Prepared in cooperation with the U.S. Environmental Protection Agency

VOLUMES OF RECENT FLOODS AND POTENTIAL FOR STORAGE IN UPLAND WATERSHED AREAS OF IOWA

Introduction

Substantial flooding at various locations throughout the United States, particularly during and after the Upper Mississippi River Basin flood of 1993, has resulted in analysis and discussion of both structural and nonstructural methods of watershed management to control flooding. The Upper Mississippi River Basin flood of 1993 resulted in the formulation of a Scientific Assessment and Strategy Team (SAST) to assist and advise decision makers about the positive and negative effects of flood-control measures and habitat restoration (Scientific Assessment and Strategy Team, 1994). SAST recognized the role of upland processes and the interconnectivity of a management strategy on other parts of the river system. If upland areas are considered for inclusion in an overall management strategy related to flooding, an analysis of watersheds that have been flooded and the amount of runoff generated during those floods is needed.

During the autumn of 1997, the U.S. Geological Survey (USGS), in cooperation with the U.S. Environmental Protection Agency, began a study to determine the volume of water associated with recent flood events in parts of the Midwestern United States and a preliminary evaluation of the potential upland areas for storage of floodwaters in selected watersheds. This analysis, although preliminary, may be useful in determining the feasibility of conducting additional, more detailed studies into the role of upland areas in a watershed management strategy. The methods and results of this preliminary hydrologic study are presented in this report.

Methods

Study Area

Iowa has had numerous recent flood events, including the historic floods of 1993, which resulted in urban and rural flood damage. Streamflow data between 1990 and 1997 were analyzed, and 11 flood events were selected from 8 watersheds throughout Iowa where streamflow-measurement sites were located in urban areas that had flood damage. The watersheds ranged in size from about 2.2 million acres to about 11,400 acres and represent a variety of topographic settings in Iowa. The watersheds included in this study are shown in figure 1. Descriptions of the flooding that occurred in the Raccoon River, South Skunk River and Squaw Creek, Clear Creek, and Perry Creek watersheds are given in Eash and Koppensteiner (1997), Einhellig and Eash (1996), Barnes and Eash (1994), and Eash (1996), respectively.

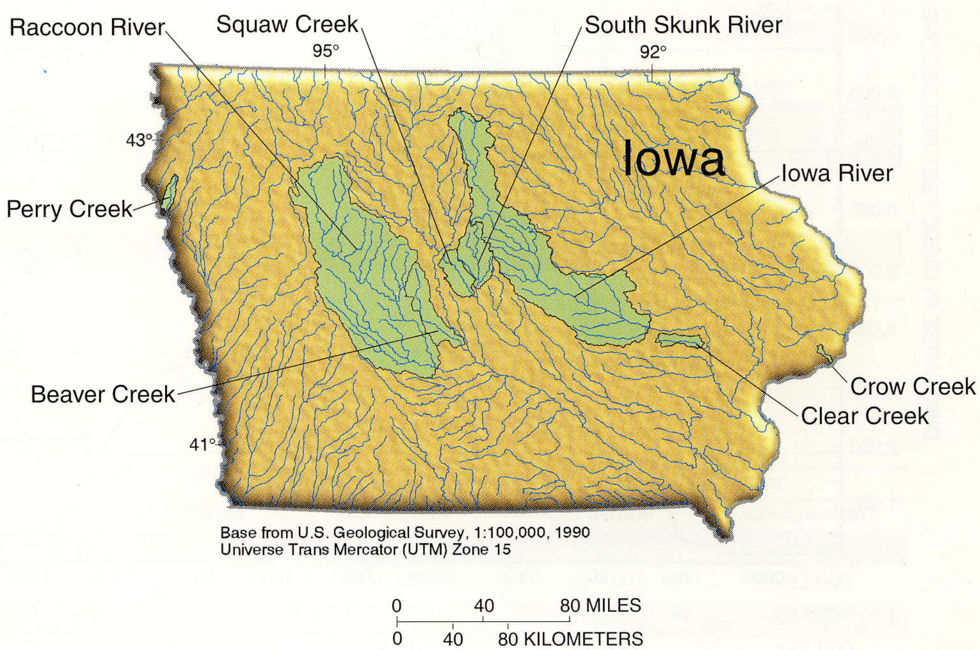

Figure 1. Location of selected drainage basins.

Sources of Data

Streamflow data for this study were obtained from the USGS's National Water Information System data base. Instantaneous measurements of stream stage (water level) that are collected every 15 minutes were converted to discharge by means of an established stage/discharge relationship at each measurement site. These discharge data were plotted to show all days in which floodflows were above the 2-year recurrence interval flood discharge for each of the 11 floods selected. An example of one of the flood-event hydrographs used in this study is shown in figure 2.

Digital elevation model (DEM) data from the USGS were used to determine land-surface elevations in the eight watersheds that were studied. DEM data at a scale of 1:100,000 were prepared from USGS 1:100,000-scale digital line graph vector data representing hypsography (elevation contours) and hydrography (stream networks), except for the Raccoon River watershed, which did not have readily available hydrography data to convert to a hydrologically enforced DEM data set within the scope of this study.

Methods of Analysis

Hydrographs similar to figure 2 were prepared for each flood event. A flood-frequency analysis was used to determine the recurrence-interval discharges for each flood event for either a single flood peak or for multiple flood peaks. Methods used for estimation of flood-frequency discharges were those found in Interagency Advisory Committee on Water Data (1982). Flood volumes in excess of the 10-, 25-, 50-, 100-, 200-, and 500-year recurrence-interval discharges, as applicable, were calculated by multiplying the discharge (rate) by the duration (time) data. For example, the flood volume in excess of the 10-year flood recurrence interval shown in figure 2 is represented by the area under the flood hydrograph curve and above the 10-year recurrence-interval discharge line—4,910 acre-ft.

A Geographic Information System (GIS) was used to process and analyze the DEM data for each watershed and identify potential flood-storage areas in each watershed according to the criteria listed below. The procedure included six main processing steps: (1) An average slope was computed for each DEM cell within a watershed by comparing the elevation of each cell with the elevations of its eight neighboring cells (each cell at the 1:100,000 scale is approximately 0.9 acre); (2) cells within each watershed were classified into four slope categories for analysis—less than 2.5 percent, less than 5.0 percent, less than 7.5 percent, and less than 10.0 percent; (3) areas of contiguous cells were identified from the cells in each slope criterion; (4) areas of less than 10 acres were arbitrarily removed from the analysis on the assumption that these areas were too small to be considered as part of a comprehensive watershed flood-storage strategy; (5) areas that intersected streams identified as second order or greater were removed from analysis based on the assumption that these areas were not upland areas but were flood-plain areas and might be inundated during a flood event; and (6) all remaining areas within each watershed meeting each slope criterion were then identified as potential upland flood-storage areas and their areas summed to compute a total

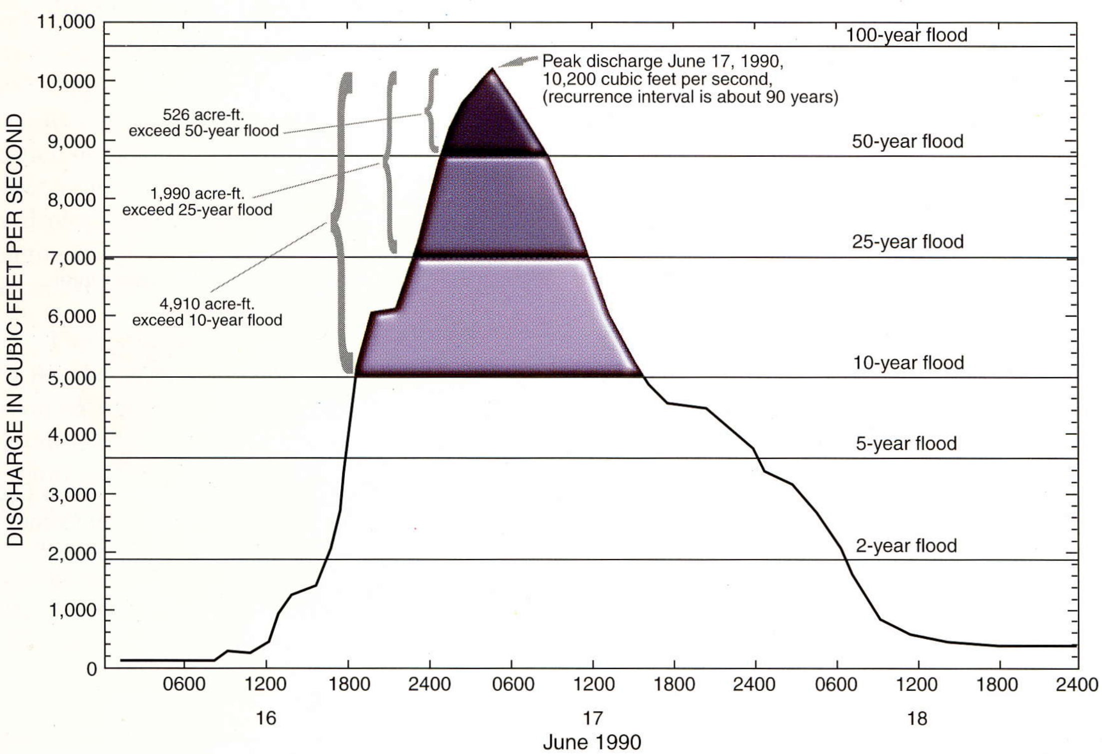

Figure 2. *Discharge hydrograph and flood volumes in excess of selected recurrence-interval discharges for the flood of June 16–18, 1990, at the Clear Creek near Coralville, Iowa, streamflow-gaging station (station number 05454300, drainage area 98.1 square miles).*

potential flood-storage area for each watershed.

Flood-storage volumes were estimated by multiplying the various land-slope-category areas within a watershed, as calculated by the GIS procedure described above, times a hypothetical uniform inundation depth, for example 1, 2, or 3 ft deep. The estimated volume was then divided by 2 to conservatively account for the depth variability within each polygonal area.

Volumes of Recent Floods

Results of the hydrographic analysis are summarized in table 1. The 11 flood events analyzed ranged in magnitude from about a 10-year recurrence interval to floods in excess of a 500-year recurrence interval. Most flood events were about 100-year recurrence interval magnitude or less. Flood volumes in excess of the 10-year recurrence interval for each event ranged from 537 acre-ft to 102,000 acre-ft. Of the eight watersheds selected for this study, five had one flood event analyzed and three had two flood events analyzed.

Potential Upland Storage Areas

Table 2 summarizes the results of the GIS land-surface-slope analysis identifying potential flood-storage areas within the eight watersheds. A comparison between the number of acres identified within each watershed for each land-surface-slope criterion and the total number of acres within the watershed is made. This table shows the amount of area within each watershed meeting each slope criterion. Amounts ranged from 0.5 percent of a watershed meeting the less-than-2.5-percent slope criterion to 72.9 percent of a watershed meeting the less-than-10-percent slope criterion. The amount of low-relief land surface within any particular watershed is related to the physiography of the watershed. Areas of Iowa that were most recently glaciated have the highest percentage of low-relief land areas.

A comparison of selected estimates of potential flood-storage volumes to computed flood volumes exceeding specific recurrence-interval discharges for the 11 flood events is given in table 3. From this comparison, it can be seen that potential flood-storage volumes calculated using the criterion of a less-than-2.5-percent slope and a 1-ft inundation depth exceeded the flood volumes in excess of the 10-year recurrence-interval discharge for 7 of the 11 flood events analyzed. Potential flood-storage volumes calculated using a less-than-5-percent

Table 1. Date and volume of selected floods in Iowa, 1990–93

Watershed	Date of flood event	Volume of flood (acre-feet) exceeding indicated recurrence interval					
		10-year	25-year	50-year	100-year	200-year	500-year
Raccoon River	7–10–93	102,000	56,300	30,900	13,700	3,420	
Iowa River	7–19–93	102,000	30,300	8,240	48.6		
Beaver Creek	7–10–93	15,200	8,150	4,230	1,600	182	
South Skunk River	7–09–93	9,040	3,920	1,830	490		
	8–16–93	7,200	3,090	1,290	248		
Squaw Creek	6–17–90	1,910	561	12.4			
	7–09–93	15,900	8,540	5,600	3,550	1,730	291
Clear Creek	6–16–90	4,910	1,990	526			
	7–06–93	1,840					
Perry Creek	5–19–90	663	123				
Crow Creek	6–16–90	537	160	15.3			

Table 2. Total area and area in selected land-surface-slope categories

[<, less than]

Watershed	Total area (acres)	Watershed area (acres) in specified land-surface-slope criterion			
		<2.5 percent	<5.0 percent	<7.5 percent	<10.0 percent
Raccoon River	2,202,240	560,000	909,000	1,140,000	1,300,000
Iowa River	1,788,160	216,000	449,000	619,000	742,000
Beaver Creek	229,120	36,200	78,800	114,000	137,000
South Skunk River	201,600	41,200	84,000	119,000	147,000
Squaw Creek	130,560	15,600	34,800	53,100	69,400
Clear Creek	62,784	2,730	6,220	9,190	12,000
Perry Creek	41,664	228	825	1,490	2,200
Crow Creek	11,392	2,250	4,180	5,790	7,040

Table 3. Comparison of flood volumes to potential upland storage volumes

Watershed	Volume of flood (acre-feet) in excess of indicated recurrence interval			Potential storage volume (acre-feet) for land-slope criterion and inundation depth	
	10-year	25-year	50-year	2.5 percent and 1 foot	5.0 percent and 2 feet
Raccoon River	102,000	56,300	30,900	280,000	909,000
Iowa River	102,000	30,300	8,240	108,000	449,000
Beaver Creek	15,200	8,150	4,230	18,100	78,800
South Skunk River	9,040 7,200	3,920 3,090	1,830 1,290	20,600	84,000
Squaw Creek	1,910 15,900	561 8,540	12.4 5,600	7,800	34,800
Clear Creek	4,910 1,840	1,990	526	1,360	6,220
Perry Creek	663	123		114	825
Crow Creek	537	160	15.3	1,120	4,180

slope and a 2-ft inundation depth exceeded floodwater volumes in excess of the 10-year recurrence-interval discharge for all 11 flood events studied.

The results of this study provide a preliminary indication that a potential for storage of water within upland areas in amounts large enough to mitigate downstream flooding might be possible, based simply on water-volume estimations. However, this study included several assumptions and simplifications to estimate potential flood-storage volumes and which need to be tested to determine their validity. Furthermore, this was a hydrologic study and did not address engineering, socioeconomic, or other aspects of floodwater storage.

The hydrographic analysis of the 11 flood events for this study is based upon only a few recent occurrences of flooding. Many factors may affect the preliminary conclusions of this study. These factors include but are not limited to: historical flood variability; timing, distribution, and travel of streamflow within a watershed; changes in flood-frequency estimates over time; and changes in watershed characteristics over time.

Additionally, the assumptions and simplifications used in the GIS analysis may be improved upon by using higher resolution DEM data, which were not available at the time of this study, and by more detailed analysis of the suitability of land areas that might be considered for flood storage.

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