SNOWMELT-RUNOFF MODEL UTILIZING REMOTELY-SENSED DATA

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INTRODUCTION

The Snowmelt-Runoff Model (SRM) has been developed to simulate discharge from mountain basins where snowmelt is an important component of runoff. The flow diagram for SRM is shown in Figure 1 which indicates that the model is of simple structure requiring input of only temperature, precipitation, and snow-covered area. The model has been successfully tested on a wide range of basin sizes and elevations (ΔH) as shown in Figure 2. The data requirements for applying SRM to a basin are shown in Table 1. Typically, the optimum conditions are seldom met and less data must be used. SRM can operate with the minimum conditions shown in Table 1. Only three satellite snow-cover observations were available for the application of SRM to the Okutadami basin in Japan, for example. When no runoff records are available, the recession coefficient can be derived from a size relationship with other known basins. Assistance for applying the model is provided in the user manual (Martinec, et al., 1983).

Results from model simulations are shown in Table 2 for 14 basins in 8 countries. The asterisks in Table 2 indicate basins where the snow-cover data were obtained from satellites. The average absolute percent volume difference for all the basins was 3% and the average R^2 value was 85%.

SRM was recently tested as one of 11 models in the World Meteorological Organization project on Intercomparison of Models of Snowmelt Runoff. On the various basin data sets, SRM typically was one of the top three models in performance. Table 3 presents a summary of strengths and weaknesses of SRM for application to a basin. Presently work is being conducted to develop a forecasting procedure for the model which will incorporate snow water equivalent data. In addition, more rigorous precipitation and evapotranspiration algorithms will be added to the model for operation during the non-snowmelt season.

RESULTS

Kings River Basin Simulations

SRM was tested on the Kings River basin in the Sierra Nevada Mountains of California. This was the largest basin on which SRM has been tested. Figure 3 shows the elevation zones (7) and respective areas that the basin was divided into for application of SRM. The elevation range of 171-4341 m is extremely large. Figure 4 illustrates the determination of the zonal mean hypsometric elevations ($\bar{h}$) using an area-elevation curve and balancing the areas above and below the mean elevation. The $\bar{h}$ value is used as the elevation to which base station temperatures are extrapolated for the calculation of zonal degree-days.

Examples of the satellite-derived snow-cover depletion curves are given in Figures 5 and 6 for 1975 and 1976, respectively. The snow-cover depletion curves for each zone are designated by a capital letter referring to the appropriate zone in Figure 3. It can be seen that the snow cover leaves the basin much more rapidly in the drought year of 1976 than in the near normal year of 1975. The data for construction of the depletion curves came from both the Landsat and NOAA satellites.

Daily temperature, precipitation, and snow cover were then input to the model for the snowmelt seasons of 1973, 1975, 1976, and 1978. Figures 7, 8, 9, and 10 show the correspondence between measured streamflow and SRM computed streamflow for the years 1973, 1975, 1976, and 1978, respectively. The average absolute percent volume difference (Dv) for the snowmelt season for these years is 5.05% and the average R^2 value (daily flows) is 0.79. Even in the extreme drought year (1976) the performance of SRM is quite good.

Okutadami River Basin Simulation

Using data supplied by the Japanese cooperators, SRM was applied to the Okutadami River basin in central Japan. Okutadami has an elevation range of 782-2346 m and the basin was divided into three elevation zones of about 500 m increments as shown in Figure 11. Figure 12 illustrates the determination of the $\bar{h}$ values for each zone using the area-elevation curve. Only three Landsat observations of snow cover were available for the snowmelt season of 1979. However, these three observations were sufficient for defining the zonal snow-cover depletion curves as shown in Figure 13.

The temperature, precipitation, and snow-cover data for 1979 were then fed to SRM and a discharge simulation for 1979 produced. The hydrograph is shown in Figure 14. The difference in volume is −5.36% and the R^2 value was 0.83. With minimum snow-cover data, the performance of SRM was commendable. There were some possible discrepancies in the runoff data that should be checked with the Japanese cooperators. The performance of SRM shows the advantages of a model not requiring several years of records for calibration before it can be run in the simulation mode.

CONCLUSIONS

SRM was run successfully on two widely separated basins. The simulations on the Kings River basin are significant because of the large basin area (4000 km^2) and the adequate performance in the most extreme drought year of record (1976). The performance of SRM on the Okutadami River basin was important because it was accomplished with minimum snow-cover data available. It is concluded that SRM can be used on these two basins. The remotely-sensed snow-cover information is the critical data input for the model.

REFERENCES

Martinec, J., Rango, A., and Major E., 1983: the snowmelt-runoff model (SRM) user's manual, NASA Reference Publication 1100, Washington, D.C., 118 pp.

Table 1
Data Requirements for Model Application

OPTIMUM CONDITIONS

1. TEMPERATURE AND PRECIPITATION RECORDED IN BASIN AT MEAN ELEVATION
2. MULTIPLE CLIMATOLOGICAL STATIONS
3. SNOW COVER OBSERVED ONCE PER WEEK
4. SEVERAL YEARS OF DAILY RUNOFF RECORDS

MINIMUM CONDITIONS

1. TEMPERATURE AND PRECIPITATION OBSERVED IN BASIN VICINITY
2. ONLY ONE CLIMATOLOGICAL STATION
3. 2-3 SNOW-COVER OBSERVATIONS DURING SNOWMELT SEASON
4. NO RUNOFF RECORDS

Table 2
Basin Characteristics and Snowmelt-Runoff Model Simulation Results

Country and Basin	Size (km^2)	Elevation range (m)	Average goodness-of-fit statistics D_v(%)	NSR^2	n
CZECHOSLOVAKIA					
Modry Dul	2.65	554	+1.7	0.95	2
FRANCE					
Durance*	2170	3319	-2.5	0.89	1
JAPAN					
Okutadami*	422	1564	-5.4	0.83	1
POLAND					
Dunajec*	700	1724	-3.8	0.73	1
SPAIN					
Lago Mar	4.5	770	N/A	N/A	N/A
SWITZERLAND					
Dischma	43.3	1478	+0.2	0.88	6
UNITED STATES					
W-3	8.42	331	+3.3	0.82	6
Dinwoody Cr.*	228	2221	+3.3	0.85	2
Bull Lake Cr.*	484	2395	+4.8	0.82	1
South Fork*	559	1408	-1.5	0.89	7
Conejos*	730	1496	+0.5	0.87	7
Rio Grande*	3419	1783	+4.4	0.86	7
Kings River*	3999	4170	+5.1	0.79	4
WEST GERMANY					
Lainbachtal	18.7	1131	N/A	N/A	N/A

D_v = percent volume difference
NSR^2 = Nash-Sutcliffe R^2 value
N/A = not available

Table 3
SRM Strengths and Weaknesses

STRENGTHS	WEAKNESSES
DAILY INPUT OF ONLY TEMPERATURE, PRECIPITATION, AND SNOW COVER	SNOW-COVER DATA NOT COMMONLY OBSERVED
NO CALIBRATION NECESSARY	SATELLITE SNOW-COVER DATA IS SOMETIMES DIFFICULT TO OBTAIN IN A TIMELY FASHION
CAN BE RUN ON MICROCOMPUTER OR EVEN HAND CALCULATOR IF NECESSARY	SNOW WATER EQUIVALENT DATA NOT YET FORMALLY INCORPORATED IN FORECASTING PROCEDURES
SIMPLE DESIGN WHERE NEW ALGORITHMS COULD EASILY REPLACE EXISTING ONES	DOES NOT HAVE RIGOROUS PRECIPITATION AND EVAPOTRANSPIRATION ALGORITHMS FOR OPERATION DURING THE NON-SNOWMELT PERIOD OF THE YEAR
OPERATES EFFECTIVELY ON BASINS IN THE SIZE RANGE 1.0-4000km^2	
USER MANUAL AVAILABLE FOR EASY APPLICATION TO NEW BASINS	
ELEVATION ZONE OPTION AVAILABLE	

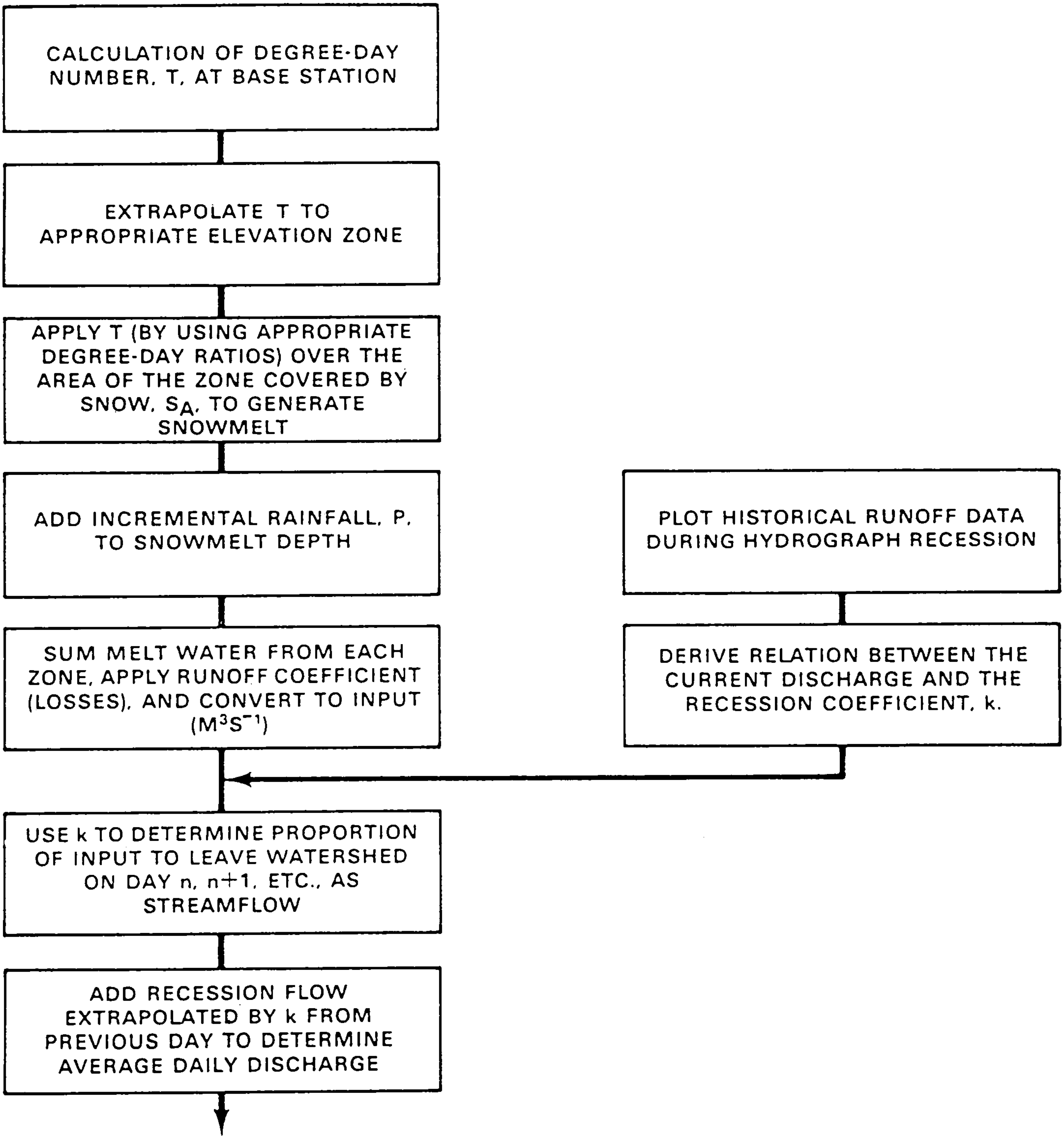


Figure 1. Flow Diagram for Snowmelt Runoff Model

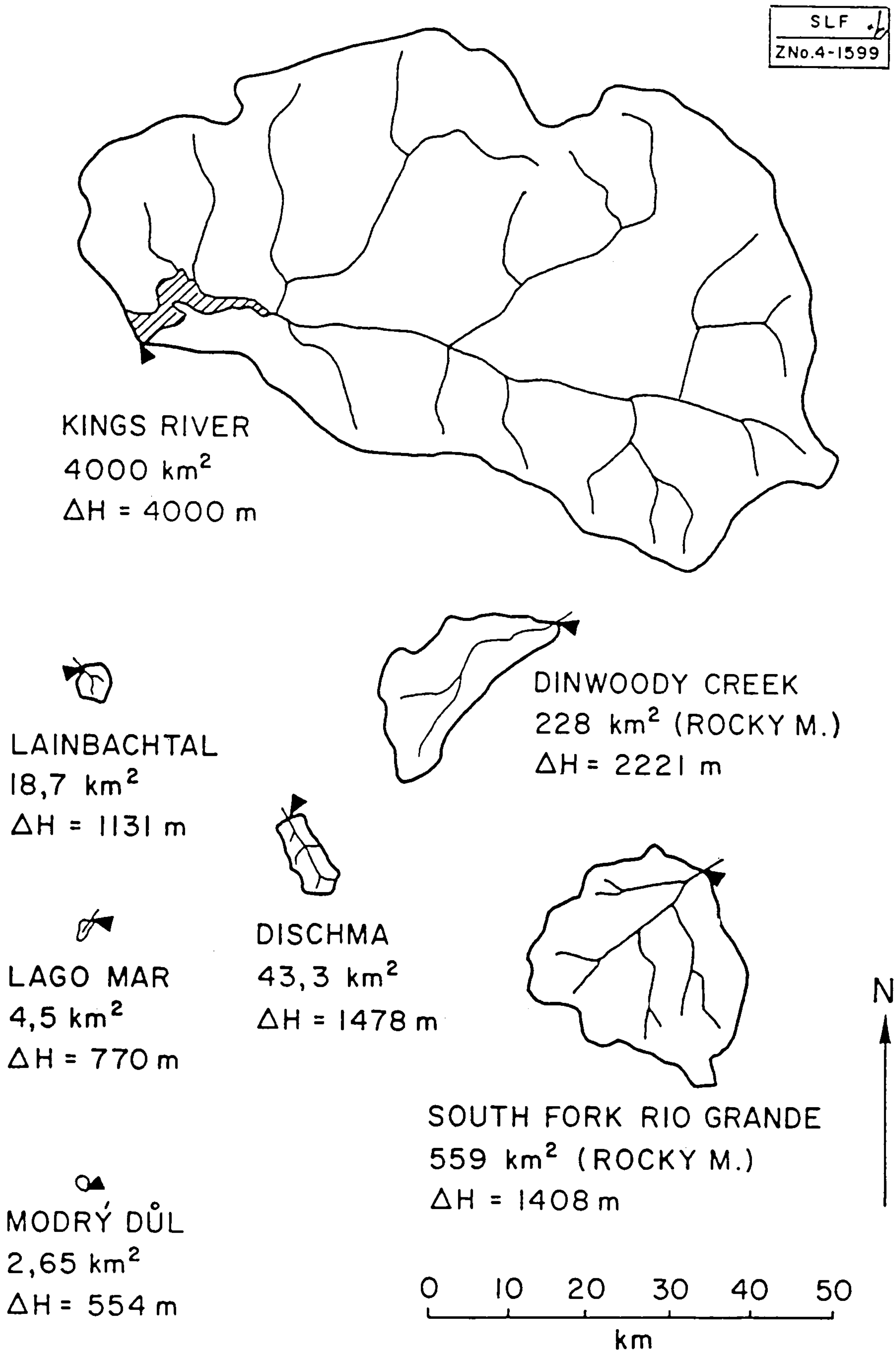
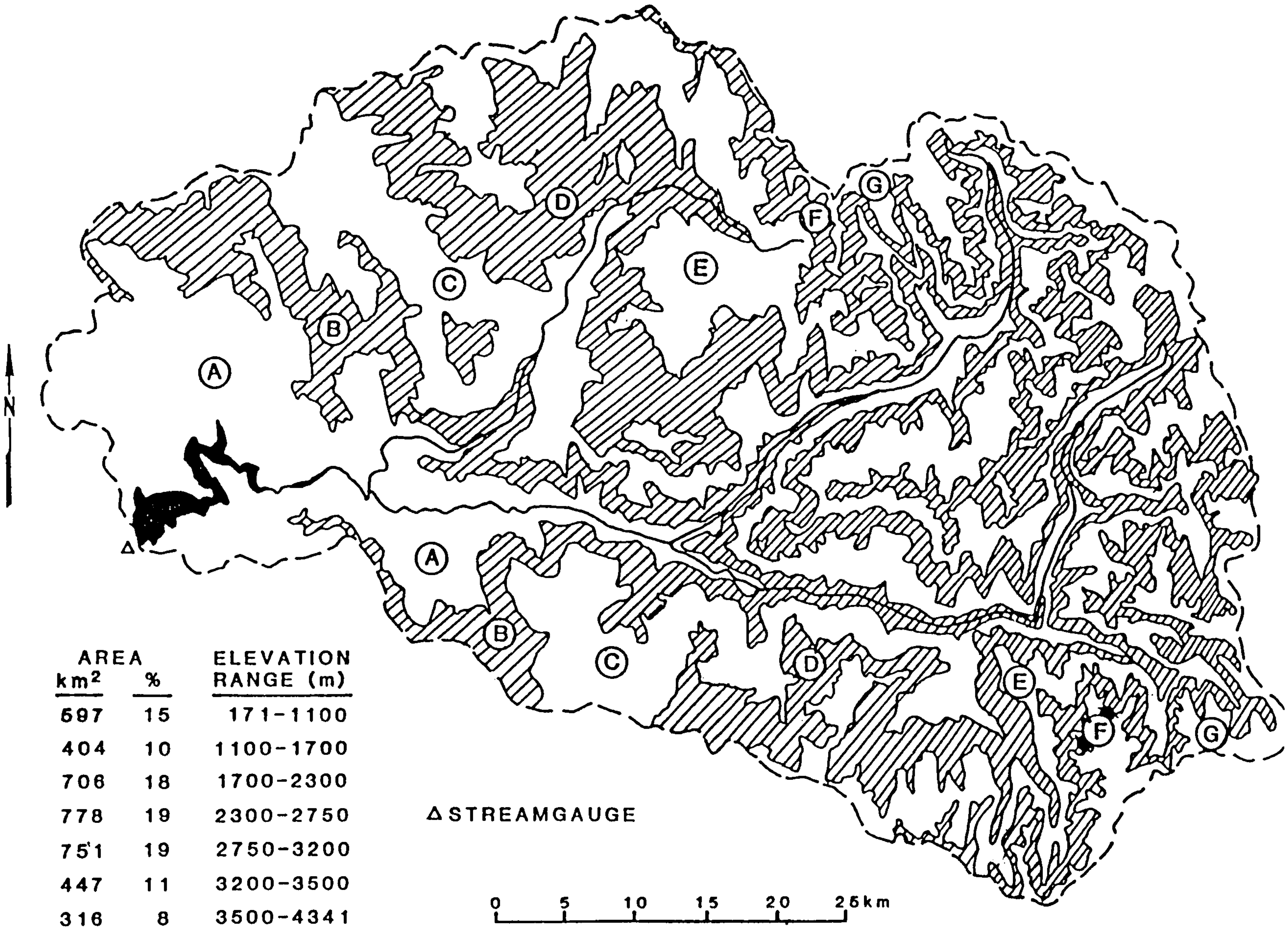


Figure 2. Size and elevation Range of some basins tested using SRM



ZONE	AREA km²	AREA %	ELEVATION RANGE (m)
Ⓐ	597	15	171-1100
Ⓑ	404	10	1100-1700
Ⓒ	706	18	1700-2300
Ⓓ	778	19	2300-2750
Ⓔ	751	19	2750-3200
Ⓕ	447	11	3200-3500
Ⓖ	316	8	3500-4341
	3999	100	

Figure 3. Elevation zones and areas of the Kings River Basin below Pine Flat Dam, California

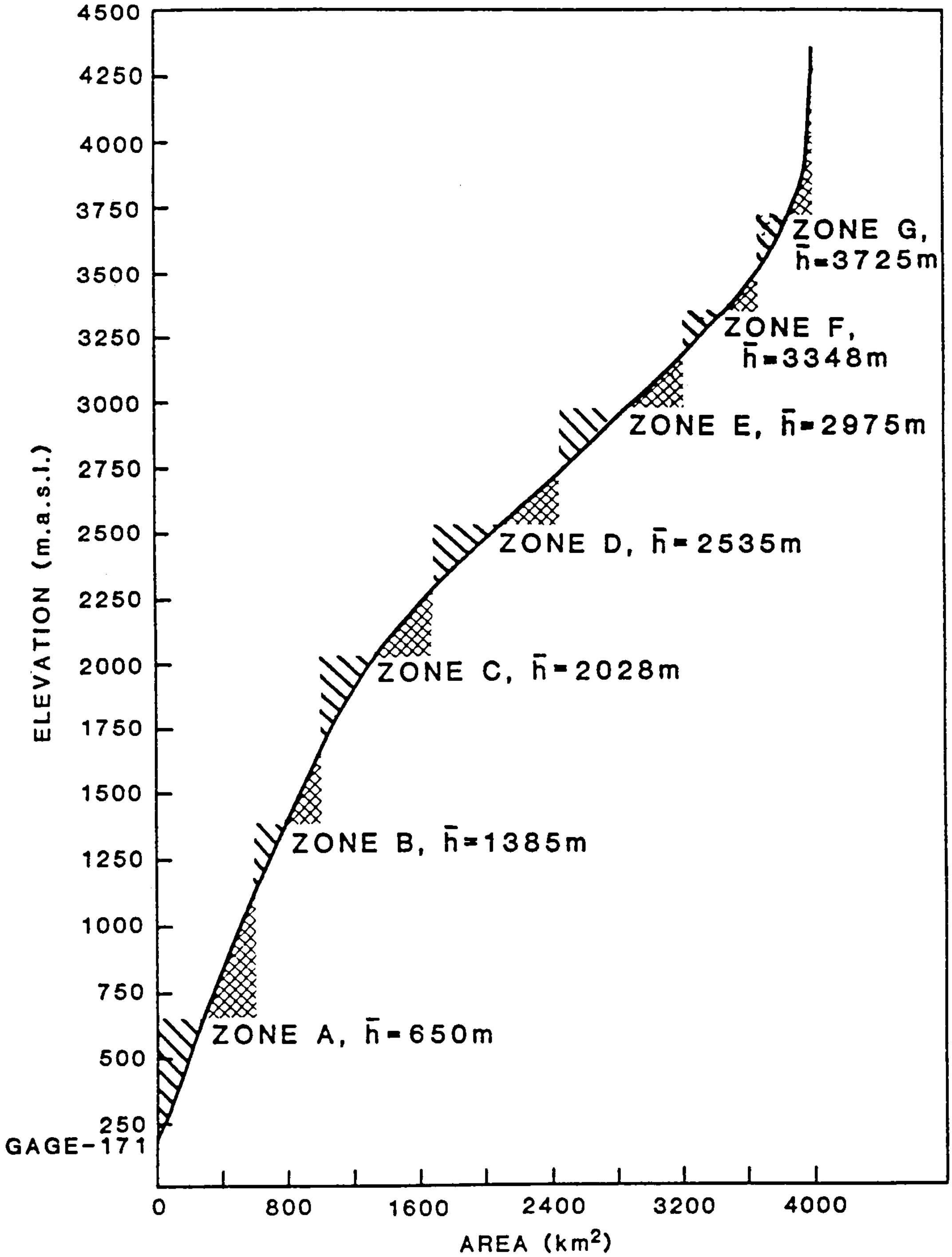


Figure 4. Determination of zonal mean hypsometric elevations ($\bar{h}$) using an area-elevation curve for the Kings River Basin, California

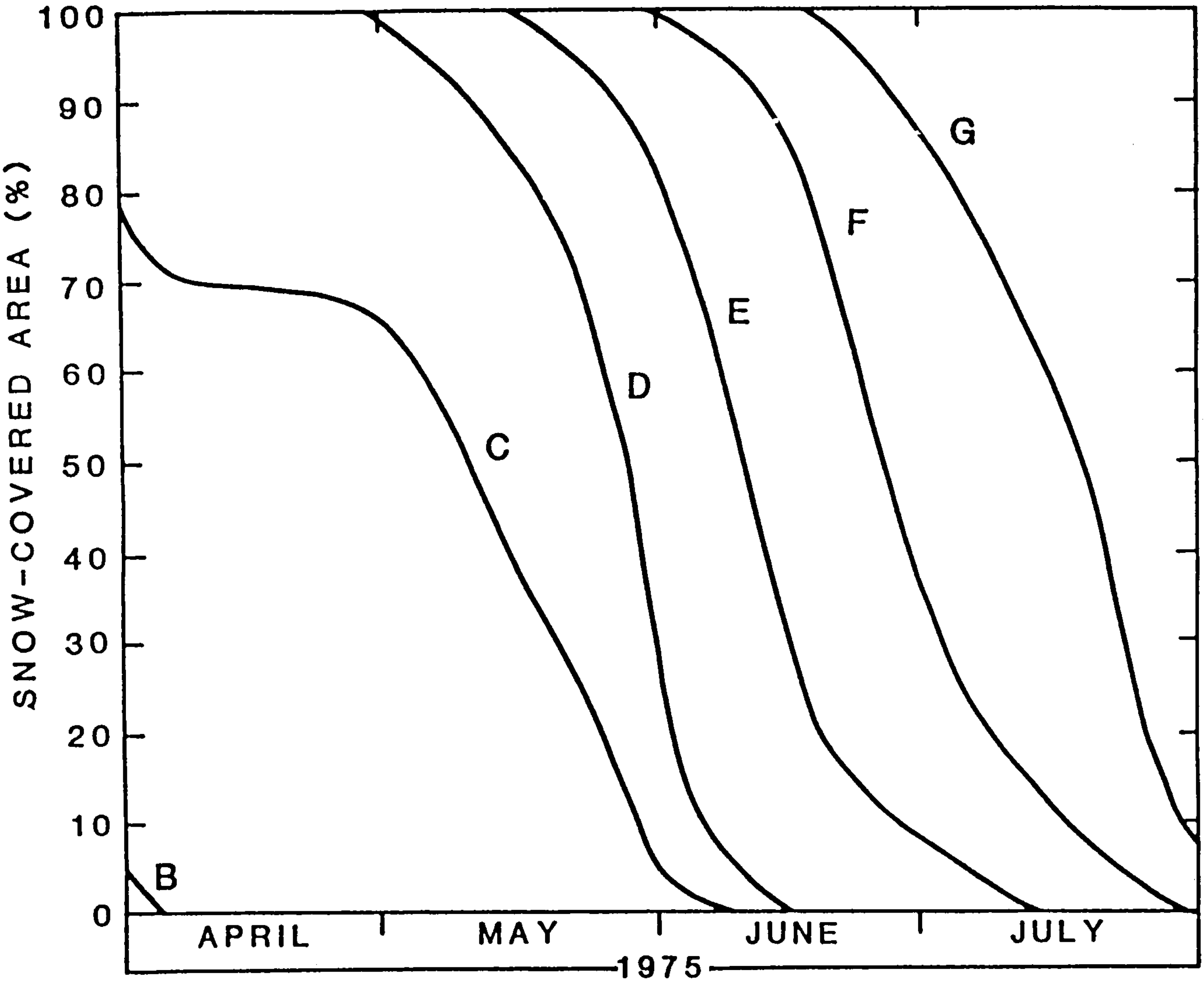


Figure 5. Landsat derived snow-cover depletion curves for elevation zones B, C, D, E, F and G in the Kings River Basin

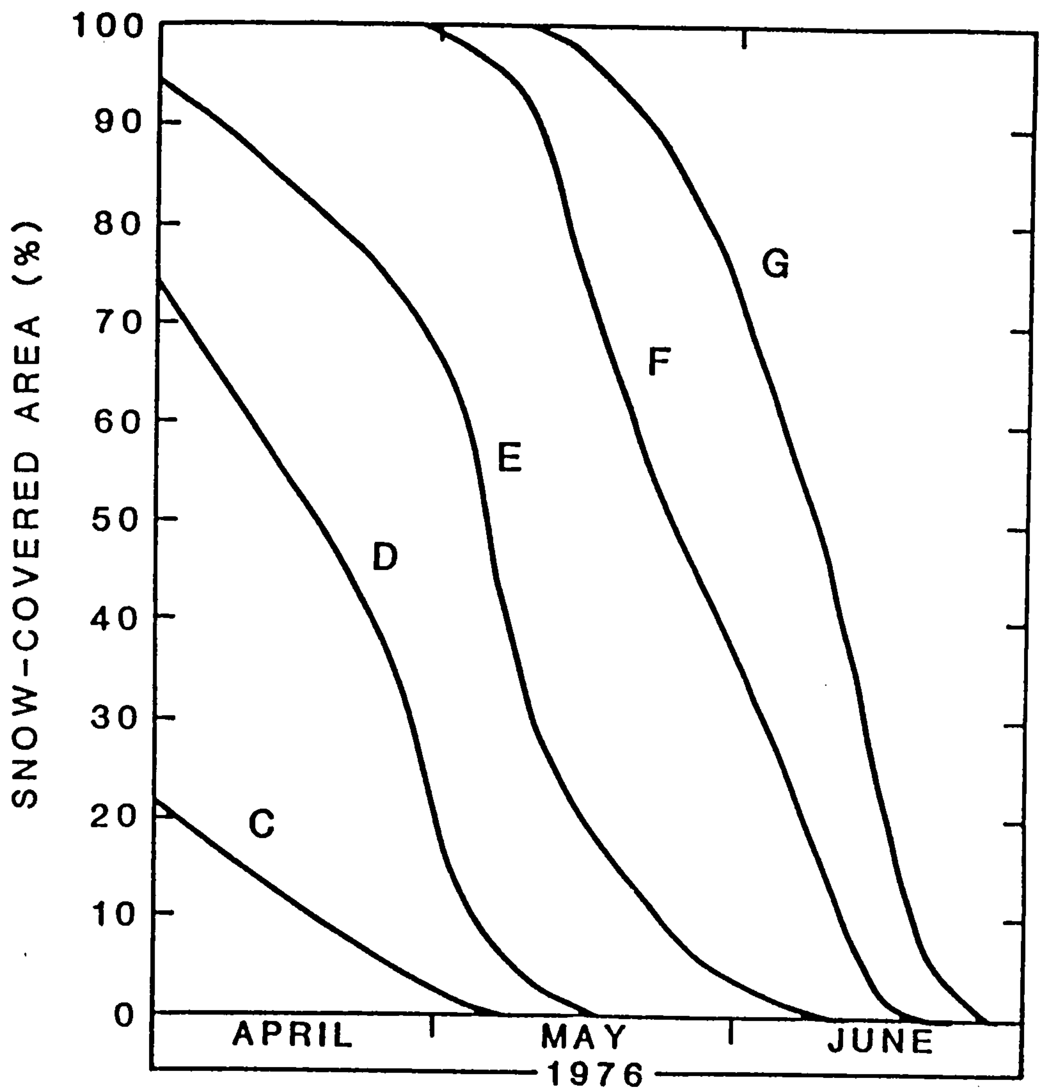


Figure 6. Landsat derived snow-cover depletion curves for elevation zones C, D, E, F and G in the Kings River Basin

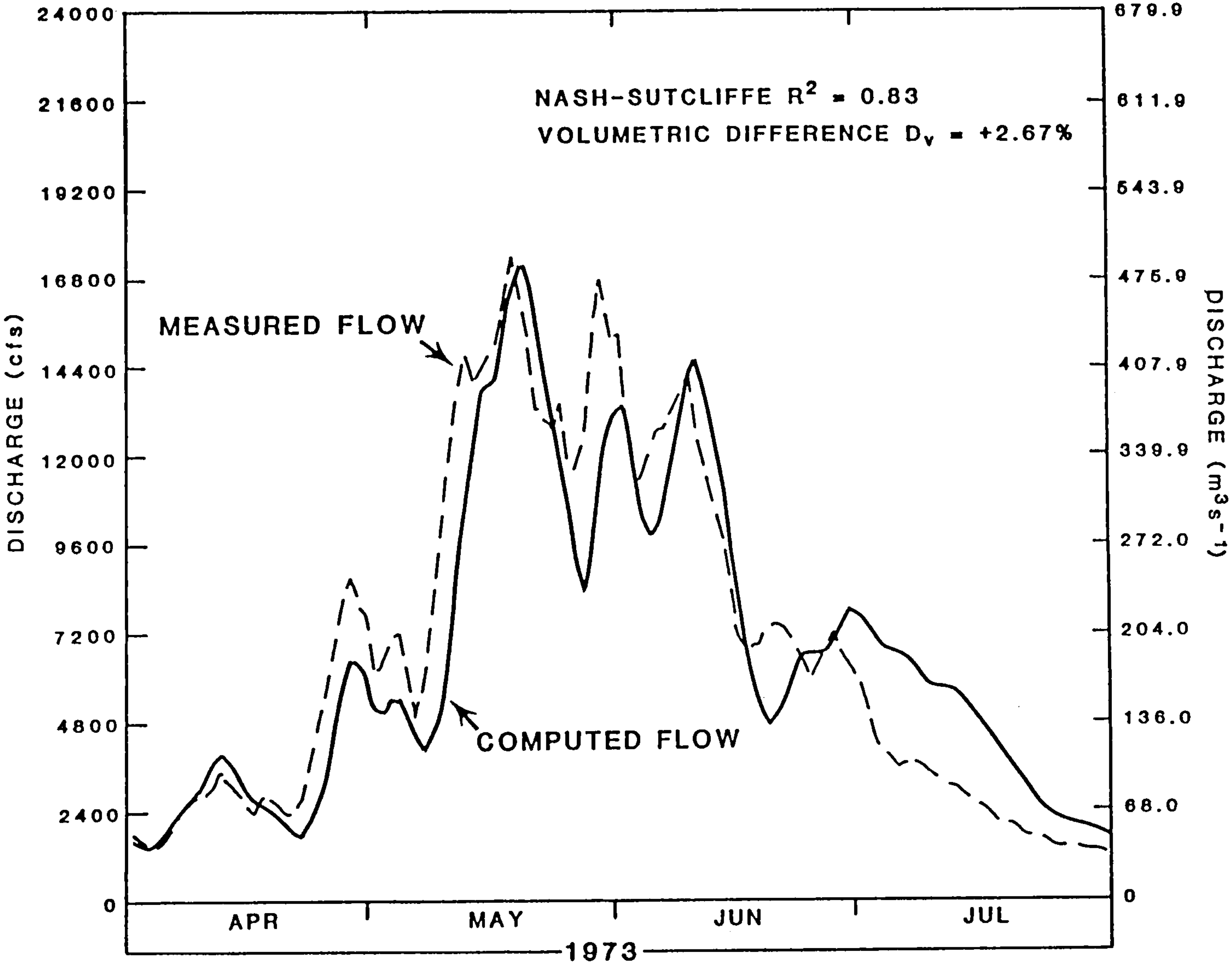


Figure 7. Discharge simulation for the Kings River Basin (3999 km^2), California using the snowmelt-runoff model

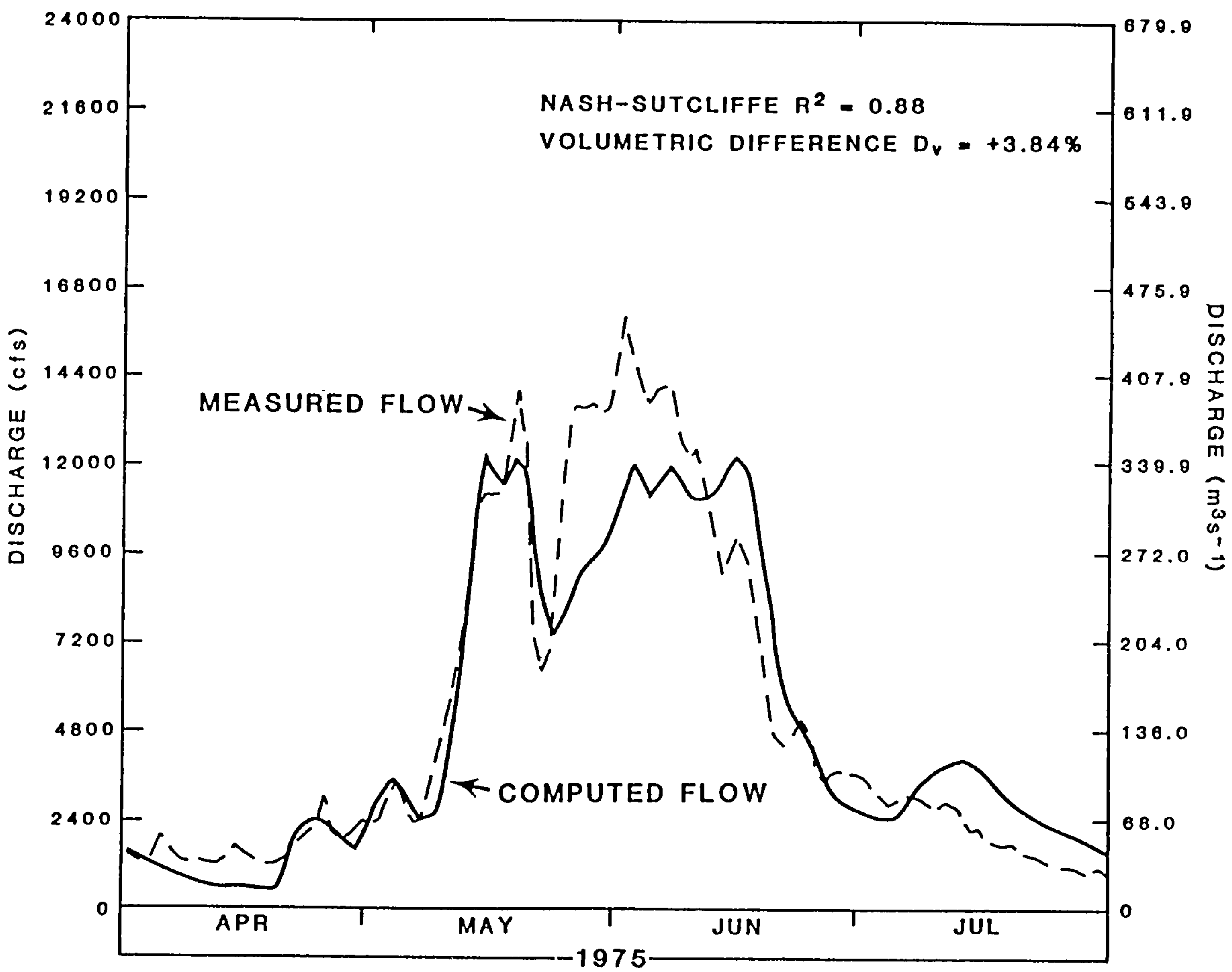


Figure 8. Discharge simulation for the Kings River Basin (3999 km^2), California using the snowmelt-runoff model

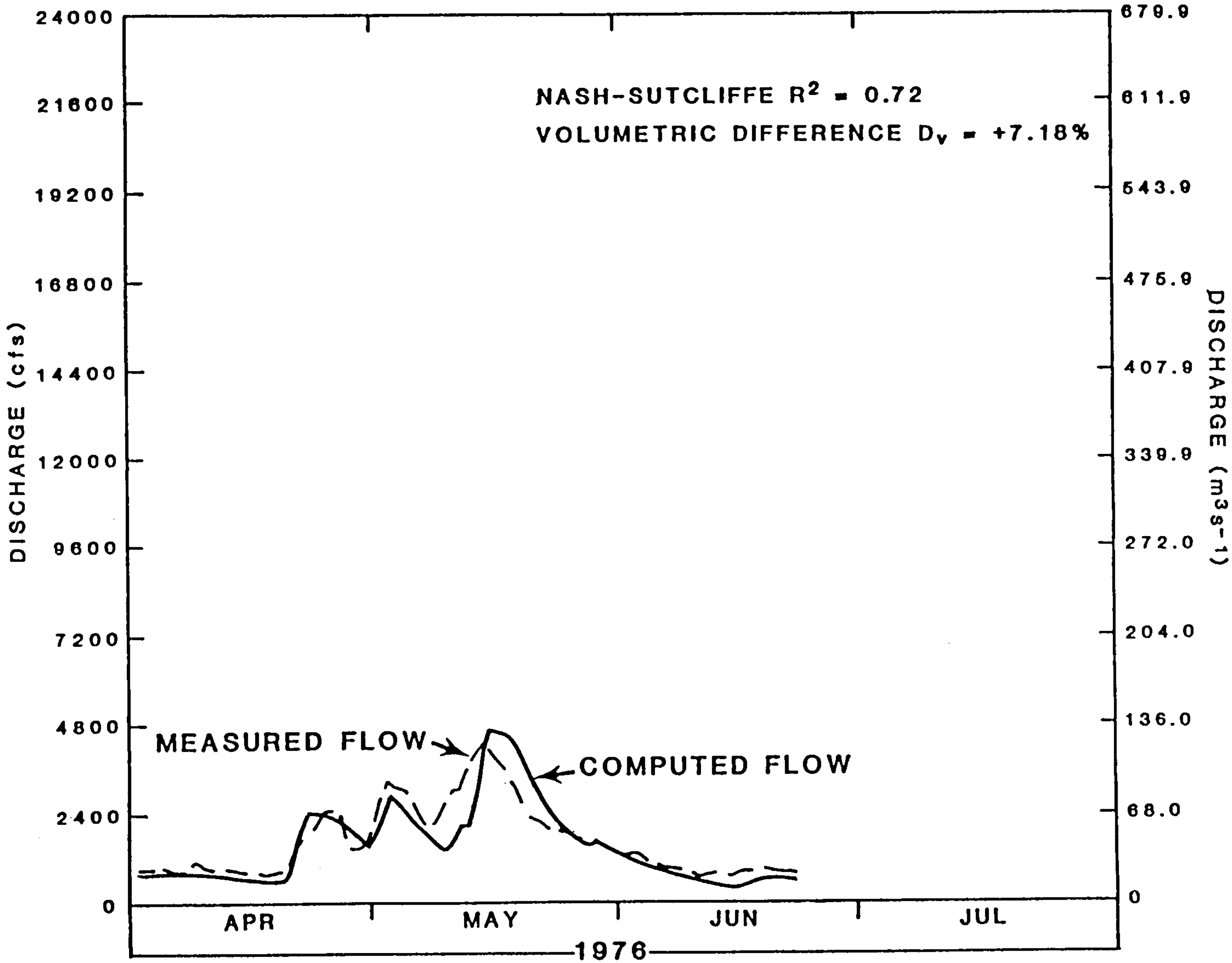


Figure 9. Discharge simulation for the Kings River Basin (3999 km^2), California using the snowmelt-runoff model

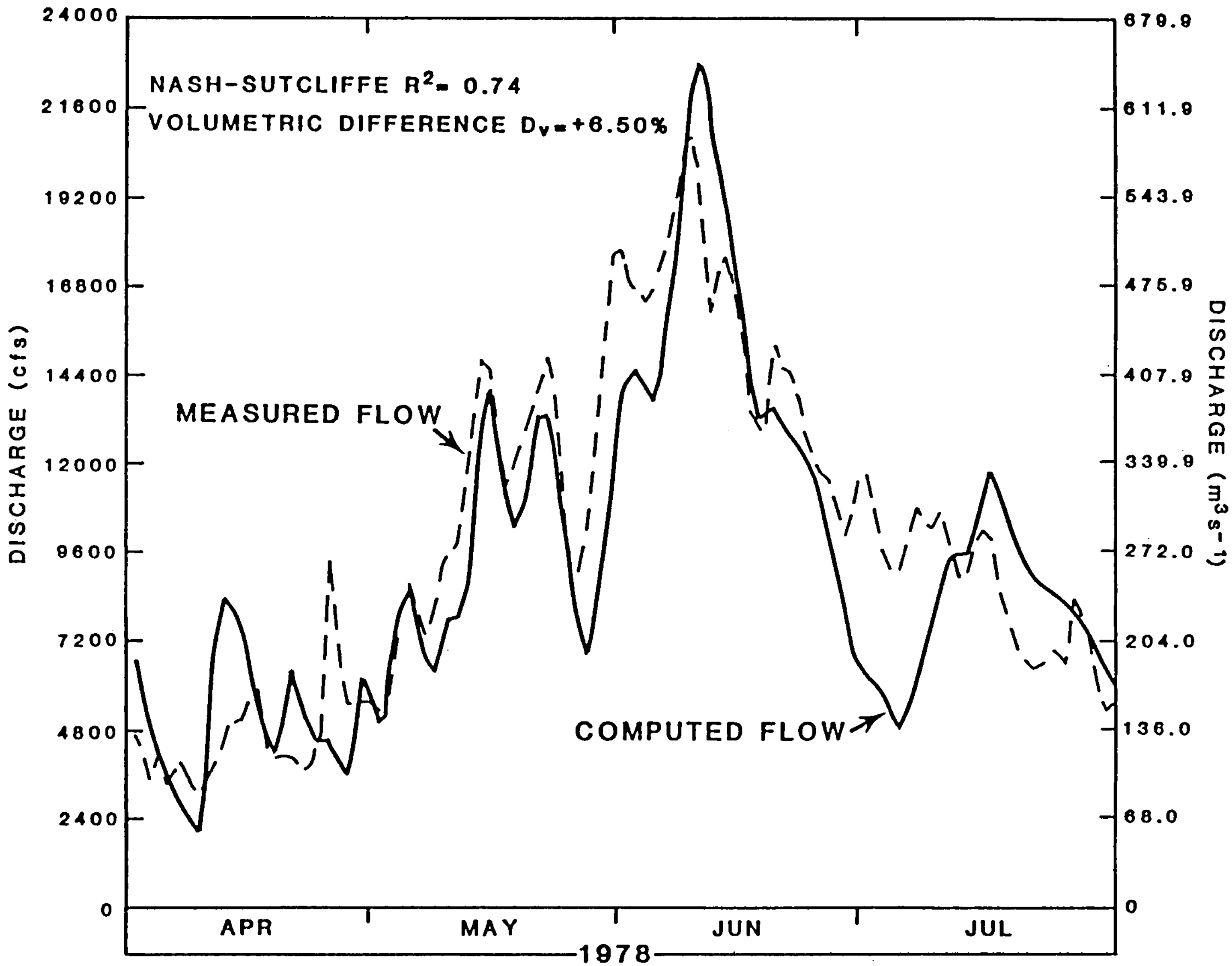


Figure 10. Discharge simulation for the Kings River Basin (3999 km^2), California using the snowmelt-runoff model

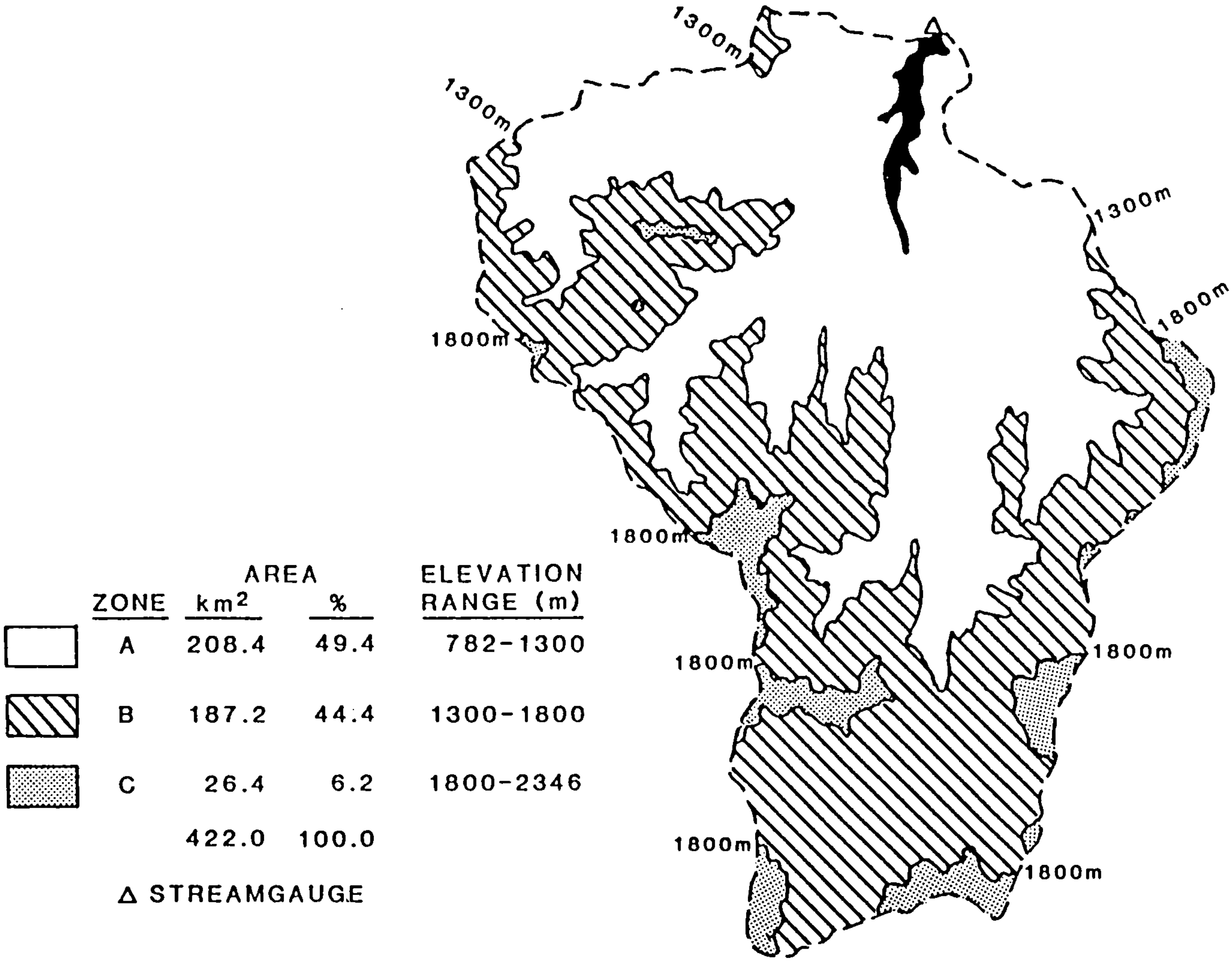


Figure 11. Elevation zones and areas of the Okutadami Basin, Japan

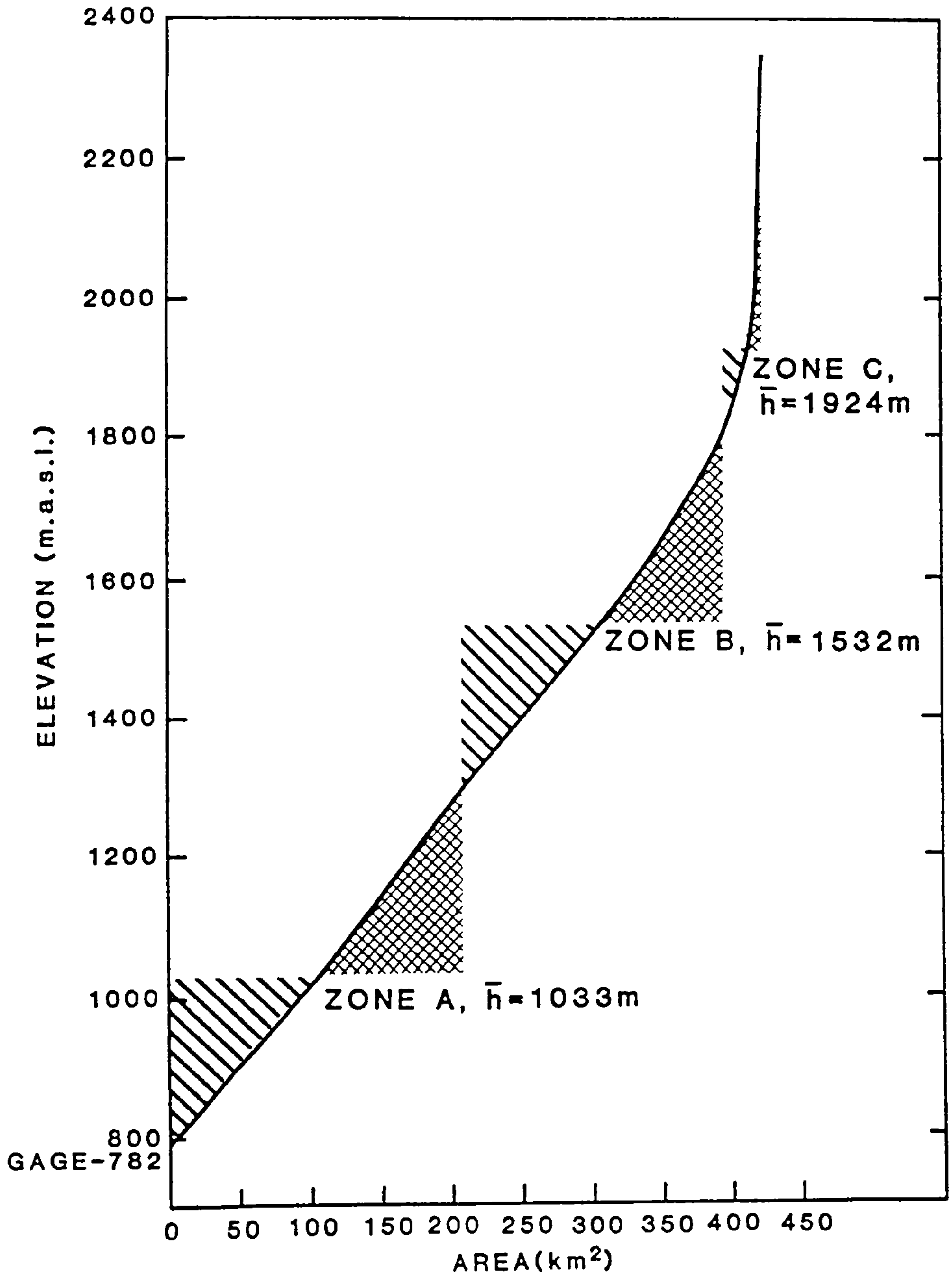


Figure 12. Determination of zonal mean hypsometric elevations ($\bar{h}$) using an area-elevation curve for the Okutadami Basin, Japan

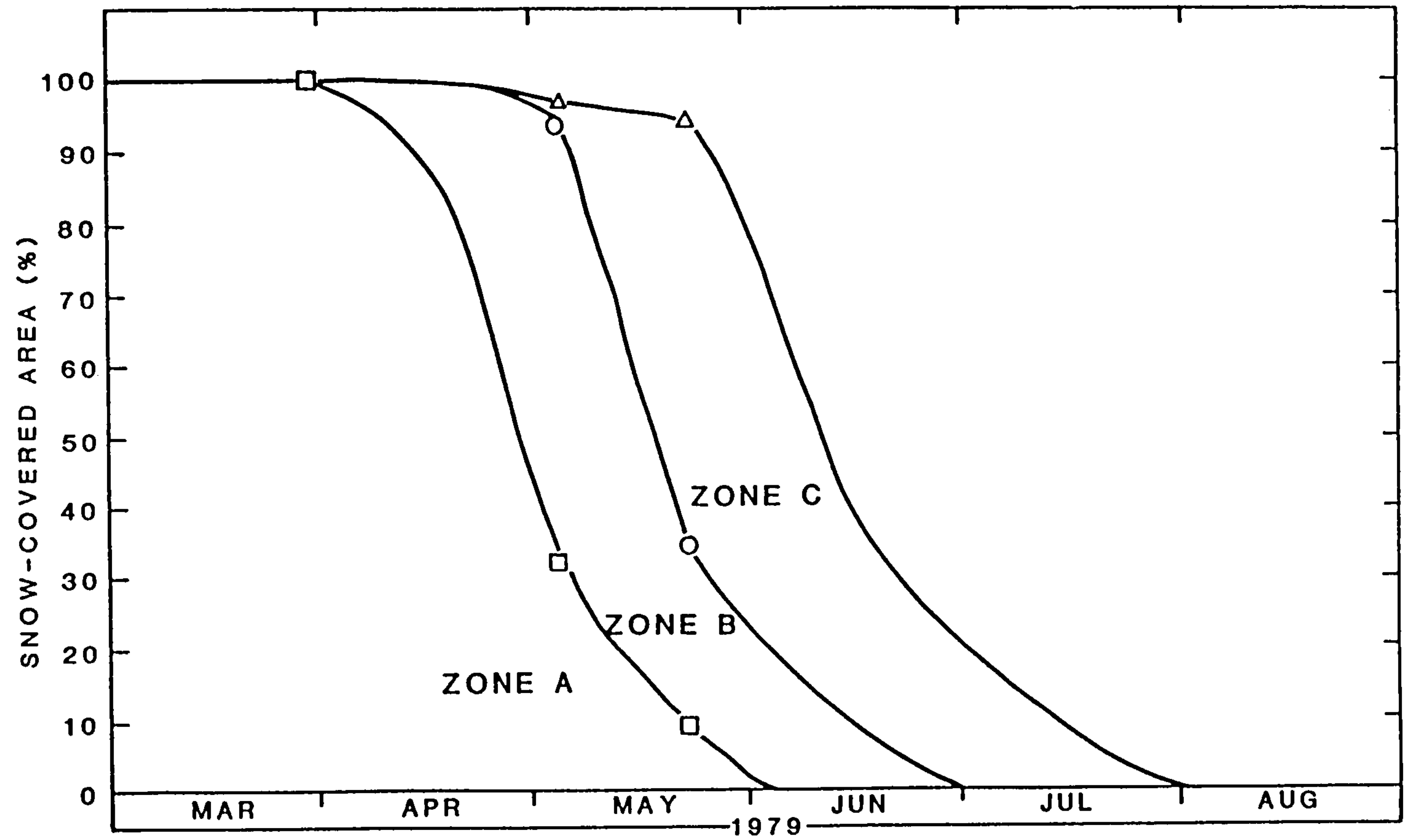


Figure 13. Landsat derived snow-cover depletion curves for elevation zones A, B and C in the Okutadami Basin

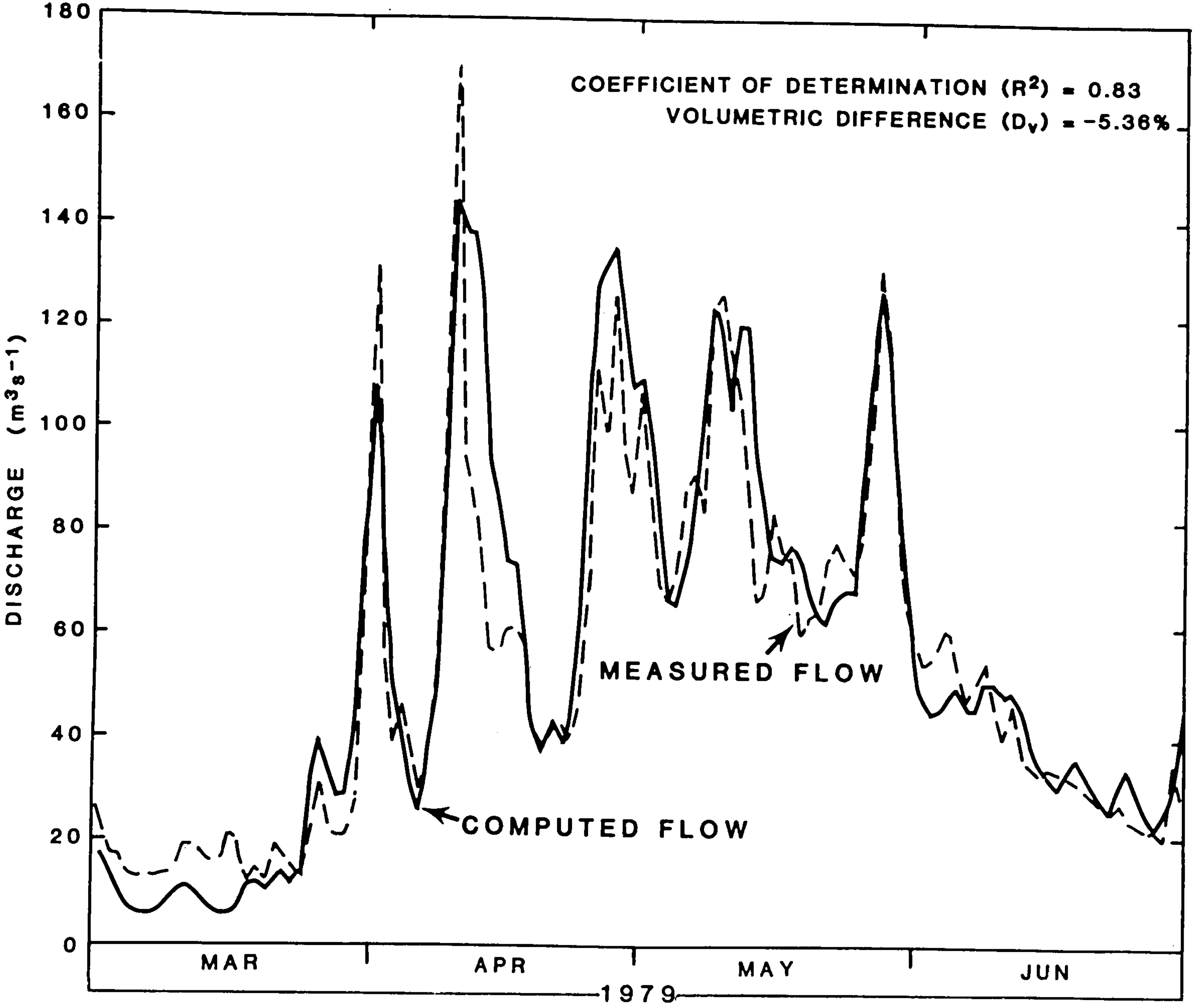


Figure 14. Discharge simulation for the Okutadami Basin (422 km²), central Japan using the snowmelt-runoff model