SNOW ACCUMULATION IN RELATION TO FOREST CANOPY

by

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ABSTRACT

SNOW ACCUMULATION IN RELATION TO FOREST CANOPY

Maximum snowpack water equivalent is measured at 123 points in the spring of 1966, 1967, and 1968. These points are distributed over three transects within a 4 square mile area in the Colorado Front Range. The north-facing slope ranges in elevation from 2900 to 3300 meters covered by *Picea engelmanni* and *Abies lasiocarpa* at the upper elevations and *Pinus contorta* at the lower. Water equivalent increases an average of 42 mm/100 m although only 28% of the total variance in water equivalent is associated with elevation. Forest cover measured by a Lemmon spherical densiometer within a cone of 114° is significant in only one of the three years. Neither crown cover by compass quadrants, crown cover within a cone of 21°, nor timber stand size classifications improve on the 114° cone canopy measurement in explaining snow accumulation variability. Individual points vary widely in their relative accumulation from year to year; the coefficient of determination for 1966 versus 1968 water equivalent is only 25%. Snow water equivalent versus snow depth gives r values of 0.86, 0.90, and 0.73 for the three years respectively.

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SNOW ACCUMULATION IN RELATION TO ELEVATION AND FOREST CANOPY

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Introduction

The weakest link in understanding the snow hydrologic cycle in mountainous terrain is probably the lack of knowledge of the areal distribution of the snowpack. The objective of this study is to assess the association of maximum snowpack water equivalent with elevation and forest canopy in a Colorado Front Range watershed.

There have been a number of similar studies in various geographic regions of the United States and Canada and many of these have been summarized in a separate paper (Meiman, 1968)[2]. These studies generally have shown an increase in the water equivalent of the snowpack at the time of maximum accumulation with increases in elevation and canopy opening. Results from these studies suggest great variability in the factors influencing snow accumulation between and within given physiographic-climatic boundary conditions. Thus the effects of elevation and forest canopy must be considered as components of a complex of factors including air mass characteristics, large scale physiography, and local relief.

Study Area and Procedure

During the summer of 1965 three transects comprised of a total of 123 observation points were established on a 10.4 km^2 area in the Upper Little Beaver watershed in the Colorado Front Range (Figure 1). These are not random samples but rather the transects were positioned to sample the timbered portion of a generally north facing slope on which timber harvest was under consideration. The study area is about 24 km east of the Continental Divide. Elevation of the observation points ranges from 2,900 to 3,300 meters. The area often is subject to very strong winds during and after snowfalls. There is very little opportunity for snowmelt during the accumulation season.

The alpine zone is located upwind from the timbered study area and constitutes a snow contributing area. There are other smaller open areas resulting from fire within the timbered study area and the larger of these are designated on Figure 1. The timber is a combination of spruce *(Picea engelmanii)* and fir *(Abies lasiocarpa)* at the upper elevations and lodgepole pine *(Pinus contorta)* with some intermixed aspen *(Populus tremuloides)* at the lower elevations. The forest cover is very heterogenious relative to age, stand density, and spatial distribution. This situation is fairly typical of Colorado Front Range conditions.

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2/ Paper presented at National Workshop Seminar on Snow Hydrology at Fredericton, New Brunswick, February, 1968.

The average height of the trees in the spruce-fir type is about 15 meters and the average crown cover 44%. Averages for the lodgepole pine are 11 meters and 44% respectively. Basal area for both forest types is approximately 30.8m^2/ha (134 ft.^{2}/Ac.).

Snow depth and water equivalent were taken each spring, 1966 through 1968, at a time judged to be near the maximum snowpack water equivalent. Actual dates of sampling were 4/16/66, 4/8/67, and 3/27/68. Federal snow samplers were used. All samples were taken approximately 30 cm down hill from the marker pole. If a fallen limb or obstruction was encountered sampling was repeated until the ground surface was reached. The stations were approximately 60 meters apart along the transects and were designated by poles extending 2 to 2½ meters above ground.

Timber stand measurements included species identification, basal area, and crown cover. The forest stand about each point was classified into U. S. Forest Service timber stand categories. Crown cover estimates were made with a Lemmon Type A spherical densiometer; the crown cover measured was, (1) that portion of the canopy appearing within a cone having a 114^o arc with measurements recorded for each quadrant centered about one of the four cardinal directions, and (2) within a cone of 21^o arc.

Results

The results of the regression analyses are tabulated in Table 1. Figure 2 illustrates the large variability in water equivalent existing within 60-meter elevation zones and Figure 3 is a plot by years of the general increase in maximum snowpack water equivalent with elevation. The lack of any relationship between stand size classification and water equivalent is illustrated in Figure 4. A summarization of the data presented in the tables and graphs and from the statistical analysis indicates the following relative to maximum snowpack water equivalent on the study area:

1. A very large year-to-year variation in the relative values of individual points.
2. A highly significant increase with elevation in all years averaging 42 mm/100m (5.04 in/1000 ft).
3. Elevation is associated with only 28% of the total variance.
4. Crown cover as measured in a 114^o arc is significant in one year only.
5. Crown cover by quadrants corresponding to the four cardinal directions does not improve the correlation.
6. Crown cover as measured in a 21^o arc does not improve the correlation.
7. Timber stand size classifications as delineated by standard U. S. Forest Service procedures are not significant.
8. Snow depth is very highly correlated.

Discussion

Perhaps the most striking finding of the study is the low R^2 values associated with both elevation and crown cover relative to maximum snowpack water equivalent. Still more discouraging is the failure of given points to reflect a consistent year-to-year accumulation relative to other points. It is not uncommon for a given point to be 20 to 30% below the average for its 60-meter elevation zone in one year and as much above the next year; many points have even greater variation. This would suggest a large influence of the interaction of wind pattern and snow availability on accumulation at any given location. Snow availability here might mean not only the total initial snowfall but also the opportunity for redistribution from tree crown and open areas exposed to wind action.

Because of the poor correlation between a standard 114° angle measurement of crown cover and maximum water equivalent it was hypothesized that either a larger area or a smaller area of measurement might be better. A larger-area-look was gained by using a timber stand classification as illustrated in Figure 4. There is no apparent consistent relation between stand classification and water equivalent. A smaller-area-look was made by reducing the viewing angle with the densiometer to 21°. Again as illustrated by the R^2 values in Table 1 there was no improvement. This was true even when eight of the obviously poor measurements were dropped from the analysis. It must thus be concluded that crown cover is either not very important for the conditions studied or that we are not measuring it correctly, i.e. as the snow "sees" it.

An encouraging finding of this study is the relatively high correlation between snow depth and water equivalent. This is especially important relative to the possibility of aerial observation of snow depth and then relating depth to water equivalent. The relatively low R^2 value for 1968 can be explained by the fact that the 1968 measurements were the earliest of the three years with respect to snowpack ripeness, hence the large variation in snowpack density.

There are three areas of investigation that seem to have promise as indicated by these results. One approach is to characterize the forest canopy from above rather than from below. A second approach would involve a systematic analysis of local snow source areas. Both of these possibilities are currently being explored utilizing large scale (1:6000) photographic analyses on a Kelsh plotter. A third effort currently underway is an examination of 700 mb wind velocities during and after major snowfalls. Perhaps an even more fruitful study of wind effects could be made on a physical model of the watershed in the wind tunnel.

Conclusions

Although elevation and crown cover are significantly related to maximum snowpack water equivalent on the study area these two factors combined can be associated with only 32% of the variance in water equivalent averaged for the three years. It would appear that a better way of describing the forest canopy, an evaluation of the role of local snow contributing areas, and an analysis of wind conditions are needed to predict snow accumulation more accurately.

Table 1. Results of Regression Analyses.

Independent Variables	Dependent Variable	Number of Observations	R^2	Standard Error of Estimate
1966 WE[1/]	1967 WE	123	.48**	70mm
1966 WE	1968 WE	123	.25**	105
1967 WE	1968 WE	123	.44**	91
Elevation	1966 WE	123	.18**	86
"	1967 WE	123	.16**	90
"	1968 WE	123	.28**	103
"	Avg. WE	123	.28**	77
Crown Cover (114°)	1966 WE	123	NS	--
"	1967 WE	123	.06*	95
"	1968 WE	123	NS	--
Elevation, Crown Cover (114°)	1966 WE	123	.20**	87
"	1967 WE	123	.21**	87
"	1968 WE	123	.30**	102
	Avg. WE	123	.32**	75
Elevation, Crown Cover (21°)	1966 WE	115	.16**	84
"	1967 WE	115	.19**	87
"	1968 WE	115	.26**	104
Snow Depth 1966	1966 WE	123	.74**	44
" 1967	1967 WE	123	.80**	43
" 1968	1968 WE	123	.54**	83
Basal Area	Crown Cover (114°)	123	.58**	9%
Crown Cover (114°)	Crown Cover (21°)	115	.52**	12%

1/ WE = Water Equivalent of snowpack near time of maximum

* Significant at 0.05 level

** Significant at 0.01 level

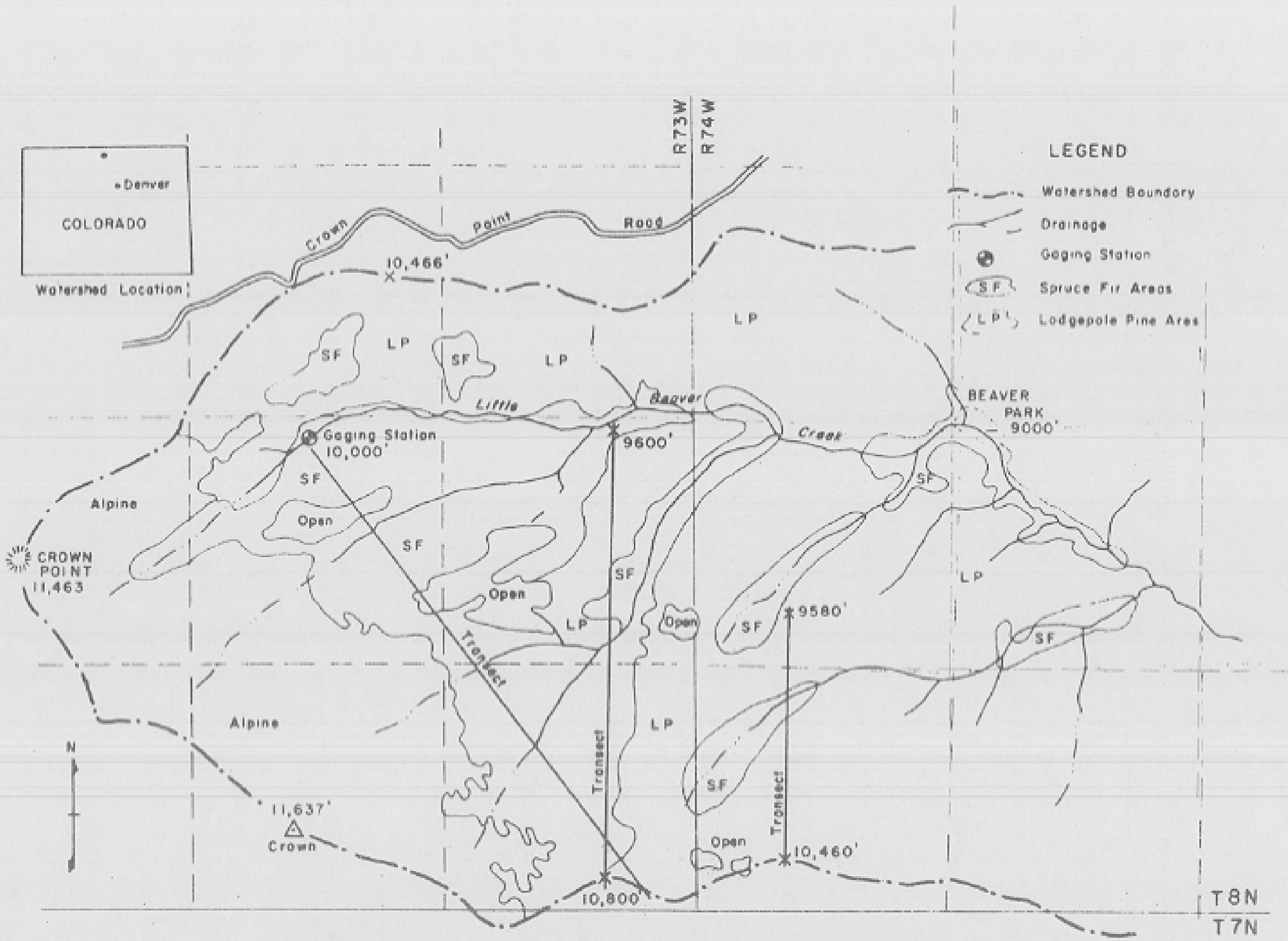


Figure I. Upper portion of Little Beaver Watershed in Roosevelt National Forest, Colorado.

0 1/4 1/2 3/4 1 Mile

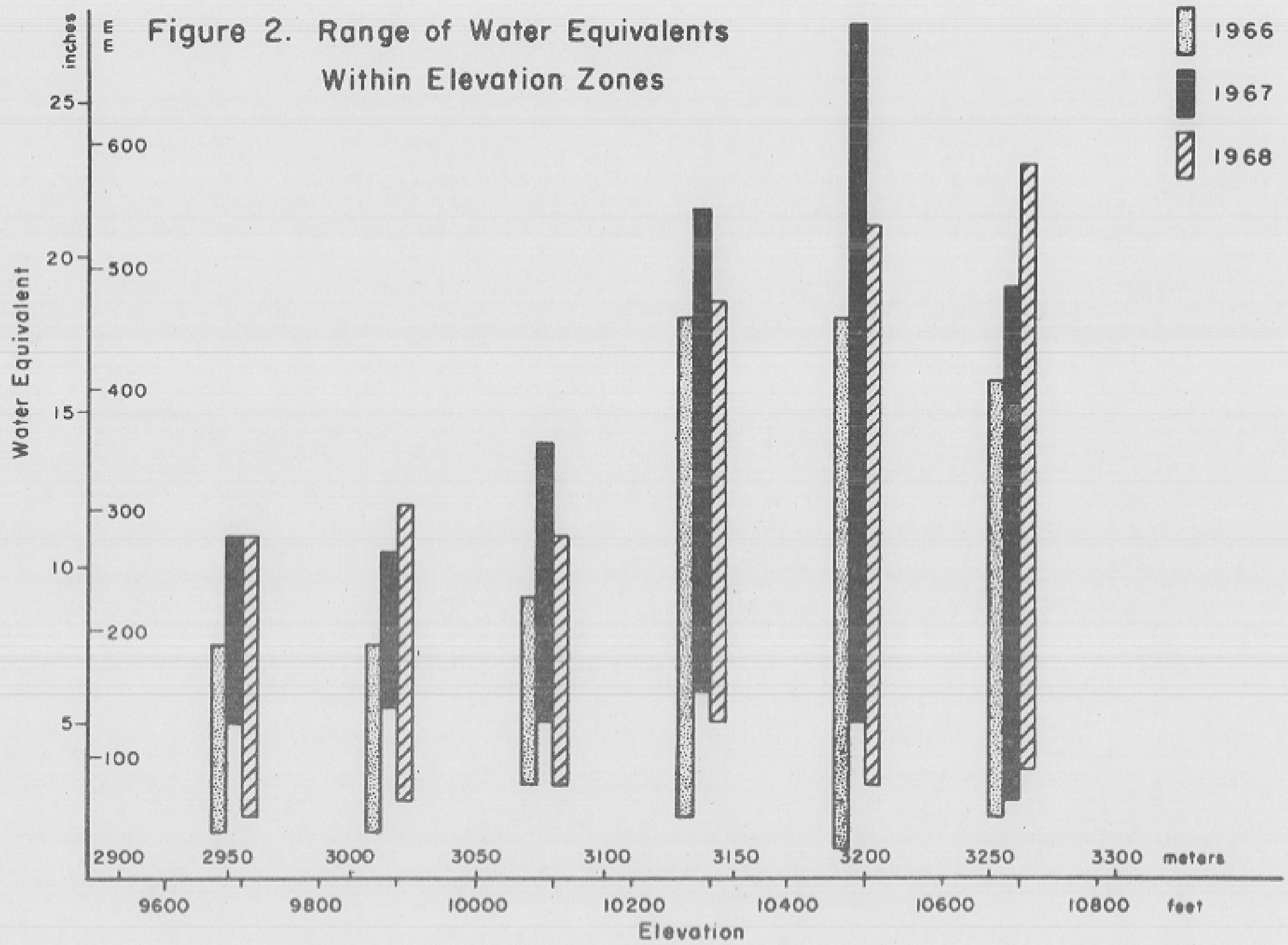


Figure 2. Range of Water Equivalents Within Elevation Zones

Figure 3. Snow Pack Accumulation Variation by Elevation Zones and Year

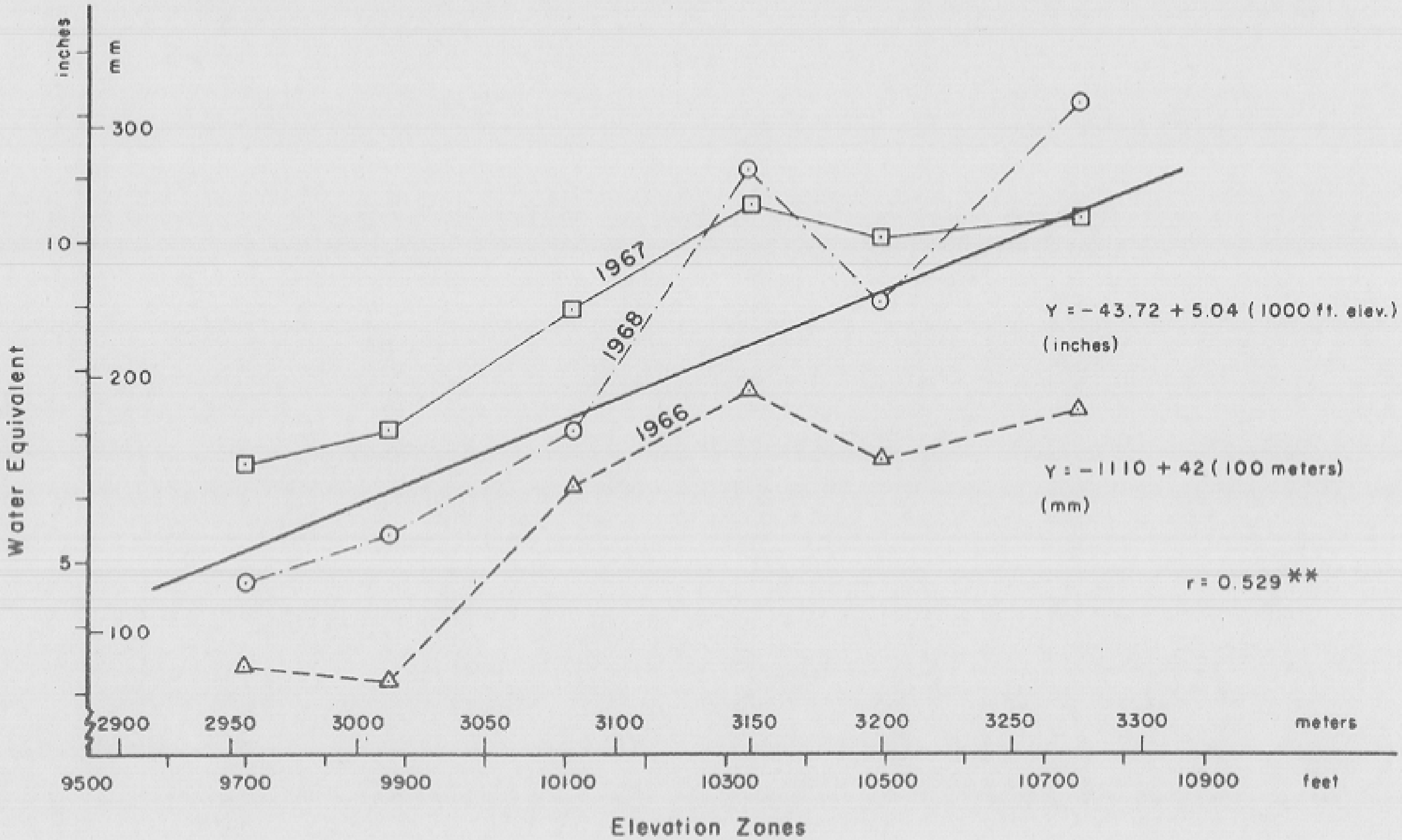
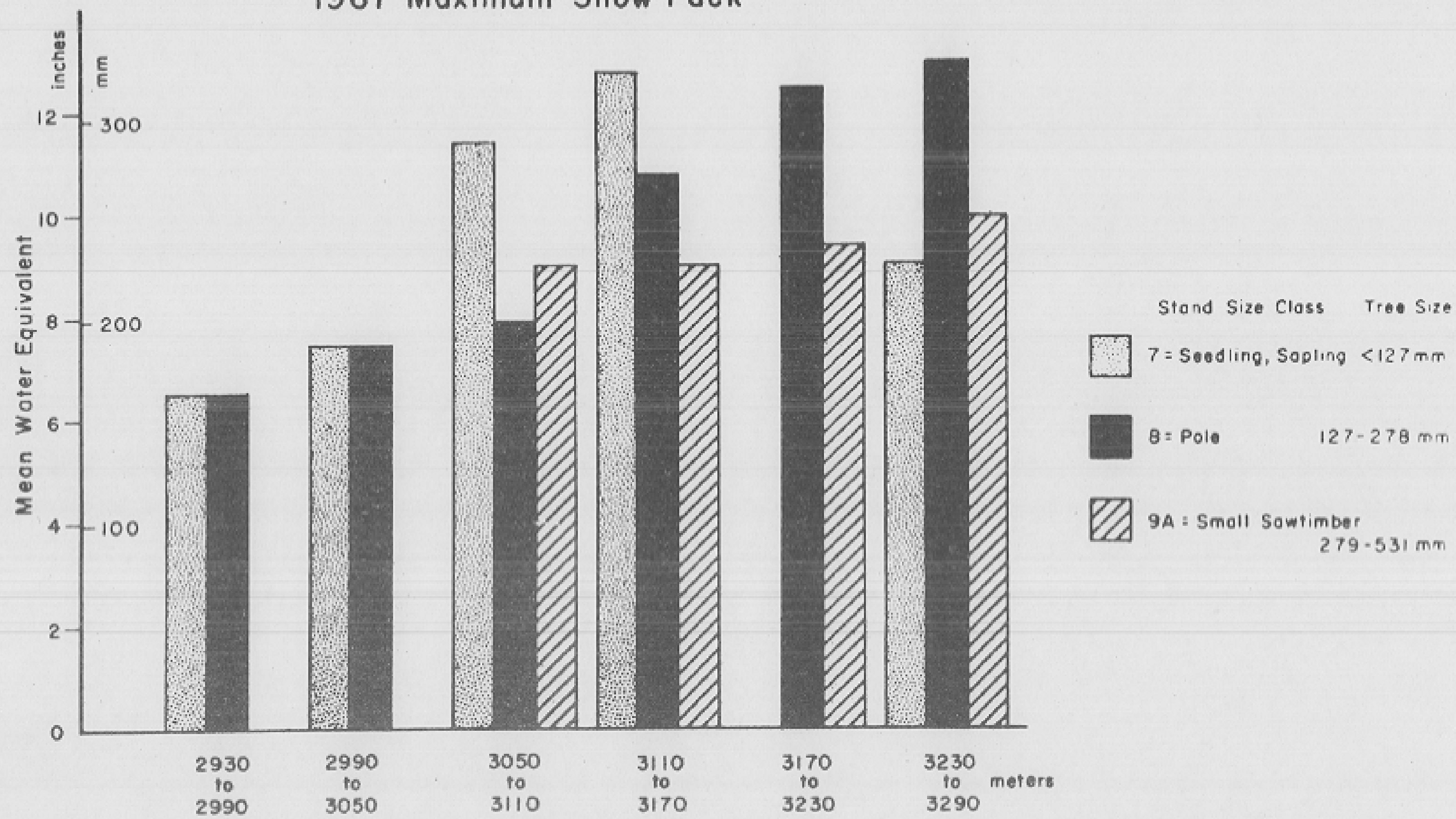


Figure 4 Distribution of Snow Pack by Tree Size Class and Elevation
1967 Maximum Snow Pack



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