer ablation studies are not attempted below the equilibrium line.

At present the following data are being collected:

(1) The winter balance (b_w) throughout almost the entire length of the glacier.

(2) The summer balance (b_s) which is partially measured in the névé area.

(3) The net balance (b_n) which is measured above the equilibrium line.

A check on the b_s measurements is obtained from the relationship

$$b_n = b_w - b_s.$$

Because there is no defined 'ground' surface from which to take measurements except the previous year's snow surface, and because the maximum depths and densities reached by the snow cannot be fully penetrated and sampled by the coring equipment, the accumulating snow is measured by increments. At each survey site a layer of coal dust is laid to mark the base of the new season's snowpack. The sites are then visited at one- to two-monthly intervals, when layers of sawdust are laid to separate the various snow layers. On each visit the snow above the previous marked layer is sampled.

FIELD-WORK PROBLEMS

Adverse weather conditions and deep snowfalls, accumulating up to 13 m in the upper névé areas, have caused many gaps in the records by preventing access to the course and overtopping the sampling-site marker poles. These poles, used to locate the marked snow layers, are of rigid PVC piping of 1½ in. diameter. This material is much lighter than steel piping and cheaper than aluminium tubing. No known instances of this type of pole being broken by high winds have been recorded as yet on the Tasman Glacier, but considerable difficulty has been experienced in providing sufficient pole length to prevent overtopping without exposing too great a pole length to wind stresses. Previously it has been the practice to install these poles by joining 1-m lengths and guying them with four guys anchored to buried sacks. However, it has been found that the guy anchors, being in the lower-density surface snow, subside by compaction at a faster rate than does the pole — causing the latter to bend considerably (Fig. 2). This year, single-length 6-m poles were tried with only one guy wire — with complete success. When these poles require additions, socketed 1-m lengths glued together to prevent any parting by wind-flexing are added. One guy only is used to correct any lean on the pole. With maximum snow depths ranging from 6 m at the equilibrium line to 13 m in the upper névé, the required length of a single pole may reach some 15 m by the end of the winter season.

The poles themselves are not used for measuring the snow depth as they are often bent or overtopped, and their bases move down through the lower snow layers because of the downward friction forces of the fast-compacting upper snow layers.

The usual sampling problems include some difficulty in penetrating to the required depths. Pit studies have been considered, but with the great snow depths, and densities reaching to over 0.60 g/cm^3 towards the end of the year, the time required for each survey visit would be greatly increased. This is not only because of the additional work involved, which would take up to 4 or 5 days, but also because the normal duration of a fine-weather spell is about 3 to 4 days, making the work subject to many more weather delays.

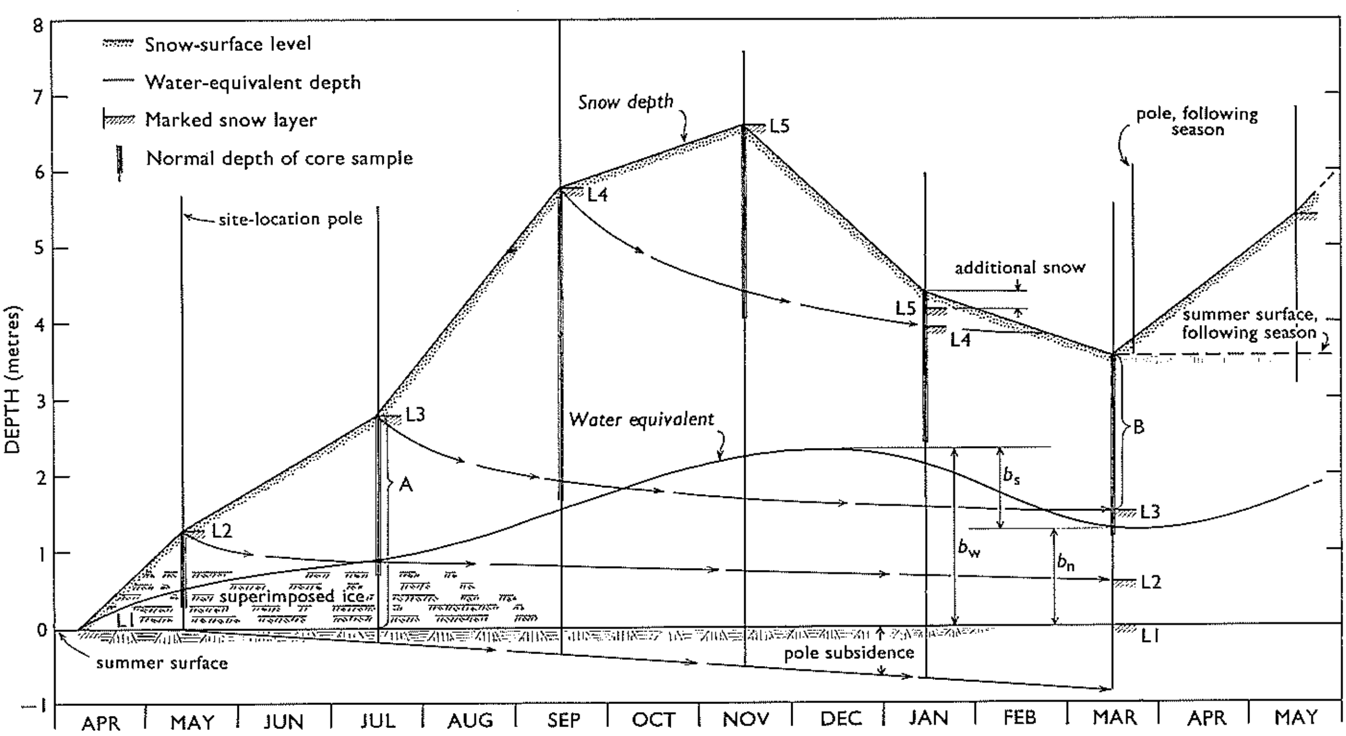

FIG. 2 — Depth-time diagram of snow depth and water equivalent, showing compaction movement of poles and marked layers. Net balance b_n is the sum of the water equivalent for A, survey 2, and the water equivalent for B, survey 6.

Ice bands and high-density snow often make it extremely difficult to reach the required depths. It has been observed that the more difficult it is to take a sample, the greater may be the error in the results. Ice bands in low-density snow often plug the cutter of the tube which then can often be pushed down as a rod, picking up no further snow below the ice band.

Early in the winter, with alternate rain and snowfalls, both the previous season's snow and the new snow freeze into layers of superimposed ice which cannot be sampled with a snow sampler. These ice layers appear to be under a lateral stress which allows an expansion after a snow sampler has passed through, often preventing its withdrawal.

The superimposed ice layers, however, disintegrate with percolating meltwater and rainwater during the summer season, thus obliterating a defined base to the year's snowpack. This fact prevents the year's snow depth from being measured by the usual probing methods. The previous summer's dust layer also appears to percolate downwards with the water movement, preventing the summer surface from being recognized in a core sample. A stratigraphic study was made of a crevasse wall adjacent to where a core sample had been taken with a SIPRE corer the previous year, and a comparison of the stratigraphic columns showed that the summer-surface dirt band had divided and appeared to have migrated some 30 cm to 90 cm downwards. Unless the first layer of coal dust is located there seems to be no method of determining the net snow depth at the end of summer, apart from the digging of pits. Pits of some 4 m to 8 m depth in snow compacted from 0.60 g/cm^3 would be required.

To eliminate this problem at the upper pole, situated at an altitude of 2,340 m, a shaft structure has been installed to give access to the lower snow levels. The structure was first installed on the summer surface at the beginning of the 1968 winter. It takes the form of a 1-m-diameter hollow tower, constructed from circular sections of corrugated galvanized iron, with a built-in ladder and a removable snowproof lid. On each visit further sections are added to the shaft to keep the top above the expected snow level of the next visit. This shaft should be semipermanent, allowing access down to the base of the 1968 snowpack for many years if additions are continued.

At present the structure is some 14 m in depth and has been extensively deformed by snow compaction and flow, but the cross-sectional area has remained unchanged. The marker layers of each survey visit have been pegged inside the shaft and these pegs have been tied by survey to a nearby bench mark on bedrock. This will enable a velocity profile of the flow of névé snow to be measured.

After sufficient snow depth has accumulated above a marked level, the corrugated iron is cut away from the side of the shaft to

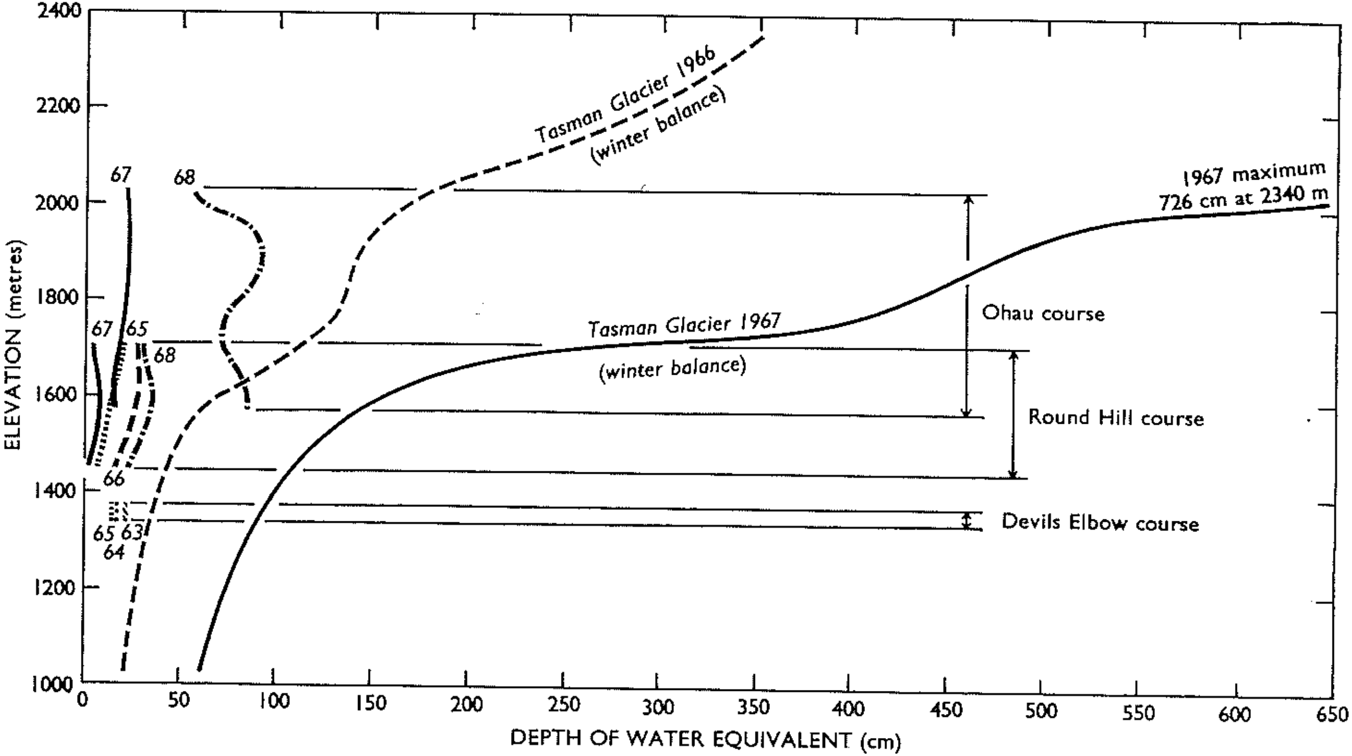

FIG. 3 — A comparison of maximum winter-snow water equivalent depths with altitude for the four courses, for various years. The curves for the seasonal snow courses are plotted from averages of a number of results over selected altitude ranges.

give access for snow sampling. As the shaft itself will influence the surrounding snow, at least the first metre of any horizontal sample taken from inside should be discarded. To date, no successful means has been developed to obtain samples from this snow, which reaches densities of 0.80 g/cm^3. If a SIPRE corer becomes available, this instrument should be suitable for the purpose.

In addition to obtaining an absolute value for the net balance at this point, the shaft could provide information on the movement of meltwater, on the processes of firnification, and on névé flow behaviour.

CONCLUSION

The present snow-survey methods for seasonal snow appear to be adequate for present requirements, but may have to be refined for any special studies that may be undertaken in the future. The great variations in snow depths at the same altitude (Fig. 3) resulting from such factors as aspect, local weather patterns, and topography demonstrate the complexity of the snow cover within the Waitaki Basin region.

The net balance values for the higher altitudes on the Tasman Glacier are not absolute, but are a sum of results from both early-winter and end-of-summer surveys. At present these figures are determined by measuring the water content to the deepest layer reached by the sampler, and to them is added the water equivalent up to this layer as measured early in the winter. This assumes that any meltwater or rainwater passes completely through the snowpack for the year. When snow-density figures from the Tasman Glacier shaft become available, this hypothesis can be tested, together with a comparison of the accuracy of the surface samples.

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