SNOW ACCUMULATION AND MELT PATTERN

IN TREE LINE STANDS OF MARMOT CREEK BASIN

by Z. Fisera'

INTRODUCTION

Marmot Creek Basin is an experimental watershed located in the Kananaskis River valley about 80 km west of Calgary. The basin was selected for study in August 1962 and is described by Jeffrey (1965). Total area of the watershed was estimated as 9.40 km$^2$. Cabin Fork boundary traverse in 1971 indicated that the Basin area is 9.58 km$^2$. Kirby and Ogilvie (1969), describing alpine habitat types of Marmot Creek watershed, classified 110 ha as rock and talus and 331 ha as nine other alpine habitat types. This includes avalanche types that extend into the forest zone, as well as timberline types occurring where the forest breaks up into tree islands and krummholz colonies. At least an additional 100 ha of alpine fir, alpine larch, and stunted Engelmann spruce have little if any merchantable timber and could be considered as alpine forest. Thus no less than 56.4% of the area of Marmot Creek watershed is alpine in character.

Snow accumulation patterns vary greatly according to elevation, aspect, slope, roughness of the terrain, and presence of forest cover. The windswept ridges and steep slopes are bare most of the winter. There is often as much as 50 cm of fresh snow deposited by a storm in these areas; however, strong winds between snowfalls (Storr 1973) move this snow to more protected locations. In April and May, when density of the snowpack increases and sun crust occurs, snow on exposed slopes and ridges may last for several days, even weeks, but it is seldom greater than 50 cm in depth. Wind-driven snow will fill all gullies and crevices in rocks and sometimes form spectacular snowdrifts on the lee side of the boulders, ridges, tree clumps and krummholz communities. Much of the snow will end up in the alpine forest. Although redistribution from forest back to open slopes was observed, it does not occur frequently; significantly greater amounts of snow are deposited in the tree line stands than taken out.

Martinelli (1959) reported that selected alpine snowfields of the Front Ranges of Colorado released on average, 58 mm water per day to summer streamflow in July and August 1955 and 1956. Several

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methods of manipulating alpine snowpack were pointed by Martinelli (1960). He stated that:

1. a 5 cm layer of sawdust decreased melt by about 50%

2. induced avalanching several times each winter would cause snow to be piled into a small area at the toe of the slope and that rate of melt in such deep snow accumulations would be slower than in the relatively shallow snow on the steep slopes

3. enlargement and reshaping of natural snow storage areas by dirt-moving equipment offers a direct and fairly simple way to trap snow

Martinelli (1964, 1965a, 1965b, 1972) adequately demonstrated great potential for alpine snowmelt retardation in order to increase summer streamflow by snow-fencing methods. For several years 2.5 m tall fences at carefully selected sites have added approximately 1200 m³ of water for each 30-38 m of fence length, measured on July 1. None of these methods has been tested to date on Marmot Creek Basin, although the option exists, particularly in snow-fencing.

Two additional methods were studied on Marmot Creek watershed

1. establishment of vegetative snow-fencing in areas of tree islands above tree line by reforestation

2. manipulation of tree line stands for maximum snowtrapping effect

It was observed that a large snowdrift at elevation 2280 m was formed each year in a depression east of a low ridge which runs on bearing N 50° W and is covered with two dense clumps of alpine fir and alpine larch approximately 3 m tall. In 1960 a 10-point snow course (21) was set up to monitor this drift. Table 1 indicates mean water content of the snow course 21 over the period of 9 years as well as water content of snow courses 19 and 14 for the corresponding period. Snow course 19 is at an average elevation of 2360 m in the open, above any vegetative cover. Snow course 14 is at an average elevation of 2140 m in the forest. The water content of snow course 14 in the critical month of May (1969-1977) was only 28.2% of the water content of snow course 21; snow course 19 was only 19.3% of snow course 21 for the same period. Year 1972 was excluded from the calculation because of incomplete results due to ice in the snowpack. It was therefore desirable to investigate if conditions at snow course 21 could be duplicated elsewhere in the basin by transplanting or otherwise propagating trees on a similar ridge in the vicinity.

The idea of reforestation above tree line is not new in Europe, particularly in Austria and Czechoslovakia. Records indicate that reforestation in the Giant Mountains of Bohemia started in approximately 1870 (Lokvenc 1958, 1962). Other authors describing reforestation projects above tree line in Czechoslovakia are Janousek (1957), Fiskun (1963) and Simkovic (1963). In Austria, Stauder (1963a, 1963b) describes successful reforestation in the Tyrol. Extensive reforestation also took place in Vorarlberg, Austria.
### TABLE 1 MEAN WATER CONTENT OF SNOW COURSE 21, 19, and 14 (centimetres)

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+ - denotes ice in the snowpack  - some points not measured  
n.a. - denotes readings not available  
nil - denotes no snow at the time of readings
OBJECTIVES

The objective of the experiment was to evaluate the possibilities of manipulation of alpine snowpack by silvicultural methods in order to prolong snowmelt to summer months when demands for water increase. Alpine snowpack contributes to summer stream-flow for several weeks after snow cover has disappeared from other areas. It is therefore desirable to retard the melt of alpine pack to the greatest possible extent.

PROCEDURES

A plot 7.6 x 36.6 m was established on the edge of a depression 200 m WSW of snow course 21 at 2310 m elevation (Fig. 1). The location is described by Kirby and Ogilvie (1969) as Phyllodoce habitat type associated with podzolic soils on moist northerly exposures. The following transplantings and seedings were made in the plot:

July 18, 1969 - 10 alpine fir (Abies lasiocarpa) 50-79 cm in height and 2 alpine larch (Larix lyallii Parl.) 86 cm and 137 cm were transplanted from a reproduction 75 m NNE of the planting site. Rocks were placed west of each plant.

Sept. 22, 1971 - 10 alpine fir stem cuttings and 20 branch cuttings 15 cm were placed in the soil to test their rooting potential.

Oct. 9, 1971 - 30 alpine fir twig cuttings 12-20 cm with lower needles removed and the lower 2.5 cm treated with Seradix 3 were planted to test the rooting agent. 10 similar cuttings were planted without rooting agent. 10 transplants 4-10 cm with root system without soil (washed) were planted (5 with Seradix 3 treatment, 3 without). Plant material originated in the natural reproduction site 100 m NE.

Oct. 21, 1971 - Alpine fir seed, collected mainly along north rim road in Cabin subbasin (elevation 1890 m and up), was seeded at various depths, some with peatmoss.

Sept. 24, 1974 - Direct seeding of alpine fir, alpine larch and Engelmann spruce (Picea engelmannii Parry) seed originating from several locations within 750 m of the site. Seeded at various depths with and without peatmoss.

In order to gain a better understanding of snow drifting patterns and to examine the possibilities of manipulating the existing tree cover near timberline, two plots each 50 x 50 m were laid out in 1972. The first plot (S.C. 23) is located in an alpine meadow with tree islands covering approximately 30% of the area. The 11% slope is as gentle as could be found
Fig. 1  Marmot Creek Middle Fork near tree-line
in the mountainous area. **Highest point is the NW corner at 2240 m and lowest is the SE corner at 2230 m.** Tree islands consist of dense alpine fir, 90 years old, 6.7.5 m high. Diameter at breast height (DBH) ranges from 5 to 20 cm. The second plot (S.C. 24) is laid out 300 m east of S.C. 23 in a stand of alpine fir 70% and alpine larch 30% (a few spruce trees are also present). Height of the fir ranges from 7.5 to 10 m, larch from 10 to 15 m. DBH varies from 5 to 25 cm in fir and 30 to 52 cm in larch. Ages in fir are up to 150 years, although most of the stems are around 90 years. Most of the larch is 280 years; one 52 cm veteran was measured at 360 years. The slope is 19%, highest elevation being 2206 m along the west boundary and lowest 2194 m near the NE corner. 

Although the stand appears to be well stocked in comparison with other tree-line stands, only 45% of the area is under tree cover. Both plots were marked with 10 stakes along the west and east boundaries, spaced 5 m apart. Snow samples at 5-m intervals were taken along the lines connecting opposing stakes with Mount Rose sampler (Figs. 2 and 3). Thus 100 points were sampled on each plot, twice a year, for a period of 4 years. First sampling was taken approximately at the time of greatest snow accumulation (May 24/73, May 5/74, May 27/75, and May 13/76). Second sampling was done within 7 days of peak flow (maximum instantaneous discharge) on Main Marmot weir. Dates of second sampling were June 27/73, June 13/74, June 16/75 and June 3/76. A profile along each line was plotted indicating terrain, forest cover, and snow water content totals for each point along the line from the June surveys. Profiles along line B on both plots are shown in Fig. 4. Values for each point are also shown in Figs. 2 and 3.

**RESULTS AND DISCUSSION**

Efforts to propagate alpine fir by transplanting from natural reproduction met with limited success. Of 17 trees transplanted on July 13/69, 7 are surviving. However, the tops of all trees are dry and only the lower branches were green in June 1977. A naturally reproduced alpine fir 12 m NW appears to be in similar condition and it is therefore possible that the site selected is too extreme for the experiment. The fact that some transplants are surviving after nearly 8 years indicates that there is some room for optimism. Direct seeding and stem and branch cuttings failed to produce any plants. Alpine fir in the tree islands above timberline propagates mostly by shoots, and the layering method...
Fig. 2  Plot  S.C. 23

Snow Accumulation Symbols
Water content in June 1973-76

- 0 - 20 cm
- 20 - 40 cm
- 40 - 60 cm
- 60 - 80 cm
- 80 - 100 cm
- 100 - 120 cm
- 120 - 140 cm
- 140 - 160 cm
- 160 - 180 cm
- 180 - 200 cm

Trees
Open

Contour intervals 50 cm
Scale meters 5 0 5 10 15
Fig. 3  Plot S.C. 24

SNOW ACCUMULATION SYMBOLS
Water content in June 1973-76

- ○ 0 - 20 cm  ○ 100 - 120 cm
- ⊗ 20 - 40  ⊗ 120 - 140
- ⊗ 40 - 60  ⊗ 140 - 160
- ⊗ 60 - 80  ⊗ 160 - 180
- ⊗ 80 - 100  ⊗ 180 - 120

Trees
Open
Contour interv. 50 cm
Scale meters

104
Fig. 4

Profiles along line E

Plat S.C. 23

2237.34

2230.88

Plot S.C. 24

2205.82

2196.10

0 2.5 7.5 12.5 17.5 22.5 27.5 32.5 37.5 42.5 47.5 50

meters
should be thoroughly investigated. Also rooting of cuttings in greenhouse which was described by MacGillivray (1969), using balsam fir (Abies balsamea L.) and container planting offer additional possibilities. Alpine fir is not considered a desirable commercial species, and for this reason not much effort has been expended on propagation. Future experiments of this kind should be conducted under the guidance of a team of experts in soil science, silviculture, physiology and related fields. Even if it may prove to be impossible to propagate trees above krummholz colonies, the possibility of improving existing tree islands by planting trees in selected locations to complement their snow-fencing and shading qualities should be thoroughly investigated. Results from such a study could be applied in fields other than hydrology, particularly avalanche and erosion control.

Prior to establishment of plots S.C. 23 and S.C. 24, it was assumed that plot S.C. 23 (tree islands) would accumulate and preserve more snow than plot S.C. 24, which is relatively well stocked. This assumption proved to be wrong. Although the tree islands on the plot are generally elongated in SE-NW direction, they do not provide adequate shelter from sun and wind. On all surveys plot S.C. 24 had more snow than plot S.C. 23. Most snow on plot S.C. 23 was preserved at sampling points A9, A10, and B8, which have trees on the west and south sides. Most of the points with better-than-average water content have some trees on the west and south sides, although this is not always apparent from Fig. 2 if trees are outside the plot. Point E2 is in a slight depression, which accounts for increased accumulation. As expected, points within tree islands had little if any snow; points located on the south and west sides of tree islands lost their snow rapidly, presumably by reflected radiation. Points 7-10 on line J are on the edge of a meadow. There are no trees west of them and they do not accumulate sufficient amounts of snow to last till June.

Similar observations were made on plot S.C. 24. A slight change in aspect in the NW portion of the plot resulted in increased water content. Although in a regular air photograph the plot appears to be relatively well stocked, close field examination revealed numerous small openings in the canopy that permitted snow to accumulate. Also alpine larch, which represents 30% of the plot's tree cover, does not intercept snow to the same extent as fir does. Relatively more snow reaches the ground under larch than under fir. Small cuts in the cover could increase snow accumulation at the following points without reducing it elsewhere on the plot: A1, A8, B1, B4, C4, C6, C7, F8, G8, G9, I8 and I9.

The area of cut on plot S.C. 24 proposed for 1977 is 135 m², or 12% of the area under tree cover, just over 5% of the area of the plot. It is assumed that a greater tree removal will probably reduce the snow storage capacities of the plot. Should the same plot be located on a north-facing slope, the storage capacities would not be seriously endangered by increasing the area of the cut. This is indicated by the increase in water content at sampling points J1 and J2, which have NE exposure. Additional evidence is provided by S.C. 21, which is at the bottom of a 50% north-facing slope where relatively little shading is
provided by tree clumps SW of the course. Here some snow is normally preserved until August. The reverse situation could be expected on a south-facing slope. Exposure to sun rays changes with degree of the slope as well as aspect. An opening on a 30% south-facing slope should therefore be smaller than an opening on a 5% slope where surrounding tree cover filters some of the solar radiation. It is extremely difficult to use a simple rule when treating alpine forest for maximum snow accumulating and storing capacity. Existence of numerous small openings in tree cover and great variations in terrain every few metres result in vast differences in the snowpack.

Peak flows on Marmot Creek occurred as early as May 27 (1976) and as late as June 30 (1963). There does not appear to be any relationship between the timing and the volume of runoff. However, it could be said that any snow that remains in the basin after that event is a valuable component of summer streamflow. Great caution should be exercised in preserving and improving the snow storage capacities of alpine forest and vegetative cover above the tree line.
REFERENCES


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