MEMORANDUM

DRAFT

Date: February 23, 2001

To: The Honorable Chair and Members
Pima County Board of Supervisors

From: C.H. Huckelberry
County Administrator

Re: **Cienega Creek Storm Flow Frequency Analysis**

Background

The Pima Association of Governments has worked with Pima County staff in developing a series of studies that contribute to the Riparian Element of the Sonoran Desert Conservation Plan. The attached study entitled *Cienega Creek Storm Flow Frequency Analysis* was conducted for the Pima County Flood Control District by the Pima Association of Governments in order to determine if stormflows on the Cienega Creek have changed over time when analyzed in terms of frequency, volume, and seasonality. In a data search that extends back to the 1950s, the authors were able to determine the daily mean flow, the flows over base, and the annual peak flows of the Cienega Creek. The attached study provides a concise summary of this sweeping review of data.

The Cienega Creek has seen change over time by these measures:

- Mean daily flows in the summer were higher in the 1960s than in the 1990s.
- Mean daily flows in the winter were higher in the 1990s than in the 1960s.
- Cienega Creek had fewer larger scale flood events in the 1990s, compared to the 1960s.
- Summer mean daily flows exceeding 10, 50, and 100 cfs occurred more commonly in the 1960s than in the 1990s.
- Winter mean daily flows exceeding 10, 50, and 100 cfs occurred more commonly in the 1990s than in the 1960s.
- In the 1990s, winter and spring flows in exceedance of the 10, 50, and 100 cfs levels also occurred later in the season.

The Cienega Creek has seen little change over time by these measures:

- No significant difference could be found between decades in terms of the size of annual peak flows.

- The seasonality of annual peak flow did not change over the study period.

The Cienega Creek is typical of other southwestern streams in these ways:

- Seasonal variations in the Creek's mean daily flow were typical of southwestern streams.

- Large scale flood events have occurred primarily in the summer, typical of southwestern streams.

Conclusion

During 1999 and 2000 a number of technical reports were issued to develop the Riparian Element of the Sonoran Desert Conservation Plan. That study series continues and has become increasingly detailed and focused on specific technical questions about specific streams and riparian reaches. This data and information will assist Pima County in establishing the best possible set of reforms, projects and programs when the Riparian Element is presented to the Board for formal adoption as part of the final Sonoran Desert Conservation Plan in the year 2002.

Attachment

Cienega Creek Storm Flow Frequency Analysis

FINAL PROJECT REPORT

Prepared by Pima Association of Governments for Pima County

PIMA ASSOCIATION OF GOVERNMENTS

REGIONAL COUNCIL

November 2000

Printed on Recycled Paper

Cienega Creek Storm Flow Frequency Analysis

November 2000

Conducted By

Pima Association of Governments

For

Pima County Flood Control District

PURPOSE

The purpose of this study was to determine if the frequency, volume, and seasonality of stormflows on Cienega Creek have changed over time. This project was conducted by Pima Association of Governments (PAG) as part of the FY 2000-2001 Work Program with Pima County Flood Control District. The project was conducted jointly, with the Pima County Flood Control District staff primarily supervising the progress of the work.

METHODOLOGY

Data Collection

Pima Association of Governments downloaded three datasets for the United States Geological Survey (USGS) streamflow-gaging station at Pantano Wash near Vail, Arizona stream gage (#09484600) from the USGS Arizona Current Streamflow Conditions website (http://az.water.usgs.gov/rt-cgi/gen_tbl_pg). At the stream gage location, Pantano Wash is synonymous with Cienega Creek. These datasets included mean daily flow for January 1959 to September 1974 and October 1989 to September 1999, annual maximum flows for 1958 to 1999, and flows-over-base for years 1958 to 1999. The USGS stream gage is located at latitude 32º02'09", longitude 110º40'37", in Section 14, Township 16S, Range 16E. The current stream gage is a water-stage recorder and concrete weir. Previously a water-stage recorder was used from January 1959 to September 1974 and a crest-stage gage was used from October 1974 to September 1989.

For the analyses presented in this report, calendar year mean daily flow data for January 1, 1959 through December 31, 1973, and January 1, 1989, through December 31, 1998, were used. The calendar years 1959 through 1998 were used in the analysis of the instantaneous flows-over-base dataset. Water years 1959 through 1998 were used for the analyses of peak annual flow. Because calendar year data was used for the daily mean flow and flows-over-base analyses and water year data is used for the annual peak flow analysis, the reader is warned that no relationship should be drawn between the annual peak flow analysis and the other analysis.

Data Analysis

Several types of graphical and statistical analysis were used to examine the data obtained from the USGS website. Histograms of average daily flows exceeding arbitrary thresholds were produced for the entire period of record. Subsets of these histograms were produced to examine differences between specific periods of the record. Descriptive statistics for average daily flow were generated by month and by year. Kruskal-Wallace tests were used to detect significant difference in average daily flow between different periods in the record. Number of flows-over-base was depicted both by year and by month. A t-test was used to determine if significant differences existed for different periods of the flow record. The annual peak flow record for the gage was depicted as a time series graph. A histogram of the seasonality of annual peaks was also presented, and an analysis of variance (ANOVA) test was used to determine if the seasonality of annual peak flows has changed through out the period of record.

RESULTS

Daily Mean Flow

Mean flow for the entire record of the Pantano gage (calendar years 1959 through 1973 and 1990 through 1998) was 6.6 cubic feet per second (cfs). The median of the daily mean flows was 1.3 cfs. Descriptive statistics were computed by month for the entire period of record (Table 1). The mean flow value plotted in a bimodal pattern similar to precipitation trends in the region, with a high summer mean flow centered around August and a high winter mean flow centered around January. Mean monthly flow (1.2 cfs to 21.8 cfs) was higher and more variable than the median (1.0 and 2.0 cfs) of mean daily flow for the period of record. This suggests that Cienega Creek flood events that raise mean monthly flow are infrequent and short in duration, as is the case with most arid-area streams (Blakemore et al. 1994)

Table 1. Descriptive Statistics of Mean Daily Flow by month for 1/1/59-12/31/73 & 1/1/90-12/31/98.

Month	Mean	Median	Standard Deviation
January	7.9	1.7	39.3
February	7.5	1.9	24.2
March	4.1	1.9	9.2
April	2.5	1.6	5.5
May	1.3	1.3	0.8
June	1.2	1.0	1.9
July	13.3	1.1	48.4
August	21.8	2.0	66.0
September	10.6	1.3	87.0
October	1.8	1.0	7.6
November	1.2	1.0	0.9
December	6.2	1.4	45.9
Total Record	6.6	1.3	39.9

The mean daily flow data set was analyzed on a monthly basis for number of days that the mean daily flow exceeded several arbitrarily selected values (10 cfs, 50 cfs, 100 cfs, and 500 cfs) (Figures 1-4). The trends exhibited by the flow at the Pantano gage mirror the bimodal precipitation pattern of the region (Webb and Betancourt 1990). The months with the highest number of days with mean flows exceeding 10 cfs, 50 cfs, 100 cfs, and 500 cfs were in summer, clustered around August, and winter clustered around February. August had the most days in each category, reflecting the large number of monsoon thunderstorms and associated flooding events that occur in that month. The month of November, which corresponds to the post-monsoon fall season, has never recorded a daily mean flow of over 10 cfs. Such flow events are also rare in the pre-monsoon season of May and June which have only seen one and three days respectively with mean flow over 10 cfs.

Two subsets of the mean daily flow data set were created, one from calendar year 1960 through calendar year 1968 (1960's) and the other from calendar year 1990 through calendar year 1998 (1990's) for comparison of flood flows before and after the Cienega Creek Natural Preserve was established in 1986. Mean daily flow in the summer monsoon season was significantly higher[1] in the month of August for the 1960's period (28.2 cfs) than the 1990's period (10.5 cfs). Conversely, mean daily flow in January was significantly[1] higher in the1990's (15.7 cfs) than the 1960's (4.3 cfs). Significant differences[1] were found in the months with low flow (May-June) and (October-November) but floods in these months are exceedingly rare. Therefore, the differences in mean daily flow in these months are due to changes in baseflow amounts not the flooding regime of the creek.

The number of mean daily flow days per month in exceedance of 10, 50 and 100 cfs thresholds were calculated for the 1960's and the 1990's. Mean daily flows over 500 cfs were not common enough to analyze. The results were examined to determine if any changes in the seasonality had occurred (Figures 5-7). In each case, summer and fall flows (July through September) exceeded the thresholds more often in the 1960's than the 1990's, suggesting that both small and large-scale summer flood events were more frequent in the 1960's. Conversely, in January through April (winter and spring), mean daily flows exceeding the thresholds occurred more frequently in the 1990's than the 1960's. The month of December, however, experienced more mean daily flows over the arbitrary limits in the 1960's than the 1990's. Therefore, more winter and spring flood events occurred in the 1990's and the timing of these winter and spring flood events have occurred later in the season.

Flows-Over-Base

On the USGS website, Cienega Creek base discharge for the Pantano Gage is assumed to be 2,000 cfs. A per-year count of instantaneous peak flows over the 2000 cfs base for the calendar years 1959 through 1998 was generated by examining the flows-over-base dataset. The maximum number of flows over 2000 cfs per year was seven, which occurred in the calendar years 1959 and 1970 (Figure 8). In twenty of the years no flows over 2000 cfs occurred. During calendar years 1960 to 1968 Cienega Creek averaged more than 2.5 instantaneous flows greater than 2000 cfs per year, while in calendar years 1990 to 1998, the creek experienced less than 0.55 flood events over 2000 cfs per year. This difference is significant at the $p<0.05$ level (two-sample t-test assuming unequal variances, Intercooled Stata 6.0).

During calendar year 1958 through 1998, flows over 2000 cfs occurred only in the months of July, August, September, October and December (Figure 9). The majority of

[1] $p<0.05$ using Kruskal-Wallace Equality of Populations Rank test, Intercooled Stata 6.0.

these flows occurred during summer monsoon months of July and August[2]; 79% (42 events out of the 53 total events) occurred in these months. Of the remaining 11 events, 10 flows occurred in the fall months of September and October. Only one flood event of over 2000 cfs occurred in the winter, which occurred in December 1967. Flows-over-base were not frequent enough to detect changes in seasonality between different periods of the flow record.

Annual Peak Flows

The series of annual peak flows for water years 1959 to 1998 is found in Figure 10. The mean peak annual flow for the period of record was 3906 cfs; annual peak flows range from 129 cfs to 13000 cfs. The 95% confidence interval for this period was 2758 to 5055 cfs. The annual peak flow data were organized by decade (water years 1960 to 1969, 1970 to 1979, 1980 to 1989, and 1990 to 1998). Annual peak flow did not significantly differ between decades (ANOVA, Intercooled Stata 6.0). Cienega Creek experienced its largest flood in the year before the flow gage was installed. A flood of an estimated 38,000 cfs occurred on August 11, 1958 (Pope et al. 1998).

During the period of record approximately 54% of the annual (water year) peak flows occurred during the summer months of July and August, approximately 36% of the flows occurred in the fall (September and October), approximately 8% occurred in the winter (November through February) and approximately 3% occurred in the spring (March through June). These data were organized by decade (see above) and analyzed for seasonality by decade (Figure 11). All four decades had similar seasonal distributions of peak annual flow events.

SUMMARY

- Seasonal variations in Cienega Creek mean daily flow were typical of streams of the southwestern United States.
- Summer mean daily flows were higher in the 1960's than they were in the 1990's; conversely winter mean daily flows were higher in the 1990's than they were in the 1960's.
- Summer mean daily flows in exceedance of 10, 50, and 100 cfs were more common in the 1960's than in the 1990's, while winter flows exceeding 10, 50, and 100 cfs were more common in the 1990's than in the 1960's. Winter and spring flows in exceedance also occurred later in the season in 1990's.
- In the 1990's, Cienega Creek experienced fewer large-scale flood events than in the 1960's.
- Like other southwestern streams, large-scale flood events on Cienega Creek occurred primarily in the summer.
- Size of the annual peak flows was highly variable and no significant difference could be found between decades.
- Seasonality of annual peak flows has not changed throughout the period of record.

[2] Webb and Betancourt's (1990) assignment of months to seasons was used in this report to facilitate future comparisons.

REFERENCES

Blakemore, E.T., H.W. Hjalmarson, and S.D. Waltemeyer. 1994. Methods for estimating magnitude and frequency of floods in the southwestern United States. Water-Supply Paper 2433. United States Geological Survey, Tucson, Arizona.

Pope, G.L., Rigas, P.D., and C.F. Smith. 1998. Statistical summaries of streamflow data and characteristics of drainage basins for selected streamflow-gaging stations in Arizona through water year 1996. Water-Resources Investigations Report 98-4225. United States Geological Survey, Tucson, Arizona.

Webb, R.H. and J.L. Betancourt. 1990. Climatic variability and flood frequency of the Santa Cruz River, Pima County, Arizona. Open-File Report 90-543. United States Geological Survey, Tucson, Arizona.

Figure 1. Days with mean flow greater than 10 cfs per month per year (Calendar years 1959-1973 and 1989-1998).

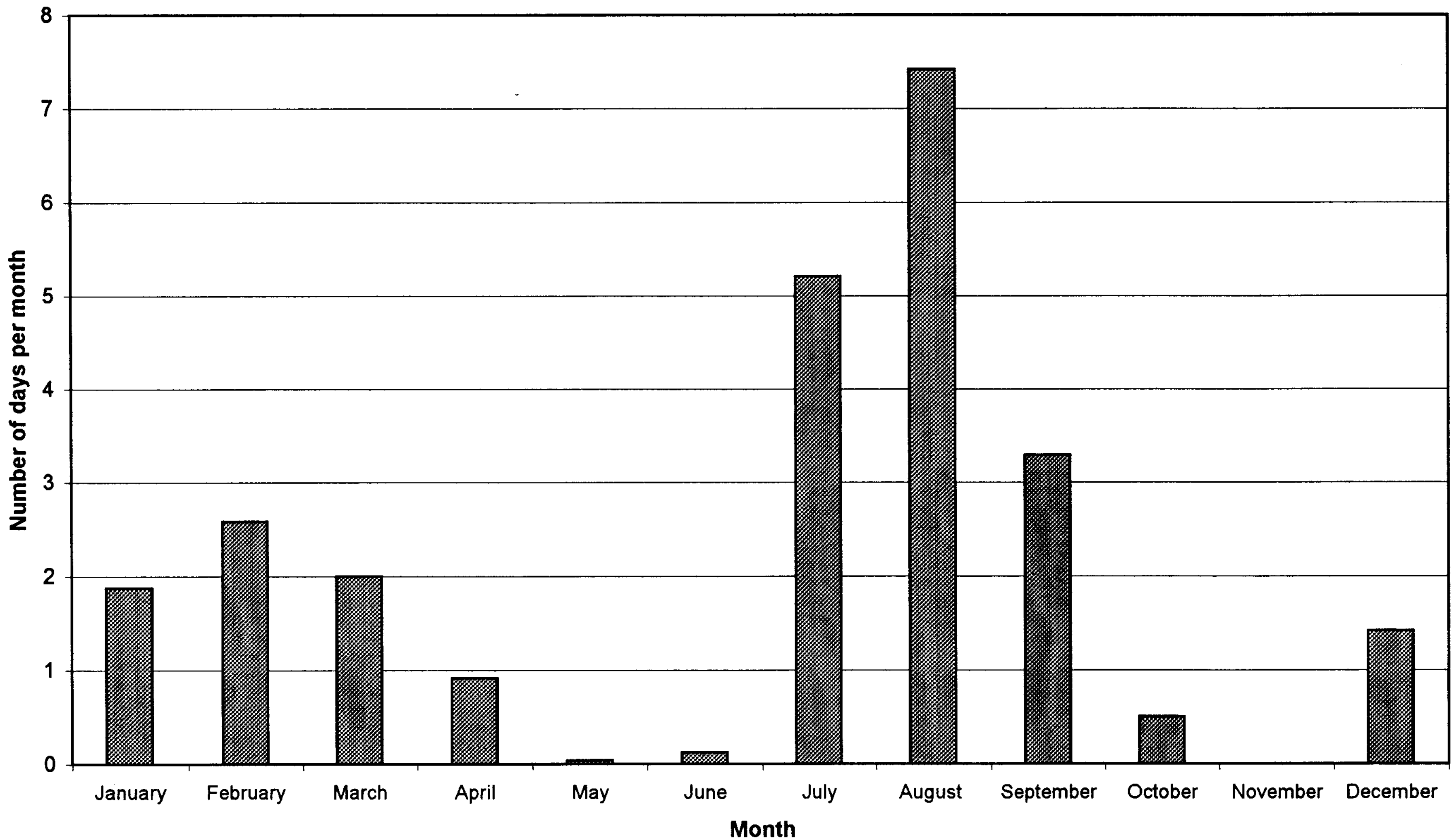

Figure 2. Days with mean flow greater than 50 cfs per month per year (Calendar years 1959-1973 and 1989-1998).

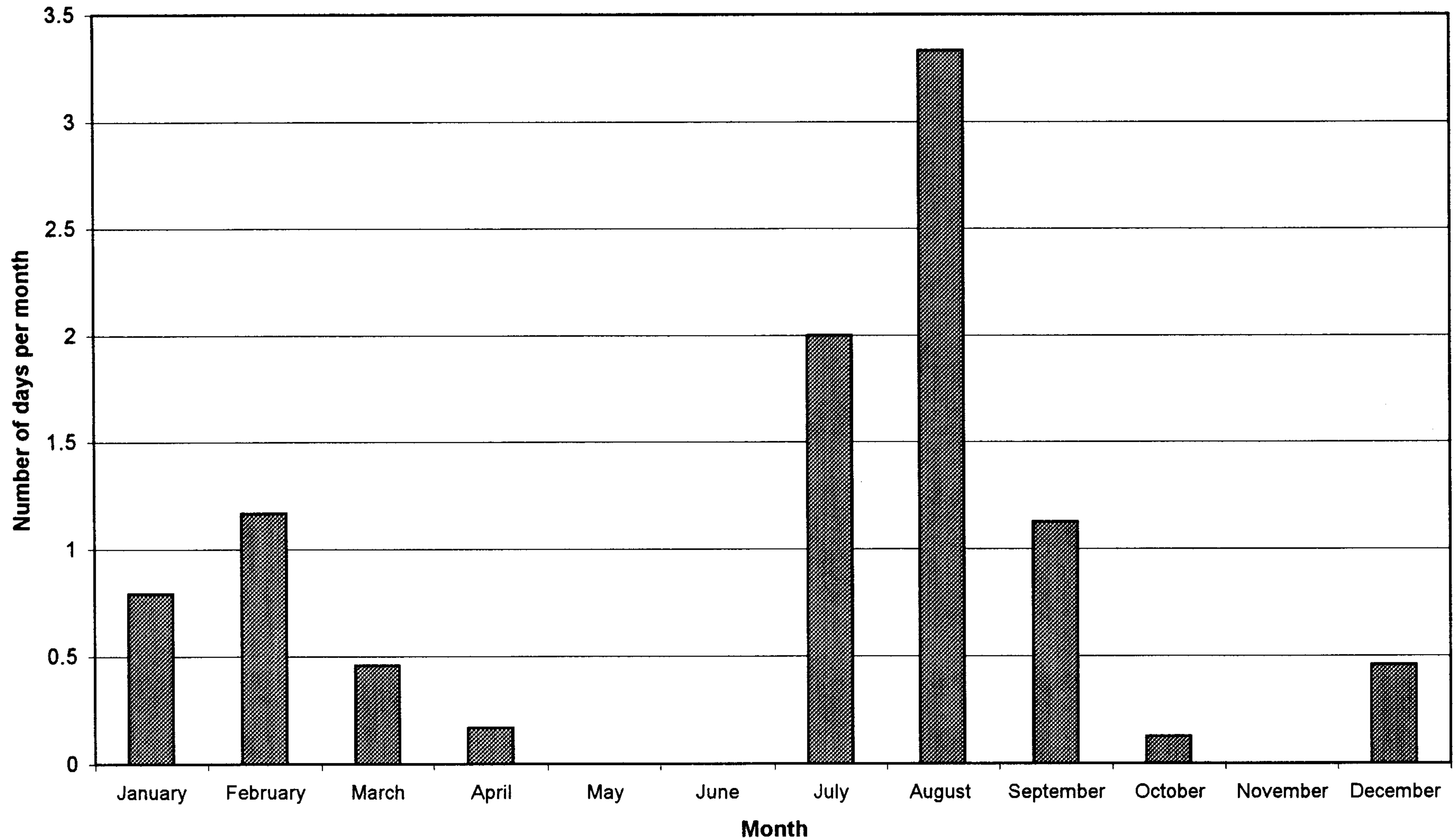

Figure 3. Days with mean flow greater than 100 cfs per month per year (Calendar years 1959-1973 and 1989-1998).

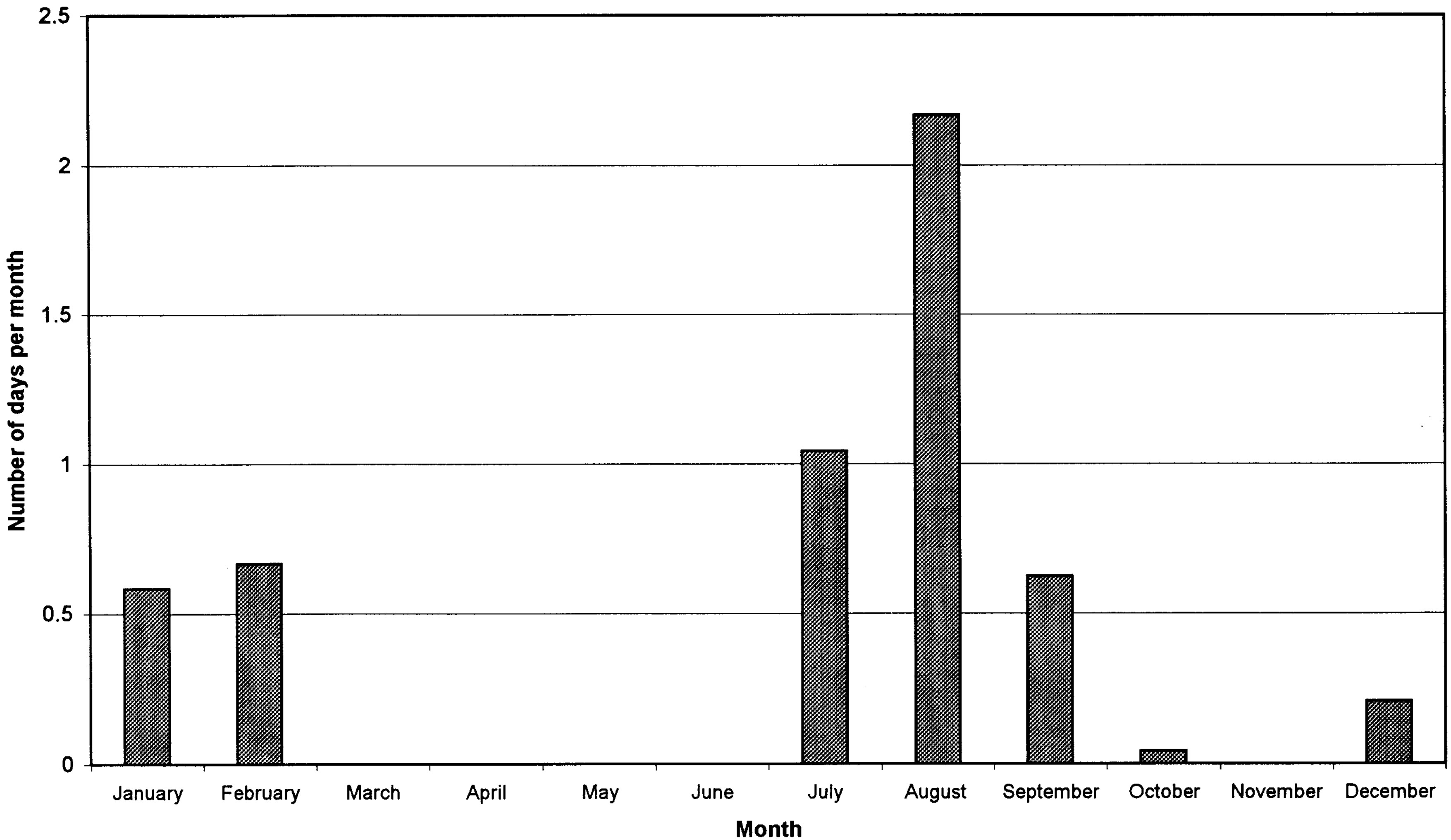

Figure 4. Days with mean flow greater than 500 cfs per month per year (Calendar years 1959-1973 and 1989-1998).

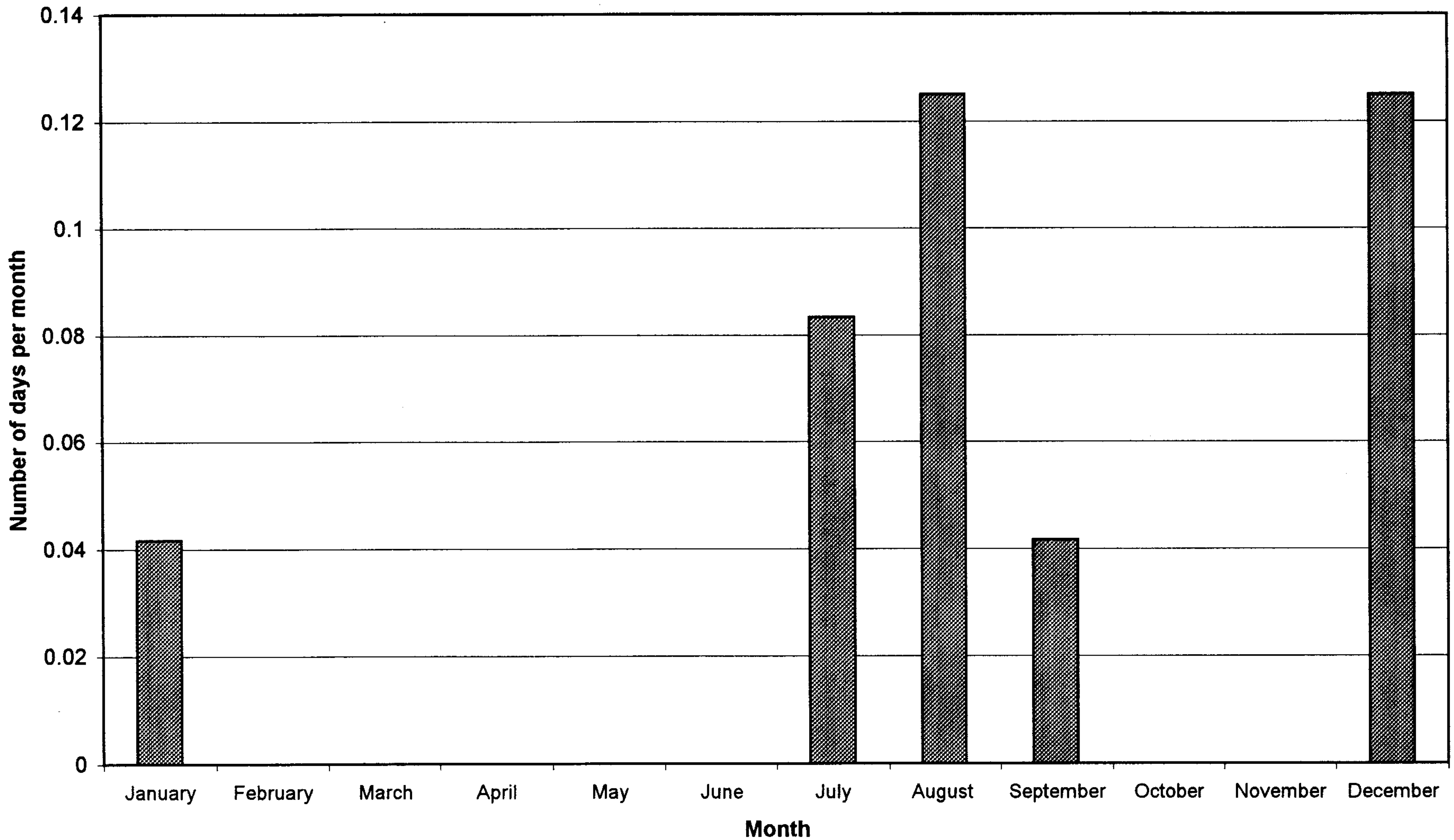

Figure 5. Comparison of seasonality of mean daily flows > 10 cfs between the calendar year 1960's and the calendar year 1990's.

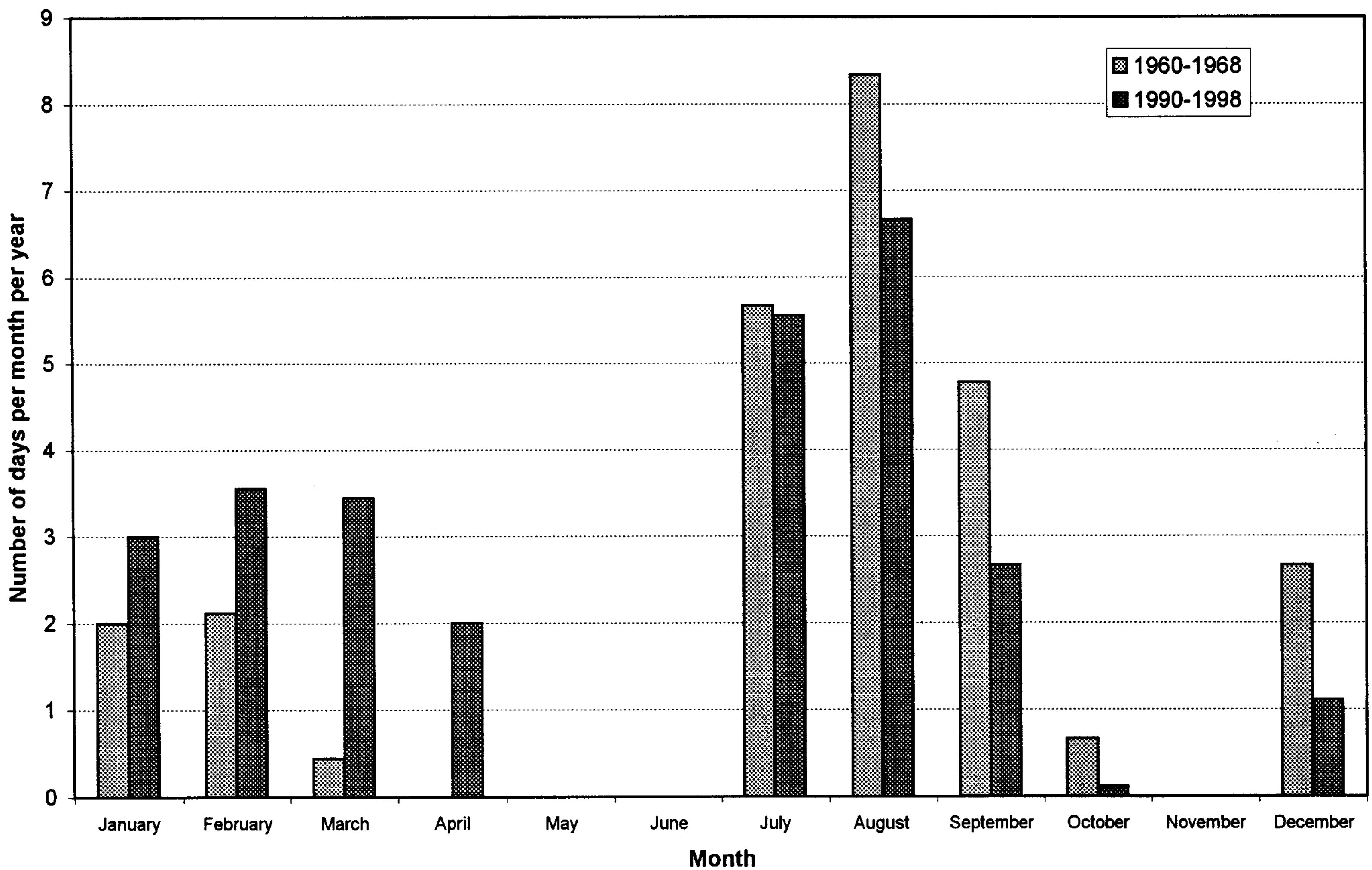

Figure 6. Comparison of seasonality of mean daily flows > 50 cfs between the calendar year 1960's and the calendar year 1990's.

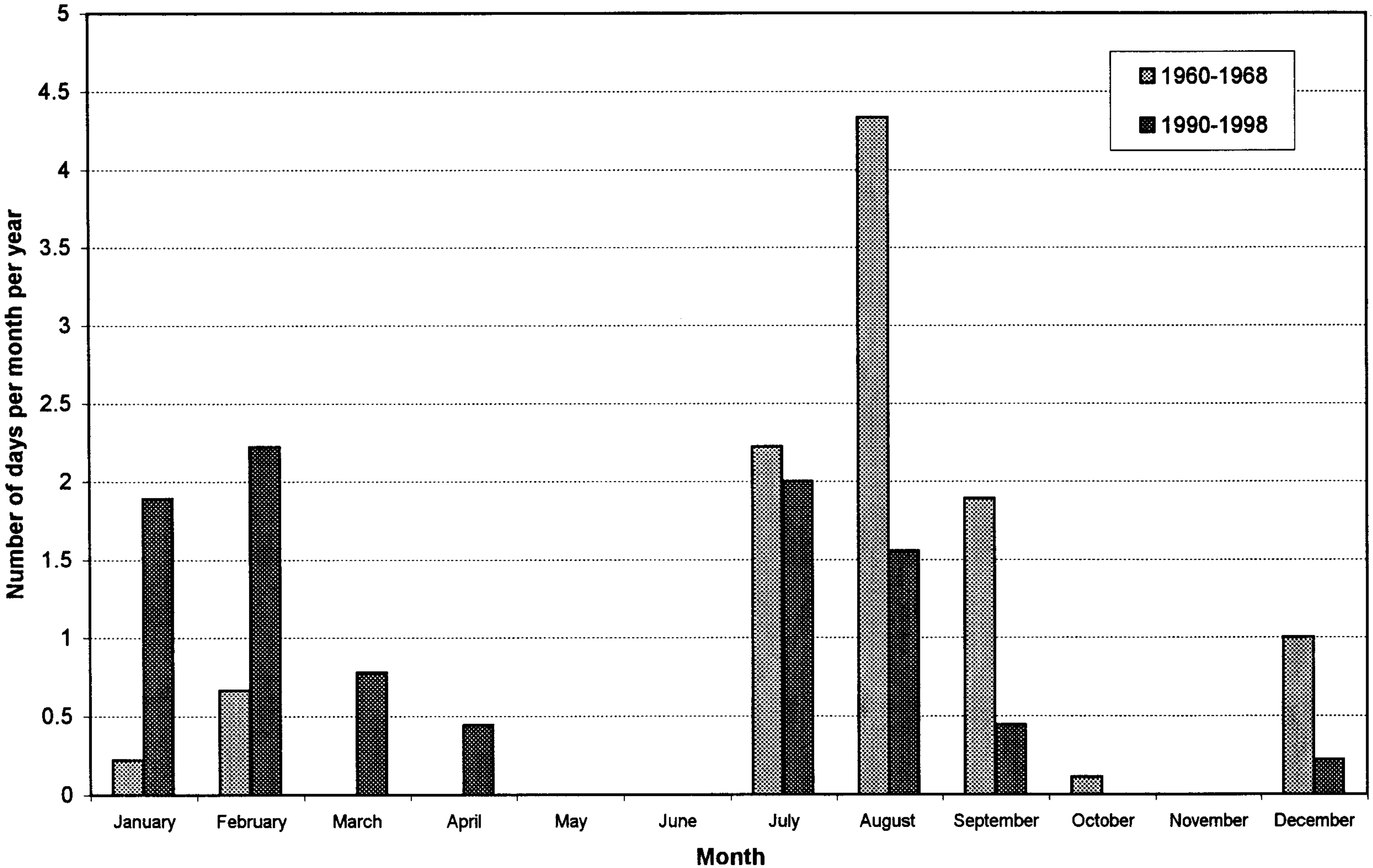

Figure 7. Comparison of seasonality of mean daily flows > 100 cfs between the calendar year 1960's and the calendar year 1990's.

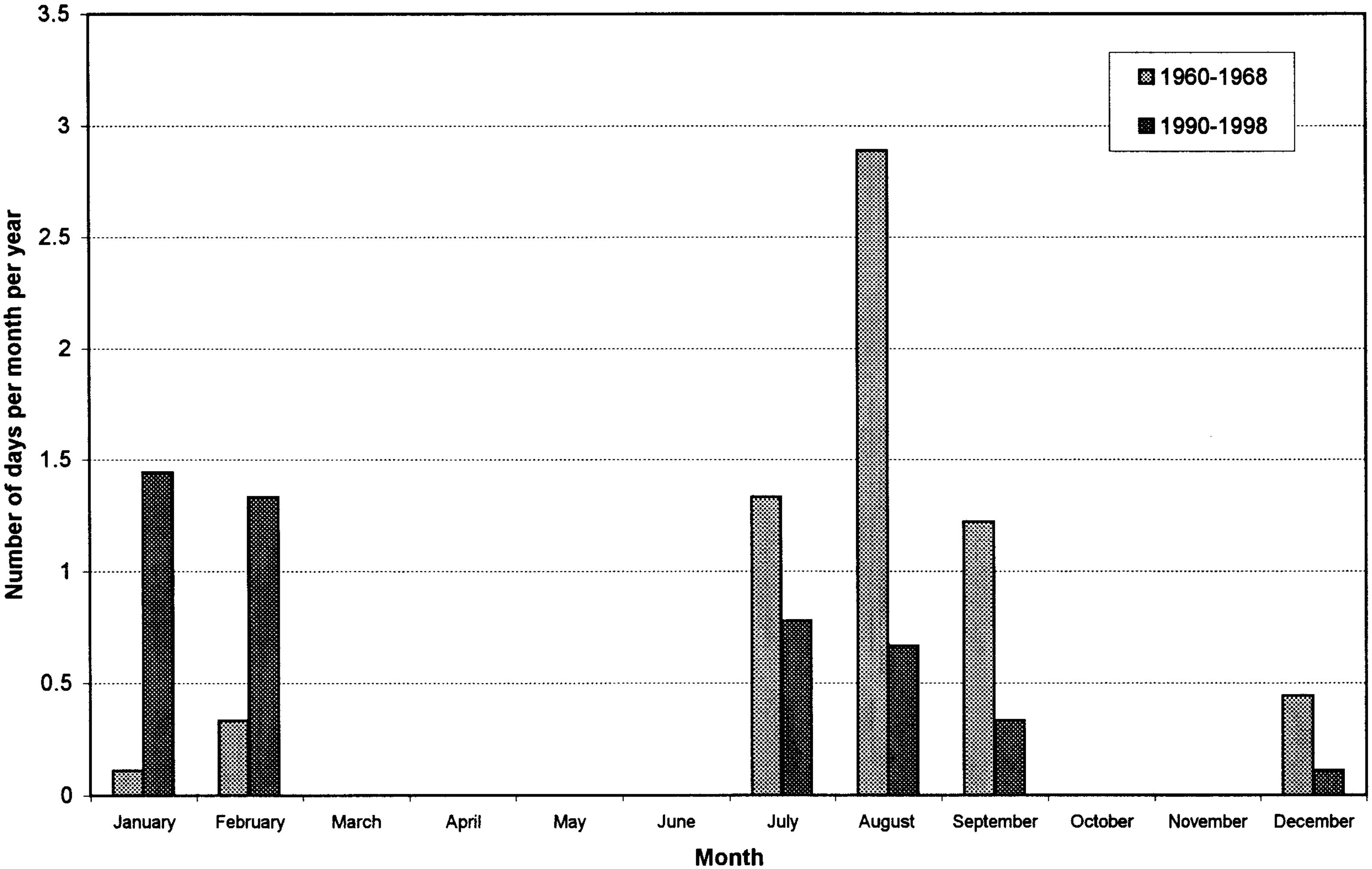

Figure 8. Number of flows over 2000 cfs per calendar year.

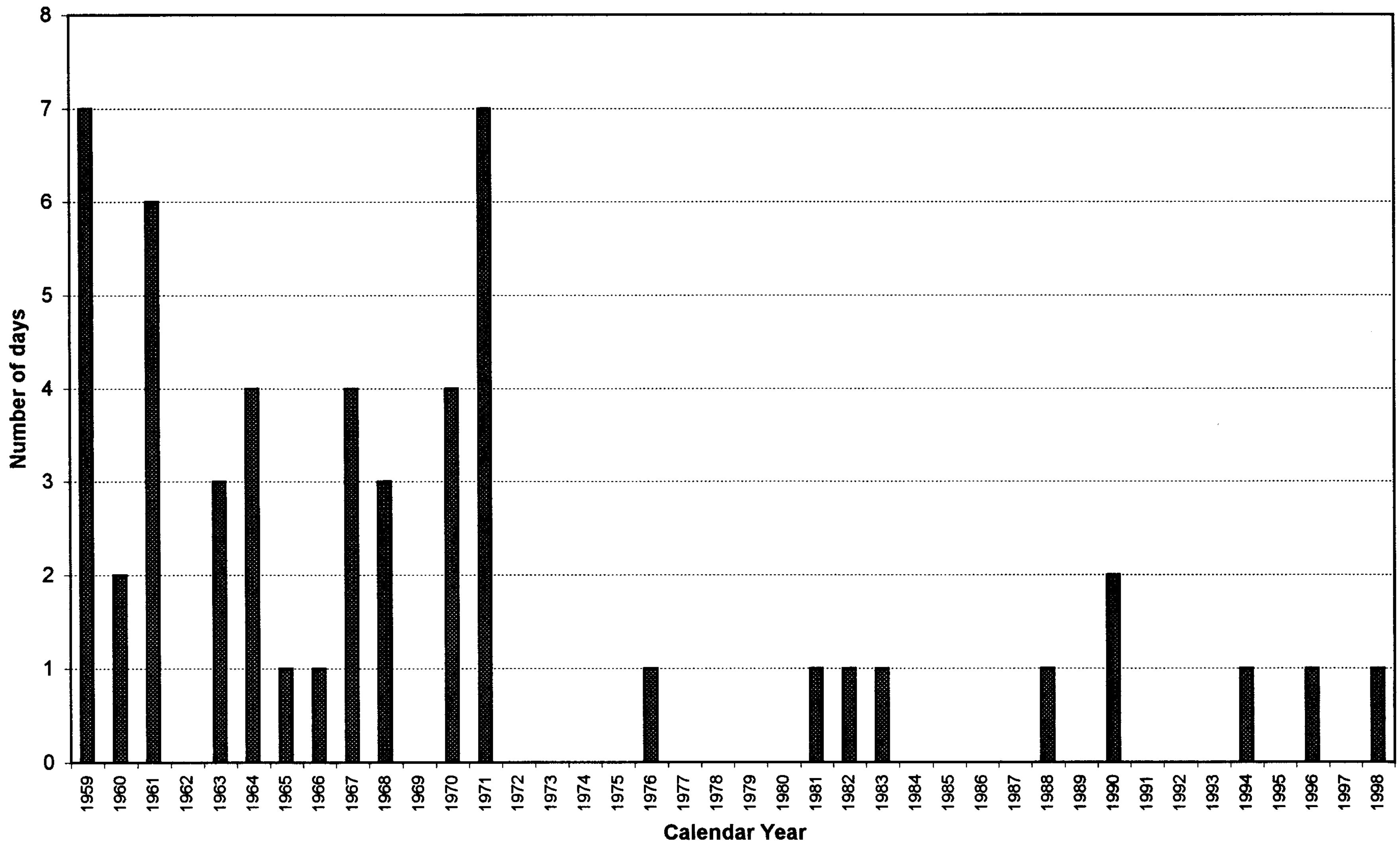

Figure 9. Number of instantaneous flows over 2000 cfs per month (Calendar years 1959-1998).

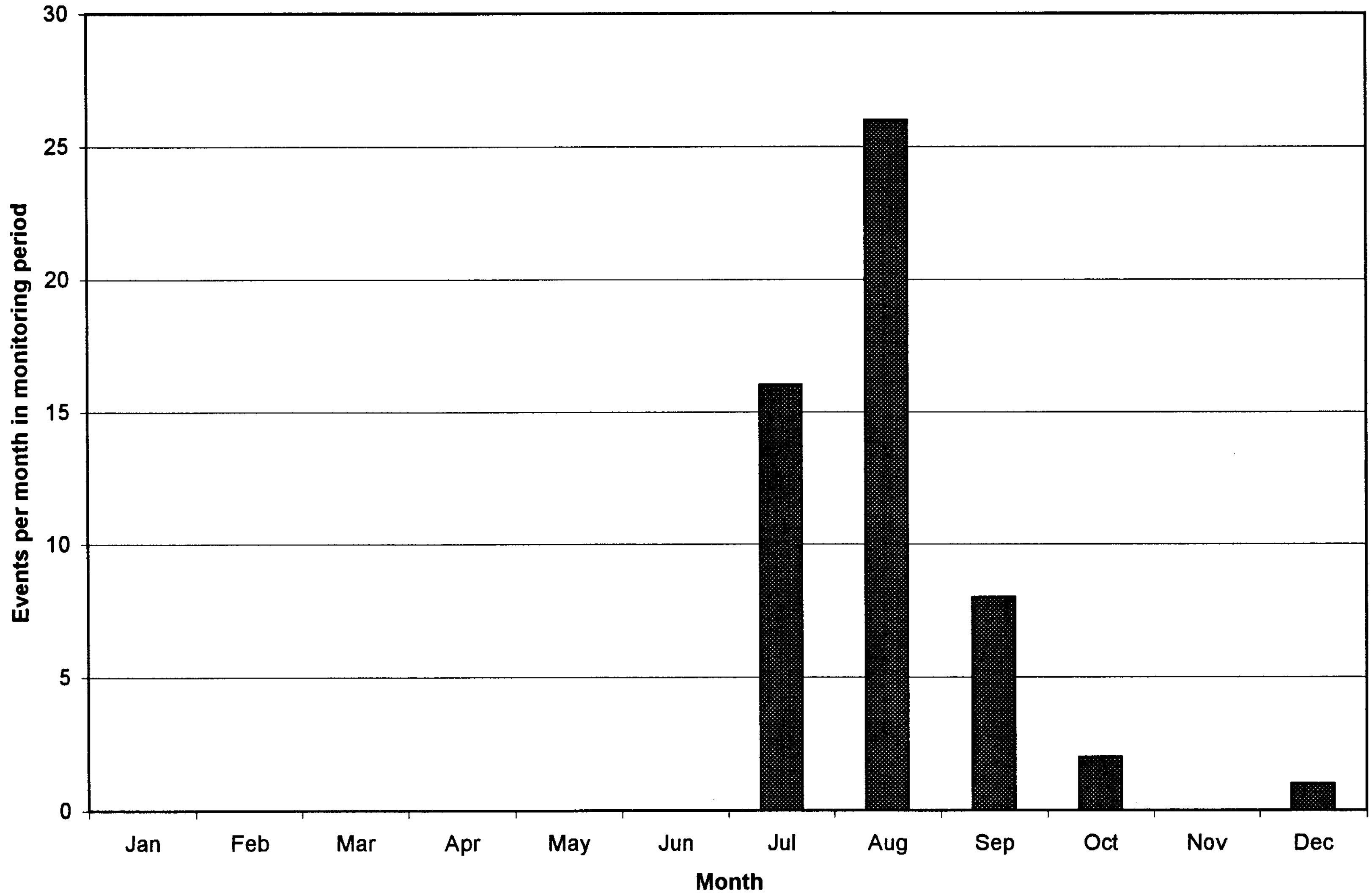

Figure 10. Water year annual peak flow in cfs.

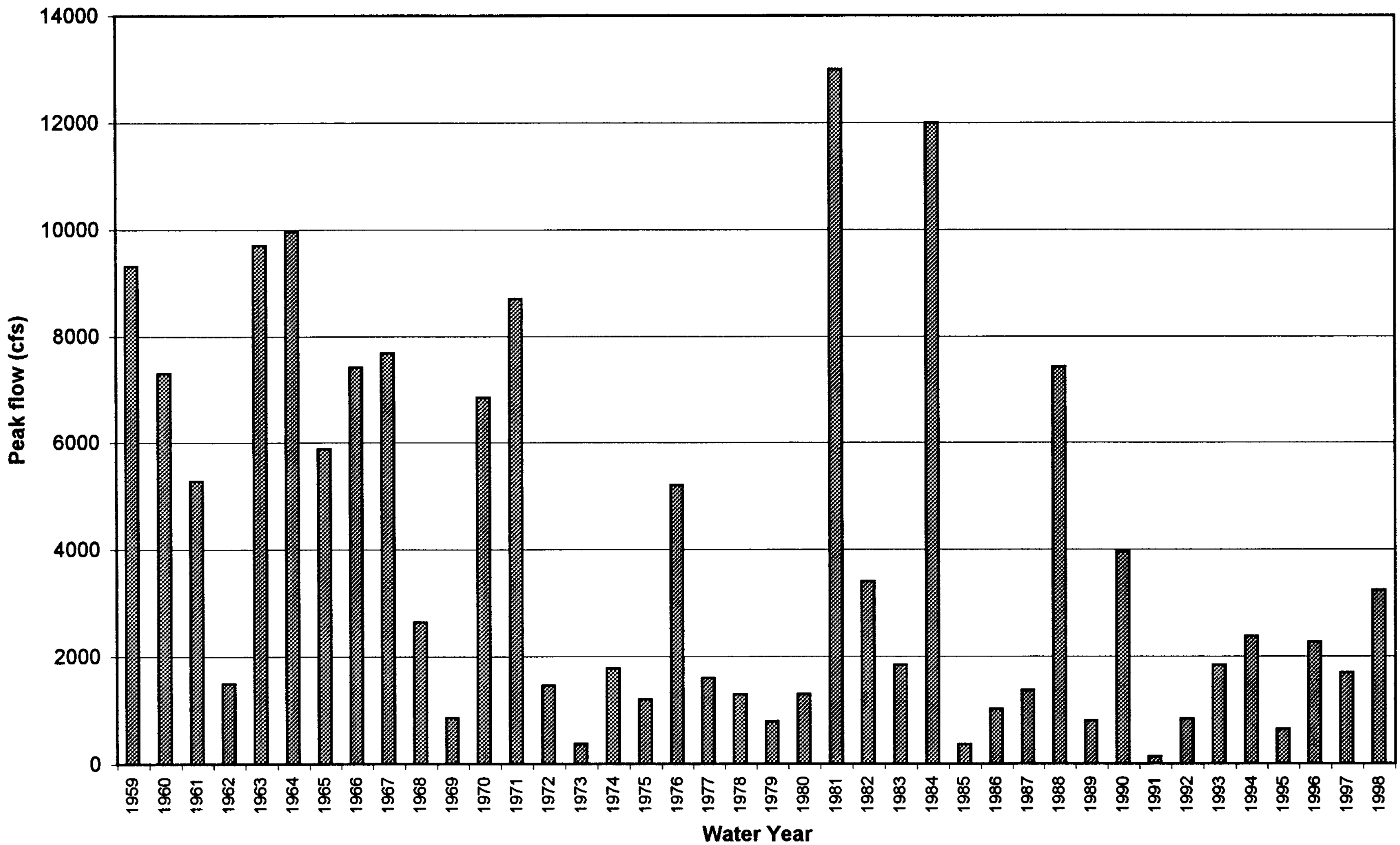

Figure 11. Seasonality of annual peak flows by decade for water years 1959-1998 .