The Floods of November, 1985: Then and Now

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Twenty-five years ago this week the floods of 1985 devastated large parts of Virginia in one of the worst natural disasters ever to affect this region. For southwest Virginia, the impacts were greatest across the Roanoke and James River valleys. The so-called Election Day Flood of November 4th, 1985 caused at least ten deaths in the Roanoke Valley along with numerous scenes of dramatic rescues, flooded roads, homes, and businesses. Total damages in the Roanoke Valley may have approached $225 million and statewide damages $800 million, numbers that would be far higher today. This short retrospective will attempt to discuss the meteorological and hydrological factors involved in causing the flood, how it compares historically with floods in this area and how a comparable flood might be handled by the National Weather Service today.

This catastrophic flood had its roots in the tropics as Hurricane Juan developed over the Gulf of Mexico on October 26th and made landfall along the Louisiana coast on the 28th. The storm went through several loops and actually reentered the Gulf before making a second landfall on the 31st (see Figure 1) The only readily available maps to look back at this event are from the Daily Weather Map series, which provide a once per day snapshot of the surface and 500-millibar (approximately 18,000 feet) charts at 12Z or 0700 AM. After making its second landfall, the remains of Juan drifted slowly northward into the Tennessee Valley over the next several days, bringing moderate to heavy rainfall across parts of our area. As Table 1 shows, there was substantial rainfall across the region each day from November 1st through the 3rd with 3-day totals ranging from 1 to 4 inches. This rainfall was directly associated with the remains of Juan and contributed greatly to the event by saturating the soils across the region. By early November, with essentially dormant vegetation, the effects of vegetation on interception and especially evapotranspiration (water lost back to the atmosphere) was greatly reduced from the growing season. Overcast skies and feeble November sunlight probably reduced evaporation to the point that nearly all the rain that fell in these days preceding the flood went into increasing soil moisture and raising stream and river levels.

By the morning of the 3rd (Figure 2), a weak low pressure area can be seen over western North Carolina with a diffuse frontal boundary just to the west of the region, stretching from the Great Lakes all the way to the Gulf of Mexico. This low may represent the center of Juan's remains as it was absorbed into the frontal boundary and dissipated. Of greater significance for future developments however, is the developing upper-level trough shown at 500-mb over the central U.S. This new trough held the frontal boundary in a near-stationary position. This also maintained a tropical connection of very moist south to southeasterly flow from the Gulf into the southern Appalachians through the 3rd with still widespread rainfall coverage across the area. A significant orographic (mountain) component of rainfall can be inferred by the high rain amounts (4.26 inches ending 12Z on the 4th) recorded at Montebello (see Table 1) located in the Blue Ridge Mountains of southwest Nelson County at about 2700 feet in elevation. The 12Z/3rd surface map also shows a low pressure center beginning to develop over the Gulf of Mexico and it is likely this low that tracks north over the next 24 hours and reaches the position shown in Figure 4.

The U.S. Daily Weather map from 12Z (0700 EST) on the 4th shows the weak (~1002 mb) area of surface low pressure over western North Carolina with a frontal boundary approaching the New River Valley acting possibly as a focus for convection. A southeast surface flow ahead of the boundary is bringing very moist air into southwest Virginia with dewpoints in the low 60s over North Carolina and upper 50s over the Roanoke Valley. These are climatologically very high moisture values for early November. Figure 4 also shows that the 500 mb trough developing over the Midwest 24 hours earlier had deepened well south into the Tennessee Valley with a powerful southerly flow on the east side of the trough, tapping deep moisture over the Gulf of Mexico and pulling it well north.

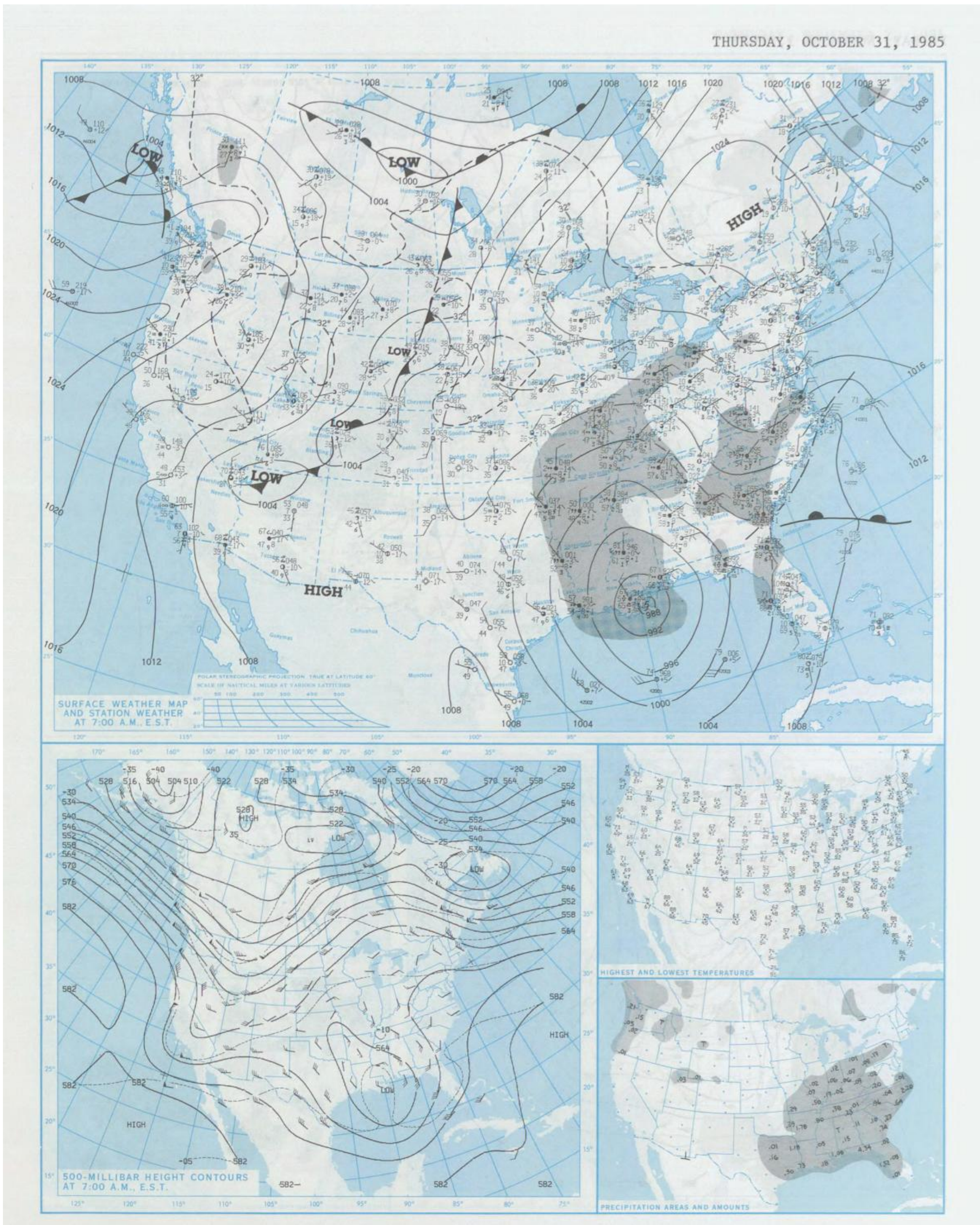

Figure 1. Surface and 500-millibar charts, 1200Z (7AM), 10/31/85

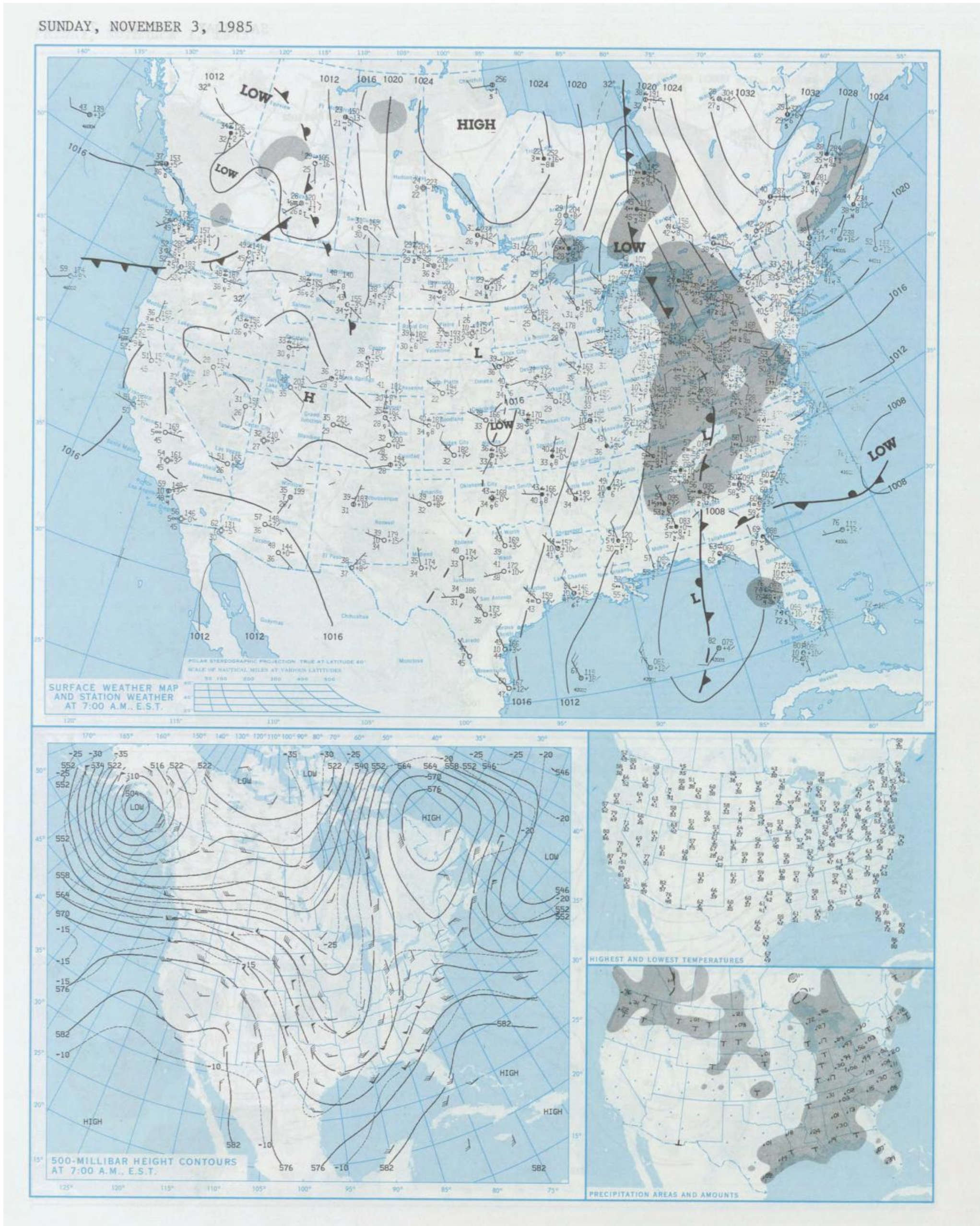

Figure 2. Surface and 500-millibar charts, 1200Z (7AM), 11/3/85

Rainfall became very intense during the morning hours of the 4th as the surface low tracked northward toward the Roanoke Valley. Appendix A, which is a written summary of the event produced just after it, describes convection (thunderstorms) lifting north from Grayson and Carroll counties during the morning hours of the 4th. Ironically, a Flood Watch for much of the area in effect up until 6 AM was cancelled around the time this area of convection began pushing north into the Roanoke and James River basins. The reasons for the cancellation of the Watch are unclear, but network radar coverage in 1985 was not nearly as complete as we see today. The coverage and intensity of the rainfall was most

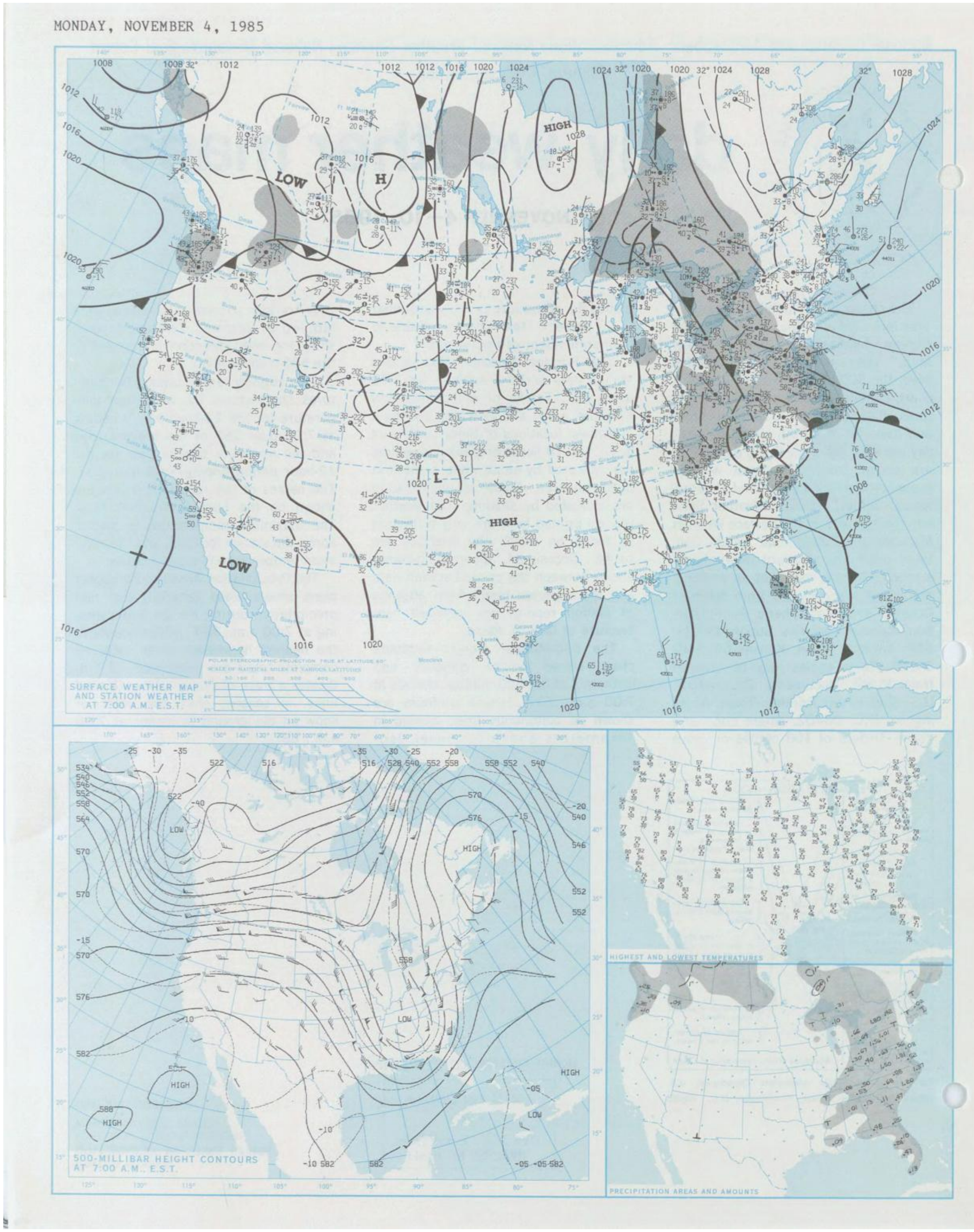

Figure 3. Surface and 500-millibar charts, 1200Z (7AM), 11/4/85

intense between 11 AM and 100 PM when Roanoke Airport picked up 1.34”, 2.02” and 0.89” each hour during that period for a total of 4.25 inches in that critical 3-hour period. The response on smaller rivers including the Roanoke was almost instantaneous as the saturated ground simply could not absorb such a deluge. Figure 4 below shows a stage hydrograph of the Roanoke River at Roanoke gage beginning around 7 AM on the 4th and continuing through until its record crest of 23.35 feet (Flood Stage is 10 feet) around 12 hours later. Rainfall continued through much of the day across the Roanoke and James

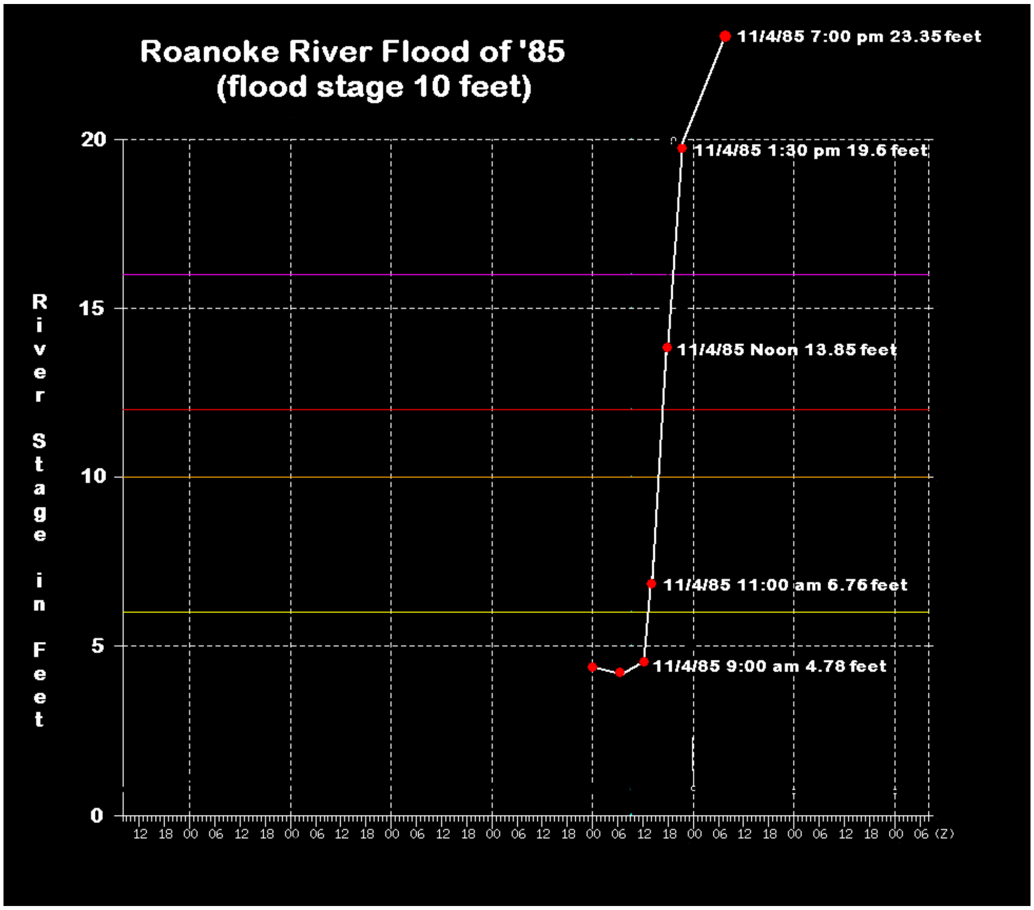

Figure 4. Hydrograph of the Roanoke River at Roanoke (RONV2) gage starting mid-morning, November 4, 1985.

river valleys with widespread flash flooding and river flooding. Downtown Roanoke was completely inundated by the Roanoke River and many other area streams such as Tinker Creek, Mason Creek and Peters Creek poured out across roadways, rail lines, bridges and into homes and businesses. Numerous rescues were performed that day and the loss of life might certainly have been higher were it not for the heroic efforts of rescue workers. Newspaper accounts written after the event and photographs depict near utter mayhem across much of the region with photos of people clinging to trees and trapped in vehicles. One helicopter crew alone rescued about 125 people during the day. A report written just after the event (see Appendix A), discusses the activities of the Weather Service Office (WSO) Roanoke on day of the flood and provides some details on fatalities that occurred. A WSO at that time was a smaller National Weather Service Office with only a handful of staff and one meteorologist. Figure 5 shows the slow progress of the surface low through the day on the 4th, as it had reached a position just west of Washington, DC by 12Z on the 5th. The 500-mb low has completely closed off over the state of Virginia contributing to the slow movement of the entire rain system.

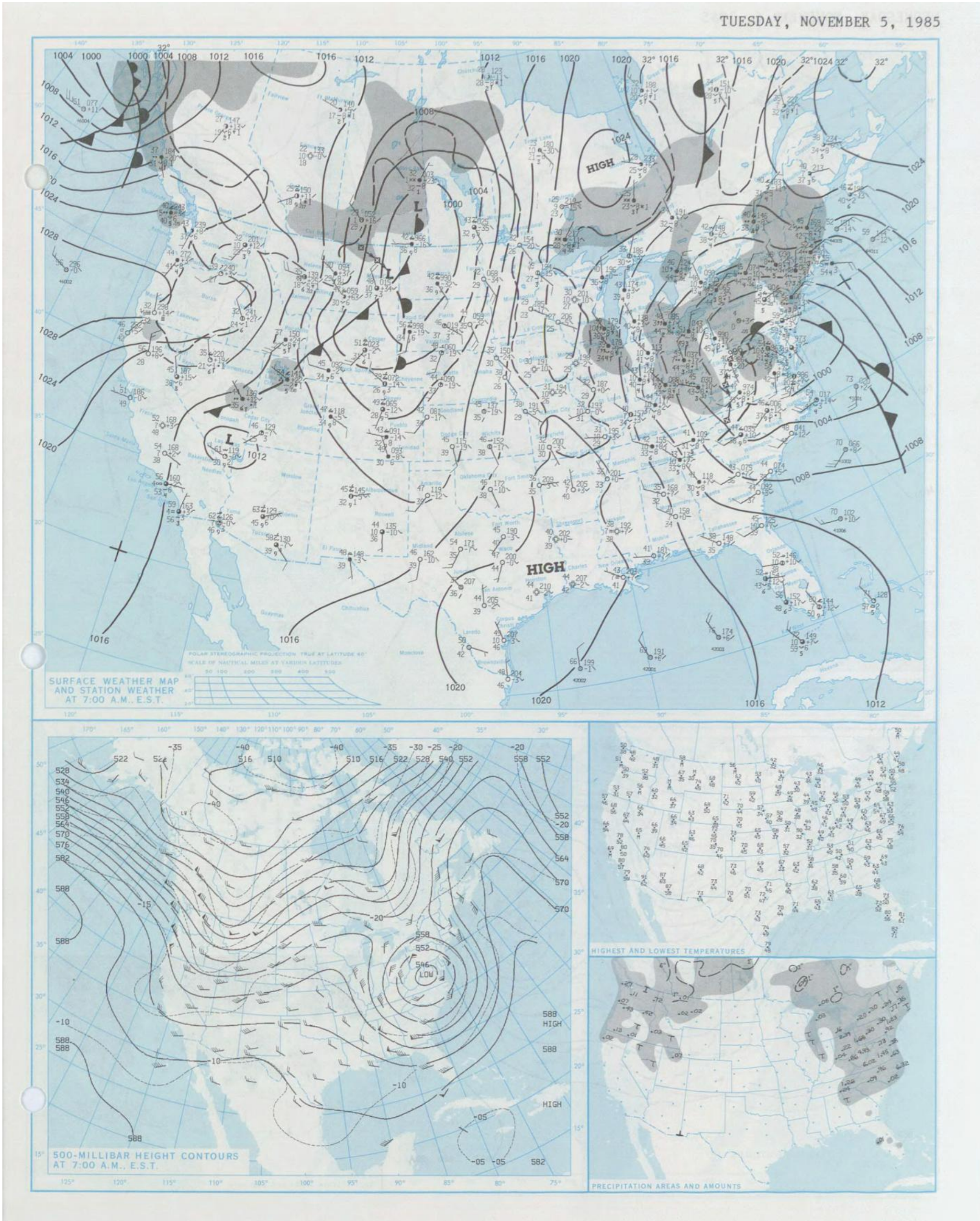

Figure 5. Surface and 500-millibar charts, 1200Z (7AM), 11/5/85

Table 1 shows 24-hour rainfall and storm totals at selected stations for the 6 days preceding and including the 4th of November when the severe flooding occurred. At Roanoke Airport the 6.61 inches in 24-hours on the 4th is still a 24-hour rainfall record for Roanoke, with records dating back to 1912. The fact that this record amount fell after more than 4 inches of rain over the preceding 4 days goes a long way to explaining the Flood of 1985. Note that most stations report 24-hour amounts at 0700 AM so that the amounts in Table 1 on the 5th fell mostly on November 4th. Figure 6 shows a rainfall map for the mid-Atlantic region for the entire period preceding and including the event.

Table 1. 24-hour daily rainfall amounts from rain gages in the James and Roanoke river basins and nearby adjacent locations, October 31-November 5, 1985

Date	10/31	11/1	11/2	11/3	11/4	11/5	**Total**
Montebello 2 NE	-	1.89	3.23	2.38	4.26	7.94	**19.70**
Glasgow 1 SE	0.02	0.70	1.96	2.50	2.92	5.55	**13.65**
Copper Hill 1 NNE	0.80	1.65	2.59	0.70	0.96	5.83	**12.53**
Covington Filt Plant	-	0.32	0.74	0.58	8.00	2.60	**12.24**
Hot Springs	0.04	0.30	0.97	0.48	1.37	8.25	**11.41**
Roanoke WSO (m)	0.98	1.39	0.93	1.06	6.61*	0.01	**10.98**
Kerrs Creek 6 WNW	-	0.60	1.51	1.39	1.70	5.62	**10.82**
New Castle	0.08	1.02	0.90	2.00	0.85	5.60	**10.45**
Mountain Grove	-	-	-	1.07	-	8.30	**9.37**
Covington	T	0.20	0.20	0.70	0.70	7.50	**9.30**
Pedlar Dam	T	0.26	0.93	1.98	2.33	3.77	**9.27**
Goshen	0.05	0.06	0.85	1.25	1.70	5.15	**9.06**
Lafayette 1 NE	.03	1.51	1.70	0.48	0.37	4.93	**9.02**
Gathright Dam	-	0.04	0.44	0.36	1.22	6.63	**8.68**
Alta Vista	T	0.21	2.87	1.16	1.87	1.63	**7.74**
Craigsville 2 S	0.04	0.10	0.25	0.97	1.30	4.81	**7.47**
Lexington	0.03	0.71	1.35	1.10	3.49	0.67	**7.35**
Bedford	T	0.15	1.41	0.55	1.33	3.90	**7.34**
Earlehurst	T	0.45	0.82	0.26	0.80	4.26	**6.59**
Lynchburg WSO (m)	0.06	1.69	1.57	1.51	1.50	0.04	**6.37**
Blacksburg 3 SE	0.03	0.08	0.10	0.85	0.20	2.55	**3.81**

m = midnight to midnight observation; * 24-hour rainfall record

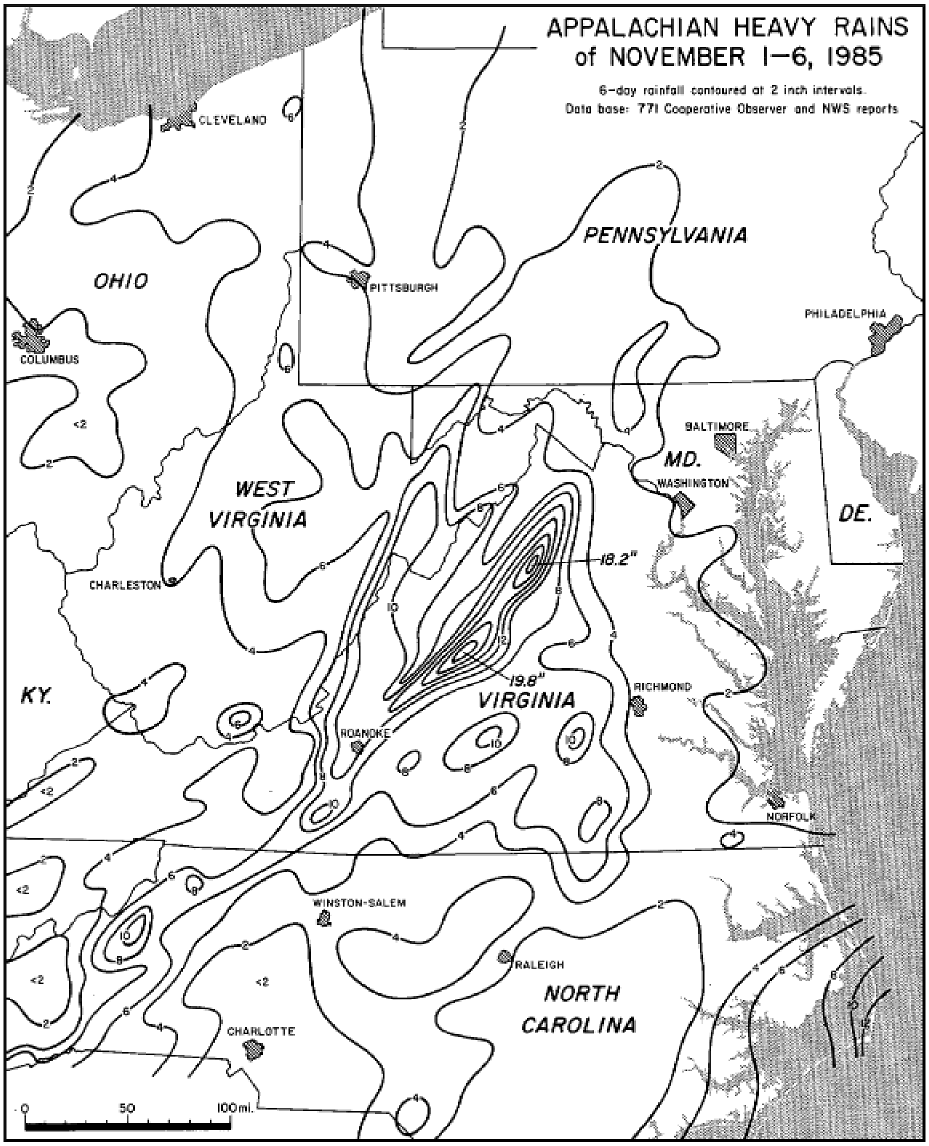

Figure 6. Mid-Atlantic Rainfall: November 1-6, 1985

As Table 2 shows, the resulting floods from the 6 days of rainfall were nearly unprecedented and have not been approached during the intervening quarter-century. At over a dozen river gaging sites the flood of 1985 stands in the top 3 of all-time flood crests and is easily the highest on record at several sites including Roanoke and Holcomb Rock (just upstream from Lynchburg). The floods of August, 1969 (remains of Hurricane Camille) and June, 1972 (remains of Hurricane Agnes) are a notable comparison. What is the statistical probability of such an event occurring? Hydrologists use a measure known as the annual probability of occurrence which many people are familiar with as the recurrence interval (e.g. '100-year flood). A 1% chance of occurrence is simply a 1 in 100 probability for the event to occur in any given year. The longer the period of record the more reliable such estimates tend to be. The Roanoke River at Roanoke gage (RONV2) had a peak discharge of 32,300 cubic feet per second (cfs) on the 4th, which is the highest on record (with data available back to 1899). This discharge equates to approximately the .005 chance of occurrence (roughly a 200-year recurrence interval; USGS, 1995). It should be stressed that the recurrence interval does not imply that such an event will occur only every 200 years! It could occur in consecutive years or much more than 200 years apart. On the James River at Holcomb Rock (HRKV2), located just upstream from Lynchburg, the discharge on November 5th was an incredible 207,000 cfs which is well beyond any other event on record (data for this gage exists back to 1900). The annual probability of occurrence for this discharge is less than .002 (or more than a 500-year recurrence interval).

Table 2. Top five 5 historic river flood crests at selected USGS gages in the Roanoke and James River basins

Roanoke River Basin:

Roanoke River at Lafayette (LAFV2)
Flood Stage: 5 feet
(1) 15.60 ft on 06/21/1972
(2) 13.34 ft on 11/04/1985
(3) 13.09 ft on 04/21/1992
(4) 12.69 ft on 02/22/2003
(5) 12.45 ft on 09/28/2004

Roanoke River at Roanoke (RONV2)
Flood Stage: 10 feet
(1) 23.35 ft on 11/04/1985
(2) 19.61 ft on 06/21/1972
(3) 18.95 ft on 04/27/1978
(4) 18.25 ft on 08/14/1940
(5) 18.10 ft on 04/22/1992

Tinker Creek near Daleville (DAEV2)
Flood Stage: 11 feet
(1) 13.36 ft on 11/04/1985
(2) 9.82 ft on 06/21/1972
(3) 9.55 ft on 07/26/1974
(4) 9.25 ft on 05/28/1973
(5) 9.17 ft on 09/21/1979

James River Basin:

Jackson River near Covington (CVGV2)
Flood Stage: 17 feet
(1) 25.47 ft on 03/18/1913
(2) 24.36 ft on 06/21/1972
(3) 23.31 ft on 11/04/1985
(4) 22.09 ft on 12/27/1973
(5) 20.97 ft on 03/18/1936

James River at Lick Run (LIRV2)
Flood Stage: 16 feet
(1) 30.40 ft on 03/12/1913
(2) 30.22 ft on 11/05/1985
(3) 27.01 ft on 06/21/1972
(4) 25.65 ft on 03/18/1939
(5) 25.53 ft on 08/20/1969

James River at Buchanan (BNNV2)
Flood Stage: 17 feet
(1) 38.84 ft on 11/05/1985
(2) 31.00 ft on 03/27/1913
(3) 30.49 ft on 06/22/1972
(4) 29.26 ft on 01/20/1996
(5) 26.80 ft on 03/18/1936

James River at Holcomb Rock (HRKV2)
Flood Stage: 22 feet
(1) 42.15 ft on 11/05/1985
(2) 35.50 ft on 08/20/1969
(3) 32.38 ft on 06/22/1972
(4) 30.99 ft on 01/20/1996
(5) 30.78 ft on 03/18/1936

James River at Bent Creek (BECV2)
Flood Stage: 16 feet
(1) 30.76 ft on 11/05/1985
(2) 27.13 ft on 06/21/1972
(3) 24.77 ft on 08/20/1969
(4) 23.02 ft on 03/18/1936
(5) 22.10 ft on 01/20/1996

James River at Scottsville (SVEV2)
Flood Stage: 20 feet
(1) 34.02 ft on 06/22/1972
(2) 31.77 ft on 11/06/1985
(3) 30.00 ft on 08/20/1969
(4) 28.24 ft on 09/07/1996
(5) 26.17 ft on 04/17/1987

James River at Bremo Bluff (BREV2)
Flood Stage - 19 feet
(1) 44.80 ft on 06/22/1972
(2) 40.70 ft on 11/06/1985
(3) 39.10 ft on 08/20/1969
(4) 36.60 ft on 09/07/1996
(5) 34.50 ft on 09/19/1944

Maury River at Buena Vista (BVSV2)
Flood Stage - 17 feet
(1) 31.23 ft on 08/20/1969
(2) 26.30 ft on 11/05/1985
(3) 19.48 ft on 06/28/1995
(4) 18.99 ft on 04/22/1992
(5) 18.90 ft on 09/07/1996

Calfpasture River at Goshen (GOHV2)
Flood Stage - 12 feet
(1) 20.23 ft on 11/04/1985
(2) 16.38 ft on 09/06/1996
(3) 13.90 ft on 04/22/1992
(4) 13.73 ft on 01/25/2010
(5) 12.87 ft on 09/09/2004

Craig Creek at Parr (CRGV2)
Flood Stage – 9 feet
(1) 24.76 ft on 11/04/1985
(2) 19.87 ft on 09/29/2004
(3) 19.29 ft on 06/21/1972
(4) 17.29 ft on 04/22/1992
(5) 17.00 ft on 01/23/1935

Could the Flood Happen Today?

Of course many of the ingredients that go into creating such an epic flood are always possible. The terrain is essentially unchanged and urban development is substantially greater than 25 years ago. Development is a major factor simply by fact that runoff is faster and more complete than in undeveloped 'natural' terrain. The region is perennially under the threat of decayed tropical systems during the tropical season from June through November. As recently as September 2004, significant flooding occurred across the region due to the remains of Hurricanes Ivan and Jeanne tracking through the mid-Atlantic area. However a hurricane or tropical storm is not necessary for severe and even record floods to occur. Extremely anomalous moisture combined with stalled frontal boundaries, training of thunderstorms over the same locations and even rain on top of snowmelt can produce dangerous flooding across our area.

In terms of the ability to forecast such a storm, the NWS has made substantial improvements. There are new or greatly improved meteorological models available to forecasters with better model physics, improved spatial and temporal resolution and can be run in ensemble mode to provide a range of probable outcomes. Satellite and radar observation platforms have also been significantly enhanced. Geostationary satellites provide frequent high resolution imagery in a variety of modes (visible, infrared, water vapor) and can be animated and overlaid with other observational data sets giving a far superior look at approaching weather systems. The WSR-88D radar implemented in the mid-1990s provides far better coverage, resolution and precipitation estimates then the WSR-57 and 74C radars in use in 1985.

These radar precipitation estimates are supported and improved by the IFLOWS rain gage network that had its inception in the early 1980s and has been expanded in many areas (partially in response to the 1985 floods). Computer software at the NWS Weather Forecast Offices (WFOs) is able to ingest radar-rainfall data much faster and assess which stream basins are being affected by heavy rain over various durations, giving forecasters a much better idea on where the worst flooding is likely to occur. This technology called Flash Flood Monitoring and Prediction (FFMP) has led to substantially increased lead-time and accuracy in the issuance of Flash Flood Warnings. The Flood of 1985 was certainly a flash flood event, but it was also a River Flood Event.

Improvements in hydrologic modeling of river basins allows for much faster and more accurate river forecasts. Assessing the degree of soil moisture saturation with Flash Flood Guidance has also seen big changes, with small-scale gridded fields available and updated frequently. Another area where significant advances have been made in river forecasting is in the science of Quantitative Precipitation Forecasting (QPF). The NWS now has the capability to generate basin-specific forecasts of rainfall for 24 to 72 hours in advance and apply that forecast precipitation to river forecasts. Hydrologists can then assess both what has fallen and what is *expected* to fall to make their river forecasts.

Of course the speed and variety of communications since 1985 have expanded beyond what might have been imagined back then. The Internet and the proliferation of social of media emerging from it (YouTube, Twitter, etc.) is one of the most obvious and revolutionary change in terms of dissemination and receipt of all types of information. Mobile phones with full internet access and texting are another revolutionary change in communications over the past 25 years.

Organizational changes within the NWS itself may help too. Reading Appendix A below, one is struck by the organizational challenges in terms of providing weather warnings to the Roanoke area. The WSFO in Washington, D.C. was responsible for issuing weather forecasts whereas the local WSO in Roanoke could not issue warnings without coordination with that office. Meanwhile, another NWS office in Raleigh, NC was responsible for issuing river flood forecasts on the Roanoke River. Today the Blacksburg NWS office has full capability and responsibility for forecasts, watches and warnings for its entire area of responsibility.

References:

1. Biese, J.A. (1985): Methods for Estimating the Magnitude and Frequency of Peak Discharges of Rural, Unregulated Streams in Virginia. United States Geological Survey, Water Resources Investigations Report 94-4148, 75 p.

Appendix: Original Storm Report from 1985

On November 4, 1985 a low pressure system moved northeastward out of the western Gulf of Mexico across Georgia and Virginia. This system brought record setting rainfall to an area already soaked by the remains of Hurricane Juan on November 2. The result was a record flood for Roanoke and vicinity.

A Flood Watch had been issued by WSFO Washington DC for southwest Virginia on Sunday November 3 and into Monday, November 4. Movement of the rainfall pattern of this low was steadily to the northeast early on the 4th. After discussion between the WSFO Washington forecaster and the WSO Roanoke Weather Specialist, the Flood Watch for southwest Virginia was cancelled on at 6AM Monday, the 4th. Radar echoes continued to move across Carroll and Grayson counties and IFLOWS data indicated some of the rain was heavy. So at 0730 AM WSO Roanoke issued Special Weather Statement (SPS) describing possible heavy rain and flooding moving out of Carroll into Floyd County.

About 0900 AM the radar pattern had evolved into a line of heavy rain and possible thunderstorms oriented NNW-SSE form western Craig County southward to central Patrick County. This caused concern, but since movement was steady the heavier rain was expected to pass soon, so another SPS was issued to describe the situation.

This MIC at WSO Roanoke had come to work at 0800 AM that morning expecting to depart shortly with his counterpart at Lynchburg. They were discussing their trip and an IFLOWS printer which he had brought with him from repair at Lynchburg. They were waiting for the rain to pass or slacken before departing to Beckley, WV, but after studying the radar picture the MIC's first delayed and then cancelled their trip.

The line of radar echoes seemed to slow markedly from 0900-1100 AM. The weather staff began trying to assimilate information from spotters, river gages and AFOS. Fortunately, there was a supernumerary on duty that morning. At approximately 0930 AM the MIC began phone discussion with the Patrick County Emergency Services Coordinator and Director. Between 0900 and 0930 the WSO also began experiencing telephone problems—intermittent at first, then almost continuously by 1000 AM which seriously hampered the WSO efforts the rest of the day.

Between 0930 and 1000 AM office efforts shifted rather quickly to Roanoke and its environs as heavy rains began to dump at the airport. At 1030 AM the MIC issued a Flash Flood Warning (FFW) for several counties including Roanoke and vicinity. It was then apparent that significant flooding was likely in several counties. Since 7 AM the staff had been plotting the Roanoke River on an hourly basis. At 10 AM the river had risen only a foot – to 5.09 feet. Rains which had been light to moderate until 0945 AM at WSO Roanoke became heavy in thunderstorms. Records show that 3.36 inches fell between 10 AM and 12 PM. The Roanoke River rose steadily to 6.76 feet at 11 AM and then shot up a whopping 7 feet in one hour by noon. Some flooding on the Roanoke River tributaries and others in adjacent counties evidently had begun by 1030 AM in some locations.

As the situation rapidly worsened the MIC began coordinating about 10 AM with the Raleigh Hydrologist, Al Gustafson, as the phone situation permitted. He issued a River Warning at 1110 AM calling for a crest of 11 feet or higher. Based on the rapid rise of the river, WSO followed that warning quickly at 1125 AM with a Flood Statement indicating “serious” flooding and at 1155 AM with its own Flood Warning for Roanoke County and the seven surrounding counties.

By noon, following the breathtaking river rise of 7 feet between 11 Am and noon, it was evident that a near record event was at hand. The Roanoke office issued a River Flood Statement to that effect at 1230 PM. Another follow-up Flood Statement was issued at 240 PM. At 315 PM Raleigh, NC WSFO issued a prediction of 23 feet to arrive shortly after dark. This prediction was correct. Follow-up issuances by WSO Roanoke, WSFO Washington and WSFO Raleigh continued through the evening and next day. A county breakdown of the 10 deaths in the general area of Roanoke:

<u>Roanoke County</u>—(3)

Two, grandmother and grandson, drove a pickup truck onto a creek bridge and stalled during early afternoon.

One, a woman drove a pickup truck into Tinker Creek about 530 PM

<u>Roanoke City</u>—(3)

One, a woman shortly after 1200 PM near a shopping plaza on Salem Turnpike. This person had earlier refused help of rescue workers.

Two women on Shadeland Avene in the Mud Lick Creek area shortly after noontime due to rapidly rising water. They had ignored warnings of people knocking on doors to get out.

<u>Franklin County</u>—(2)

Traffic accident on Route 220 due to a falling tree killed driver and passenger.

<u>Botetourt County</u>—(2)

One, 83-year old woman the following day (11/5) due to the rising James River. This woman had earlier refused to evacuate.

One, a young man trying to help other to save a car during the early afternoon Monday.

<u>Damage Estimates</u>—in the extraordinary range, probably $225 million in Roanoke alone, with reports of $600 million in SW Virginia.