CEG 403 **SPRING 2003**

HOMEWORK #2, *(Due: Tuesday, February 4th)*

WATER BUDGET OF MONO LAKE

(from Lee and Fetter, "Hydrogeology Laboratory Manual")

Purpose: This assignment will familiarize the student with the components of the hydrologic cycle. In doing so, the student will need to analysis hydrologic data and become familiar with commonly used units in hydrology.

Problem: Determine the average annual groundwater flow into or out of Mono Lake, California.

Approach: Use the continuity equation on the water budget of Mono Lake and solve for the unknow groundwater flow term.

Background of Mono Lake Basin

Mono Basin is a closed lake system (i.e., there is no outlet) located in Central California near the Nevada-California state line. It is located about 780 kilometers east of San Francisco, California and about 160 kilometers south of Reno, Nevada. The total watershed area is 1747 km^2 (See Figure 1) which includes the surface area of Mono Lake (215 km^2). The basin floor has an elevation of approximately 1948 meters. The Sierra Nevadas are to the east of Mono Lake and form the easterly boundary of Yosemite National Park. They have peak elevations of approximately 3900 meters. The drainage from the Sierra Nevadas is the predominate source of runoff into Mono Lake through three creeks (Mill, Lee Vining, and Rush Creek).

The climate of the Mono Basin has cold-wet winters and dry summers with cold nights and hot days. The majority of precipitation in the winter is in the form of snow which melts into runoff in the spring and summer. Table 1 lists the average annual precipitation for several stations in the Mono Basin.

1. Water Budget

Write the continuity equation for *Mono Lake* including all terms that you think may be significant. Consider addition to the lake as positive and removal from the lake as negative. The groundwater flow term is unknown, so you will have to assume a direction of flow (i.e., in or out of the lake).

2. Precipitation

There are several precipitation stations that the National Oceanic and Atmospheric Administration and the Los Angeles Department of Power and Water maintain in the vicinity of Mono Basin.

TABLE 1

PRECIPITATION, MONO BASIN		
Station Name	Elevation (meters)	Average Annual Precipitation (mm)
Bodie	2551	525
Benton	1665	225
Ellery Lake	2926	650
Gem Lake	2734	575
Cain Ranch	2097	350

(a) Arithmetic Average: Using the precipitation data, determine the effective average annual precipitation (hectare-m) for the *Mono Lake watershed* (which includes Mono Lake) and, separately, for *Mono Lake only*. Use only those stations that are located within the basin (See Figure 2).

(b) Thiessen Method: Use the Thiessen Method on all of the stations shown in Figure 2 to determine the average annual precipitation (hectare-m) for *Mono Lake only*.

(c) Compare the results of average annual precipitation (hectare-m) over Mono Lake using the two procedures in (a) and (b).

3. Evaporation

The evaporation from Mono Lake can be estimated with recorded evaporation data at Cain Ranch which has a 4-foot (1.22 meter) diameter Class A galvanized land pan. The following pan data was recorded at Cain Ranch:

Volume of water needed to recharge the Class A evaporation pan (corrected for precipitation):

May	127.6 liters (L)	August	279.9 L
June	194.6 L	September	187.0 L
July	356.2 L	October	126.8 L

(a) Calculate the pan evaporation (m) for this period (May-October).

(b) Data for the winter months are normally not recorded, because in much of the U.S. freezing prevents measurement. Extrapolate the May-October evaporation to annual pan evaporation (m) using Figure 3.

(c) Correct the value in (b) for pan effect using the map in Figure 4 to determine the annual lake evaporation (m).

(d) Calculate the annual lake evaporation (hectare-m) from *Mono Lake only*.

4. Runoff

There are three main streams that flow into Mono Lake (See Figure 1). These streams are gaged by the Los Angeles County Department of Water and Power (LADWP) and have the following average annual runoff:

Lee Vining Creek	2.47 cubic meters per second (m^3/s)
Rush Creek	1.27 m^3/s
Mill Creek	1.05 m^3/s

(a) What is the combined average annual runoff of these streams (hectare-m)?

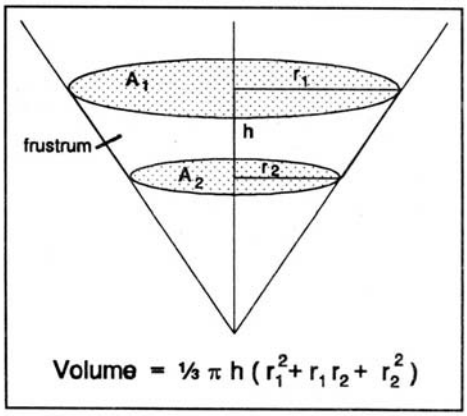
(b) The LADWP has been diverting water from these three streams (below the gaging stations) for many years. The diverted water is taken to the Los Angeles Aqueduct which conveys water to the City of Los Angeles. These diversions average 12,989 hectare-m per year. What is the average flow into Mono Lake from these three streams taking into account the diversions by LADWP (hectare-m)?

(c) There are several springs that discharge into Mono Lake near the shoreline. The average total flow from all of these springs is estimated to be 20,933 liters per minute (L/m) which should be considered as surface runoff. What is the average annual spring runoff (hectare-m)?

(d) Summarize the average annual surface runoff (hectare-m) from all sources into *Mono Lake*.

5. Storage

Mono Lake appears to be elliptical; however, morphometric studies of the lake have determined that the volume can be approximated by assuming that the lake is a circular and has uniformly sloping sides. Thus, the storage of the lake can be approximated by determining the change in volume in the frustrum of the cone, as shown in the diagram.



The LADWP had recorded that Mono Lake had a water surface elevation of 1952.8 meters in June 1954. The water surface had fallen to an elevation of 1948.0 meters in June 1964 due to diversions by LADWP. The surface area in June 1954 was 231.4 km^2, and the surface area in June 1964 was 199.3 km^2.

(a) Determine the respective radii (meters) of the lake in 1954 and 1964.

(b) Calculate the change in storage (hectare-m) of Mono Lake from June 1954 to June 1964.

(c) What is the average annual change in storage (hectare-m) from June 1954 to June 1964?

6. Groundwater Flow

The only unknown in this exercise is the groundwater flow either into or out of Mono Lake. Use the results from the earlier parts of this exercise to answer the following questions. (Note: use the precipitation value from the Thiessen Method)

(a) For the time period 1954 to 1964, what is the average annual groundwater flow into or out of Mono Lake (hectare-m)?

(b) What is the direction of the groundwater flow? Justify your answer.

(c) To arrive at the estimate of groundwater flow, what assumptions have you made about other elements of the water budget?

7. Summary

Summarize the annual water budget for Mono Lake by constructing a table as shown below:

TABLE 2

ANNUAL WATER BUDGET FOR MONO LAKE (1954-1964)			
Inflow (hectare-m/yr)		**Outflow + Change in Storage (hectare-m/yr)**	
Runoff		Evaporation	
Precipitation			
Groundwater Flow		Change in Storage	
Total Inflow		Total Outflow + Change in	

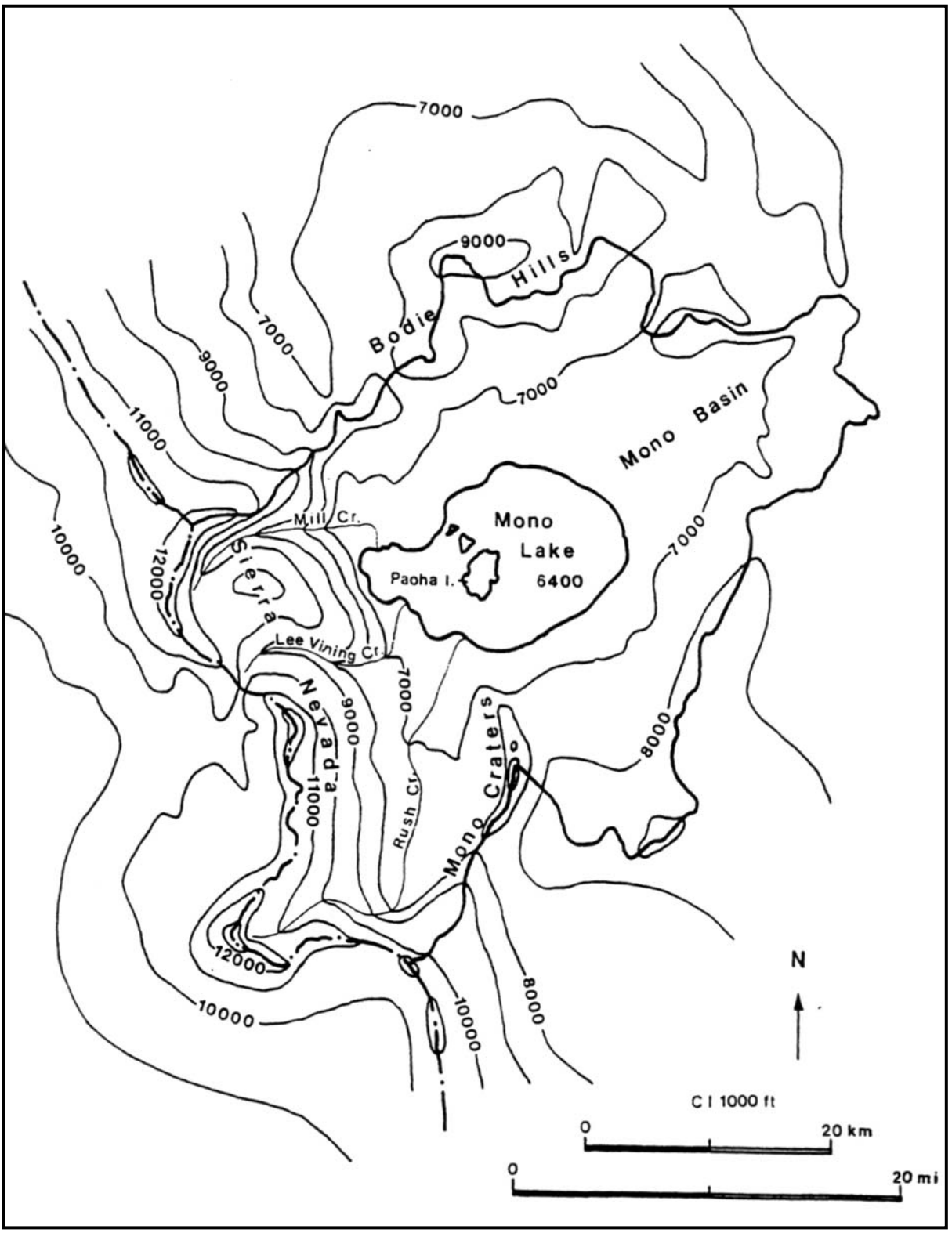


Figure 1: Topographic map of the Mono Lake - Sierra Nevada region. The heavy line is the divide of the Mono Basin.

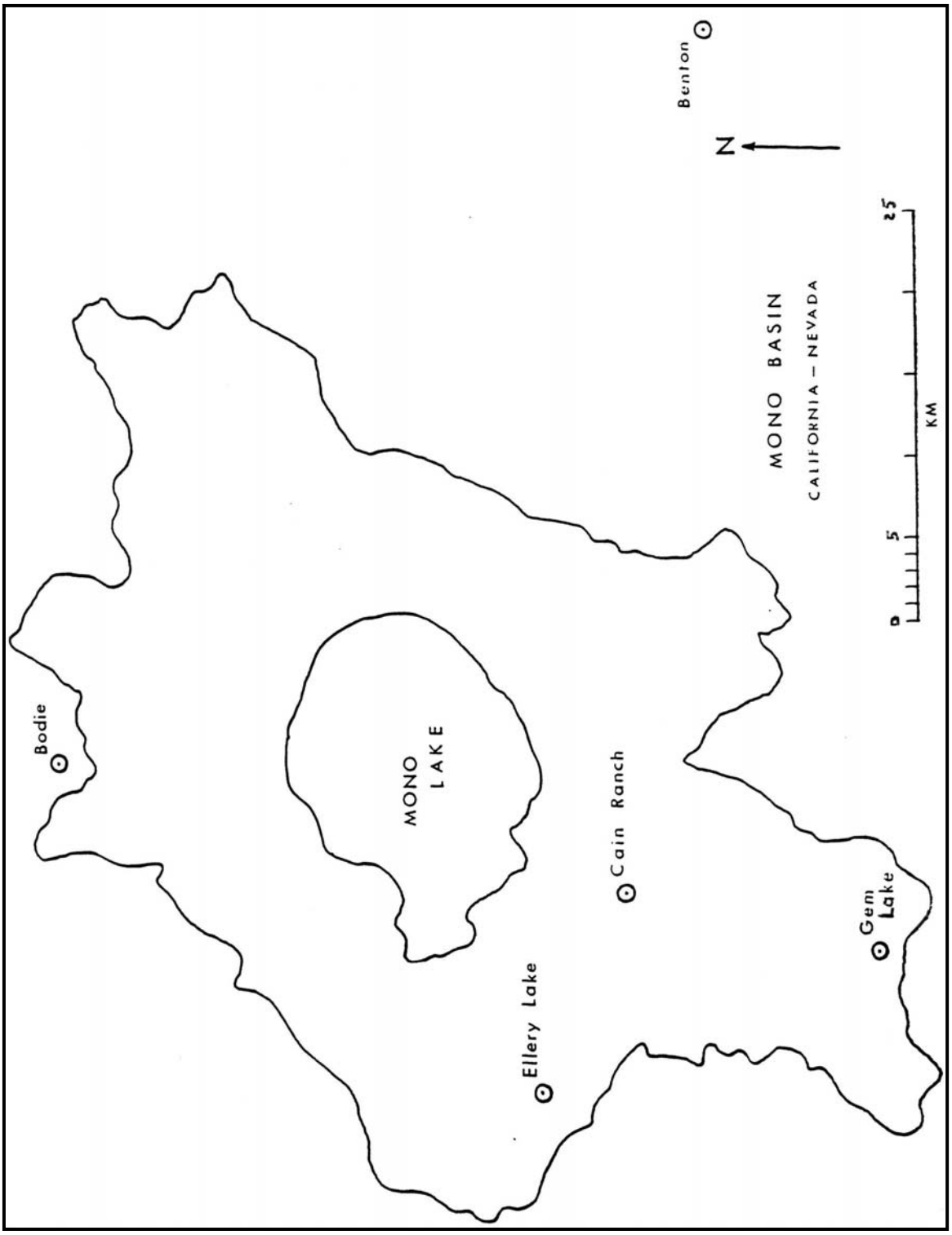


Figure 2: Precipitation stations in and around Mono Basin.

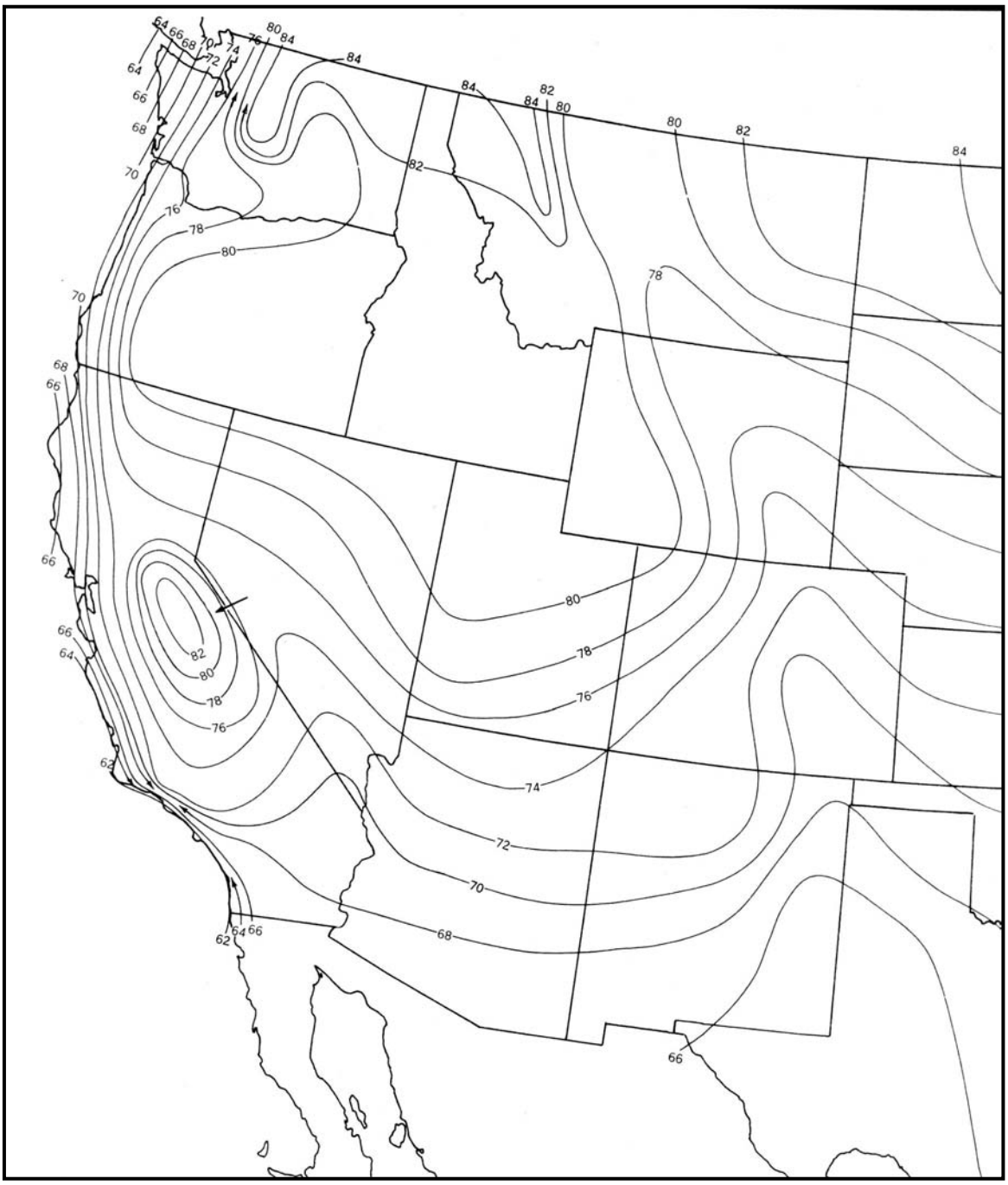


Figure 3: Average May-October evaporation (percent of annual) in the western United States.

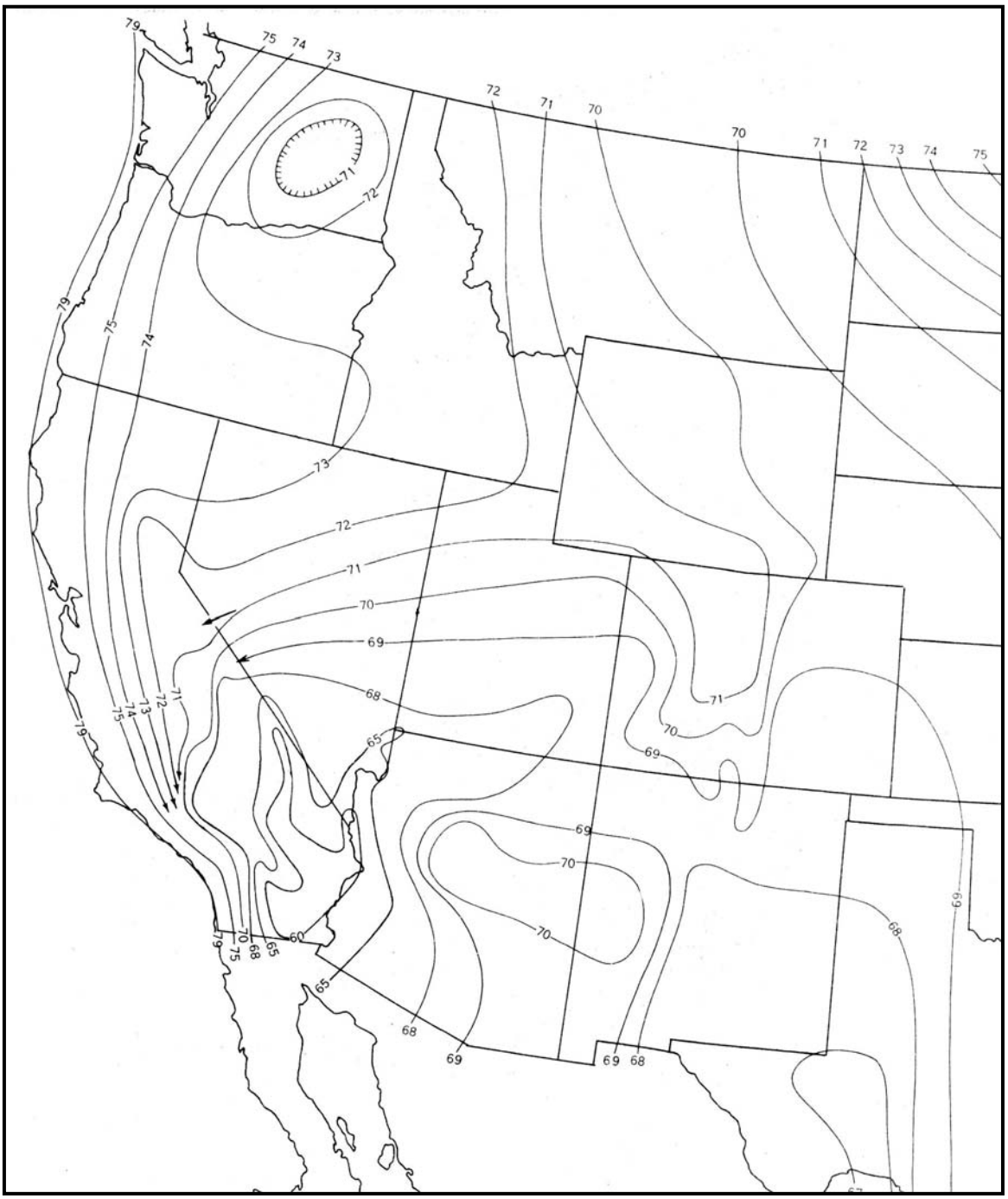


Figure 4: Average annual Class A Pan coefficient (in percent) in the western United States.