

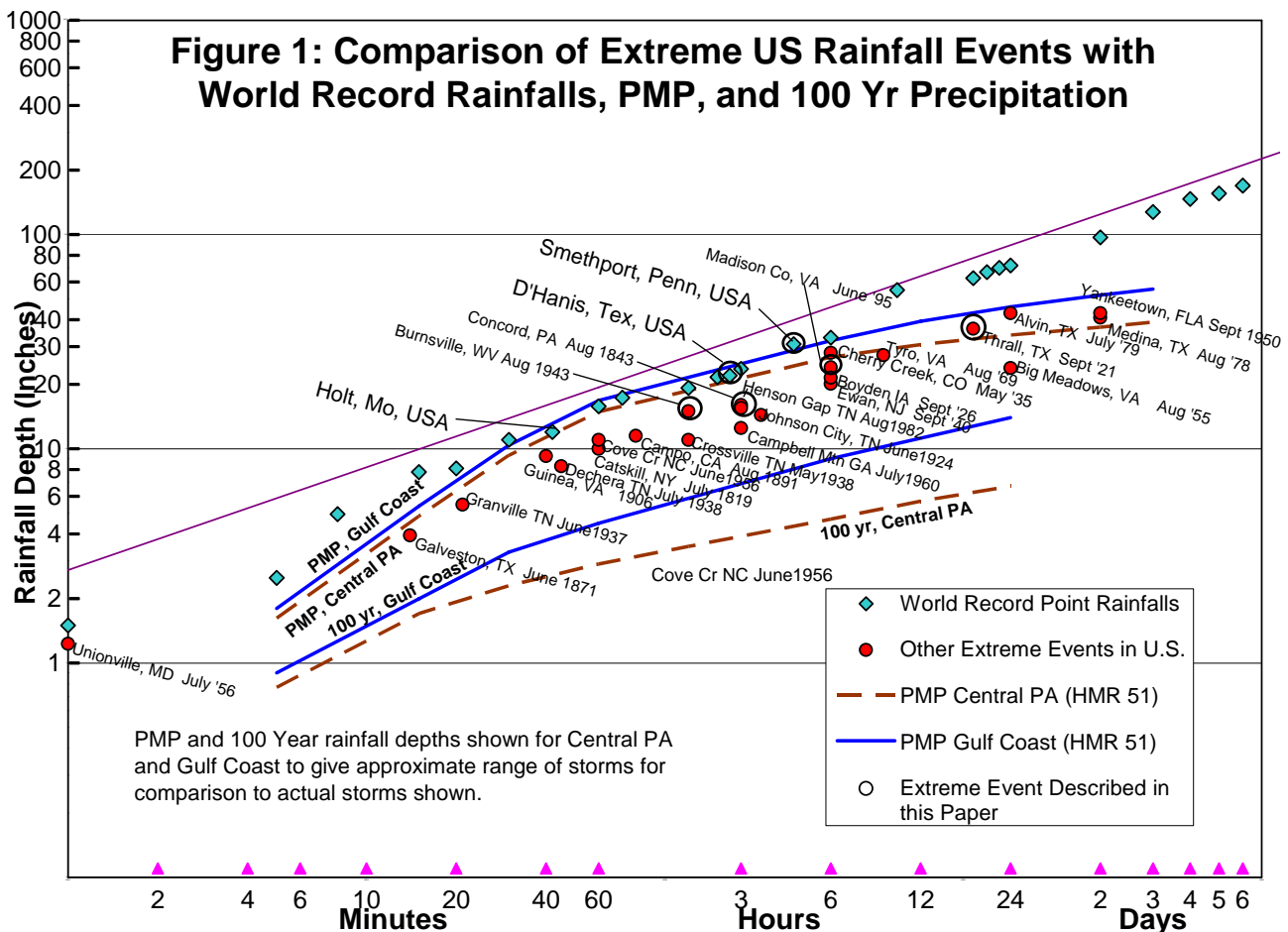
EXTREME EVENTS: GRAPHS, PHOTOS, VIDEOS

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Abstract: This paper presents a few extreme storm events that have served as the basis for the development of PMP estimates for the Eastern United States (HMR 51). Other extreme storm events that have approached PMP magnitudes will also be presented. These rainfall depths are graphed with world record rainfalls, PMP rainfall, and 100-year rainfall as a basis of comparison. Photos and testimonies of these extreme events have been presented to provide expanded discussion of limited experiences that in various ways affect all of us in the dam safety community. Videos of two floods are presented at the conference.

Introduction

It is difficult to imagine the extreme precipitation events that have led to the PMP estimates contained in NOAA's various HMR publications. In an effort to provide perspective on the magnitude and intensity of these storms, a sampling of extreme events are



presented here. Graphs showing precipitation and/or discharges for the various described events are presented along with photos and observations of witnesses and/or researchers. The conference presentation will focus more on visual depictions while verbal descriptions will be presented in this paper.

Figure 1 is a graph showing world record rainfalls, PMP estimates (10 sq.mi., per HMR 51), and miscellaneous extreme events in the United States (primarily eastern US). Several of the extreme rainfalls presented in this paper are highlighted in the figure.

Flood of May 31, 1935 near D'Hanis, TX

This storm was a world record event for its duration. Approximately 22 inches of rain fell in 2.75 hours (see Figure 1). The peak discharge of Seco Creek measured at the Rothe ranch (11 mi above D'Hanis) was 230,000 cfs for a drainage area of 142 square miles. This discharge is one of the highest ever measured for a basin of this size. Average rainfall over the basin was about 9 inches.¹ The entire town of D'Hanis was under water, 17 homes were washed away, and more than a mile of Southern Pacific railway was totally destroyed. Five people were killed, and the death toll would have been much higher had the storm occurred at night.

Flood of August 4-5, 1943 in Central West Virginia

A notable flood of short duration and high intensity occurred during the night of August 4-5, 1943 in Central West Virginia. The affected area was about 50 miles long and 10 miles wide in the diamond-shaped Kanawha River Basin, with elevations generally ranging from about EL 600 to EL 1500 (Figure 2). Point rainfall amounted to as much as 15 inches in 2 hours. According to the U.S. Weather Bureau (1943), the record-breaking rains were accompanied by "one of the worst, if not the worst, electrical storms of record". Twenty-three people perished in the flood, all of whom lived along relatively small tributaries.² Six precipitation gages

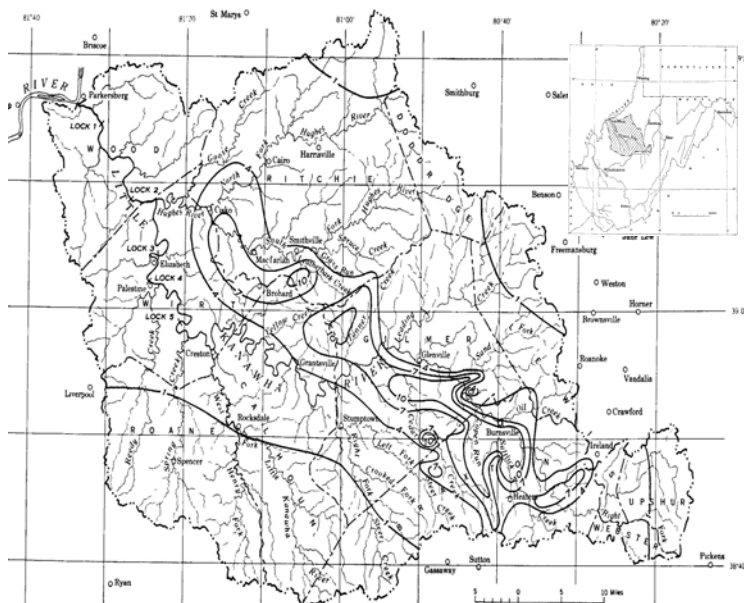


Figure 2: Isohyetal map of Little Kanawha River Basin (Source: USGS WSP 1134A)

in the area recorded rainfall depths of only 0.31 inches to 5.0 inches, therefore failing to provide a complete picture of the scattered intense rainfall pockets in the area. Representatives of the Corps of Engineers, the Weather Bureau, and the West Penn Power Company thoroughly investigated the storm, interviewing local residents and thus obtaining an

¹ USGS Water Supply Paper 796, Major Texas Floods of 1935, pp 232-235

² Erskine, H.M., Flood of August 4-5, 1943 in Central West Virginia, USGS Water Supply Paper 1134-A, 1952, p. 4.

additional 118 data points from the amount of water collected in pails, tubs, jars and other containers that were uncovered and open during the storm.³

The single largest property damaged from the flood was a 10-mile stretch of the B & O Railroad, where six railroad bridges and much track was destroyed. Heavy deposits of sand and gravel washed down many small runs. An example of the damage from the storm is shown in Figure 3. Some of the highest unit discharges were 4,700 cfs (3,100 cfs/mi²) for the North Fork Yellow Creek (1.51 mi²) and 7,400 cfs (3,060 cfs/mi²) for Laurel Fork above White Pine (2.42 mi²). Discharges were estimated by the slope-area method.⁴



Figure 3: This home was swept ½ mile downstream and came to rest in the creek bed. All six inhabitants perished. (Source: USGS WSP 1134A)

Floods of July 18, 1942 in North-Central Pennsylvania (Smethport)

The July 18, 1942 storm in Smethport, Pennsylvania was a world record storm. Precipitation was as high as 30.8 inches in 4.75 hours. The principal affected areas were in Elk, Cameron, McKean, and Potter Counties in Pennsylvania, and Cattaraugus, Allegany, and Stueben Counties in New York. Three separate drainage basins were involved: the Susquehanna, flowing into the Chesapeake Bay; the Allegheny, the headwaters of the Ohio River; and the



Figure 4: Residence near Heaters with its four occupants inside was washed one mile down O'Brien Fork of Saltlick Creek and lodged on a displaced section of railroad track (Source: USGS WSP 1134-B)



Figure 5: Rock and mud deposit from a hillside wash draining about 2 acres (Source: USGS Water Supply Paper 1134-B)

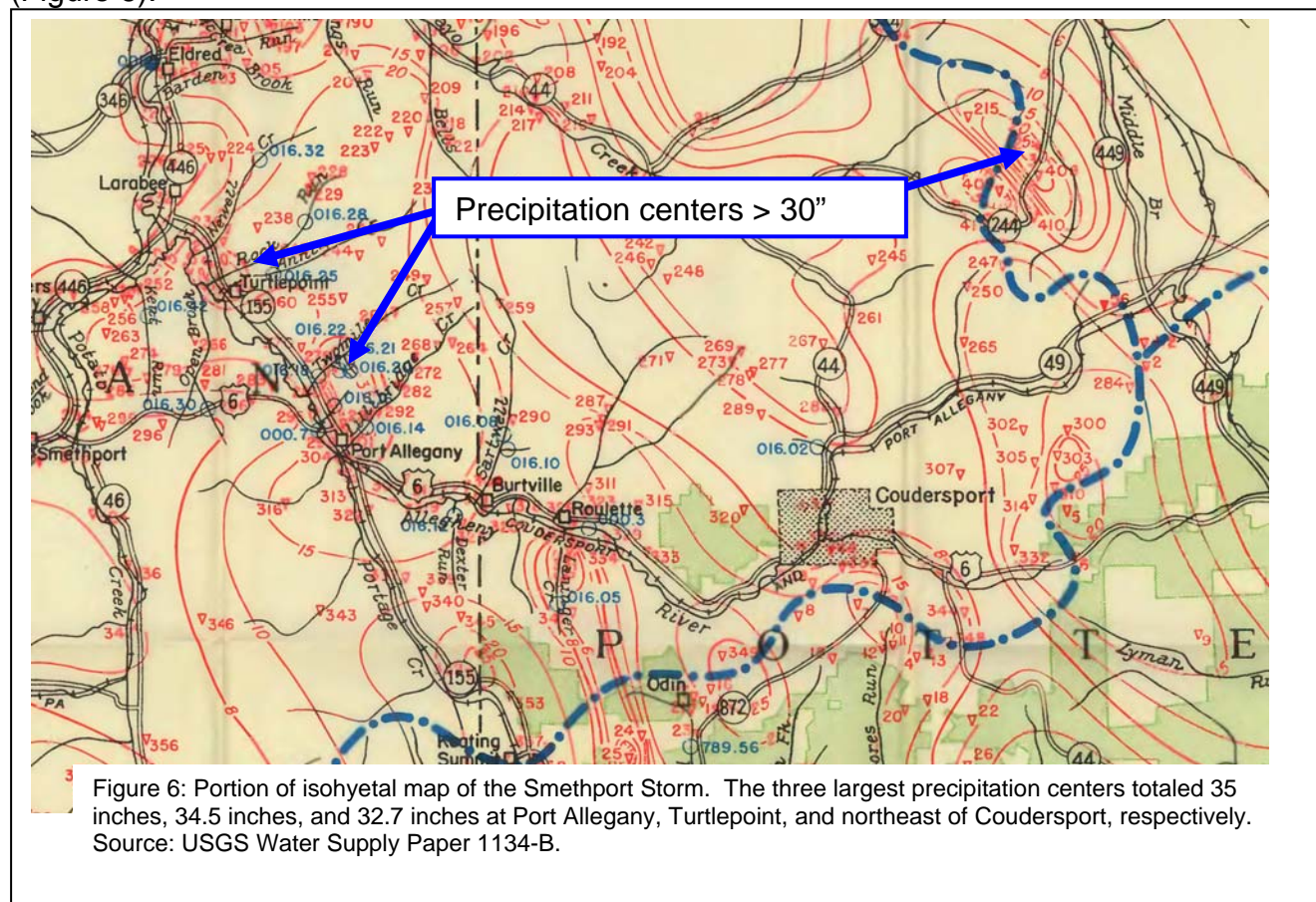
Genesee, tributary to the Saint Lawrence River. The distribution of rainfall over three basins explains the lesser severity of flooding on the main stems of these rivers, compared to the headwater streams and runs of each basin. Figures 4 and 5 show two examples of the flood damage.

³ Ibid., p. 12.

⁴ Ibid., p. 32.

Rainfall measured at official stations was 8.2 inches or less, with most stations recording substantially less. Based on the magnitude of flood damage, James Stewart, hydraulic engineer of the West Penn Power company, concluded that rainfall greatly exceeded these official records.⁵ Concerned with the spillway capacity of his company's dams, Stewart spearheaded an effort to collect rainfall data throughout the area. Stewart identified a local resident who recorded 30.8 inches of rain in a container and, together with abundant evidence of streams moving massive quantities of rock, he approached the Corps of Engineers, the Weather Bureau, and the Geological Survey.⁶ In a joint conference in Pittsburgh, it was decided that the Corps of Engineers and the West Penn Power Company would cooperate in the investigation of all available precipitation data on the storm. Nearly 500 records of precipitation were obtained from interviews and surveys of residents throughout the region. Interestingly, it was noted that "the country, rather than the city, is the place to obtain records...because the farmer often has empty containers set out in the open, whereas the city inhabitant rarely does."⁷ One in 12 to 15 contacts in the country resulted in a rainfall record, while only one in 200 to 300 contacts in towns and cities resulted in a record.

The maximum precipitation center received more than 35 inches at Port Allegany, with two additional centers of more than 30 inches at Turtle Point and northeast of Coudersport, PA (Figure 6).



⁵ Eisenlohr, William. Floods of July 18, 1942, in North-Central Pennsylvania, USGS Water Supply Paper 1134-B, 1952

⁶ Ibid.

⁷ Ibid, p. 72.

The damage from the storm was extensive. The dikes at Emporium, PA were overtopped, flooding most of the town. Dams above Austin and Johnsonburg, PA overtopped and breached. Buildings were knocked off of foundations, and 75 miles of Pennsylvania Railroad track was severely damaged (Figures 4 & 5). Sections of the Coudersport and Port Allegany Railroad and the Baltimore & Ohio Railroad were so badly damage that they were never rebuilt. Fifteen people perished in the flood, and many were left homeless. The following is a record of various observations of residents regarding the storm as recorded by Eisenlohr:

“Wind directions were erratic; for example, at two different locations they were in exactly opposite directions within a distance of one mile. Quite often the wind seemed to travel up or down a hollow, irrespective of the direction of cloud travel. There were many reports of thunderstorms coming first from one direction, then returning from another; of storms that traveled perpendicular to the path of previous storms; storms that seemed to mill or circle; and of storms that seemed to come together. As far as lightning is concerned, there was uniform testimony that a much higher percentage of lightning strokes occurred between clouds rather than between cloud and ground as compared with ordinary storms.”⁸

“In the Austin, PA region, many people said the rain did not come down in drops, and they had the visual impression, at least, that the rain came down in streams which they likened to strings and ropes... there were people who had not been able to reach shelter and were afraid they would drown during the downpour through lack of oxygen. One man expressed the effect by saying it was just like breaking water after a long dive, lungs bursting, with water pouring down over his head.”⁹

At the location where the observer recorded more than 30.8 inches in 4.75 hours, maximum rainfall intensity was estimated at about 10 inches per hour, and reportedly there was no “streaming” for that rate. However, at other locations such as around Austin, the rainfall rate for very short periods ranged from 15 to nearly 40 inches per hour. Eisenlohr hypothesized that for such high rates of rainfall the drops would be so close together as to coalesce into streams and sheets as a result of mutual mass attraction, possibly explaining the



Figure 7: Houses knocked off their foundations and pushed together in Johnsonburg, PA (Source: USGS Water Supply Paper 1134-B)

⁸ Ibid., p. 67.

⁹ Ibid.

phenomenon where very different catches were recorded in containers only a few feet apart.¹⁰

There were reports that flood waves from 1 to 3 ft in height formed on top of previous flood flows on many streams. On the East Branch of the Clarion River at Glenn Hazel, there were three rolling waves each about 1.5 ft high and about 100 yards apart.¹¹ There were reports of massive quantities of gravel and rock being washed down small gullies and deposited as alluvial fans at the mouths; and even reports of bedrock being ripped out and carried downstream. There were numerous reports of debris flows or “blowouts”, where all overburden above the rock became fluid and flowed down steep hillsides. One debris flow swept from the top of a hill to its bottom in Kettle Creek, a distance of more than a mile. The flow was narrow at the top and roughly a quarter mile wide at the bottom. Some slides moved for hundreds of feet with trees upright, and some of the trees were later found to continue growing in the new location “as though nothing had happened.”¹² Figure 9 shows a comparison of some of the estimated flood discharges during the 1942 storm, compared with other historical observed floods in the region and PMFs for Pennsylvania.



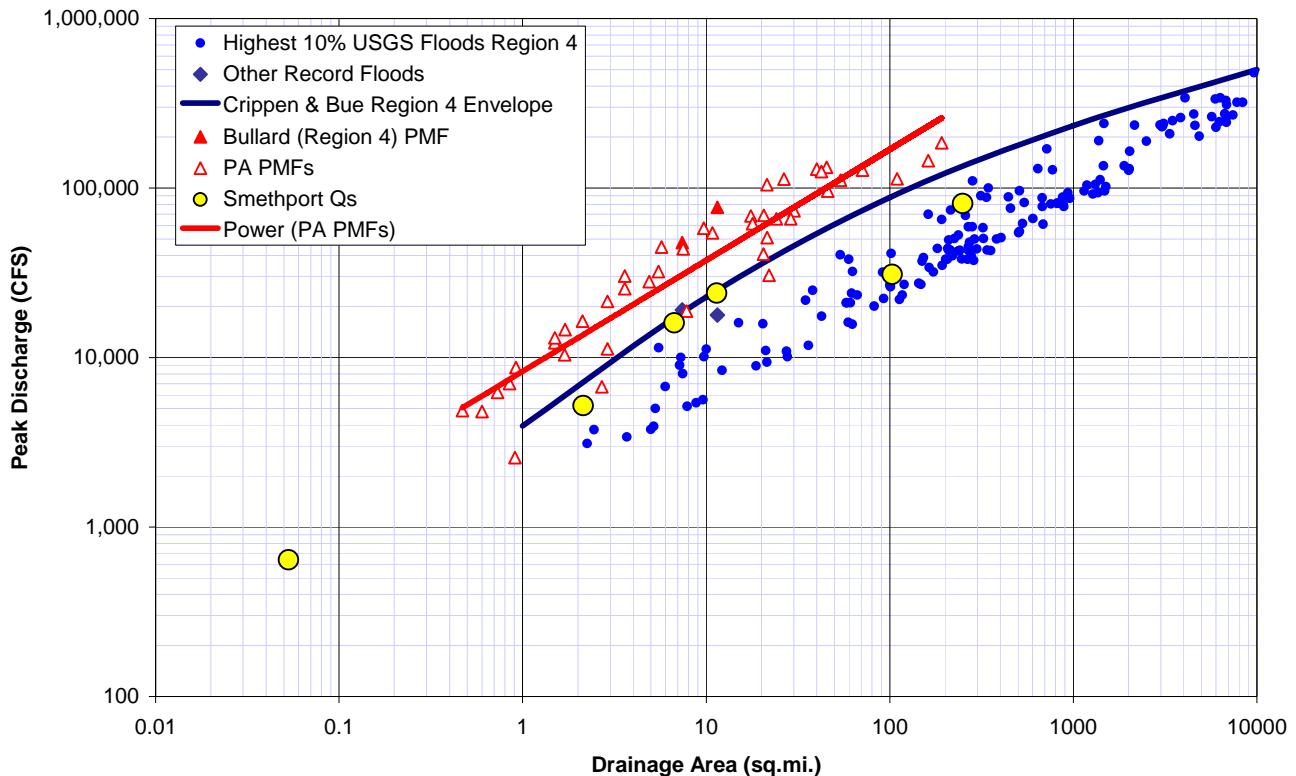
Figure 8: Flooding stages at half-hour increments in Emporium, PA July 1942 (Source: Ginny's Genealogy Page)

¹⁰ Ibid., pp 67-68.

¹¹ Ibid., p. 74.

¹² Ibid., p. 78.

Figure 9: Comparison of Peak Discharges Smethport, PA (July 1942) Storm with Other Observed Flows and Computed PMFs Northern Appalachian (Crippen & Bue Region 4)



Flood of August 5, 1843, Delaware County, PA

Ninety nine years earlier, another intense short duration rainfall occurred in southeastern Pennsylvania. Although the flood predates photography, several excerpts of the flood are provided to paint a picture of the extreme event.

“In those sections of the county where its greatest violence was expended, the character of the storm more nearly accorded with that of a tropical hurricane, than with anything which appertained to this region of country. The clouds wore an unusually dark and lowering appearance, of which the whole atmosphere appeared in some degree to partake, which circumstance, no doubt, gave that peculiarly vivid appearance to the incessant flashes of lightning which was observed by every one. The peals of thunder were loud and almost continuous. The clouds appeared to approach from different directions, and to concentrate at a point not very distant from the zenith of the beholder.

[The wind's] velocity was such that with the immense quantity of water falling (which it carried with it in one continuous sheet., as it were), rendered it impossible to see a distance of more than fifty yards.¹³

¹³ Delaware County Institute of Science, 1910, The flood of 1843 [report of a special committee, reprinted]: Delaware Co. Inst. Sci. Proc., vol. 6, no. 1, 1910, pp. 1-46; vol. 6, no. 2, 1911, pp. 54-86.

Other accounts of the event refer to the rain falling “more in streams than in drops”. The flood stages in the streams exceeded any recorded levels prior to this time. The heavy rain reportedly occurred near the headwaters of the streams, unknown to residents of the lower valleys. The rapid rise of the streams caused the loss of 12 lives. There were many accounts of an “almost instantaneous rise” in the water from 5 to 8 or 10 feet. At one point on Crum Creek the water reportedly rose 7 or 8 feet in 10 minutes. Farther downstream at Avondale the water level was reported to have risen 19 feet in a little over one-half hour.¹⁴

Hurricane Agnes – June 1972

Major flooding throughout much of the eastern United States was the result of Hurricane Agnes in June 1972. At the time of the flood, Agnes was the most destructive Hurricane in U.S. history, causing \$3.1 billion in damages in 12 states, and claiming 117 lives. Although Agnes was ranked as one of the weakest hurricanes in intensity, it was unusual in the vast area it covered with rainfall. During the waning stage of its life, Agnes merged with an extratropical cyclone centered over the northeastern U.S., causing a reinforced low to stagnate over western Pennsylvania for about 24 hours, adding to the already high rainfall accumulations.¹⁵ The



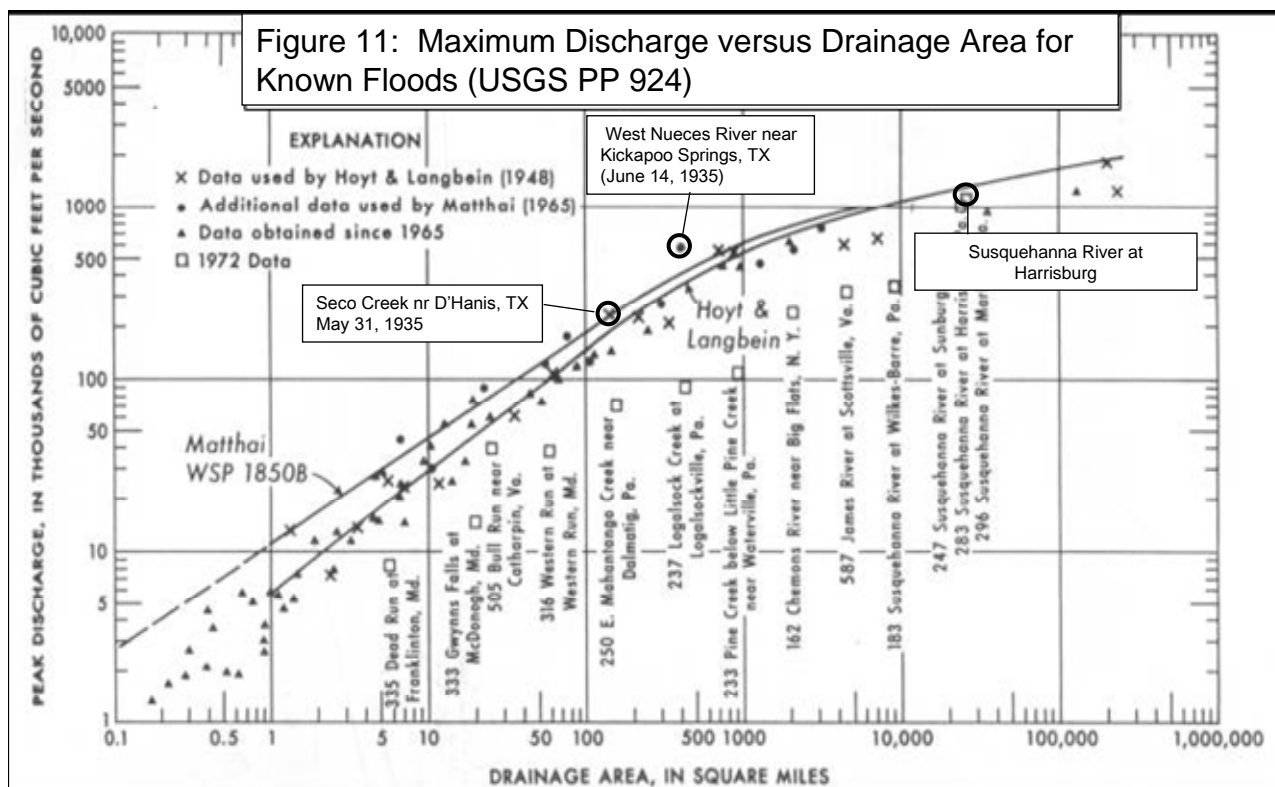
Figure 10: Susquehanna River at Harrisburg during Hurricane Agnes, June 1972 (Source USGS PP 924)

greatest 24-hr rainfall was 14.8 inches in the Mahantango Creek Basin, Pennsylvania. Total precipitation exceeded 15 inches at several locations from Virginia to New York. Agnes rainfall set the record for durations greater than 24 hours and areas greater than 10,000 square miles.

Rainfall was 84% of the PMP for a 50,000 square mile area centered near Zerbe, PA. Accordingly, the greatest flooding was on relatively large drainage basins. Figure 11 shows the peak flows at various locations throughout the Mid Atlantic region. Some of the damage at the largest drainage areas can be seen in Figure 10, Susquehanna River at Harrisburg, where the drainage area is approximately 24,000 square miles.

¹⁴ Ibid, p. 28

¹⁵ Hurricane Agnes Rainfall and Floods, June-July 1972, USGS Professional Paper 924, PP 1-2.



September 8-10, 1921, Thrall, Texas

This storm event, locally known as "The Great Thrall/Taylor Storm", is a world record storm for a duration of 18 hours. The storm entered Mexico as a hurricane from the Gulf and then drifted northward. Like several other storms in the region, this storm followed a pattern that ran along the Balcones Escarpment, then centered over Williamson and Travis Counties. At Thrall, approximately 36 inches of rain fell in 18 hours and 40 inches of rain in total. There were 224 fatalities across the seven counties that were affected.¹⁶

Austin received 18.23 inches of rain in 24 hours, and resulted in six fatalities in Travis County, all on Onion Creek. Less rain fell in Bexar County, but there was greater damage there. In a paragraph titled "Less Warning Than War", the Austin American described the flood thus:

"Only in San Antonio the flood victims had less warning than the booming of a distant cannon. The stories told by those who fled before the flood waters seem to make it clear that the Alazan Creek, usually a placid rivulet of water, became a rushing torrent in less than half an hour. The water, it is said, rose eight feet in approximately twenty minutes. So it was not long before the first of the houses near the creek bed floated from their foundations and it was a barrage of these that hurled themselves against the International & Great Northern trestle. By midnight between forty and fifty houses that a few minutes before vomited men, women and children in all stages of dress and undress, were being churned into a shapeless mass of debris where they lodged against the railroad bridge. Their tremendous weight and pressure against the trestle

¹⁶ Austin City Connection Website, Flood Control and Safety

soon cracked that structure in the middle, which pushed itself against a second trestle that broke shortly after under the strain."¹⁷



Figure 12: Damage in the San Antonio business district. Photo from Austin City Connection Website.

Flood of June 25-27 1995, Madison County, VA

In late June 1995, intense rainfall and flooding struck portions of western Virginia along the eastern slope of the Blue Ridge. The flooding resulted in three fatalities and millions of dollars in damage. Although many convective storms occurred over this region during this three day period, one particular convective system that occurred on 27 June developed over Madison County, Virginia (eastern slopes of the Blue Ridge Mountains), and remained relatively stationary, producing up to 24 inches of rain in only 6 hours (see Figure 1). The flooding caused numerous debris flows along the Blue Ridge, as shown in Figure 13. One debris flow

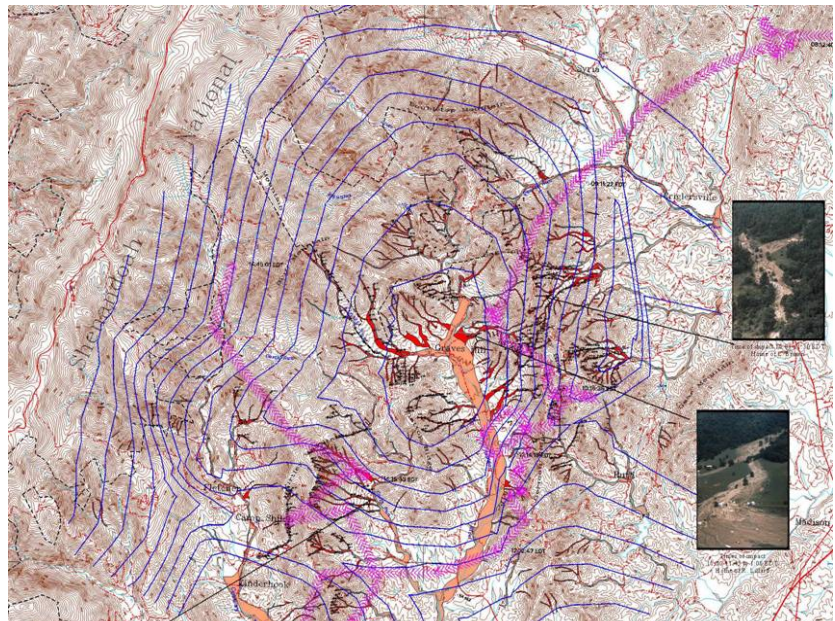


Figure 13: Map showing isohyets, storm track (purple), and debris flows (red) in Madison County, VA during June 1995 flooding. Source: USGS OFR 96-13

¹⁷ Ibid.

destroyed a house in its path and killed the resident. The stream gage at the Rapidan River at Ruckersville was destroyed, but not before recording a record stage of 31.3 feet, or approximately 106,000 cfs, which is about 350% of the next highest peak over a 64-year record period. Figure 14 shows White Oak Dam after the flood. Its earthen emergency spillway was severely eroded, but did not breach due to the control section which was excavated through a narrow rock ridge.



Figure 14: Damage to White Oak Dam emergency spillway, June 1995 (Photo courtesy of Rapidan Service Authority).

Summary

Although the extreme floods presented in this paper are rare, they remind us that historical precipitation has approached the magnitudes of the PMPs predicted by HMR 51. Historical accounts of witnesses and researchers provide anecdotal evidence and insight into these extreme events, and lay the foundation for the investigations following such events. They also provide a very real and pragmatic frame of reference for the importance of adequate spillway capacity for our high hazard dams.

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