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Cover photo: Located in far east Texas and stretching into Louisiana, Caddo Lake is known for its extensive forests of baldcypress trees draped with Spanish moss. This famous lake is home to a rich ecosystem and a wide variety of wildlife. The cover photo was taken during normal water levels, but in 2011 the lake's levels dropped significantly during the drought. Photo credit: Texas Water Resources Institute

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Floods in Central Texas, September 7–14, 2010

Karl E. Winters, P.E.[1]

Abstract: Severe flooding occurred near the Austin metropolitan area in central Texas September 7–14, 2010, because of heavy rainfall associated with Tropical Storm Hermine. The U.S. Geological Survey, in cooperation with the Upper Brushy Creek Water Control and Improvement District, determined rainfall amounts and annual exceedance probabilities for rainfall resulting in flooding in Bell, Williamson, and Travis counties in central Texas during September 2010. We documented peak streamflows and the annual exceedance probabilities for peak streamflows recorded at several streamflow-gaging stations in the study area. The 24-hour rainfall total exceeded 12 inches at some locations, with one report of 14.57 inches at Lake Georgetown. Rainfall probabilities were estimated using previously published depth-duration frequency maps for Texas. At 4 sites in Williamson County, the 24-hour rainfall had an annual exceedance probability of 0.002. Streamflow measurement data and flood-peak data from U.S. Geological Survey surface-water monitoring stations (streamflow and reservoir gaging stations) are presented, along with a comparison of September 2010 flood peaks to previous known maximums in the periods of record. Annual exceedance probabilities for peak streamflow were computed for 20 streamflow-gaging stations based on an analysis of streamflow-gaging station records. The annual exceedance probability was 0.03 for the September 2010 peak streamflow at the Geological Survey's streamflow-gaging stations 08104700 North Fork San Gabriel River near Georgetown, Texas, and 08154700 Bull Creek at Loop 360 near Austin, Texas. The annual exceedance probability was 0.02 for the peak streamflow for Geological Survey´s streamflow-gaging station 08104500 Little River near Little River, Texas. The lack of similarity in the annual exceedance probabilities computed for precipitation and streamflow might be attributed to the small areal extent of the heaviest rainfall over these and the other gaged watersheds.

Keywords: flood, Hermine, Texas, 2010, annual exceedance probability

[1]U.S. Geological Survey, Austin, Texas

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INTRODUCTION

Severe flooding occurred in the greater Austin metropolitan area in central Texas September 7–14, 2010 because of heavy rainfall associated with Tropical Storm Hermine. Storm totals exceeded 12 inches near Georgetown, Texas. More than 10 inches fell in parts of Austin, Texas. Numerous homes were damaged along Brushy Creek and Lake Creek in Williamson County (Rasmussen 2010). Flood-related deaths were reported in Austin, Georgetown, and Killeen (Associated Press 2010). One of these deaths occurred as 2 vehicles were swept into Bull Creek at Farm Road 2222 in Austin (Austin American-Statesman 2010). The U.S. Geological Survey, in cooperation with the Upper Brushy Creek Water Control and Improvement District, determined rainfall amounts and annual exceedance probabilities for rainfall resulting in flooding in central Texas in Bell, Williamson, and Travis counties in September 2010. They documented peak streamflows and the annual exceedance probabilities for peak streamflows measured at several Geological Survey's streamflow-gaging stations in the study area (Figure 1).

PURPOSE AND SCOPE

This report documents Tropical Storm Hermine-associated rainfall during September 7–8, 2010, and runoff during September 7–14, 2010, near Austin, and selected statistical characteristics of these data. Rainfall and runoff in Bell, Travis, and Williamson counties in central Texas are described. The report gives rainfall data from various sources and estimates annual exceedance probabilities for 24-hour rainfall totals at selected stations for September 7–8, 2010. The report presents hyetographs of rainfall data collected from 2 rain gages near Georgetown. It documents stage (height of the water surface in a stream above an established datum), streamflow, and mean velocity measurements made during the flood along with peak streamflows computed by the slope-area indirect method. The report presents peak stage and streamflow data for selected Geological Survey streamflow-gaging stations along with the estimated annual exceedance probabilities for peak streamflow for selected gages.

CONDITIONS LEADING TO THE FLOOD

As Tropical Storm Hermine approached the Texas Gulf Coast on September 3, 2010, rainfall of about 1 to 2 inches fell in the study area, with the larger amounts falling in central and western Travis County. An additional quarter-inch fell near the Travis-Williamson County line on September 4. No measurable precipitation fell during September 5–6. Tropical Storm Hermine made landfall about 30 miles south of Brownsville, Texas on September 6 at 9 PM with peak winds of 69 miles per hour and a minimum pressure of 989 millibars. With a forward speed of 18 miles per hour, the center of circulation reached San Antonio, Texas at 1 PM September 7. Light rain (about 0.14 inch per hour) fell between 4:30 AM and 6 PM on September 7. The heaviest rain fell between 6 PM September 7 and 4 AM on September 8. During this period, rainfall rates were as much as 1 inch per hour in parts of Williamson County. Rainfall during the 24-hour period ending September 8 at 6 AM exceeded 12 inches at some locations in the study area, with one report of 14.57 inches at Lake Georgetown. Rainfall quickly diminished after 6 AM September 8 as Tropical Storm Hermine moved out of the study area (NWS 2010). Widespread flooding occurred September 7–14, 2010.

RAINFALL DEPTHS AND ANNUAL EXCEEDANCE PROBABILITIES

Rainfall depth contours were determined using the National Weather Service-gridded rainfall data (NWS 2010) for the 24-hour period ending at 6 AM September 8, 2010. These data are based on Next Generation Weather Radar estimates (NWS 2010). The data have a spatial resolution of about 2.5 miles (4 kilometers). The 24-hour rainfall totals are shown in Figure 2.

Rainfall data collected by Upper Brushy Creek Water Control and Improvement District (Dustin Mortensen, Civil Engineer, Freese and Nichols, Inc., written communication 2010), Geological Survey (USGS 2012), and 2 local airport stations (FAA 2012) were used to verify the isohyetal contours (Jain and Singh 2005) derived from the National Weather Service-gridded rainfall data. Rainfall data collected by the Geological Survey were measured at selected Geological Survey surface-water monitoring stations (Table 1). The 24-hour rainfall totals for most of the stations listed in Table 1 compare favorably with the isohyetal contours of National Weather Service-gridded rainfall data shown in Figure 2. However, the 24-hour totals recorded by 4 of the water control and improvement district rain gages (sites 46, 51, 54, and 56) near Round Rock, Texas (Figures 1 and 2), differed appreciably from the National Weather Service-gridded rainfall data (Figure 2). These sites are where the isohyetal contours are close together, indicating that large differences in rainfall amounts occurred over a small area. Sites 51, 54, and 56 are less than 5 miles apart and recorded similar 24-hour rainfall totals (0.91, 0.98, and 0.91 inches), respectively, indicating that the National Weather Service-gridded rainfall totals might not be accurate near these gages. The largest rainfall totals for the 24-hour period ending 6 AM September 8, 2010 (more than 12 inches), were measured west of Georgetown, at sites 5, 42, 49, and 58 (rain

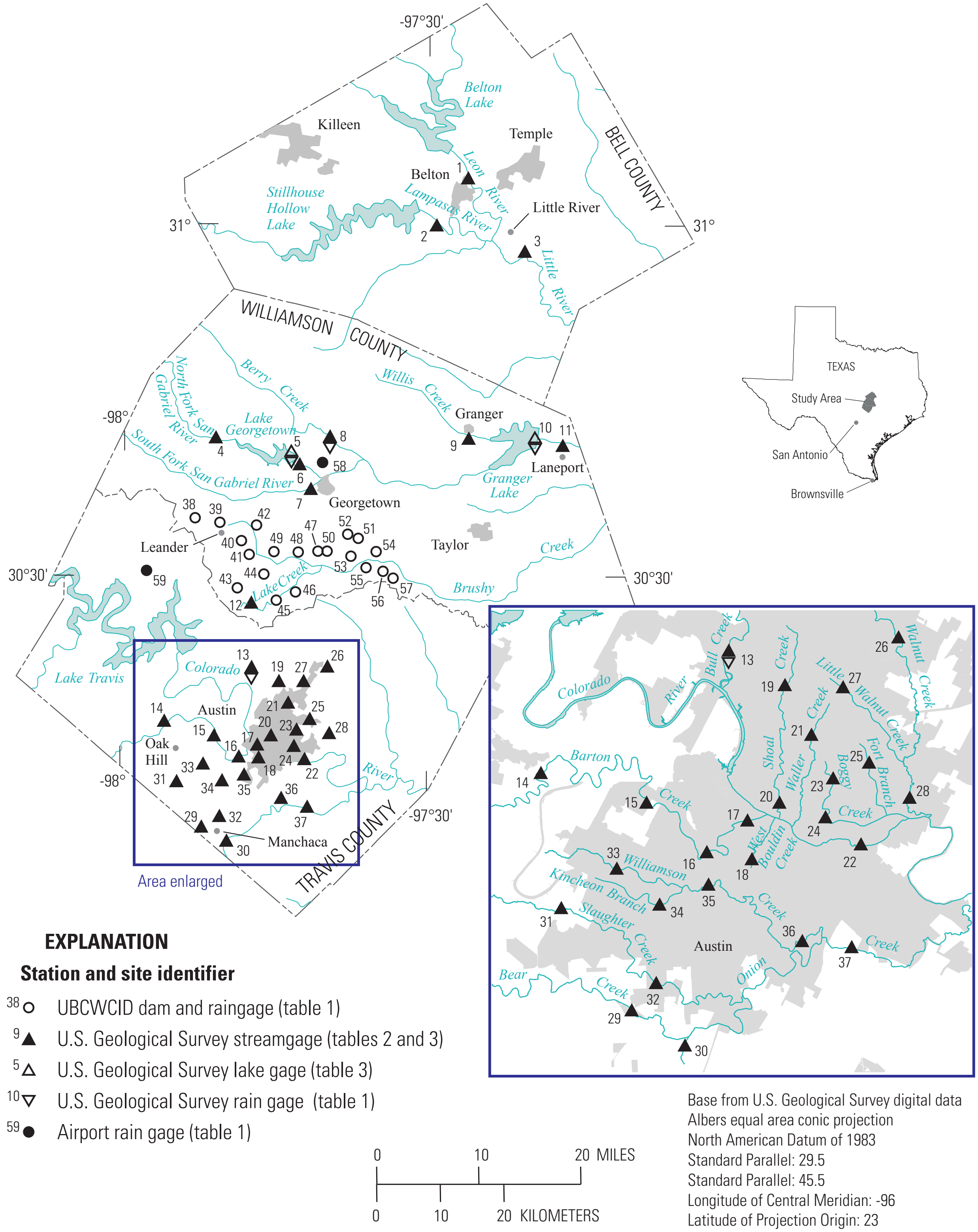

Figure 1. Map showing the locations of selected rain gages, reservoir gages, streamflow-gaging stations, and Upper Brushy Creek Water Control Improvement District dams in the study area of Bell, Williamson, and Travis counties, Texas.

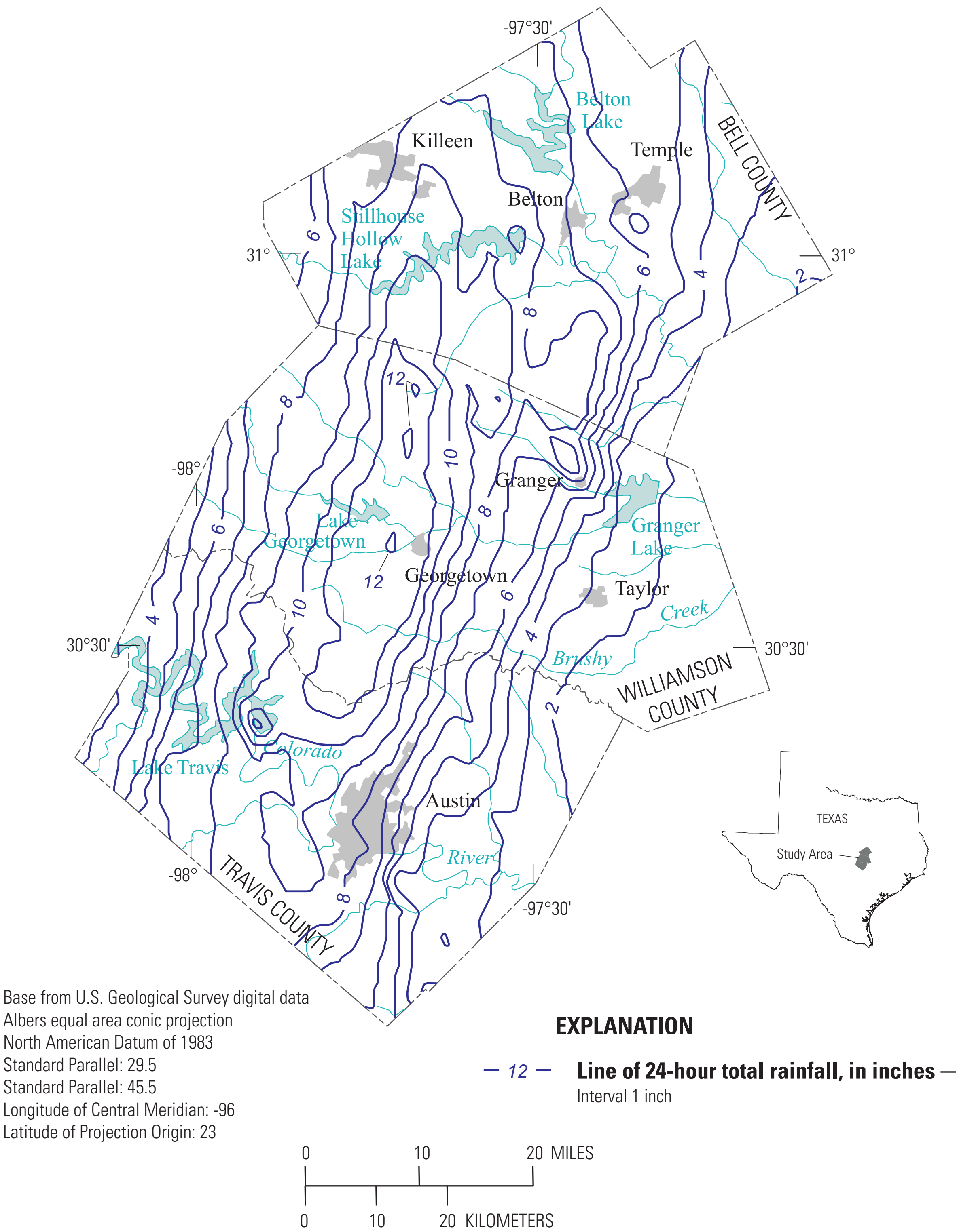

Figure 2. Map showing the 24-hour total rainfall ending 6 AM September 8, 2010, in Bell, Williamson, and Travis counties, Texas (modified from NWS 2010).

Table 1. Rainfall totals and associated annual exceedance probabilities based on depth-duration frequency of rainfall by Asquith and Roussel (2004). [--, not applicable; nd, not determined; Upper Bushy Creek Water Control and Improvement District (UBCWCID); U.S. Army Corps of Engineers (USACE)]

			Rainfall depth (inches)		
Site number (Fig. 1)	Station number	Station name	24-hr period ending 6 AM 9/8/2010	Sliding 24-hr maximum[1]	Annual exceedance probability
5	08104650	Lake Georgetown near Georgetown, Texas[2]	12.07	12.66	0.002
8	08105095	Berry Creek at Airport Road near Georgetown, Texas[2]	11.43	11.45	0.003
10	08105600	Granger Lake near Granger, Texas[2]	0.47	0.64	--
13	08154700	Bull Creek at Loop 360 near Austin, Texas[2]	9.67	9.77	0.008
38	--	UBCWCID dam 1[3]	9.8	9.84	0.008
39	--	UBCWCID dam 2[3]	9.73	9.84	0.008
40	--	UBCWCID dam 3[3]	11.61	11.81	0.003
41	--	UBCWCID dam 4[3]	10.87	10.91	0.004
42	--	UBCWCID dam 5[3]	12.16	12.45	0.002
43	--	UBCWCID dam 6[3]	nd[4]	nd	nd
44	--	UBCWCID dam 7[3]	10.67	10.79	0.005
45	--	UBCWCID dam 8[3]	11.02	11.26	0.004
46	--	UBCWCID dam 9[3]	1.77	1.97	--
47	--	UBCWCID dam 11[3]	6.73	7.09	0.036
48	--	UBCWCID dam 12[3]	10.51	10.94	0.004
49	--	UBCWCID dam 13A[3]	12.01	12.28	0.002
50	--	UBCWCID dam 14[3]	6.42	6.97	0.038
51	--	UBCWCID dam 15[3]	0.91	1.14	--
52	--	UBCWCID dam 16[3]	4.96	5.51	0.143
53	--	UBCWCID dam 17[3]	5.23	5.55	0.125
54	--	UBCWCID dam 18[3]	0.98	1.70	--
55	--	UBCWCID dam 19[3]	4.37	4.73	0.217
56	--	UBCWCID dam 20[3]	0.91	0.95	--
57	--	UBCWCID dam 21[3]	3.3	3.66	0.333
58	KGTU	Georgetown airport[5]	11.12	12.31	0.002
59	K5R3	Lago Vista airport[5]	9.64	9.83	0.011
60	--	USACE rain gage near Lake Georgetown	14.57[6]	nd	nd

[1]Determined by sliding (moving) a 24-hour window through successive values of incremental rainfall data; the first 24-hour window began at 12 AM on September 7, 2010, and the last window began at 12 AM on September 8, 2010.
[2]Data obtained from the U.S. Geological Survey National Water Information System (USGS 2012).
[3]Data obtained from Dustin Mortensen, Civil Engineer, Freese and Nichols, Inc., written communication, 2010.
[4]The rain gage at dam 6 was damaged during the September 2010 storm.
[5]Data obtained from the Federal Aviation Administration (2012).
[6]For a 24-hour period ending 8 AM on September 8, 2010.

gages at the Geological Survey's surface-water monitoring station 08104650 Lake Georgetown near Georgetown, the Water Control and Improvement District's dam 5 and 13A, and the Georgetown airport, respectively; Figures 1–2; Table 1). These 24-hour rainfall totals agreed within about 10% with the National Weather Service-gridded rainfall data. Cumulative 24-hour rainfall totals for sites 5 and 42 are shown in Figure 3. A rain gage operated by the U.S. Army Corps of Engineers, about 0.5 mile north of Georgetown Lake (site 60, Figure 1; Table 1), recorded 14.57 inches during the 24-hour period ending at 8 AM September 8, 2010 (John Rael, Hydraulic Engineer, U.S. Army Corps of Engineers, written communication 2012).

Rainfall annual exceedance probabilities for the September 2010 flood were estimated using depth-duration frequency maps for Texas (Asquith and Roussel 2004). Annual exceedance probability is the reciprocal of the "*x*-year rainfall." When describing flood frequency, annual exceedance probability is the reciprocal of the "*x*-year flood." For example, a 50-year flood has an annual exceedance probability of 1/50 = 0.02, equivalent to a 2% chance of occurring in any given year. The "*x*-year flood" terminology is no longer preferred, as it is often

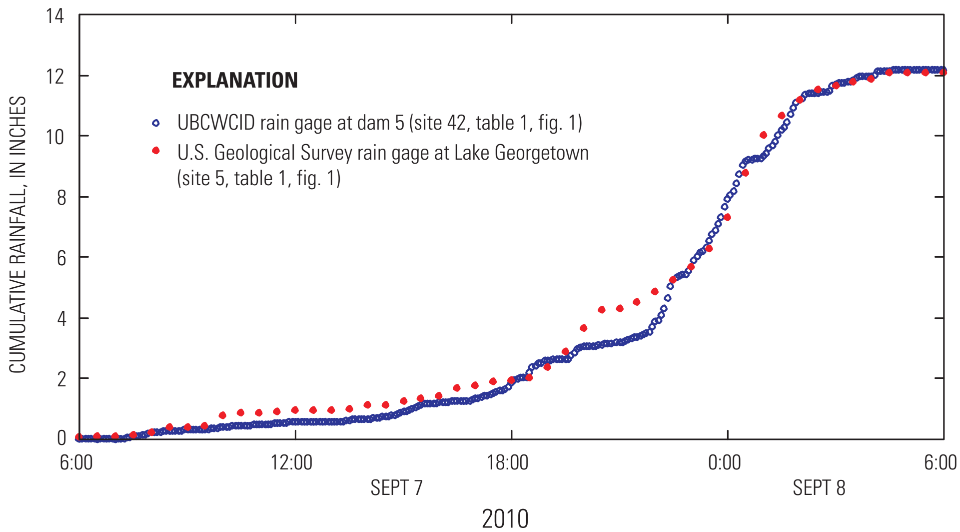

Figure 3. Cumulative rainfall for 24-hour period ending 6 AM September 8, 2010, at Upper Brushy Creek Water Control and Improvement District dam 5 and U.S. Geological Survey surface-water monitoring station 08104650 Lake Georgetown near Georgetown, Texas.

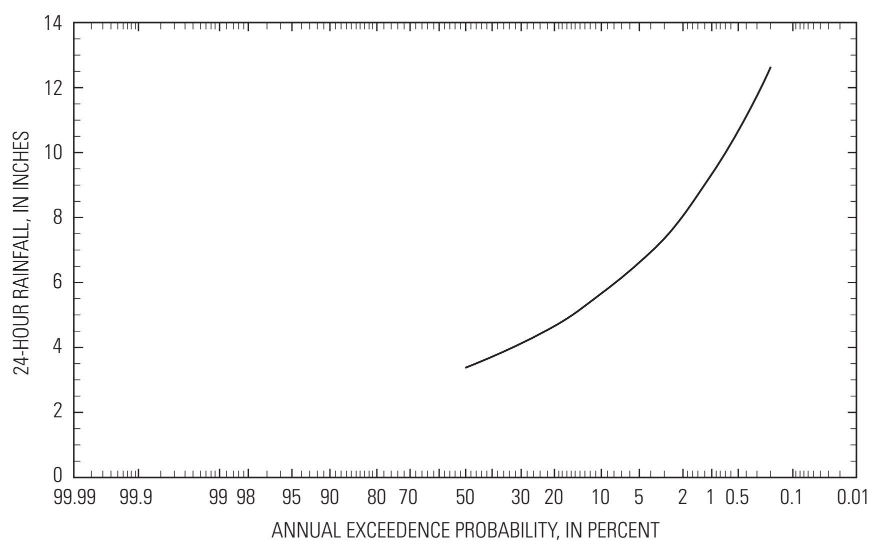

Figure 4. Annual exceedance probabilities for 24-hour rainfall totals in Williamson County, Texas, derived from Asquith and Roussel (2004).

misunderstood to imply an interoccurrence period between events (Holmes and Dinicola 2010). To determine rainfall annual exceedance probabilities for Williamson County, the 24-hour rainfall totals from maps of various return periods (Asquith and Roussel 2004) were interpolated to develop the relation shown in Figure 4. The annual exceedance probability values listed in Table 1 were computed using the maximum 24-hour rainfall amount and depth-duration frequency of rainfall by Asquith and Roussel (2004). This maximum rainfall was determined by sliding (moving) a 24-hour window through successive values of (primarily 5-minutes) incremental rainfall data; the first 24-hour window began at 12 AM September 7, 2010, and the last window began at 12 AM September 8, 2010. The maximum intensities typically occurred during a 24-hour window ending at 4:30 AM September 8, and these values are only slightly larger than those recorded for the 24-hour period ending at 6 AM September 8 (Table 1). The rainfall recorded at sites 5, 42, 49, and 58 (Figures 1–2, Table 1) had an annual exceedance probability of 0.002, a 1-in-500 chance of occurring in any year.

PEAK STREAMFLOWS AND ANNUAL EXCEEDANCE PROBABILITIES

Peak streamflow values are generally computed from stage-discharge rating curves (Kennedy 1983, and Rantz and others 1982). Measurements of streamflow are used to define stage-discharge rating curves, and measurements made during floods are especially necessary for reliable computation of peak streamflow (Turnipseed and Sauer 2010). Streamflow measurement data from 19 Geological Survey streamflow-gaging stations and flood-peak data from 35 Geological Survey streamflow-gaging stations and 2 reservoir gages were evaluated; peak streamflows measured during the September 2010 runoff event were compared to previous known maximum flood peaks from the period of record for each station. All Geological Survey data were obtained from its National Water Information System (USGS 2012).

When it is logistically impossible to measure the peak streamflow because of difficulties accessing the site at the time of the peak or because of rapid changes in stage, it is often possible to indirectly compute the peak streamflow "after-the-fact," using methods based on principles of open-channel hydraulics. The slope-area computation method incorporates channel cross-section geometry and roughness (a measure of frictional resistance to flow) to compute the peak streamflow associated with a flood profile defined from interpretation of high-water marks (Dalrymple and Benson 1967). For selected peaks associated with the September 2010 flood, slope-area computations were performed using the Geological Survey slope-area computation program (Fulford 1994). Six slope-area computations of peak streamflow made following the September 2010 flood are included in Table 2.

Selected streamflow measurements made September 7–8, 2010 are listed in Table 2. The streamflow of 50,700 cubic feet per second measured at site 3 (Geological Survey streamflow-gaging station 08104500 Little River near Little River, Texas [hereinafter Little River gage]) was the largest discharge measured, and this measurement was made near the peak of the flood. Slope-area computations were performed at sites 8, 12, 13, 29, 34, and 36 (Table 2). These indirect measurements of peak discharge are probably less accurate compared to direct measurements of streamflow. For example, the slope-area computation for site 29 (Geological Survey streamflow-gaging station 08158819 Bear Creek near Brodie Lane near Manchaca, Texas) differed by 11% from the discharge estimated from the stage-discharge rating curve in use for this site, which is based in part on a direct measurement from 2004 of 6,900 cubic feet per second (stage 12.40 feet).

The peak streamflow at a location divided by the contributing area upstream from it, (cubic feet per second per square mile), described here as unit runoff, is a measure of the intensity of a watershed's response to a storm and is useful for comparing peak discharges from different sites (Fontaine and Hill 2002; Rowe and Allander 2000). The drainage area for each Geological Survey streamflow-gaging station is available in its 2010 annual data report (USGS 2010). Peak stages, streamflows, and unit runoff for the September 2010 flood are shown in Table 3, along with data from the previous known maximum flood. Only streamflow from unregulated drainage areas was considered; if dams were present, unit runoff was based on the drainage area of the unregulated part of the basin. On September 8, 2010, site 6 (Geological Survey streamflow-gaging station 08104700 North Fork San Gabriel River near Georgetown [hereinafter North Fork San Gabriel gage]) recorded the highest peak streamflow (7,330 cubic feet per second) since regulation of streamflow at this site began in 1980. Site 13 (Geological Survey streamflow-gaging station 08154700 Bull Creek at Loop 360 near Austin [hereinafter Bull Creek at Loop 360 gage]) recorded the highest peak streamflow in its 32-year history. In addition to sites 6 and 13, the September 2010 flood was the highest recorded flood at 9 other sites (8, 9, 12, 19, 21, 23, 24, 25, and 34) in the study area, although none of these 9 sites had more than 7 years of record. Streamflow hydrographs for site 7 (Geological Survey streamflow-gaging station 08104900 South Fork San Gabriel River at Georgetown) and site 13 are shown in Figure 5.

The relation between peak streamflow and unregulated drainage area for 35 Geological Survey streamflow-gaging stations September 7–8, 2010, in Bell, Williamson, and Travis counties is shown in Figure 6, along with selected flood peaks used to define an envelope of maximum floods for a

Table 2. Data from selected streamflow measurements made at U.S. Geological Survey streamflow-gaging stations during September 7–8, 2010. [mi^2, square miles; ft, feet; ft^3/s, cubic feet per second; ft/s, feet per second; nd, not determined]

Site number (Fig. 1)	Station number	Station name	Drainage area (mi^2)	Date and time (24-hr)	Stage (ft)	Measured streamflow (ft^3/s)	Mean velocity (ft/s)
3	08104500	Little River near Little River, Texas	5,228	9/8/2010 1330	40.51	50,700	3.0
8	08105095	Berry Creek at Airport Road near Georgetown, Texas	71.4	9/8/2010 0305	28.72	25,900[1]	4.9
9	08105505	Willis Creek near Granger, Texas	57.8	9/8/2010 1747	10.68	697	3.2
12	08105886	Lake Creek at Lake Creek Parkway near Austin, Texas	2.18	9/8/2010 0035	8.59	3,510[1]	6.7
13	08154700	Bull Creek at Loop 360 near Austin, Texas	22.3	9/8/2010 0140	14.97	16,900[1]	13.4
15	08155240	Barton Creek at Lost Creek Blvd near Austin, Texas	107	9/8/2010 1113	9.54	6,280	5.5
16	08155300	Barton Creek at Loop 360, Austin, Texas	116	9/8/2010 1311	10.83	6,990	6.0
18	08155541	West Bouldin Creek at Oltorf Road, Austin, Texas	1.77	9/7/2010 1305	2.13	40.7	2.4
19	08156675	Shoal Creek at Silverway Drive, Austin, Texas	5.59	9/7/2010 1405	3.49	51	1.0
20	08156800	Shoal Creek at W 12th Street, Austin, Texas	12.3	9/7/2010 1245	3.87	325	3.8
24	08158035	Boggy Creek at Webberville Road, Austin, Texas	3.44	9/7/2010 0917	1.28	84.5	nd
25	08158045	Fort Branch Boggy Creek at Manor Road, Austin, Texas	1.47	9/8/2010 0900	3.33	18.8	3.3
28	08158600	Walnut Creek at Webberville Road, Austin, Texas	51.3	9/8/2010 0930	13.45	2,870	2.9
29	08158819	Bear Creek near Brodie Lane near Manchaca, Texas	23.8	9/8/2010 0025	11.92	5,330[1]	6.5
32	08158860	Slaughter Creek at Farm Road 2304 near Austin, Texas	23.1	9/8/2010 1147	3.53	357	1.6
34	08158927	Kincheon Branch at William Cannon Blvd, Austin, Texas	6.73	9/8/2010 0015	5.05	2,340[1]	5.7
35	08158930	Williamson Creek at Manchaca Road, Austin, Texas	19	9/7/2010 1830	5.73	700	3.1
36	08158970	Williamson Creek at Jimmy Clay Road, Austin, Texas	27.6	9/8/2010 0200	17.87	4,860[1]	4.2
37	08159000	Onion Creek at U.S. Highway 183, Austin, Texas	321	9/8/2010 1300	16.93	7,580	3.1

[1]Peak streamflow computed using slope-area method (Fulford 1994).

Table 3. Flood-peak data at selected U.S. Geological Survey surface-water monitoring stations in Bell, Williamson, and Travis counties, Texas. [mi², square miles; ft, feet; ft³/s, cubic feet per second; --, not applicable]

				Characteristics of systematic record		September 2010 flood						Previous known maximum[1]		
Site number (Fig. 1)	Station number	Station name	Drainage area (mi²)	Length (yrs)	Period (water yrs)	Date	Time	Peak stage (ft)	Peak stream-flow (ft³/s)	Unit runoff (ft³/s/mi²)	Annual exceedance probability	Date	Peak stage (ft)	Peak stream-flow (ft³/s)
1	08102500	Leon River near Belton, Texas	3,582	56	1955[1]–2010	9/8/2010	0900	5.36	1,330	115[2]	0.88	3/6/1992	9.74	10,200[1]
2	08104100	Lampasas River near Belton, Texas	1,321	34	1967[1]–2010	9/8/2010	0400	11.83	2,140	265[2]	0.49	6/26/2007	18.99	6,390[1]
3	08104500	Little River near Little River, Texas	5,228	48	1963–2010	9/8/2010	1400	40.58	50,700	129[2]	0.02	5/17/1965	42.85	79,600
4	0810464660	North Fork San Gabriel River at Reagan Blvd near Leander, Texas	210	2	2009–2010	9/8/2010	0045	15.26	13,700	65.2	--	10/22/2009	17.22	18,300
5	08104650	Lake Georgetown near Georgetown, Texas	247	31	1980–2010	9/14/2010	0130	798.65	--	--	--	3/4/1992	835.86	--
6	08104700	North Fork San Gabriel River near Georgetown, Texas	248	31	1980[1]–2010	9/8/2010	0100	14.15	7,330	4,730	0.03	3/4/1992	13.05	6,070[1]
7	08104900	South Fork San Gabriel River at Georgetown, Texas	133	43	1968–2010	9/8/2010	0345	21.98	24,500	184	0.10	6/27/2007	31.65	57,500
8	08105095	Berry Creek at Airport Road near Georgetown, Texas	71.4	7	2004–2010	9/8/2010	0305	28.72	25,900	363	--	6/27/2007	23.05	12,400
9	08105505	Willis Creek near Granger, Texas	57.8	2	2009–2010	9/8/2010	0700	23.16	10,000	173	--	9/11/2009	22.20	8,870
10	08105600	Granger Lake near Granger, Texas	730	31	1980–2010	9/10/2010	1000	513.75	--	--	--	3/5/1992	530.11	--
11	08105700	San Gabriel River at Laneport, Texas	738	31	1980[1]–2010	9/8/2010	1045	4.87	8.3	1.1[2]	--	3/5/1992	21.86	7,540[1]
12	08105886	Lake Creek at Lake Creek Parkway near Austin, Texas	2.18	1	2010–2010	9/8/2010	0035	8.59	3,510	1,610	--	--	--	--
13	08154700	Bull Creek at Loop 360 near Austin, Texas	22.3	32	1979–2010	9/8/2010	0140	14.97	16,900	758	0.03	5/13/1982	11.96	13,700
14	08155200	Barton Creek at State Highway 71 near Oak Hill, Texas	89.7	29	1976–2010	9/8/2010	0255	15.77	7,560	84.3	0.24	7/2/2002	22.82	25,300
15	08155240	Barton Creek at Lost Creek Blvd near Austin, Texas	107	22	1989–2010	9/8/2010	0640	10.81	8,450	79.0	0.21	5/28/1929	--	39,400
16	08155300	Barton Creek at Loop 360, Austin, Texas	116	35	1976–2010	9/8/2010	0755	12.51	8,790	75.8	0.21	5/28/1929	--	39,400
17	08155400	Barton Creek above Barton Springs at Austin, Texas	125	12	1999–2010	9/8/2010	0900	14.02	5,770	46.2	0.25	7/2/2002	18.21	17,200
18	08155541	West Bouldin Creek at Oltorf Road, Austin, Texas	1.77	3	2008–2010	9/7/2010	2240	3.48	351	198	--	9/12/2009	5.06	987
19	08156675	Shoal Creek at Silverway Drive, Austin, Texas	5.59	3	2008–2010	9/7/2010	2345	9.59	3,190	571	--	5/23/2009	7.94	2,210
20	08156800	Shoal Creek at W 12th Street, Austin, Texas	12.3	36	1975–2010	9/8/2010	0030	16.95	6,250	508	0.18	5/24/1981	23.22	16,000
21	08156910	Waller Creek at Koenig Lane, Austin, Texas	1.09	3	2008–2010	9/7/2010	1940	4.79	501	460	--	9/4/2009	4.29	392
22	08158000	Colorado River at Austin, Texas	39,009	113[3]	1898[3]–2010	9/8/2010	0330	27.67	37,700	148[2]	0.09	4/29/1941	23.55[4]	47,600[1]
23	08158030	Boggy Creek at Manor Road, Austin, Texas	1.67	3	2008–2010	9/7/2010	1950	5.65	638	382	--	4/27/2008	5.32	573
24	08158035	Boggy Creek at Webberville Road, Austin, Texas	3.44	3	2008–2010	9/7/2010	2320	3.52	663	193	--	4/27/2008	2.82	467
25	08158045	Fort Branch Boggy Creek at Manor Road, Austin, Texas	1.47	3	2008–2010	9/7/2010	2330	5.58	426	290	--	9/4/2009	5.59	370
26	08158200	Walnut Creek at Dessau Road, Austin, Texas	26.2	17	1975–2010	9/8/2010	0155	19.66	9,660	369	0.10	5/25/1981	26.20	21,600
27	08158380	Little Walnut Creek at Georgian Drive, Austin, Texas	5.22	9	1983–2010	9/7/2010	1950	8.93	3,130	600	0.17	9/14/1985	11.90	3,490
28	08158600	Walnut Creek at Webberville Road, Austin, Texas	51.3	45	1966–2010	9/8/2010	0040	21.43	8,790	171	0.20	1/13/2007	26.30	16,400
29	08158819	Bear Creek near Brodie Lane near Manchaca, Texas	23.8	7	2004–2010	9/8/2010	0025	11.92	6,010[5]	252	--	11/22/2004	12.40	6,900
30	08158827	Onion Creek at Twin Creeks Road near Manchaca, Texas	181	7	2004–2010	9/8/2010	0125	15.33	5,480	30.3	--	11/17/2004	23.72	19,200
31	08158840	Slaughter Creek at Farm Road 1826 near Austin, Texas	8.24	33	1978–2010	9/7/2010	2245	10.22	3,710	450	0.14	12/20/1991	10.68	6,330
32	08158860	Slaughter Creek at Farm Road 2304 near Austin, Texas	23.1	13	1979–2010	9/8/2010	0155	8.18	4,280	185	0.20	6/11/1981	12.40	8,340
33	08158920	Williamson Creek at Oak Hill, Texas	6.3	22	1979–2010	9/7/2010	2240	9.49	2,510	398	0.17	5/18/1992	9.97	4,750
34	08158927	Kincheon Branch at William Cannon Blvd, Austin, Texas	6.73	3	2008–2010	9/8/2010	0015	5.05	2,340	348	--	9/12/2009	1.97	403
35	08158930	Williamson Creek at Manchaca Road, Austin, Texas	19	21	1976–2010	9/7/2010	2335	14.65	4,720	248	0.15	6/11/1981	16.00	8,490
36	08158970	Williamson Creek at Jimmy Clay Road, Austin, Texas	27.6	15	1975–2010	9/8/2010	0200	17.87	4,860	176	--	6/11/1981	17.25	14,100
37	08159000	Onion Creek at U.S. Highway 183, Austin, Texas	321	35	1976–2010	9/8/2010	0600	20.37	9,540	29.7	0.37	9/9/1921	38.00	138,000

[1]For period since streamflow regulation began.
[2]For unregulated part of the basin.
[3]Regulated by Mansfield Dam since 1941. The 36-year period 1975-2010 is more typical of current dam operations and was used in determining annual exceedance probability for the September 2010 flood.
[4]Adjusted to present datum.
[5]Based on stage-discharge rating curve extended to a measurement made in 2004.

range of drainage areas documented in the United States by the Geological Survey (Costa and Jarrett 2008). Asquith and Slade (1995) developed envelope curves for maximum peak streamflows in Texas. These were not considered for this study because the areal extent of the 2010 flood is at the convergence of 3 regions with different maximum peak streamflow characteristics as described in Asquith and Slade (1995). In Figure 6, the peak streamflow of 7,330 cubic feet per second recorded

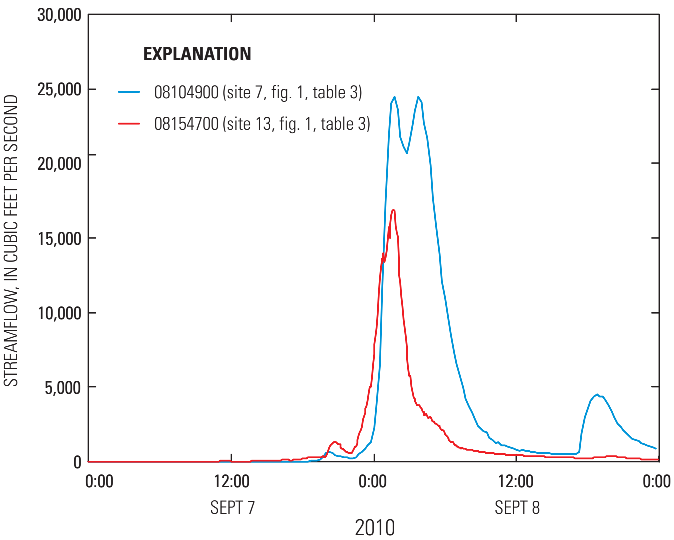

Figure 5. Streamflow hydrographs for U.S. Geological Survey streamflow-gaging stations 08104900 South Fork San Gabriel River at Georgetown and 08154700 Bull Creek at Loop 360 near Austin.

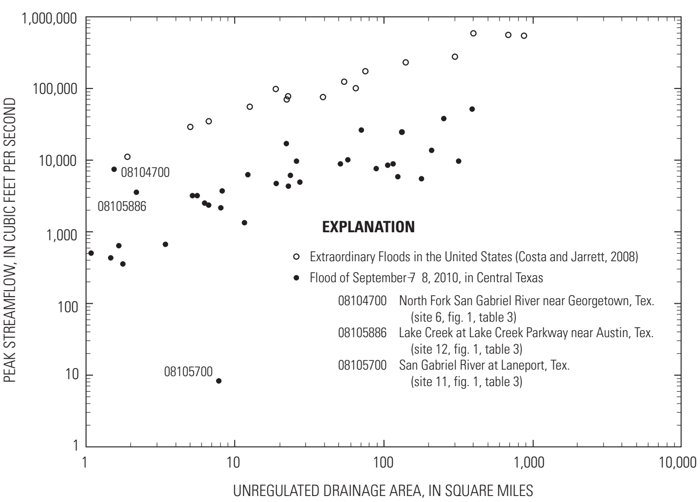

Figure 6. Relation between peak streamflow and unregulated drainage area at 35 U.S. Geological Survey streamflow-gaging stations September 7–8, 2010, in Bell, Williamson, and Travis counties and selected flood peaks used to define an envelope of maximum floods documented in the United States by the U.S. Geological Survey.

at site 6 is plotted versus the unregulated drainage area of this site (1.55 square miles). Because releases from Lake Georgetown did not begin until September 14 (USACE 2011), the peak streamflow recorded for site 6 is the runoff from the unregulated area downstream from the dam. The peak discharge for site 6 plots just below the data for the envelope of maximum floods (Figure 6); the centroid of the unregulated part of the basin between Lake Georgetown and site 6 is about 0.5 mile from the reported 24-hour rainfall of 14.57 inches at the Corps Georgetown Lake office. The peak streamflow at site 12 (Geological Survey streamflow-gaging station 08105886 Lake Creek at Lake Creek Parkway near Austin) was 3,510 cubic feet per second; the drainage area for this site is 2.18 miles, (Figure 6, Table 3). Site 11 (Geological Survey streamflow-gaging station 08105700 San Gabriel River at Laneport), 4 miles downstream from Granger Lake, recorded a peak streamflow of 8.3 cubic feet per second (Figure 6). The unregulated part of the drainage area of site 11 received only 2 inches of rain (Figure 2) and the water-surface elevation at Granger Lake did not reach the spillway.

The annual exceedance probabilities listed in Table 3 for peak streamflows were computed for 20 streamflow-gaging stations in the study area, based on the annual flood peaks for the period of systematic record. Because many of these stations have dams and/or substantial development within the basin, annual exceedance probabilities were based strictly on the systematic record without consideration of regional flood-frequency equations (e.g., Asquith and Roussel 2009). Annual exceedance probabilities were computed using methods outlined in Bulletin 17B (Interagency Advisory Committee on Water Data 1982). Calculations were made using the Geological Survey program Peak flow FreQuency (PeakFQ) (Flynn et al. 2006). For stations where the streamflow is regulated, peak streamflows for the period prior to when regulation began were not used in the analysis. For site 22 (Geological Survey streamflow-gaging station 08158000 Colorado River at Austin) (Figure 1, Table 3) the period 1975–2010 was used in the analysis, as annual peak streamflows during this period appear to reflect consistent reservoir operations.

The annual exceedance probability was 0.03 for sites 6 (North Fork San Gabriel gage) and 13 (Bull Creek at Loop 360 gage) (Table 3). The annual exceedance probability for site 3 (Little River gage) was 0.02. Generally, annual exceedance probabilities for 24-hour rainfall were lower than for peak streamflows. The lack of similarity in the annual exceedance probabilities computed for precipitation and streamflow could be partly attributed to the small areal extent of the heaviest rainfall over the gaged watersheds (Figure 2). Peak streamflows on Brushy Creek are not known; however, much of the basin received more than 10 inches of rainfall, and the annual exceedance probability was less than 0.01 at several rain gages

(Table 1). Additionally, the distribution of streamflow-gaging stations by drainage basin size is not uniform across the study area. The geometric mean of the drainage areas for streamflow-gaging stations in Travis County is 22.4 square miles, while that for Williamson County, where the most intense rainfall occurred, is 89.5 square miles. Only one site (site 12, Geological Survey station 08105886 Lake Creek at Lake Creek Parkway near Austin) in Williamson County had a drainage area less than 50 square miles; however, none of the streamflow-gaging stations for the smaller basins in Williamson County have sufficient record length to compute annual exceedance probabilities for peak streamflow. The lack of stream gages on smaller watersheds in Williamson County limits the understanding of peak streamflows (and associated annual exceedance probabilities) for the September 2010 flood.

SUMMARY

Heavy rainfall associated with Tropical Storm Hermine September 7–8 resulted in widespread flooding September 7–14, 2010, in Bell, Williamson, and Travis counties near the Austin metropolitan area in central Texas. The U.S. Geological Survey, in cooperation with the Upper Brush Creek Water Control and Improvement District, determined rainfall amounts and annual exceedance probabilities for rainfall resulting in flooding in central Texas in Bell, Williamson, and Travis counties during September 2010 and documented peak streamflow amounts and the annual exceedance probabilities for peak streamflows measured at several streamflow-gaging stations in the study area. Total 24-hour rainfall exceeded 12 inches at some locations, with one report of 14.57 inches at Lake Georgetown. Annual exceedance probabilities of rainfall were estimated using depth-duration frequency maps for Texas. At 4 sites in Williamson County where more than 12 inches of rain fell in 24 hours (as recorded by rain gages at the Geological Survey surface-water monitoring station 08104610 Lake Georgetown near Georgetown, the Water Control and Improvement District dam 5 and 13A, and the Georgetown airport), the 24-hour rainfall had an annual exceedance probability of 0.002. Streamflow-measurement data from 19 Geological Survey streamflow-gaging stations are presented, including slope-area computations of peak streamflow. Flood-peak data from 35 Geological Survey streamflow-gaging stations and 2 reservoir gages are presented, along with previous known maximums. The peak streamflow at site 6 (North Fork San Gabriel River gage) approached the envelope of maximum floods for a range of drainage areas documented in the United States. The annual exceedance probability for peak streamflows were computed for 20 streamflow-gaging stations in the study area. The annual exceedance probability was 0.03 for the peak streamflow at site 6 and at site 13 (Bull Creek at Loop 360 gage). The annual exceedance probability was 0.02 for the peak discharge for site 3 (Little River gage).

The lack of similarity in the annual exceedance probabilities computed for precipitation and streamflow could be partly attributed to the small areal extent of the heaviest rainfall over the gaged watersheds. Additionally, the distribution of streamflow-gaging stations by drainage basin size is not uniform across the study area. The lack of stream gages on smaller watersheds in Williamson County limits the understanding of peak streamflows (and associated annual exceedance probabilities) for the September 2010 flood.

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