THE DESIGN OF SNOW SAMPLERS FOR CANADIAN SNOW SURVEYS

by

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A standard snow sampler consists of a cylindrical tube with a cutter on the end to allow the tube to penetrate vertically into the snow. The interior of the cutter is held to a precise diameter and the desired operation is to cut the snow sharply without compacting it so that the core entering the cutter will proceed up the interior of the tube with a minimum of compression and effectively represent a cylindrical cross-section of the snow cover. To make an adequate measurement the entire cylindrical core from the upper surface of the snow to the underlying soil must be removed and weighed.

The important design problems are discussed below -

1. The Cutter

The cutter is a most important feature of a sampler and must be 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. It must not snowplow or compact the snow so that an excessive amount of snow is accepted by the interior of the cutter. The cutter must seize the core base with sufficient adhesion to prevent the core from falling out when the sampler is withdrawn.

It might appear that a large diameter cutter would give less error than a small cutter. If it is assumed that an error which may occur around the cutter wall will cause an effective error r in the radius of the core,

$$M = L \times r^2 \times .578$$

M = mass in ounces taken by the sampler

r = radius of cutter (inches)

L = equivalent depth of water (inches)

$$\frac{\Delta M}{M} \times 100 = \frac{2\Delta r}{r} \times 100$$

It follows that the percentage error in the measure of water equivalent due to the edge effect is inversely proportional to the radius of the cutter. This line of argument assumes that similar types of cutter teeth will cause the same error per inch of cutter circumference regardless the circumference of the cutter. This may not be self-evident. However, one might be led to conclude that a large diameter cutter would tend to reduce errors of this type.

It is necessary that the cutter retain the sample core when it is withdrawn from the sampling hole. In some cases, it is necessary to let the cutter penetrate into the frozen ground and the presence of dirt or leaves on the end of the sampler will tend to assure that the entire snow core has been sampled. Small diameter cutters retain the sample much better than large cutters. In the case of large cutters, e.g. 3" in diameter, it is in some cases difficult to retain the snow when it is very dry and fluffy. In this case, it is necessary to dig down and hold the snow core in with a suitable spatula. This equipment provided in the case of the Russian sampler.

The force acting down on the cutter walls is proportional to the mass of the core held up. If it is assumed that the upward force per inch of circumference is K then K = 1/2 Lr x .578 oz./inch. It follows that a greater adhesive force at the wall is required with a large cutter. This partially explains the difficulty encountered with larger diameter cutters in retaining the core and indicates that care must be taken to design the cutter with some type of adhesive lip on its inner side to provide some effective resistance to the downward fallout tendency of the core.

The shape of the cutter teeth is a matter of considerable importance. In cutting through icy layers where the icy material is approximately incompressible, it is necessary to allow sufficient backfeed on the cutter to remove the ice chips. It is also desirable to keep the cutter as thin as practicable, but in general somewhat larger than the outside diameter of the driving tube. This construction allows the chips to find a dumping area when carried backward by the feed on the cutter. The horizontal cutting surface on the cutter blade should be sloped slightly backward to carry the chips away from the interior of the cutter and should be kept sharp so that there is a definite separation of the snow at the inner wall of the cutter.

The number of teeth will have some bearing on the operation of the cutter. In the case of the Mount Rose Sampler, it appeared that the sixteen tooth version is superior under certain circumstances to the eight tooth version. The widely spaced cutter teeth tend to break up the icy material into relatively large chunks which jam into the cutter and may be one cause of the plugging of certain varieties of Mount Rose Samplers. The sixteen tooth cutter, however, while making a smoother cut and allowing slower rotation, makes the cutting procedure more difficult in terms of effort.

The Sampler Tubing

In most cases, the inside diameter of the driving tube is larger than the I. D. 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, however, the core will tend to move over and rub on the sidewalls of the driving tube. It is necessary, therefore, to make certain that the walls are as smooth as possible so that the core may proceed upward without undue friction. In general, the Mount Rose type samplers are constructed of aluminum alloy and anodized. While the surface may appear smooth, it cannot be assumed that this will assure non adhesion of the snow especially when sampling is made of wet spring snow with a coarse grained structure. The application of wax may improve the properties to the tube in regard to sticking.

The Mount Rose Samplers are provided with slots so that the core length may be determined. In general, especially with wet snow, due to compression, the core length inside may be considerably different from the true depth of the snow measured on the outer scale markings on the sampler. The slots also provide an entrance for a cleaning tool. The slotting arrangements has an advantage in that gross errors due to plugging may be immediately detected and obviously erroneous samples discarded at once. However, it has been alleged by certain authors (3) that in the case of very long samplers, e.g. (10 feet or more) the slots allow extra snow to enter the sampler and thereby increase the apparent measured water content by as much as six percent in some cases when compared to similar sampling made with a tube without the slots. This error was found apparently to be insignificant in lesser snow depths. The reason given for the entrance of snow at under deep snow conditions is that the excessive twisting that is sometimes necessary in penetrating the snow layers will force the exterior snow into the sampler via the slots.

The standard Mount Rose type Sampler is constructed in 30 inch lengths which may be screwed together. This Sampler when provided with the sufficient extensions may be used to penetrate snow up to a depth of 30 feet.

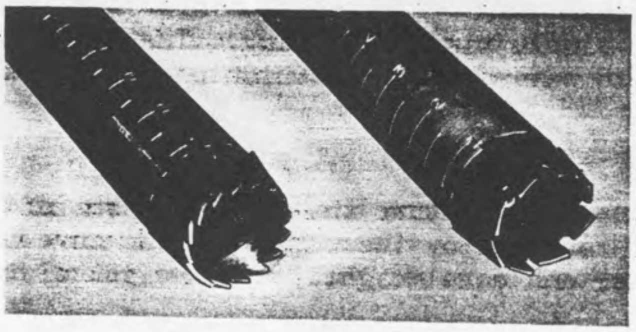


Photo 1 Carpenter Cutter Leopold and Stevens Cutter

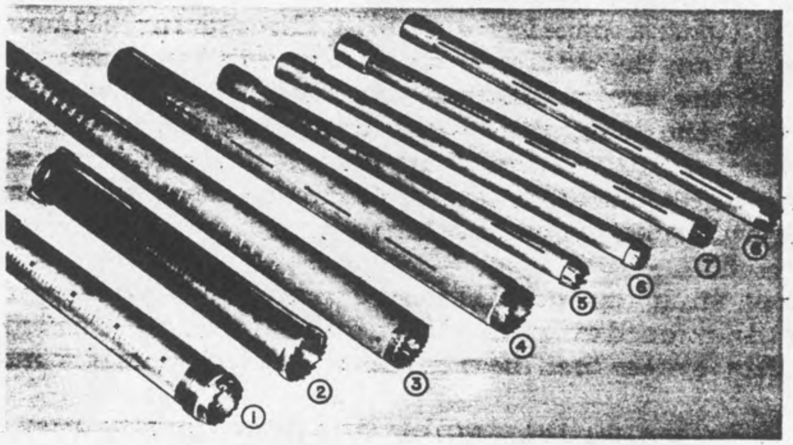


Photo 2 (1) Italian CN-1 (2) Soviet BC-3 (3) Prairie Sampler (4) Monette Type (5) Hydraid (6) Exco (7) Carpenter (8) Leopold and Stevens

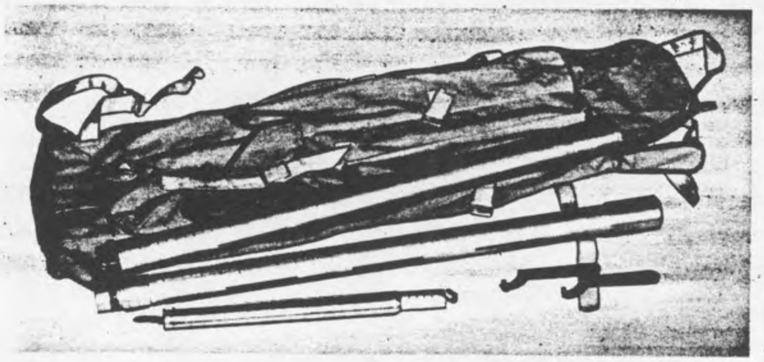


Photo 3 Typical Mount Rose Kit

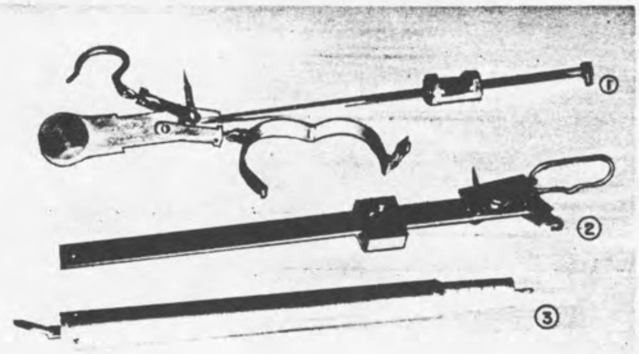


Photo 4 (1) Italian Scale (2) Soviet Scale (3) Mt. Rose Balance

Larger diameter samplers such as the Russian type and the so-called Prairie type consist of a single piece of tubing. The Italian Sampler, on the other hand, is built in several lengths which may be screwed together.

The Weighing Apparatus

The standard method used to measure the water content of the snow samples is to weigh the snow core taken up by the sampler. The core is retained in the sampler and the sampler and core weighed. The weight of the sampler has a known constant value.

The weighing is generally accomplished by means of a spring scale or by a special balance. The spring scale used for the Mount Rose type sampler is cylindrical in shape and has a capacity of 135 ounces which allows depth up to 15 feet to be measured (with a density of 30%). The spring balance is the most practical approach as it may be easily set up and read even under windy conditions. The accuracy of the spring balance, however, leaves something to be desired. In the case of the Mount Rose Sampler, where the radius is small, one ounce represents one inch of water equivalent. The balance can hardly be accurate to more than ±0.3 ounces and error of this order become an appreciable in a percentage sense at low water equivalents.

The scale balances while potentially more accurate, are very difficult to use especially under windy conditions. It is doubtful if the intrinsically greater accuracy of this system can be realized except in calm conditions.

Another system is to bag up the samples in plastic containers and return them to the base station where they may be accurately weighed or melted into water and measured with a graduate. In practice, this procedure is difficult to carry out as the samples must be bagged without loss, carefully labelled, and carried back to the base. The advantage of measurement with a balance in the field is that any gross errors due to plugging of the sampler, snow ploughing, or losses due to part of the sample falling out, may be readily recognized and repeat readings taken at once. The results may be noted down on site with other pertinent observations and if a good notebook is used, there can be little chance of confusion as to location or conditions.

In all measurements of this type the extremely difficult physical conditions under which observations must frequently be made should always be kept in mind and practical consideration should prevail in sampler designs.

Experimental Tests Carried Out

Various types of Samplers were obtained for experimental evaluation. The various types tested are listed in Table 1, together with their characteristic dimensions. The general construction of these samplers is illustrated in Fig. 1.

TABLE 1

Mount Rose Type

area = $.7854XD^2$

Manufacturer	# Teeth	Length	# Parts	I-D Cutter	Area in^2
(1) Leupold & Stevens	8	60 in.	2	1.478	1.7157
(2) Carpenter	16	60 in.	2	1.487	1.7366
(3) Hydraid	8	60 in.	2	1.493	1.7507
(4) Extrusion Co. (No. 1)	16	60 in.	2	1.497	1.7600
(5) Extrusion Co. (No. 2)	16	60 in.	2	1.497	1.7600

Larger Diameter Samplers

Manufacturer	# Teeth	Length	# Parts	I-D Cutter	Area in^2
(6) Soviet BC-43			1	3.157	7.8278
(7) Italian CN-1			3	2.755(70 mm)	5.9612
(8) Monette Ex		40 in.	1	2.775	6.0481
(9) Prairie		43 in.	1	2.904	6.6234

The diameter of a standard Mount Rose Sampler is 1.485 inches (1.7319 in^2). A sampler of this area will cut a core such that 1 ounce represents 1 inch of water content (1 cubic inch water weighs .5779 ounces).

Test Operations on January 30, 1963

A series of 55 samplings were carried out at the Meteorological Station at Mount Forest, Ontario. These samples were taken in an ordered pattern over an area judged to have a uniform snowcover with a depth of approximately 14 inches. A buried crystalline crust and coarsely crystalline firm snow was present below 3 inches of medium firm snow. Samples were spaced at 6 inches. The samplers under test were assigned numbers as indicated in Table 1. The results of the individual samplings are indicated in Fig. 2 (1); 2 (2). In these figures the sampler type is indicated and measured water equivalent and average core density plotted.

The conclusions that may be drawn from the tests on this day may only be applied to conditions of minimal snow depth and with a firm crystalline structure.

TABLE 2

Frequency of Measured Density

	23	24	25	26	27	28	29	30
(1) Leupold & Stevens	4	6	1	3	2	2		
(2) Carpenter					1	5	5	4
(3) Hydraid						2		1
(4) Extrusion Co.					1	1		1
(6) Soviet				3	1	2		
(7) Italian		1	2	2	1	1		

In Table 2 the frequency of the various measured densities, as determined by the various samplers are listed. It should be noted that the 16 tooth sampler (type 2) appears to give a more consistent frequency distribution, peaking at 29 per cent. The larger diameter samplers, although the number of observations are less in number appear to indicate an average density of 26 per cent.

The rather wide scatter of sampler (1) is attributed to the fact that the 8 tooth cutter encountered difficulties in the type of snow sampled due to the tendency of the cutter to break up the crystalline snow into large pieces which caused jamming ploughing.

Operations of February 6, 1963 - Mount Forest

A series of 92 samples were taken. The average snow depth was between 19 and 13 inches. The individual results of the sampling is indicated in Fig. 3 (1), 3 (2), 3 (3), 3 (4). The frequency density table is indicated in Table 3.

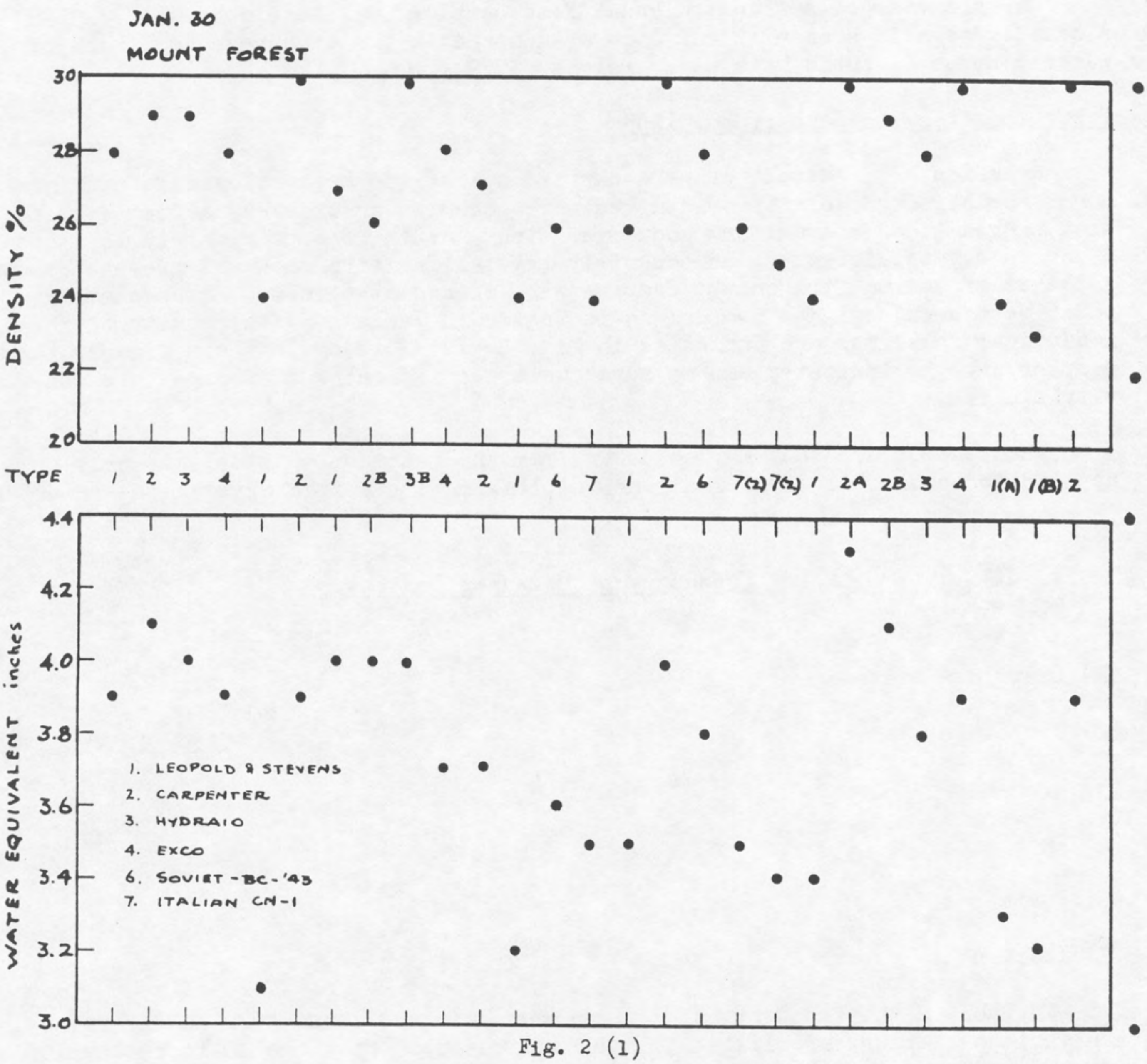

JAN. 30
MOUNT FOREST
DENSITY %
30
28
26
24
22
20
TYPE
1 2 3 4 1 2 1 2B 3B 4 2 1 6 7 1 2 6 7(2) 7(2) 1 2A 2B 3 4 1(A) 1(B) 2
WATER EQUIVALENT inches
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
1. LEOPOLD & STEVENS
2. CARPENTER
3. HYDRAIO
4. EXCO
6. SOVIET - BC - '43
7. ITALIAN CN-1

Fig. 2 (1)

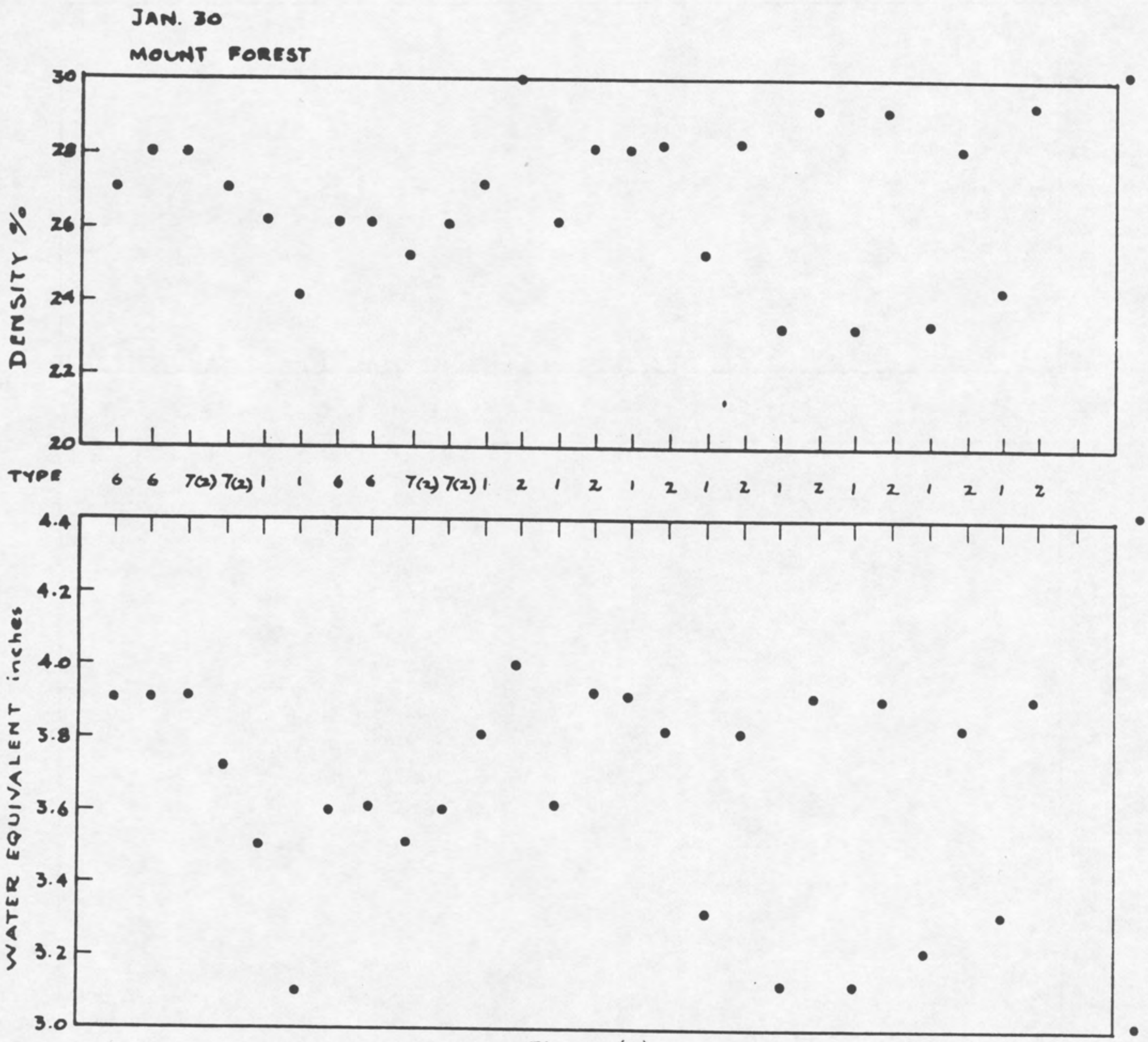

JAN. 30
MOUNT FOREST
DENSITY %
30
28
26
24
22
20
TYPE
6 6 7(2) 7(2) 1 1 6 6 7(2) 7(2) 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2
WATER EQUIVALENT inches
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0

Fig. 2 (2)

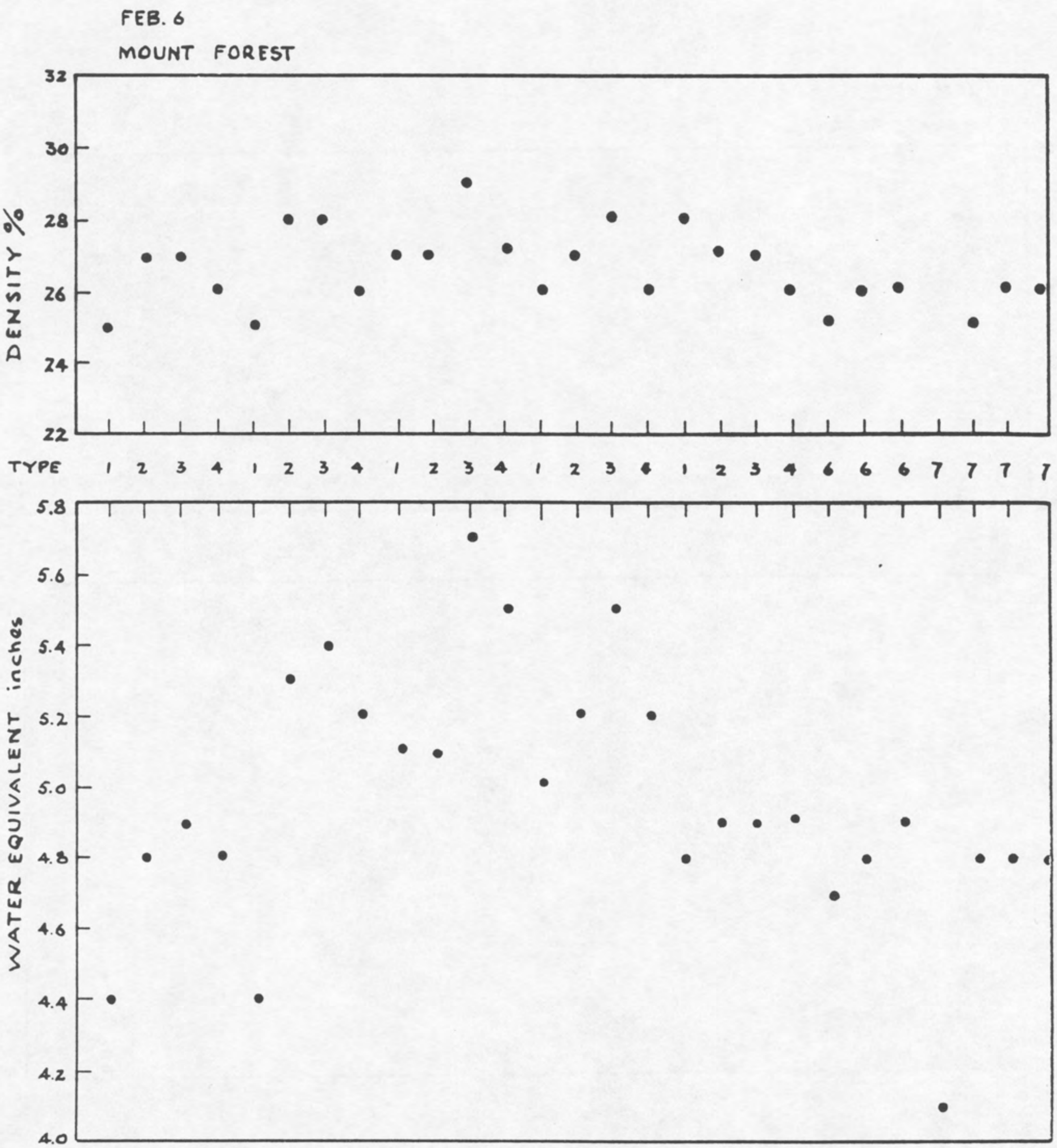

FEB. 6
MOUNT FOREST
DENSITY %
32
30
28
26
24
22
TYPE
1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 6 6 6 7 7 7 7
WATER EQUIVALENT inches
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0

Fig. 3 (1)

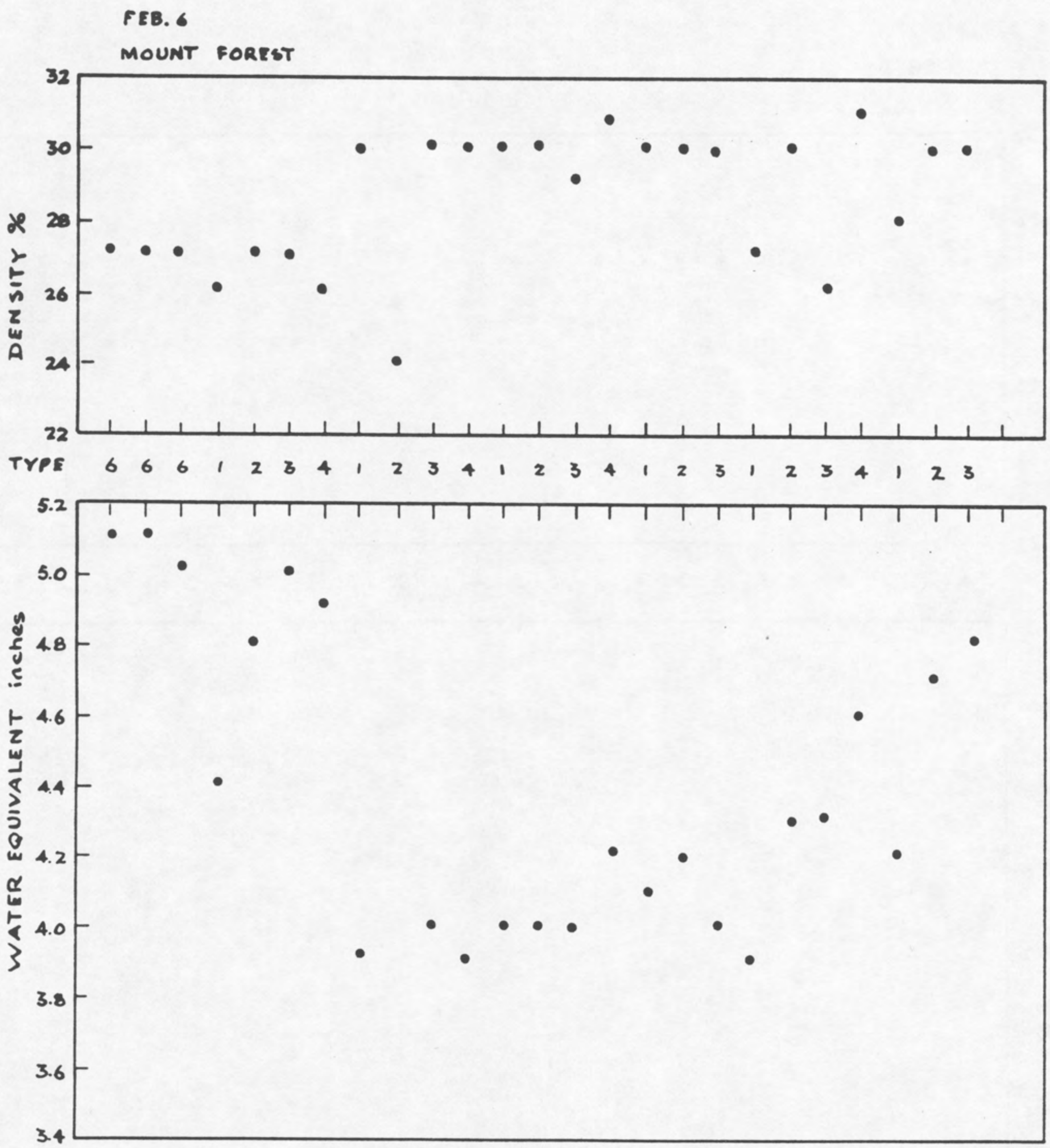

FEB. 6
MOUNT FOREST
DENSITY %
32
30
28
26
24
22
TYPE
6 6 6 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 1 2 3 4 1 2 3
WATER EQUIVALENT inches
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4

Fig. 3 (2)

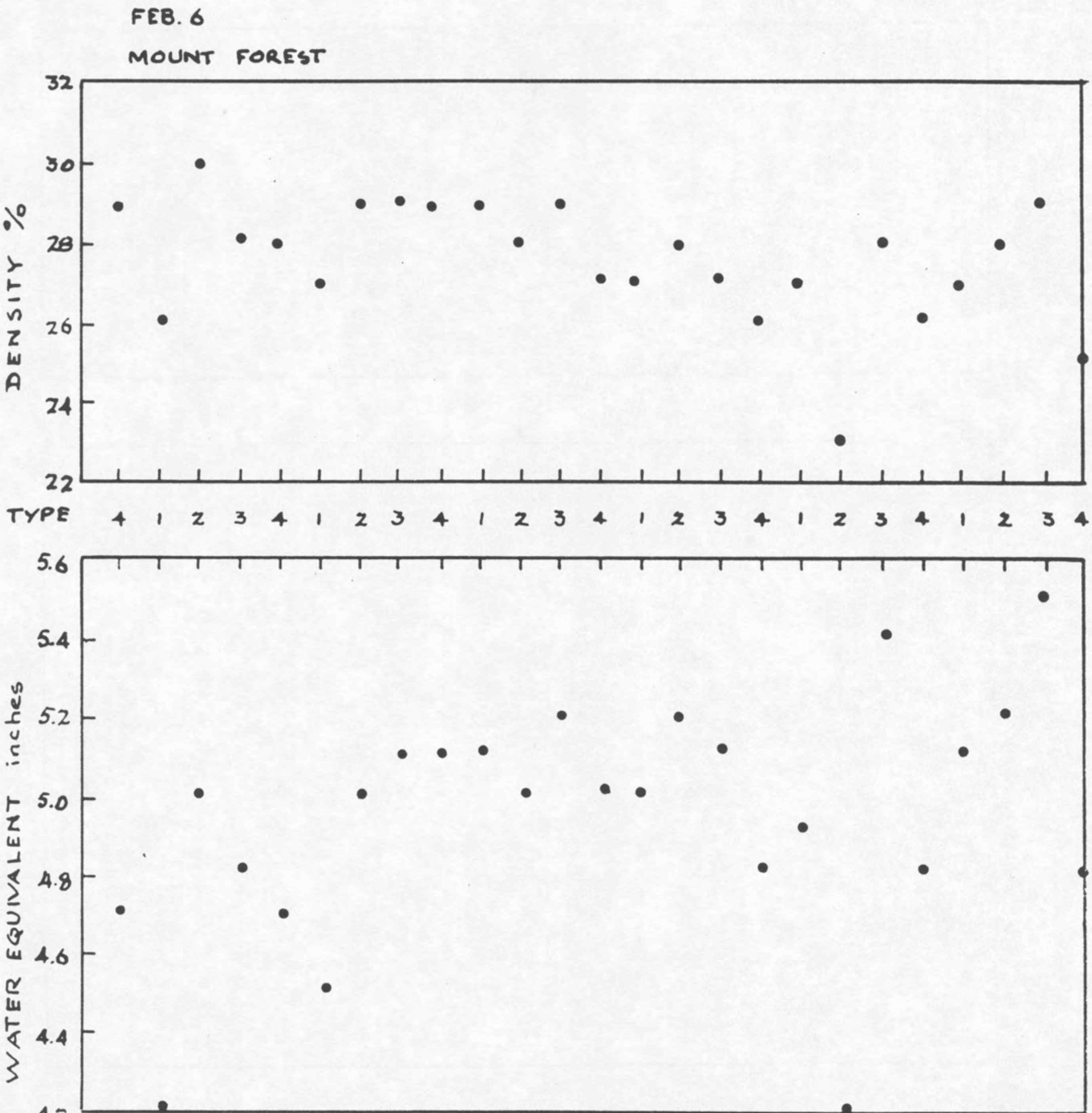

FEB. 6
MOUNT FOREST
DENSITY %
32
30
28
26
24
22
TYPE
4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4
WATER EQUIVALENT inches
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2

Fig. 3 (3)

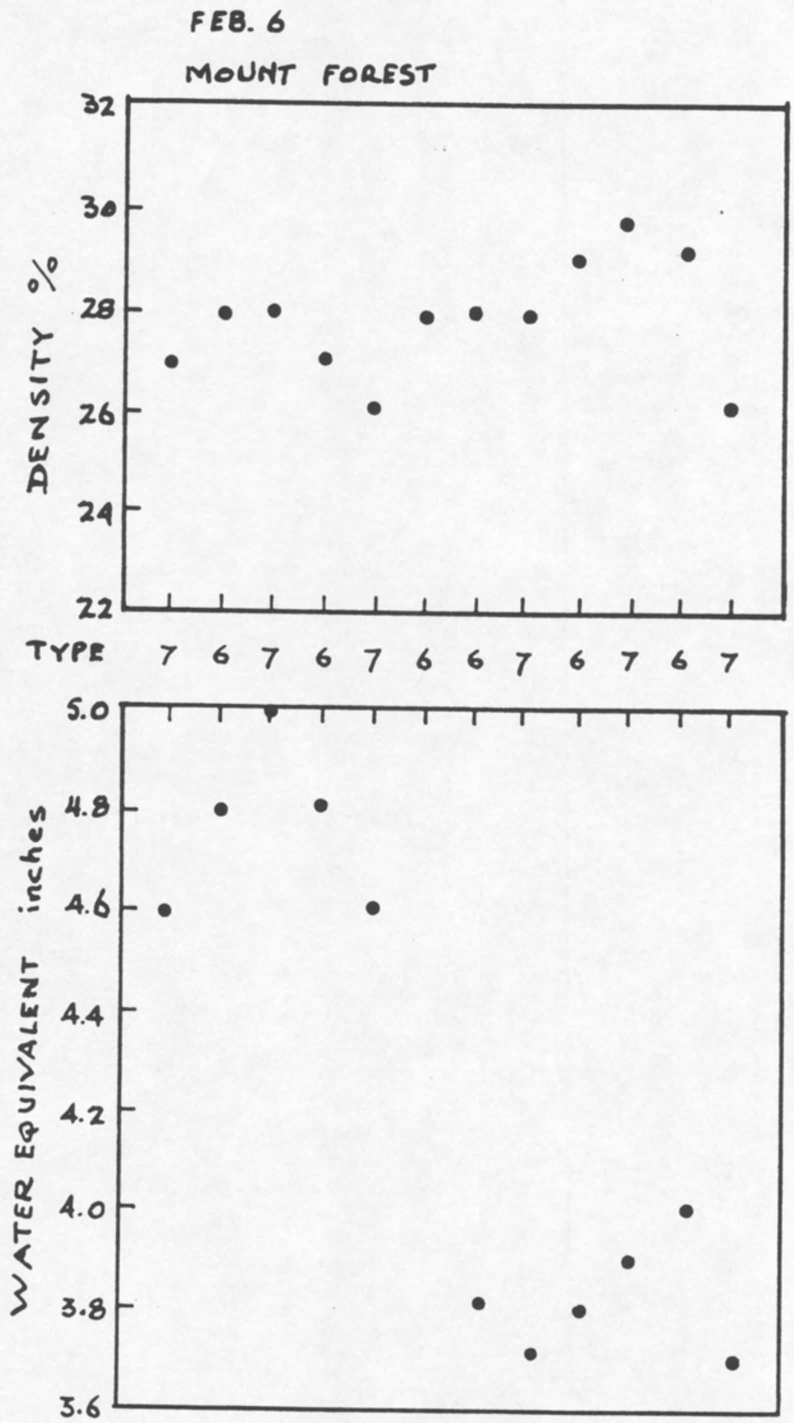

FEB. 6
MOUNT FOREST
DENSITY %
32
30
28
26
24
22
TYPE
7 6 7 6 7 6 6 7 6 7 6 7
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
WATER EQUIVALENT inches

Fig. 3 (4)

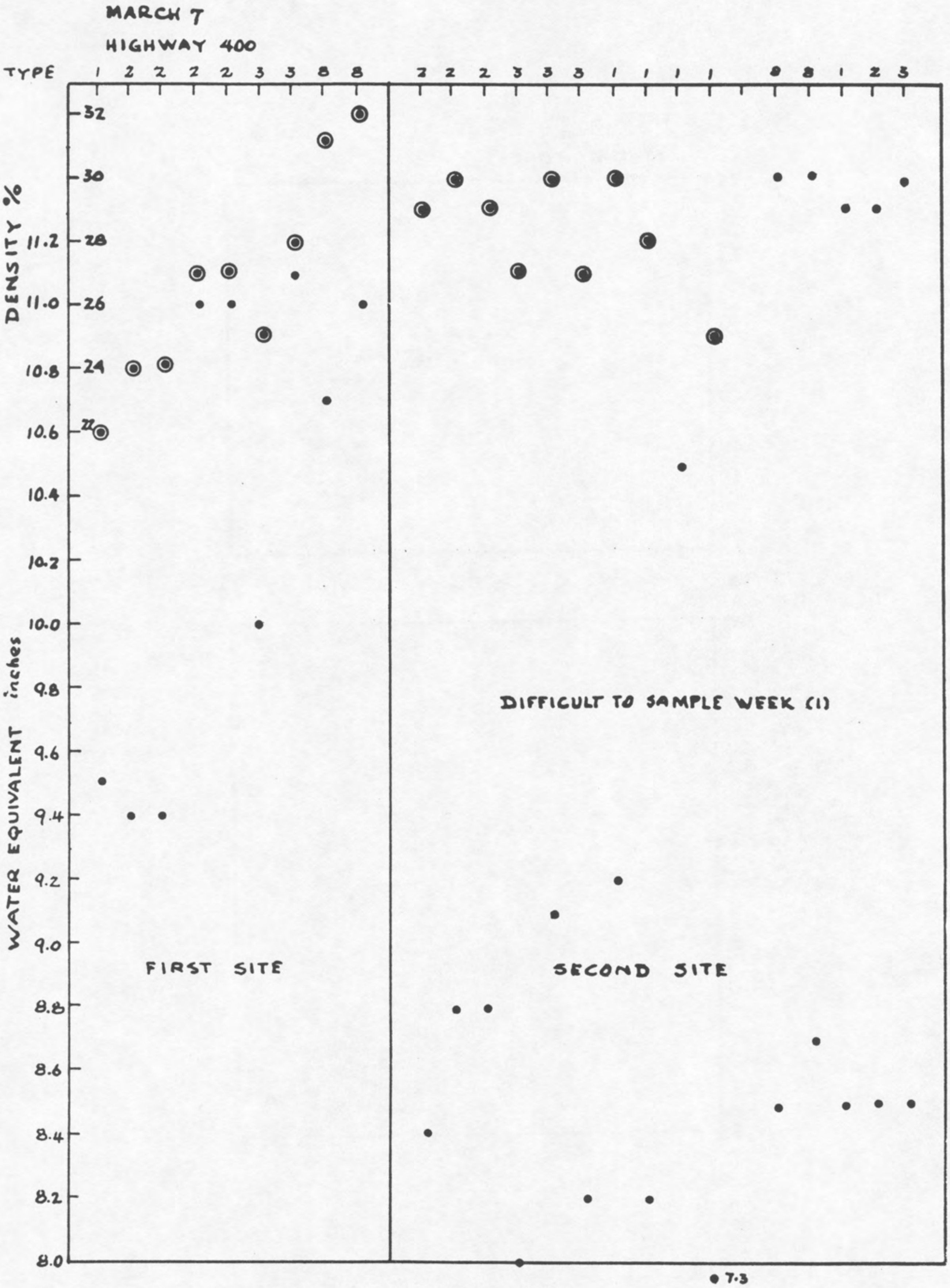

MARCH 7
HIGHWAY 400
TYPE
DENSITY %
WATER EQUIVALENT inches
DIFFICULT TO SAMPLE WEEK (1)
FIRST SITE
SECOND SITE
7.3

Fig. 4 (1)

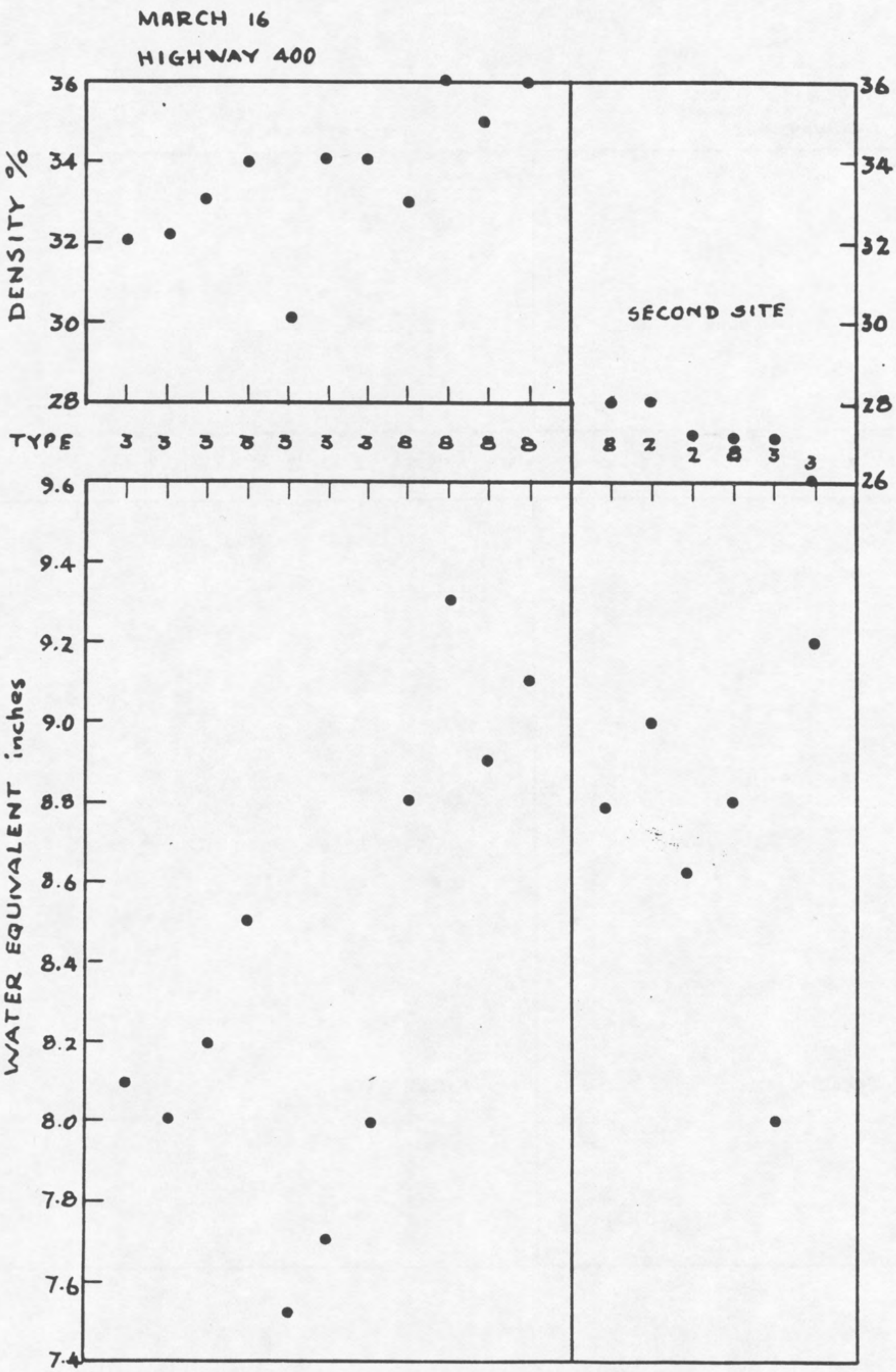
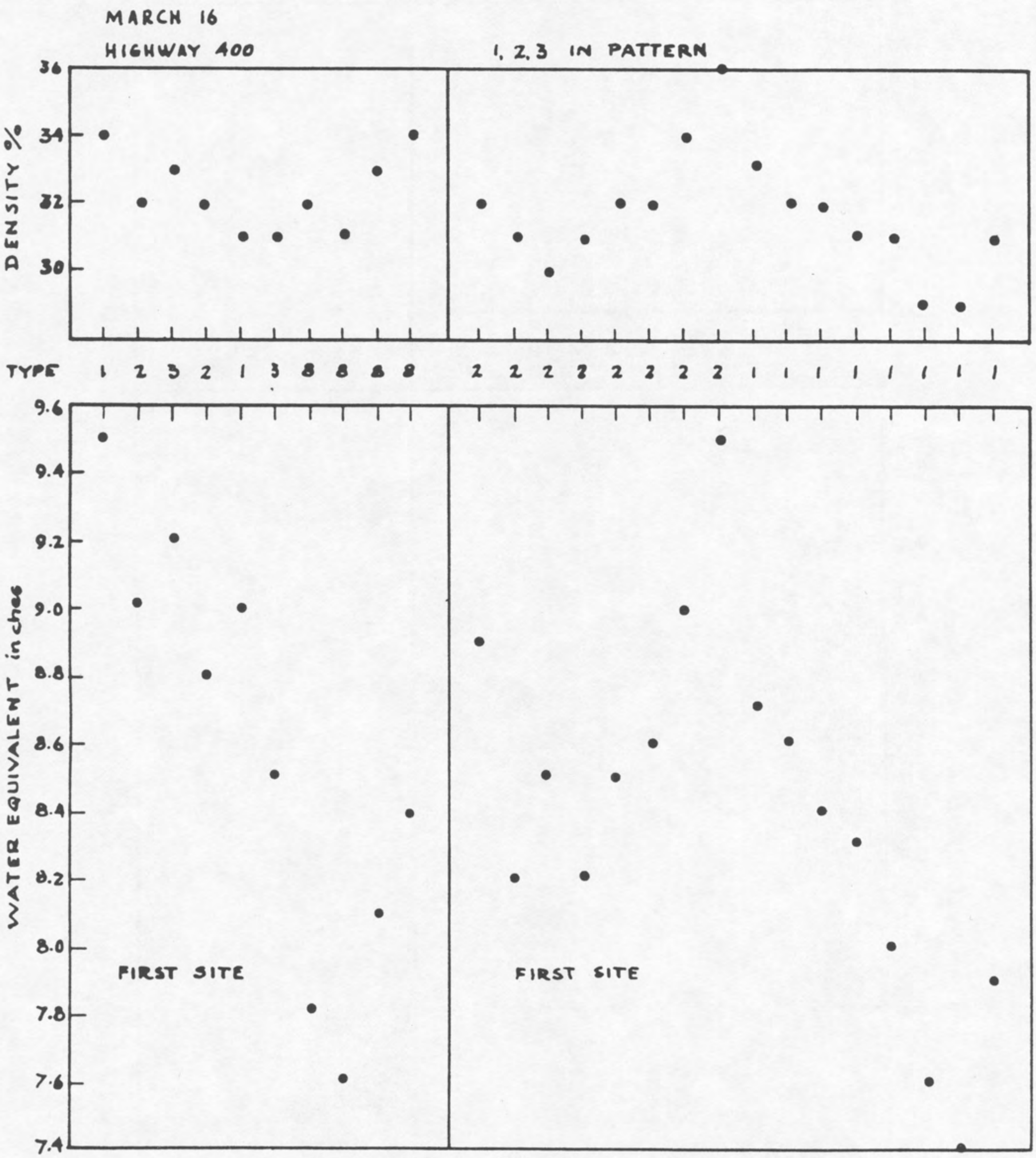

MARCH 16
HIGHWAY 400
DENSITY %
36
34
32
30
28
26
SECOND SITE
TYPE
3 3 3 3 3 3 3 8 8 8 8 8 2 2 8 3 3
WATER EQUIVALENT inches
9.6
9.4
9.2
9.0
8.8
8.6
8.4
8.2
8.0
7.8
7.6
7.4

Fig. 4 (2)



MARCH 16
HIGHWAY 400
1, 2, 3 IN PATTERN
DENSITY %
36
34
32
30
TYPE
1 2 3 2 1 3 8 8 8 8
2 2 2 2 2 2 2 2 1 1 1 1 1 1 1 1
WATER EQUIVALENT inches
9.6
9.4
9.2
9.0
8.8
8.6
8.4
8.2
8.0
7.8
7.6
7.4
FIRST SITE
FIRST SITE

Fig. 5

TABLE 3

The density frequency table for all samplers is given below:

	22	23	24	25	26	27	28	29	30	31	32
(1) Leupold & Stevens				2	3	6	3	1	3		
(2) Carpenter		1	1			6	4	1	4		
(3) Hydraid					1	4	4	5	3		
(4) Extrusion Co.				1	7	2		2	2	2	
(6) Soviet				1	3	4	3	2			
(7) Italian				1	4	1	2		1		

Operations on March 7 and 17, 1963

An attempt was made to find an area with appreciable snow depths. The snow on this occasion was from 18 to 40 inches and was markedly different to the snow encountered on the previous tests. The air temperature was 25 - 28 Farenheit and the snow was dense. Considerable difficulty was encountered with the Mount Rose type samplers due to clogging. The results of the individual measurements are given in Fig. 4 (1) and 4 (2). During these tests, a prototype of a large diameter sampler which will be discussed below.

Conclusions from the Tests

It was evident from the tests that there was a marked difference between the performance of the various samplers.

The results seemed to indicate that the 16 tooth Mount Rose type sampler was more consistent and presented less handling difficulty due to plugging than 8 tooth samplers. It seemed probable that more accurate results would be obtained from the large diameter samplers in minimal snow conditions. The Soviet sampler appeared to give consistent results. The Italian sampler was found to be unsatisfactory under the snow conditions encountered.

The results tended to show that the water equivalent may probably be determined to ±0.25 inches up to snow depths of 40 inches. The accuracy in the determination of the water equivalent is 6 per cent.

Design of Snow Sampling Equipment for use in Canada

Available observations indicate that the maximum snow depth is less than 40 inches over 60 per cent of the land area of Canada. Consideration was, therefore, given to the design of a medium diameter sampler to improve the accuracy of measurements up to 40 inches. It was proposed to use a Mount Rose type sampler at sites where the maximum snow cover exceeded 40 inches.

The M.S.C. 40 inch snow sampler consists of a single cutter section of 43 inches in length. A 16 tooth cutter is provided. The I.D. of the cutter is 2.776 inches and has been selected so that 1 inch of water equivalent weighs 3.5 ounces.

The entire kit is illustrated in Fig. 5. It should be noted that the tubing is supplied with staggered slots for observing the core and for cleaning; it is provided with an exterior inch scale.

The sample is weighed by means of a spring balance of a type commonly used with a Mount Rose sampler. It is provided with a scale marked directly in water equivalent.

In addition to the M.S.C. 40 inch sampler, it was decided to standardize on a Mount Rose type sampler with a 16 tooth cutter. A specification was drawn up on a design which was identical with one of the Mount Rose type samplers tested.

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