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Characteristics of Arizona Ponderosa Pine Stands on Sandstone Soils

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Abstract

Limited information is available for ponderosa pine forest types growing on sedimentary-derived soils. Based on a 4-year study of ponderosa pine watersheds on sedimentary soils, annual water yield is about 25% of that from volcanic soils, herbage production is lower even though forest densities are less, and forest site index is higher.

[1] *Central headquarters is maintained at Fort Collins, in cooperation with Colorado State University. Baker is located at the Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University.*

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Introduction

In the Salt-Verde River Basin, an area that provides many natural resources and uses to central Arizona, about 57% of the ponderosa pine[2] forest type grows on volcanic-derived soils. The remaining 43% occurs on soils derived from sedimentary materials (Baker and Brown 1975, Ffolliott et al. 1972). Most of the available information about ponderosa pine ecosystems has been obtained on volcanic soils with only limited work on sedimentary soils. To get more complete information, the Heber watersheds were established in 1972 as a cooperative project between the USDA Forest Service and the University of Arizona.

In 1972-73, stream gages were built on two small watersheds, 60 acres (24.3 ha) each, on soils derived from sandstone, located near Heber in central Arizona (fig. 1). Precipitation gages and a hygrothermograph were also installed. Streamflow was measured on each watershed, and sediment, water quality, timber, range, and wildlife were sampled. Data are based on 4 years of record from water year 1973 through 1976.

This report describes present physiographic, hydrologic, and biotic characteristics of the Heber watersheds. The information obtained on the watersheds has been combined for this presentation. General comparisons also are made between these characteristics and those previously developed for ponderosa pine forests on volcanic soils.

[2]Scientific names of plants and animals mentioned in the text are listed at the end of this report.

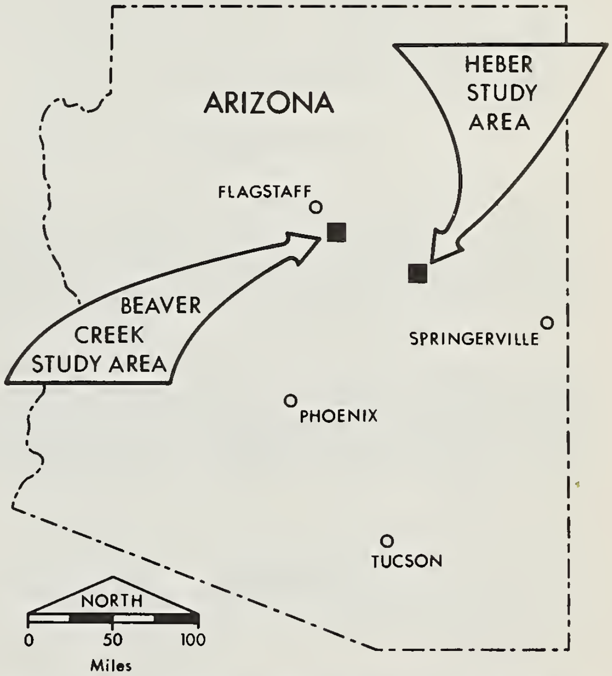

Figure 1.—The Heber and Beaver Creek watersheds. The latter areas occur on volcanic soils.

Present Land Management

Present management on the Heber watersheds is similar to that on surrounding ponderosa pine forests growing on sedimentary soils. The forest overstory has been cut over. The most recent harvest using group selection cutting removed approximately 40 to 50% of the merchantable sawtimber. No timber has been cut on the watersheds since the early 1960's.

The area has been under intensive fire protection since the early 1900's. However, occasional wildfires, caused mostly by lightning, have burned portions of the area. In addition, slash has been piled and burned after recent timber cuttings.

Herbage produced under the forest overstories provides summer forage for cattle under a rest-rotation grazing system. However, less than 25% of the herbage produced annually is normally consumed.

The Heber watersheds furnish seasonal habitat for mule deer, elk, Merriam's turkey, Abert squirrel, and cottontail. Many nongame species of wildlife are also found.

Hunting, camping, and other casual recreational activities are common throughout the area, which is quite accessible from the metropolitan centers of central Arizona.

Physiography

The watersheds exhibit the relatively flat topography common on the Colorado Plateau, with few slopes over 10%. Elevations range from 6,800 to 7,000 feet (2,073 to 2,134 m). Cretaceous undivided material, unnamed but with mineralogy similar to that of the Coconino sandstone formation, lies beneath the watersheds. Soils developed from this material are in the McVickers series, with fine, sandy loam surface textures.

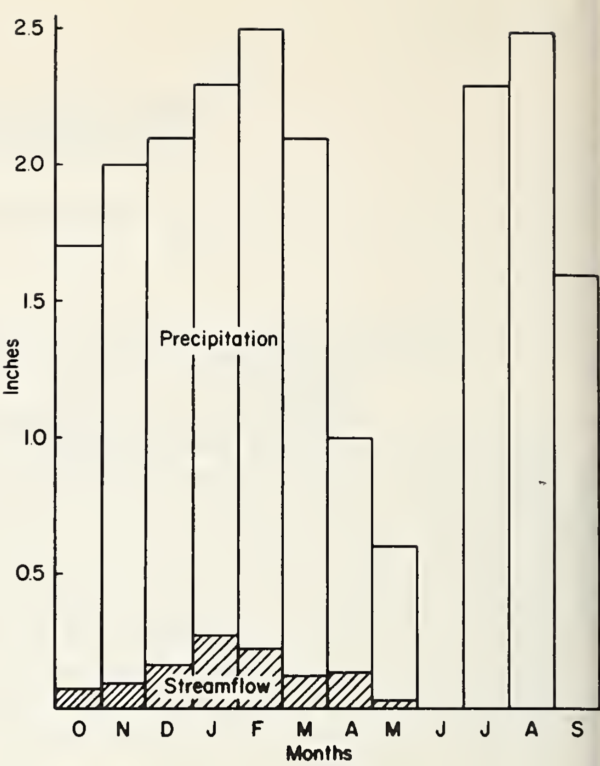

Figure 2.—Comparison of average annual precipitation and streamflow on the Heber watersheds.

Hydrology

Temperature

Annual temperature regimes are similar to those observed in other Arizona ponderosa pine forests (Schubert 1974). Annual temperature measured adjacent to the watersheds is 49°F (9°C).

Precipitation

The watersheds receive an average of 21 inches (53.3 cm) of precipitation annually, an amount commonly associated with Arizona ponderosa pine forests (Schubert 1974). The averages were determined from precipitation gages located on and adjacent to the watersheds.

Two major precipitation seasons characterize the area (fig. 2). Sixty-five percent of the precipitation falls from October through April. The remainder falls primarily in July through early September.

Most of the streamflow originates as snowmelt runoff. However, as is common throughout the ponderosa pine forests in Arizona, the snow regime is quite variable. For example, peak seasonal water-equivalents in 1972-73, a year of record snowfall in Arizona (Barnes et al. 1974), averaged 7.5 inches (19.0 cm). In 1974-75, it averaged 1.2 inches (3.0 cm).

Streamflow

Streamflow was measured by 3-foot H flumes instrumented with digital stream stage recorders at the mouth of each watershed.

Annual streamflow measured at the flumes has varied from 0.02 to 5.0 inches (0.05 to 12.7 cm), with an average of 1.1 inches (2.8 cm) per year.[3] Ninety-eight percent of the annual streamflow occurs from October through April as a result of snowmelt or winter rains. Summer storms, while often intense, rarely produce runoff (fig. 2).

[3] *On one watershed, only a 3-month streamflow record is available for WY 1972-73.*

Approximately 5% of the annual precipitation becomes streamflow. From October through April, streamflow is 8% of precipitation; from May through September, it is only a trace.

Since streamflow depends upon the snow regime, snowmelt runoff efficiency — that portion of the snowpack on-site that is converted to measurable runoff — is an important hydrologic characteristic. Snowmelt runoff efficiencies on these watersheds are relatively low, less than 15% (Solomon et al. 1975).

Sediment and Water Quality

Samples of water were collected at the mouths of the watersheds at time of runoff to describe water quality, both physical and chemical.[4] Collections were taken to coincide with weekly instrument maintenance.

Suspended sediment concentrations and chemical quality characteristics of the streamflow are summarized below; pH ranged from 6.6 to 8.1.

Constituent	Range (mg/l)
Suspended sediment	3-181
Total soluble salts	23-99
Bicarbonate	14-44
Calcium	3-10
Carbonate	0
Chloride	1.4-13
Fluoride	0.02-0.16
Magnesium	0.30-0.75
Nitrate	0.03-0.75
Sodium	1-5
Sulfate	1-60

Timber

The forest overstory is uneven-aged stands of cut-over ponderosa pine with intermingling Gambel oak and alligator juniper. The average site index is 77 (Minor 1964).

[4]*This phase of the study was supported, in part, with funds provided by the U.S. Department of the Interior as authorized under the Water Resources Research Act of 1964, Public Law 88-379.*

Trees were inventoried on the two watersheds. A systematic set of thirty 0.1-acre (0.04 ha) plots was established on each watershed. All trees on each plot were tallied, and four trees from each plot were measured for height, diameter, age, and growth.

The forest overstory statistics are listed below:

	Basal area per acre (ft^2)	Volume per acre (ft^3)
Ponderosa pine	57	1,482
Gambel oak	7	136
Alligator juniper	1	13
Total	65	1,631

Ponderosa pine sawtimber averages 6,888 fbm per acre, with less than 5% in grade 3 or better (Gaines 1962).

Annual growth of the ponderosa pine stands averages 35.6 cubic feet (2.5 m^3/ha) and 136 fbm per acre as estimated by stand table projections (Ffolliott 1965).

Number of trees per acre is an important characteristic of a forest stand. The distribution of number of trees per acre by diameter class indicate an uneven-aged ponderosa pine stand structure (table 1).

Table 1.—Average number of trees per acre, by species and diameter size class (inches d.b.h.), on the Heber watersheds.

Diameter class	Ponderosa pine	Gambel oak	Alligator juniper	All species
Midpoint				
2	18.34	0.17	1.10	19.52
4	22.01	.67	.67	23.35
6	17.67	2.01	.33	20.01
8	11.83	1.33	.50	13.66
10	6.17	1.00		7.17
12	3.16	.83		3.99
14	3.67	.33		4.00
16	2.33	.50		2.83
18	1.83	.33		2.16
20	2.87	.67		3.54
22	2.76	.33		3.09
24	2.38	.17		2.55
26	1.17			1.17
28	.63		.16	.79
30	.67		.17	.84
32	.38			.38
34				
36	.17			.17
Total	98.04	8.34	2.84	109.22

Timber quality, as indexed by stem characteristics and defect features that influence the recovery of primary wood products (Barger and Ffolliott 1970), is similar to that observed in cutover ponderosa pine forests in Arizona.

Range

Total herbage production averages 104 pounds per acre (116 kg/ha), consisting of 53 pounds (50 kg/ha) of perennial grasses, 32 pounds (36 kg/ha) of forbs and half-shrubs, and 19 pounds (21 kg/ha) of shrubs. Principle grasses and grasslike plants include mutton bluegrass, blue grama, bottlebrush squirreltail, Arizona fescue, black dropseed, and sedge. Forbs are showy aster, showy goldeneye, western ragweed, and broom snakeweed. Shrubs, in addition to Gambel oak, include New Mexican locust and ceanothus.

The range inventories involved plot measurements of herbage production and utilization. On each of the watersheds, 30 clusters of three 9.6-square foot (0.9-m^2) plots were established. Herbage production was determined by weight estimate and checked by clipping and weighing (Pechanec and Pickford 1937a). Utilization was measured by the ocular-estimate-by-plot method (Pechanec and Pickford 1937b).

Forest Floor

The forest floor, defined as the accumulation of dead organic matter above mineral soil, affects the hydrologic cycle, tree regeneration, herbage production, and fire behavior. Total forest floor depths and weights average 1.0 inch (2.5 cm) and 7.0 tons per acre (15,680 kg/ha) respectively, with the greatest accumulation in the well-decomposed H layer (Ffolliott et al. 1976). Empirical equations for predicting forest floor depths and weights from timber basal area are similar to those developed on volcanic soils (Ffolliott et al. 1968).

Wildlife

Wildlife use has been estimated from counts of deer, elk, and cottontail fecal droppings. In addition, occurrence of browse was recorded to assess habitat quality.

Assuming one pellet group per acre per month is equivalent to 1.5 deer or elk per square mile (Neff 1968), deer and elk populations, as calculated from 1973-76 data, averaged 6 and 1.5 per section, respectively.

Estimates of cottontail populations, derived from a defecation rate of 475 pellets per day, ran as high as 14 per section (Costa 1976). The highest densities were found where ponderosa pine regeneration provided sufficient food and cover (Costa et al. 1976).

Frequencies of occurrence of browse species tallied on 1/100-acre (0.004 ha) plots, 5 feet (1.5 m) high, were:

	Percent
Ponderosa pine	87
Gambel oak	32
Ceanothus	24
Alligator juniper	5

Comparisons With Ponderosa Pine Forests on Volcanic Soils

Since ponderosa pine forests in Arizona are found on both sedimentary soils, such as on the Heber watersheds, and volcanic soils such as those on the Beaver Creek watershed (fig. 1), a comparison of hydrologic and biotic characteristics for the same time period may be useful to land managers.

While temperatures and precipitation regimes on the Heber and Beaver Creek watersheds are similar, average annual runoff measured at the flume on the latter is approximately four times the runoff from the former. More than 90% of the streamflow from both areas occurs from October through April.

Snowmelt runoff efficiencies on the Heber watersheds are lower than those on the Beaver Creek watershed (Solomon et al. 1975). Efficiencies on sandstone soils were less than 10% in 1972-73; corresponding efficiencies on the volcanic soils ranged from 45 to 90% for the same time.

Suspended sediment concentrations and average values of dissolved chemical constituents on the Beaver Creek watershed (Brown et al. 1974) are similar to those observed on the Heber watersheds.

The forest overstory on the Heber watersheds is less dense than on Beaver Creek (Brown et al. 1974). This difference is due partly to different timber cutting histories on the two areas. However, growth rates at Heber are greater than those estimated on Beaver Creek. Forest densities were less on the Heber watersheds, and, therefore, individual tree growth rates were higher. Site index on the sandstone soils averaged 77, but only 60 on the volcanic soils.

Excluding reproduction, there are fewer trees in all size classes on the Heber watersheds than on the Beaver Creek watershed (Brown et al. 1974). However, the density of reproduction was approximately twice as great on the sandstone soils. Openings in Arizona ponderosa pine stands on sedimentary soils are more commonly characterized by dense reproduction than are openings in stands on volcanic soils (Ffolliott and Clary 1975).

Total herbage production levels on the Heber watersheds are less than estimated for untreated conditions on the Beaver Creek watershed (Brown et al. 1974).

Herbage production on the Heber watersheds at a given level of tree density or depth of forest floor was approximately one-half that produced on the Beaver Creek watershed (Clary and Ffolliott 1966, Clary et al. 1968).

The depths and weights of the forest floor on the Heber watersheds are similar to those found on volcanic soils as characterized on the Beaver Creek watershed (Ffolliott et al. 1968).

The primary difference in browse frequencies observed on the Heber and Beaver Creek watersheds is the greater occurrence of ceanothus at Heber.

Summary

The physiographic, hydrologic, and biotic information that characterizes the Heber watersheds is assumed to be representative of ponderosa pine ecosystems on porous sandstone soils in north-central Arizona. Based on this information and that obtained from ponderosa pine ecosystems on soils derived from volcanic materials, the following comparisons can be made regarding products and uses of the land:

- Annual water yield measured at the flume from sandstone soils is approximately 25% of that from volcanic soils.
- Physical and chemical water qualities (suspended sediment concentrations and dissolved chemical constituents) are similar on both soil types.
- Forest densities on the sandstone soils are less than on the volcanics, and, therefore, annual growth of the ponderosa pine stands on sandstone is greater because of higher individual tree growth rates. Site index is also higher on the sandstone soils. Timber quality is similar on both areas.
- Total herbage production on the sandstone soils is less than has been estimated on the volcanics. Furthermore, herbage production on sandstone soils at a given level of tree density or depth of forest floor is less than produced on volcanic soils.

Literature Cited

Baker, Malchus B., Jr. and Harry E. Brown. 1975. Multiple use evaluations on ponderosa pine forest land. Ariz. Watershed Symp. 18:18-25.

Barger, Roland L. and Peter F. Ffolliott. 1970. Evaluating product potential in standing timber. USDA For. Serv. Res. Pap. RM-57, 20 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Barnes, James C., Clinton J. Bowley, and David A. Simmes. 1974. The application of ERTS imagery to mapping snow cover in the western United States. ERTS Type III Final Report, Nat. Tech. Inf. Serv. E74-10400, 80 p.

Brown, Harry E., Malchus B. Baker, Jr., James J. Rogers, et al. 1974. Opportunities for increasing water yields and other multiple use values on ponderosa pine forest lands. USDA For. Serv. Res. Pap. RM-129, 36 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Clary, Warren P. and Peter F. Ffolliott. 1966. Differences in herbage-timber relationships between thinned and unthinned ponderosa pine stands. U.S. For. Serv. Res. Note RM-74, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Clary, Warren P., Peter F. Ffolliott, and Donald A. Jameson. 1968. Relationship of different forest floor layers to herbage production. USDA For. Serv. Res. Note RM-123, 3 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Costa, Ralph. 1976. Cottontail (*Sylvilagus auduboni*) response to ponderosa pine forest management. MS Thesis. Univ. of Ariz., Tucson, 42 p.

Costa, Ralph, Peter F. Ffolliott, and David R. Patton. 1976. Cottontail responses to forest management in southwestern ponderosa pine. USDA For. Serv. Res. Note RM-330, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Ffolliott, Peter F. 1965. Determining growth of ponderosa pine in Arizona by stand projection. U.S. For. Serv. Res. Note RM-52, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Ffolliott, Peter F. and Warren P. Clary. 1975. Differences in herbage-timber relationships on sedimentary and igneous soils in Arizona ponderosa pine stands. Prog. Agric. in Ariz. 27(3):6-7.

Ffolliott, Peter F., Warren P. Clary, and James R. Davis. 1968. Some characteristics of the forest floor under ponderosa pine in Arizona. USDA For. Serv. Res. Note RM-127, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Ffolliott, Peter F., David L. Fisher, and David B. Thorud. 1972. A physiographic survey of the ponderosa pine type on the Salt-Verde Basin. Ariz. Agric. Exp. Stn. Tech. Bull. 200, 60 p.

Ffolliott, Peter F., Warren P. Clary, and Malchus B. Baker, Jr. 1976. Characteristics of the forest floor on sandstone and alluvial soils in Arizona's ponderosa pine type. USDA For. Serv. Res. Note RM-308, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Gaines, Edward M. 1962. Improved system for grading ponderosa pine and sugar pine saw logs in trees. U.S. Dep. Agric. For. Serv., Pacific Southwest For. and Range Exp. Stn., Tech. Pap. 75, 21 p.

Minor, Charles O. 1964. Site-index curves for young-growth ponderosa pine in northern Arizona. U.S. For. Serv. Res. Note RM-37, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Neff, Donald J. 1968. The pellet-group count technique for big game trend, census, and distribution: a review. J. Wildl. Manage. 32:597-614.

Pechanec, Joseph F. and G. D. Pickford. 1937a. A weight estimate method for determination of range or pasture production. J. Am. Soc. of Agron. 29:894-904.

Pechanec, Joseph F. and G. D. Pickford. 1937b. A comparison of some methods of determining percentage utilization of range grasses. J. Agric. Res. 54:753-765.

Schubert, Gilbert H. 1974. Silviculture of southwestern ponderosa pine: the status of our knowledge. USDA For. Serv. Res. Pap. RM-123, 71 p. Rocky Mt. For. and Range Exp. Stn. Fort Collins, Colo.

Solomon, Rhey M., Peter F. Ffolliott, Malchus B. Baker, Jr., Gerald J. Gottfried, and J. R. Thompson. 1975. Snowmelt runoff efficiencies on Arizona watersheds. Ariz. Agric. Exp. Stn. Res. Pap. 274, 50 p.

Agriculture—CSU, Fort Collins

PLANTS

Common Name	Scientific Name
Trees	
alligator juniper	*Juniperus deppeana*
Gambel oak	*Quercus gambelii*
ponderosa pine	*Pinus ponderosa*
quaking aspen	*Populus tremuloides*
Shrubs	
Fendler ceanothus	*Ceanothus fendleri*
New Mexican locust	*Robinia neomexicana*
Grasses, Grasslike Plants, and Forbs	
Arizona fescue	*Festuca arizonica*
black dropseed	*Sporobolus interruptus*
blue grama	*Bouteloua gracilis*
bottlebrush squirreltail	*Sitanion hystrix*
broom snakeweed	*Gutierrezia sarothrae*
showy goldeneye	*Viguiera multiflora*
mutton bluegrass	*Poa fendleriana*
sedge	*Carex* spp.
showy aster	*Aster commutatus*
western ragweed	*Ambrosia psilostachya*

ANIMALS

Common Name	Scientific Name
Mammals	
Abert squirrel	*Sciurus aberti*
cottontails	*Sylvilagus* spp.
elk	*Cervus canadensis*
mule deer	*Odocoileus hemionus*
Birds	
Merriam's turkey	*Meleagris gallopavo*

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Keywords: *Pinus ponderosa*, sandstone soils, water yield.

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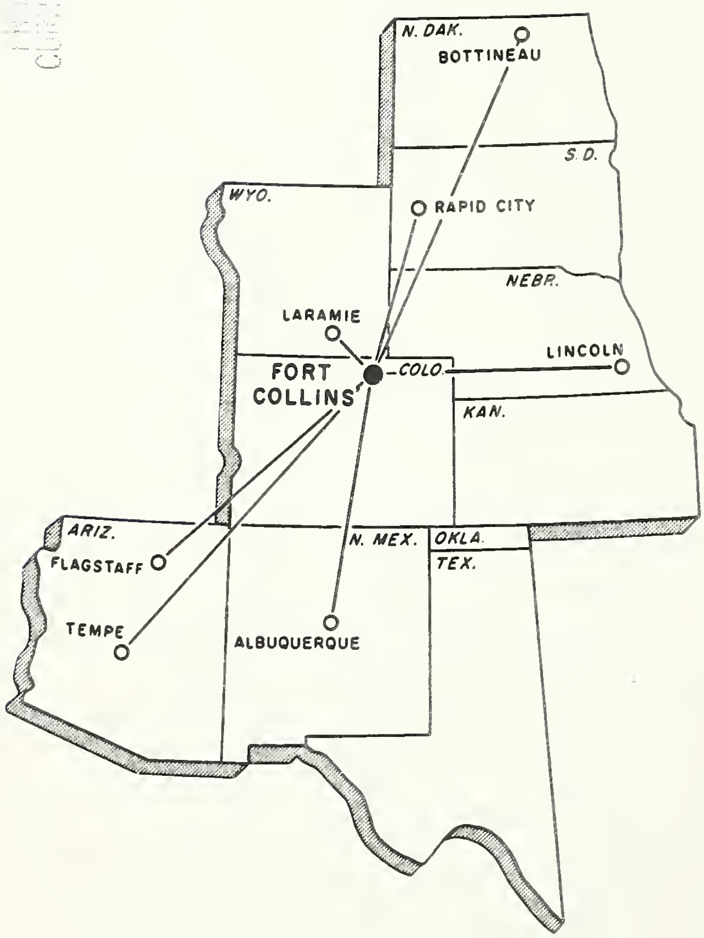
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