A COMPARISON OF SEASONAL FLOOD FREQUENCY FOR ANNUAL-PEAK AND PARTIAL-DURATION FLOOD SERIES IN MISSISSIPPI

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INTRODUCTION

Flooding represents one of the greatest weather-related hazards in Mississippi. During the period 1968-1988, eight significant floods have occurred in Mississippi (Southard et al. 1990). In particular, a series of 1974 floods in south-central Mississippi caused 8 deaths and $50 million in damage, and in 1983 more than $100 million of damage was caused by floods in central and northeastern Mississippi. One of the greatest difficulties facing planners and engineers is that the probability of flood hazards does not remain consistent throughout the year. With the progression of the seasons, atmospheric circulations shift which changes moisture inflows and precipitation patterns for any given region. Thus, a knowledge of flood seasonality (the frequency of floods within a given season) is required by officials to determine seasonal runoff forecasts for hydroelectric power, irrigation, crop calendars, recreational activities, and emergency preparedness schedules.

The calculation of flood seasonality is rather simple and straight forward. A proportion or percent of the total flood population occurring in one season will suffice. However, two types of flood data can be used to calculate flood seasonality, annual peak flood series (APS), and partial duration flood series (PDS). The APS represents a series of the highest instantaneous peak flow discharge for each year at a given stream gauge station. The PDS represents all instantaneous peak discharges greater than a given 'base flow' at a given stream gauge station (Dunne and Leopold 1978). Much research has been completed which compares APS to PDS, but this work pertains almost exclusively to a comparison of magnitude (Langbein 1949, 1960). In fact, conversion factors are given in order to substitute PDS for APS or vice versa (Dunne and Leopold 1978). Despite this work, one fundamental questions still remains: can it be assumed flood seasonality is the same for APS and PDS? The purpose of this study is to compare flood seasonality of APS and PDS for the state of Mississippi, determining the spatial patterns in differences and similarities.

DATA AND METHODOLOGY

For this study, a total of 31 Mississippi stream gauge stations were selected from the U. S. Geological Survey (USGS) Hydro-climatic Data Network (HCDN) CD-ROM (Figure 1). Requirements for stream gauge selection were a minimum of 31 continuous water years of observations (October 1, 1960 - September 31, 1990) and location on an undiverted and unregulated stream. The HCDN was specifically designed by the USGS for hydroclimatic analysis, including streams with minimal human impact (Slack and Landwehr 1992). The use of dammed or diverted streams is improper for this study because human activities -- dam releases and generation of hydroelectric power -- possess their own seasonality, which, in turn, interferes with the climatically produced seasonality of APS and PDS.

After selection of the 31 stream gauge stations, the APS and PDS for each stream gauge station were taken from the Earth Info Inc. Peak Flow 1995 CD-ROM to calculate flood seasonality. Flood seasonality is expressed as a proportion of the total floods 1960-1990 occurring in either winter, spring, summer, or fall. The seasons were defined in this study as winter (December, January, February), spring (March, April, May), summer (June, July, August), and fall (September, October, November). In addition to the calculation of APS and PDS seasonality, the difference between APS and PDS seasonality was also calculated. A positive number produced by the difference indicates that the APS overestimates the seasonal frequency of the PDS. A negative number indicates that the APS underestimates the seasonal frequency of the PDS. The kriging algorithm of the computer software Surfer for WindowsTM is used to construct contour maps of APS and PDS seasonal frequency and difference in APS-PDS seasonal frequency for the state of Mississippi.

RESULTS

On average for the state of Mississippi, the greatest proportion of APS occur in the spring (0.535), followed by winter (0.374), fall (0.056), and summer (0.032). Maps indicate that there is spatial variability in seasonal frequency throughout the year. For winter, maps indicate the greatest APS flood frequency is in northeastern Mississippi (approximately 0.45) (Figure 2A). Winter flood frequency decreases moving towards the southwest (approximately 0.25). The heavy winter precipitation that produces floods can be linked to extratropical low pressure systems and associated fronts which form in the Gulf of Mexico or eastern Colorado (Henderson and Vega 1996; Keim 1996). These storms track east-northeast into the Ohio Valley, creating intense rainfall and flooding in northern

Mississippi, Tennessee, Kentucky, southern Illinois, and southern Indiana (Gamble 1997; Whittaker and Horn 1981, 1984).

In regard to spring, flood frequency is highest in southwestern Mississippi (approximately 0.65), and decreases moving towards northeast Mississippi (approximately 0.40) (Figure 2B). This spatial pattern is best explained by the track or path of spring storms which cause floods. Extratropical low pressure systems track from the Gulf of Mexico into southwestern Mississippi towards the northeast (Whittaker and Horn 1981, 1984). These storms produce high amounts of precipitation, especially near the coast where they have a tendency to stall (Henderson and Vega 1996; Keim 1996). These high precipitation levels combine with the high soil moisture levels of spring to produce frequent, high magnitude floods (Gamble 1997; Muller and Faiers 1984).

Summer frequency of APS is very low across the state of Mississippi (ranging approximately from 0.00 to 0.05) (Figure 2C). Heavy rainfall does occur in Mississippi during the summer months, particularly in the form of thunderstorms (Robinson and Henderson 1992). However, the length of days and the high air temperatures combine to create a high potential evapotranspiration across the state (Wax 1982). This high potential evapotranspiration causes soils to dry, leaving little moisture in the soil column. When heavy rain does fall, the majority of the rain infiltrates the dry soil column and is therefore unavailable for overland flow and steam flow, decreasing the probability of floods. Fall is similar to summer in that the APS frequency is very low. However, fall APS frequency can be higher than summer (approximate range of 0.00 to 0.15), and a spatial pattern exists in fall APS frequency. High values exist in southwest Mississippi (approximately 0.10) and decrease to the northeast (approximately 0.00-0.05) (Figure 2D). The fall APS frequency maxima may be attributed to tropical systems which develop over the Gulf of Mexico and move inland (Hirschboeck 1990). Such storms create larger amounts of precipitation along the coast and then lower precipitation as the storms move inland losing energy and moisture (Anthes 1982).

On average, for the state of Mississippi, the greatest proportion of PDS occur in the winter (0.442), followed closely by spring (0.0.430), and then fall (0.094), and summer (0.035). The spatial patterns in seasonal flood frequency for Mississippi are less clear for PDS as compared to APS. PDS winter frequency displays no clear gradient from southwest to the northeast (Figure 3A). A winter PDS frequency maxima (frequency >0.45) exist both in the southwest and northeast portions of the state, with lower frequency values (0.35-0.45) in the central portion of the state. Overall, the range in PDS winter frequency is much smaller than APS (0.35-0.45 as compared to 0.20-0.50), making identification of spatial patterns much more difficult. For spring, the PDS frequency maxima still exists in the southern portion of the state, but has shifted towards the east, and the gradient of decrease from south to north is much less for the PDS as compared to the APS (Figure 3B). In summer, the PDS and APS display similar information, very low flood frequency across the state without a systematic spatial pattern (Figure 3C). The fall PDS frequency spatial pattern shifts to a decrease in frequency west to east, rather than the APS pattern of a decrease from southwest to northeast (Figure 3D). This shift may be the result of higher PDS fall frequency in west-central Mississippi as compared to the APS fall frequency.

Maps of the difference in APS and PDS seasonal frequency indicate that overall for the state of Mississippi, APS overestimates spring flood frequency and underestimates winter, summer, and fall flood frequency (Figure 4). The magnitude of the difference between APS and PDS seasonal frequency is not consistent across the seasons or across the state. The greatest difference in APS-PDS seasonal frequency occurs in the spring. The APS overestimates PDS seasonal frequency by as much as 0.25 in the southwest-central region of Mississippi (Figure 4A). The reason for such a large difference in spring flood frequency is that APS contains floods of greater magnitude than PDS. Given the high soil moisture and heavy rainfall that can occur during the spring in Mississippi, there is a preponderance of high magnitude floods during this season (Southard et al. 1990). For example, Table 1 provides a list of the ten highest flood discharges for Bayou Pierre near Willow, Mississippi. Seven of the top ten floods occurred in the spring. Thus, since the APS uses the highest flood discharge of each year, the seasonal frequency will be biased to the season with the greatest number of high magnitude floods, or spring in Mississippi. The remaining of the seasonal flood frequencies are underestimated by the APS because floods in winter, summer, and fall are generally of a lower magnitude across the state of Mississippi.

CONCLUSIONS

It cannot be assumed that the seasonal frequency of APS and PDS are equal across the state of Mississippi. The bias towards high magnitude floods in the APS causes an overestimate of spring flood frequency and an underestimate of winter, summer, and fall flood frequency. Planners and flood managers who incorporate flood seasonality into activities must be conscious of the potential differences in using APS or PDS data. In particular, activities concerned with the seasonality of high magnitude floods should use APS, while activities requiring consideration of seasonal frequency for all floods, regardless of magnitude, should use the PDS.

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Table 1. The ten greatest flood discharges for Bayou Pierre near Willow, Mississippi.

Discharge (cfs)	Month and Year	Recurrence Interval (yrs)
88000	April 1983	146
63800	April 1980	73
56600	May 1983	48
53100	January 1994	36
51000	April 1974	29
46600	May 1990	24
46400	January 1979	20
44200	February 1979	18
42900	March 1980	16
42100	March 1984	14

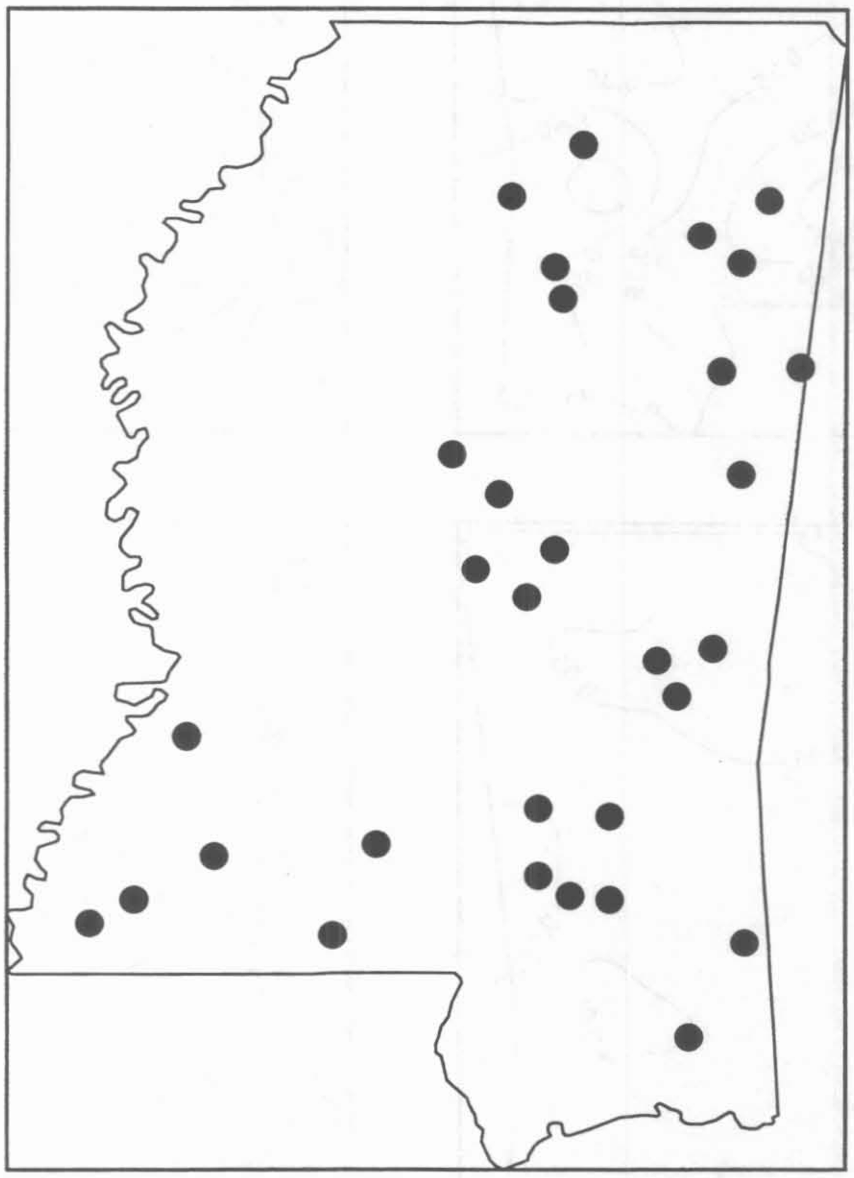

Figure 1. HCDN Stream Gauge Station Locations Included in Analysis

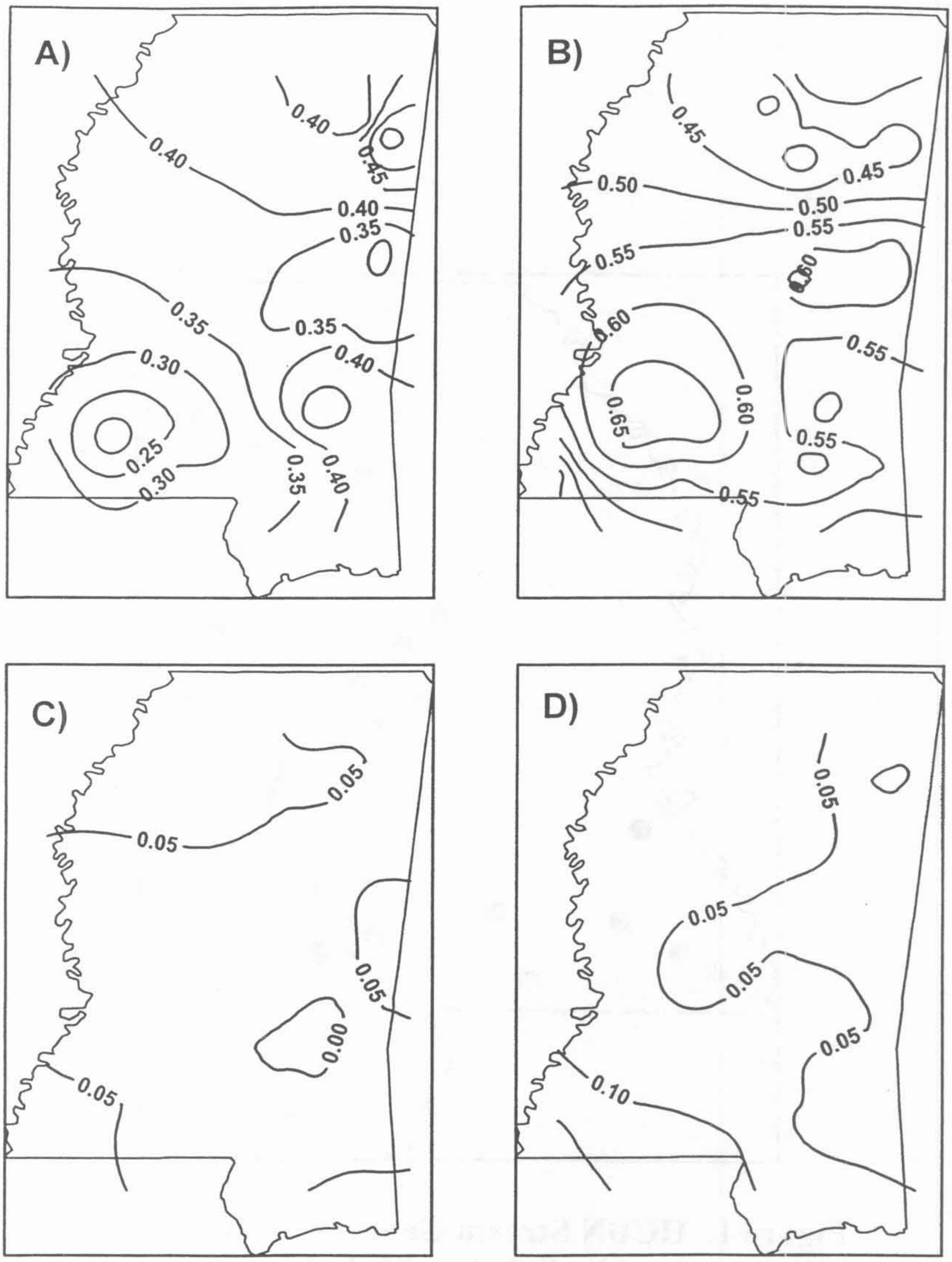

Figure 2. Annual Peak Flood Series Seasonal Frequency: A) Winter, B) Spring, C) Summer, D) Fall

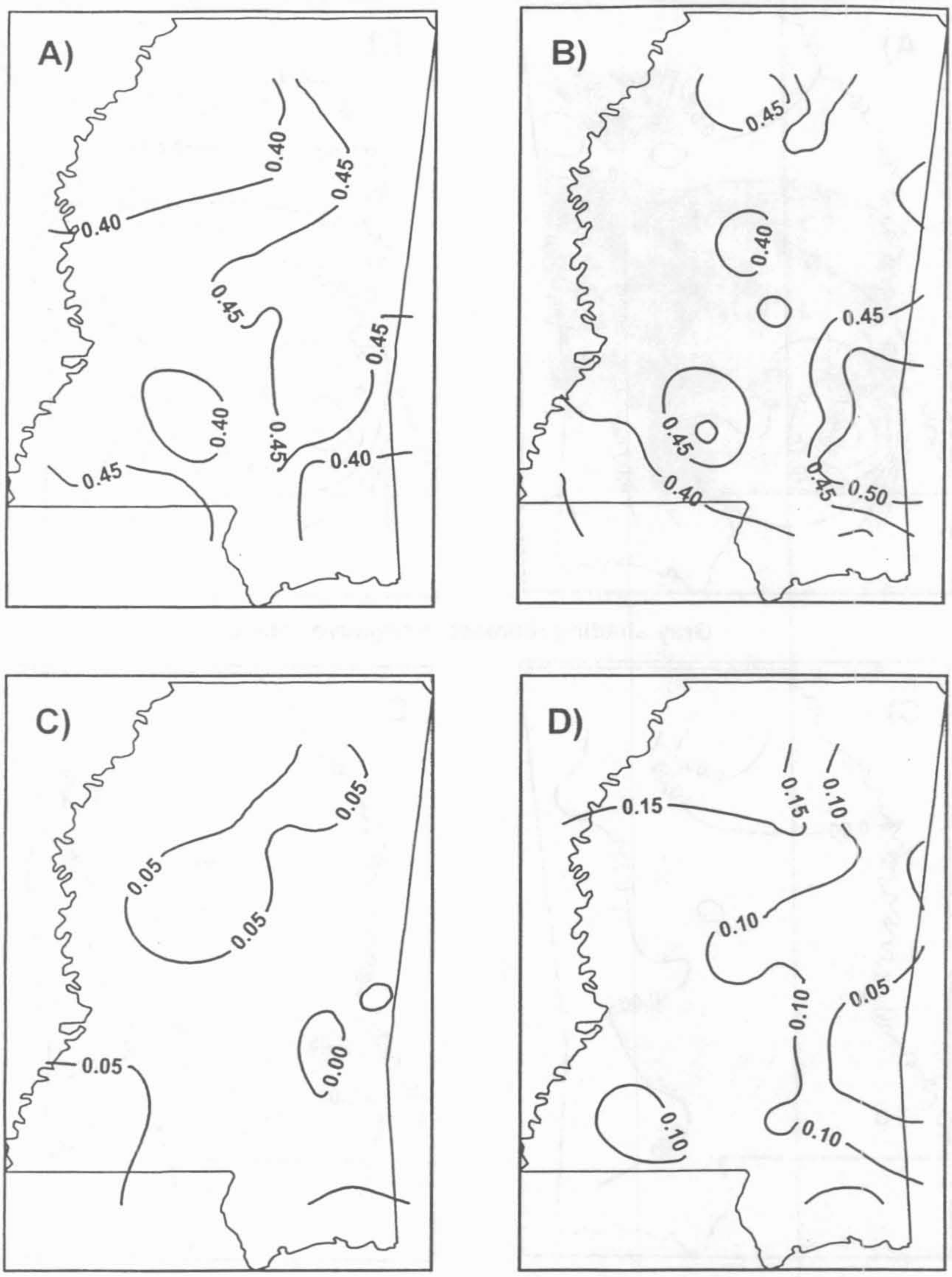

Figure 3. Partial Duration Flood Series Seasonal Frequency: A) Winter, B) Spring, C) Summer, D) Fall

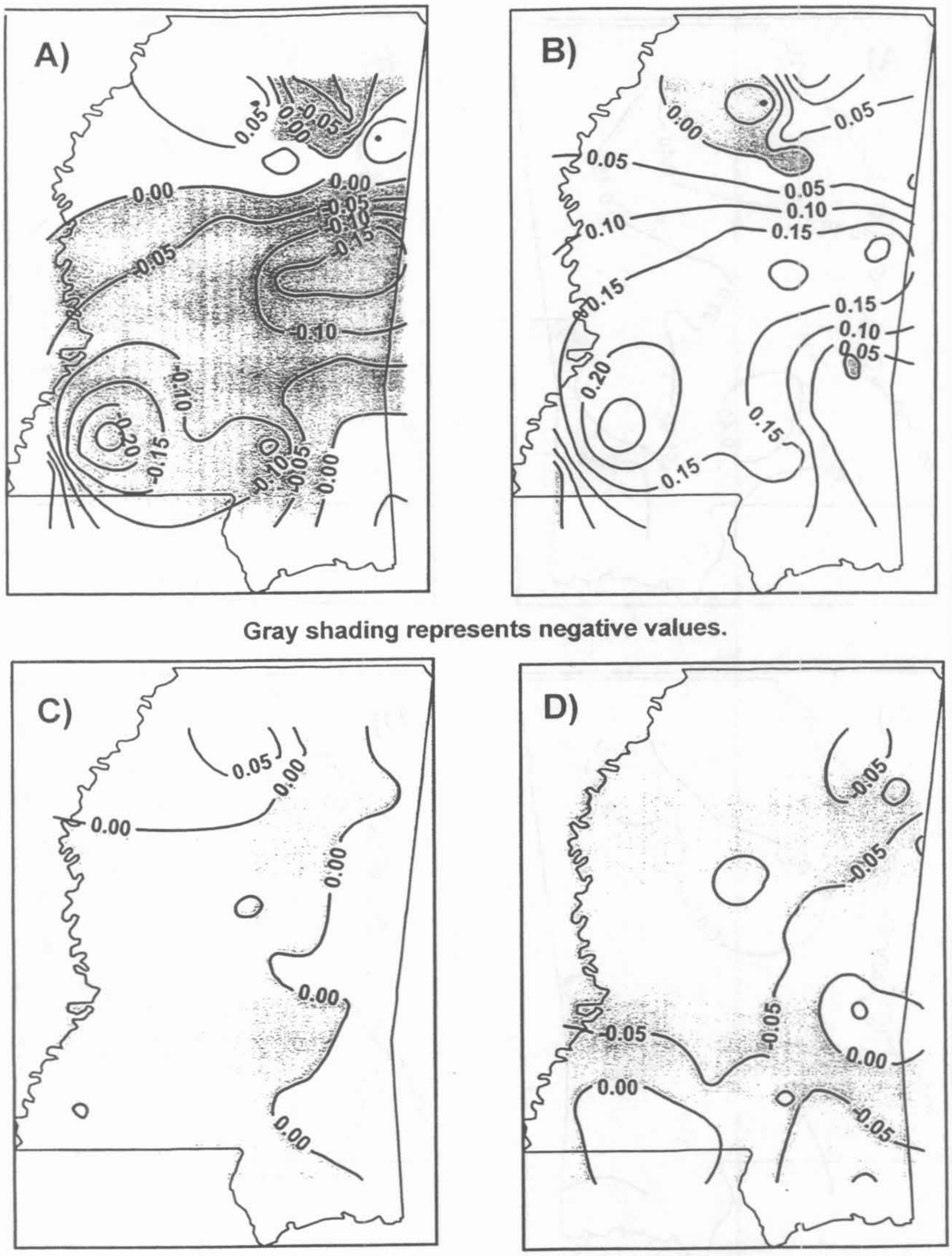

Figure 4. APS - PDS Seasonal Frequency:
A) Winter, B) Spring, C) Summer, D) Fall