Quantification of snowpacks related to inventory-prediction variables may help define forest-snow interactions useful in developing land management systems designed to increase water yields in the ponderosa pine (*Pinus pondersoa* Laws.) type in Arizona. Previous studies (Ffolliott *et al.*, 1965, Ffolliott and Hansen 1968) reported empirical relationships between snowpack conditions at a point in time and inventory-prediction variables, but little work has been directed toward evaluation of snowpack conditions over time.

An exploratory investigation was conducted to evaluate a storage-duration index (Wilm 1948) in relation to inventory-prediction variables. The objective of the investigation was to obtain information for quantifying snowpack storage conditions on site.

The storage-duration index provides an integrated single estimate of initial snow storage and subsequent melt rates. The index is developed for arbitrarily defined time periods by adding together snowpack water equivalent measurements made in successive surveys for the period. Theoretically, maximum index values are obtained with large initial storage followed by slow melting, while low initial storage followed by rapid melting provides minimum index values (Wilm 1948).

Snowmelt is a major source of runoff and water yield for the reservoir systems in central Arizona.

Describing Arizona Snowpacks in Forested Condition with Storage-Duration Index

*by Peter F. Ffolliott and David B. Thorud**

Description of Investigation

The exploratory work discussed herein was designed to evaluate the storage-duration index as related to inventory-prediction variables readily available or easily obtained by the land manager. The variables selected were forest density, potential insolation, and elevation. These variables are important in describing snowpack conditions.

Study Area

The study utilized 75 sample plots located on the Beaver Creek Watershed (Brown 1971) in north-central Arizona.** These plots, located on aerial photographs and then established on the ground, sample a range of forest density and physiographic conditions common to ponderosa pine on the study area. Each plot consisted of 13 sample points systematically arranged within a circular 1/5-acre area.

Ponderosa pine comprises over 85 percent of the forest density, with Gambel oak (*Quercus gambelii* Nutt.) and alligator juniper (*Juniperus deppeana* Steud.) intermingled. The site index (Meyer 1961) is 70 feet at 100 years, and the sawtimber volume averages 5,800 board feet per acre.

Topography varies from essentially level to slopes in excess of 45 percent. Elevation ranges from 7,300 to 7,800 feet. The soils are derived from basalt, with an intermixture of cinders (Williams and Anderson 1967). Annual precipitation averages 24 inches, half of which normally occurs between November 15 and April 15.

Winter precipitation during 1967-6 and 1968-69, the two years of stud was 18.8 and 20.2 inches, respectivel The timing of precipitation event differed between years, however.

Methods

Snowpack water equivalent wa measured with a snow tube and scal at all sample points before and durin the snowmelt-runoff period for bot years of study (Table 1). Durin 1967-68, measurements were made a (1) peak snowpack accumulatio prior to the start of runoff, (2) mid way between peak accumulation an approximate peak daily runoff, an (3) approximate peak daily runoff indicated by a nearby stream gag Only the first and last measurement were made during 1968-69, as th snowpack melted at a rapid rat Measurements were not made afte [illegible]

Table 1 — Snowpack water equivalent measurement dates.

Event	Year of Study 1967-68	Year of Study 1968-69
Peak snowpack accumulation, prior to start of runoff	**February 10**	**March 10**
Midway between peak accumulation and approximate peak daily runoff	**February 24**	**(no measurements)**
Approximate peak daily runoff	**March 9**	**March 24**

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***This study was conducted in cooperation with the Rocky Mountain Forest and Range Experiment Station, Flagstaff, Arizona.*

Table 2 — Regression equations of storage-duration index versus forest density, slope steepness and aspect (potential insolation), and elevation.

ear	Equation	Correlation Coefficient
967-68	$Y = -0.112 - 0.0163X_1 - 0.0433X_2 + 0.0894X_3$	0.56
968-69	$Y = -0.186 - 0.0105X_1 - 0.0488X_2 + 0.0102X_3$	0.53

= storage-duration index
$_1$ = basal area in square feet per acre
$_2$ = potential insolation on index date (February 20) in Langleys (Frank and Lee 1956)
$_3$ = elevation in feet.

pproximate peak daily runoff beause of increasing snowpack depleion.

Snowpack measurements taken at ach point were averaged by plot. hen, storage-duration index was deeloped for each plot by adding toether the snowpack water equivalent neasurements taken at the abovedefined periods.

Forest density, expressed in square eet of basal area per acre, was estinated by point sampling techniques sing a basal area factor of 25. A subample of five sample points provided he basis for estimating basal area at ach plot.

Potential insolation, in Langleys gram calories/cm^2), received on an ndex date (February 20) was obained from slope steepness and aspect neasurements at each plot (Frank nd Lee 1966). The elevation of each lot was estimated from 7½ minute J.S. Geological Survey topographic naps.

Multiple regression analysis was sed to empirically define relationhips between the storage-duration ndex values and the combine effect f the tested inventory-prediction ariables.

Results and Discussion

Relationships between storage-duraion index values and inventory-preiction variables were similar for both ears of study (Table 2). The useulness of these relationships is not ecessarily in predicting storage-duraon index values *per se,* however, but identifying sites with desired snowack storage conditions.

On the Beaver Creek Study Area, or example, large initial storage folowed by slow melting is associated ith low forest densities, low potenal isolation values, and high elevaons, as sites exhibiting all three haracteristics possess maximum index alues. Low initial storage followed y rapid melting is associated with the pposite site characteristics.

Storage-duration index values and snowpack equivalent at peak seasonal accumulation are similarly associated with forest density, potential insolation, and elevation, as evidenced by this investigation and a previous study of forest-snow relationships on Beaver Creek (Ffolliott and Hansen 1968). This indicates that high initial storage under low forest densities, low potential insolation values, and high elevations is not necessarily offset by accelerated melting, but remains high throughout the melt period. Conversely, low initial storage associated with the opposite site characteristics may not persist due to rapid melting.

The results of this investigation may suggest possibilities for empirically identifying hydrologic strata on a watershed in terms of initial storage and subsequent melt rate criteria. Once identified, land management systems designed to affect snowpack storage conditions may be prescribed. Forest density is the only tested inventory-prediction variable that can be manipulated. Therefore, by decreasing forest densities on high elevation sites with low potential insolation, the storage-duration index values should be increased. Increasing forest densities on low elevation sites with high potential insolation values should have the opposite effect.

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