

GB
1399.2
.G65
1995

FLOODING OF LATE JUNE 1995

OVER THE

**SHENANDOAH VALLEY, POTOMAC HIGHLANDS, AND
VIRGINIA PIEDMONT**

An Assessment of Operations at WSFO Sterling



The U.S. 29 bridge linking Greene and Madison counties disappears under the surging Rapidan River. The rain that fueled Tuesday's flooding was predicted to continue today.

Written by

**Barry Goldsmith,
Barbara McNaught Watson,
and Melody Hall**

DOC/NOAA/National Weather Service
Sterling Forecast Office
44087 Weather Service Road
Sterling, VA 20166

FLOODING OF LATE JUNE 1995
OVER THE
SHENANDOAH VALLEY, POTOMAC HIGHLANDS, AND
VIRGINIA PIEDMONT

An Assessment of Operations at WSFO Sterling

Table of Contents:

I. Event Overview

- A. Impact of Floods**
- B. Synoptic Analysis**

II. Forecast and Warning Operations at WSFO Sterling

- A. Forecast of Heavy Rains and Flooding**
- B. Flash Flood Watches Issued**
- C. Warnings Issued, Radar Operations, and Verification**
- D. River Flooding and Hydrologic Services**

III. Flash Flood Operations in Sterling's Forecast Area, but outside the CWA

IV. Conclusions

Appendices:

- A. Details of Flash Flood Watch Issuances by Sterling**
- B. Log of Flash Flood Warnings and Statements**
- C. Log of Official Rainfall Reports and Rainfall Observation Map**
- D. WSR-88D Storm Total Precipitation Maps**
- E. Pictures of flood aftermath and river gages**
- F. Example Flash Flood Warning and Flash Flood Statement during the height of the flooding event**

GB
1399.2
.G65
1995

LIBRARY

N.O.A.A.
U S Dept. of Commerce

FLOODING OF LATE JUNE 1995 OVER THE SHENANDOAH VALLEY, POTOMAC HIGHLANDS, AND VIRGINIA PIEDMONT

An Assessment of Operations at WSFO Sterling

By Barry Goldsmith, Barbara Watson, and Melody Hall

I. Event Overview

A. Impact of Floods

Severe flash flooding, and in some cases record river flooding, occurred across portions of west-central Virginia during the week of June 25, 1995. Lesser, but still substantial, flooding occurred over the Potomac Highlands of Maryland and West Virginia. Outside of remnant tropical-storm flood events, this case may be recorded as a one-in-50 year event for portions of the Shenandoah Valley, the central Virginia piedmont, and the Potomac Highlands. However, in Madison County and along the Rapidan, it is figured to be a 500 year flood.

Only three persons are known to have perished in the Sterling County Warning Area (CWA) from the floods. A 3-year-old girl was swept down the Gooney Creek near Front Royal on June 27th, and a man was killed in Rappahannock Co. In Madison County, a woman was killed when her home collapsed upon her. At least 20 people were injured of which 10 were hospitalized. Thus far, property damages in Virginia have been estimated at \$120 million¹ with an additional \$82 million in agricultural losses. These numbers do not include the cost of cleanup and recovery. Over 400 roads were closed with more than half damaged or washed out by mudslides and floods. Some 80 bridges were washed out or damaged, including a four-lane bridge on Federal Highway 29, a main thoroughfare between Washington and Charlottesville. (See Cover and Appendix E, picture 1). Thousands of residents were stranded in small towns and 800 people were evacuated from homes. More than 2000 homes were damaged or destroyed.

The hardest hit area was centered on southern Madison County, where as much as 20 inches of rain may have fallen. One report from Madison indicated that as much as 10 inches of rain fell in two hours. More than 25 people in Madison had to be rescued by air during the flooding. Half the farms in the county sustained damage. The entire hay crop was lost and half

¹ Numbers are provided by Virginia Department of Emergency Services. These numbers are only a rough estimate at the time of this report, August 1, 1995. Damage assessment is still ongoing. Once assessments are completed, a more accurate accounting of damages will be included in Storm Data for June 1995.

the corn crop. Hundreds of livestock were killed and 500 to 1000 miles of fencing was damaged or washed away. In Madison County alone, total damages were estimated at \$64 million with an additional \$29 million in agricultural losses. The estimated cost of recovery to get the farm land suitable once more for crops may be as high as \$1000 per acre.

Other flash flooding caused road closures from rock slides, mudslides, and bridge washouts, in Allegany County, Maryland and Mineral County, West Virginia. On June 27, near one million dollars in damage occurred to 200 buildings in Allegany County near Westernport. Total damage estimates including roads was \$1.76 million. In adjacent Mineral County, \$1.1 million in damages are estimated with 66 homes and 8 businesses damaged. Heavy rains in the mountains caused mudslides and washed debris up against bridges. Temporary debris dams backed up water and then broke causing additional flooding downstream. In Piedmont (Mineral County), over five and a half inches of rain fell on the 27th with most of it falling between 2 and 4 pm. Flooding occurred in both Piedmont and Keyser.

Up to 17 inches of rain also fell in Augusta County, Virginia. Earthen dams in southeastern Augusta County were perilously close to failure at one point, but survived as the rain areas shifted away. The heavy rains in Madison and Orange Counties led to a record river flood crest on the Rapidan. Nearly the entire town of Rapidan experienced flooding with damage to almost all the buildings. River flooding ensued along the Rappahannock River and affected areas downstream 1 to 2 days after the heaviest rains fell. The Rappahannock crested at 5 feet above flood stage at Remington and 7 feet above flood stage at Fredericksburg.

B. Synoptic Analysis

Strong upper-level confluence over the western Canadian Maritime provinces helped develop unseasonably strong surface high pressure centers, which moved into northern New England. Backdoor cold fronts developed in advance of the highs, but could push no further south than the Middle Atlantic states. The first front moved slowly through the forecast area during the 20th and 21st before dissolving. The front aided in lifting a tropical air mass ahead of it, causing thunderstorms to develop. Meanwhile, an enlarging subtropical low over the Mississippi Valley, whose circulation extended into the eastern Tennessee and Ohio Valleys, sent impulses rotating across the Appalachians providing added lift. One such impulse moved from northern Georgia into eastern Tennessee late in the week of the 18th, producing locally torrential rainfall, which caused isolated flash floods in western Virginia. One such flood resulted from a dam break in Campbell County, Virginia. Seven cars were washed off a bridge and one person perished in a rescue attempt. Other areas received light to moderate rains.

As the impulse moved first into western Pennsylvania, then towards the upper Midwest, convection became more isolated. However, a low temperature-dew point spread prevented significant drying from occurring. Early on the week of the 25th, the lead impulse had weakened after it had moved to the upper Midwest. However, the overall circulation broadened, keeping weak upper diffluence over much of the middle Atlantic region. At this

time, a much stronger back door cold front, in advance of a 1030 mb surface high over New England, moved into the central forecast area. Unfortunately, the battle between the tropical air (represented by southerly flow aloft) and the polar air (northerly flow aloft) was fought over the region, and ended in a draw. Thus, the surface front stalled immediately east of the Blue Ridge Mountains.

The combination of a stalled front, surface-850 mb east to southeast winds (upslope flow), excessively moist air, and weak upper diffluence, caused another round of heavy rain, this time on previously saturated soil. Widespread flooding and flash flooding occurred between June 26th and June 29th. The most notable flooding occurred in Sterling's CWA on June 26th and 27th. The action shifted into portions of southwestern Virginia (NWSO Blacksburg's CWA) during the afternoon and evening of the 28th. By the 29th, the front dissipated, and isolated convection produced scattered flash flood events. Isolated flash flood events continued through July 1, before the entire system was pushed east of Virginia by increasing westerly flow aloft.

II. Forecast and Warning Operations at WSFO Sterling

A. Forecast of Heavy Rains and Flooding

The NWS Sterling staff lived up to its name during the entire event. Strong wording was used in most zone forecast products issued from June 23 to July 1. Synoptic explanations (found under the header WBCSFDWBC), issued to give surrounding NWS offices and other meteorologists the technical reasoning used by the public forecaster to prepare the preliminary zone forecasts, were sound, especially prior to the most serious floods.

The June 27th midnight public forecaster conveyed the seriousness of threat, and virtually pinpointed the location of the most devastating floods through sound meteorological reasoning, in his synoptic explanation. The ultimate conclusions were reached in part by using several data sources.

First, hand-analyses of surface pressure, surface pressure change, 850 mb equivalent potential temperature, 850 mb heights/temperature/moisture, 500 mb heights/temperature/moisture, and 250 mb heights/isotachs were performed to get a three-dimensional "feel" of the atmosphere. After the short-range model data had arrived, PCGRIDDS software was used to assess the synoptic situation in finer detail than conventional charts provide. Third, radar composites were helpful in determining the fetch and strength of easterly flow into the potential flood region. The WSR-88D VAD wind profile (VWP) was instrumental in showing strengthening low-level flow (see the SFD below).

Highlights of the synoptic explanation Follow....

STATE FORECAST DISCUSSION
NATIONAL WEATHER SERVICE STERLING VA
345 AM EDT TUE JUN 27 1995

LOOKS LIKE IT COULD BE ANOTHER UPROARIOUS SHIFT WITH THE POTENTIAL FOR MUCH MORE WIDESPREAD FLOODING/FLASH FLOODING THAN WE'VE SEEN IN THE LAST SEVERAL DAYS. TODAY IS THE DAY THAT EMERGENCY MANAGERS REALLY NEED TO PAY ATTENTION...

...SINCE MIDNIGHT...THE KLWX 88D VWP HAS SHOWN BNDRY LYR WINDS INCRSG FROM 10 KT TO 25 KT AND AN AREA OF RW/TRW HAS PERSISTED IN A DVLPG CONVRGC ZONE ACRS NRN VA INTO THE PANHANDLES. THE STAGE IS SET...

...EXPECTING THE EASTERLY FLOW TO BECOME MORE ESTABLISHED...SHIFTING THE LOW-LEVEL THETA-E AND PW AXIS TOWARD W CNTRL ZONES...

...STABILITY FORECASTS INDICATE THAT MEAN AMS WILL BE QUITE UNSTABLE...ALOFT...WE'LL BE IN A DIFFLUENCE REGION BETWEEN JETS WHICH WILL AID IN MAINTAINING TSTMS ONCE THEY FIRE UP. MY GREATEST AREA OF CONCERN FOR SIGNIFICANT FLOODING LIES ACRS THE NRN/CNTRL SHENANADOAH VLY AND THE ADJ ZONES (INCLUDING THE UPSTREAM FOOTHILLS)...

Finally, a collective of privately and publicly-owned automated surface observations provided ground-truth rainfall amounts prior to and during the flooding. Skywarn volunteer observers were activated on the 27th. Through amateur radio, they provided additional rainfall reports, as well as damage and flood reports.

B. Flash Flood Watches Issued

Flash flood watches were issued, extended, and reissued, as necessary, for much of western Virginia between June 23 and July 1. For specific details of watch issuances, see appendix A. Estimated watch lead times for the most devastating floods (June 27th) were as follows:

MADISON CO	14 hr 11 min
ORANGE CO	14 hr 11 min
RAPPAHANNOCK CO	16 hr 11 min
WARREN CO	16 hr 11 min
CULPEPER CO	16 hr 31 min
GREENE CO	21 hr 47 min

Emphasizing the flood threat further, a flood potential statement (WBCESFWBC) was issued at 0645 EDT, just as the Madison/Orange County flooding began. The statement included a call-to-action for emergency managers (especially in west central and northwest Virginia, as well as mentioning the panhandles of Maryland and West Virginia) to pay attention to weather updates today because significant flooding was possible. Flood potential statements are issued only when there is a high risk of widespread flooding over portions of the forecast area.

C. Warning Issued, Radar Operations, and Verification

During the week of June 23 - 30, Sterling forecasters issued 55 warnings. Twenty-one were extensions of previous warnings. In Madison County alone, the initial warning was extended five times, giving a total warning time of 13 hours and 26 minutes. Preliminary statistics showed 42 of 55 warnings verified, 4 unverified, and 9 awaiting confirmation. Twenty-one of the 34 non-extended warnings have verified thus far, with only 6 having zero lead times.

All eleven warnings issued on June 27th have verified thus far. A detailed log of warnings and lead times is found in Appendix B. Lead times on the initial warnings for the most devastated counties were:

MADISON CO	1 hr 56 min
ORANGE CO	37 min
RAPPAHANNOCK CO	2 hr 37 min
WARREN CO	2 hr 37 min
CULPEPER CO	50 min
GREENE CO	0 min (ongoing event)

Lead times based on initial flooding, however, may not accurately tell the story, since the devastating floods did not truly begin until sometime between 1000 and 1200 EDT over southern Madison and northwest Orange Counties. Hence, "true" lead times could be as much as 5 hours and 30 minutes.

The excellent verification and lead times in Virginia are a credit to the entire office operation. WSR-88D operators soon recognized precipitation algorithm underestimation, which allowed the issuance of timely accurate warnings. The ratio of ground truth to radar estimates was about 1.8:1. This is likely a result of 1) the beam overshooting that portion of the cloud where the heaviest precipitation was occurring and 2) the ZR relationship being off due to the tropical-like environment that the storms were in. Appendix C is a list of reported rainfall values for the event and a map. This can be compared to Appendix D which shows WSR-88D storm precipitation total for that week.

As the flash flooding became more and more life-threatening, radio stations were called and asked to activate EBS and Skywarn was activated to provide amateur radio reports. The public service unit made continuous contact with emergency service personnel in all affected counties;

however, many were so overwhelmed with response efforts that they didn't have time to talk. Skywarn spotters and automated gages provided reliable observations of measured precipitation. Skywarn amateur radio operations provided the first ground-truth report around 2 pm from Madison County of 10 inches in Etlan (northern part) and indicated that half of it fell during the previous 4 hours. That observation, combined with the WSR-88D imagery, indicated that the southern part of the county was being hit hardest. Skywarn amateur radio also brought the first reports of road closures and road and bridge washouts.

Warning services were not as good for Mineral County, WV and Allegany County, MD, however, this area was under a flash flood watch. The WSR-88D did not indicate the magnitude of heavy rain like that that was falling in Virginia (see appendix D - top left-center of Storm Total Precipitation map). Hence, attention remained on central Virginia and no warnings were issued for Mineral or Allegany County. By the time reports began to reach the Sterling Office via Skywarn, NAWAS, and phone, the heavy rain had moved away from the area of concern. This information was incorporated into updated flood statements. The heaviest of rains fell over a small rural mountain area that is not covered by our observer network.

Our closest cooperative observer was in Keyser. His report did not reach our office for two days because the flash flood washed away half of his workshop/office, and flooded his basement, washing away his gage and ROSA phone. Mountain beam blockage caused additional problems to those mentioned above in estimating rainfall. Storm total according to the WSR-88D over the observers sight was only 1.5 to 2.0 inches. That produces a ratio closer to 4:1 and means that totals on the mountains to the west of Keyser in Allegany County, MD may have reached 10 inches or more.

Radar precipitation estimates improved later in the week as the final front approached the region, with the estimated ratio of ground truth to radar estimates at 1.25:1. The better resolution may have been related to the change from a tropically-convective (e.g. high relative humidity in a large portion of the column) towards a mid-latitude-convective (e.g. dry layers embedded within the column) atmosphere.

D. River Flooding and Hydrologic Services

River flood warnings and follow-up statements were routinely issued for the Rapidan and Rappahannock Rivers by the hydrology and public service unit staff. The warning period began at 0830 June 27 and continued until 1445 EDT June 30.

With the ground nearly saturated, heavy rains on the 27th in Madison and Orange Counties became direct runoff and flowed into the Rapidan. The Rapidan is a fast response river and had already exceeded flood stage on the morning of the 27th. The river continued to quickly climb. The USGS stream gage (not telemetered) near Ruckersville in Greene County was destroyed by the raging water (see Appendix E, picture 2). The flood crest was estimated (by

water marks to have reached 31.6 feet which is a 500-year flood for that gaging point. This exceeded the old record of 20.8 feet set at that point in October 1942 by almost a foot.

Flooding also knocked out phone lines cutting off communication to the NWS telemeter river gage equipment south of Culpeper. Sterling WSFO got assistance from the Search and Rescue Team from the town of Rapidan. They relayed river height reports from the NWS staff gage on the old mill. Before losing communication with the NWS gage, the river crest was forecast to reach 24 to 26 feet. Using this information, warnings were updated with a crest forecast of 28 feet. Additional readings estimated a crest of 27 feet to have occurred about 4 am on the 28th. Using a crest-relation chart, a crest near 30 feet was forecast for Culpeper Wednesday morning, the 28th. From water marks, the crest near Culpeper was later determined to be a record of 30.4 feet. (See Appendix E, picture 4). The old record was 30.30 feet which occurred on October 16, 1942.

The Rapidan River flows into the Rappahannock River, which was also accumulating rains from northern Madison County, Rappahannock and Culpeper Counties. On the 28th, the river crested 5 feet above flood stage at Remington. Farther downstream on the 29th, the river crested in the city of Fredericksburg at 7 feet above flood stage. The forecast point for the city is at the city dock which has a staff gage. The Fredericksburg Fire Department called in regular reports of the river level. Substantial damage was reported at both locations, and at numerous others along the river.

Excellent hydrologic service was provided by the Sterling staff. A River Flood Warning issued at 1130 EDT June 27 stated that "...THE RAPIDAN IS FORECAST TO CREST BETWEEN 19 AND 21 FEET THIS AFTERNOON..." but, more importantly, that should "THE BASIN RECEIVE AN ADDITIONAL 4 INCHES OF RAIN TODAY...A HIGHER SECONDARY CREST IS EXPECTED WEDNESDAY (June 28) MORNING ON THE RAPIDAN NEAR CULPEPER..."

A follow-up warning issued at 1615 EDT June 27 mentioned that the initial crest was 20.1 feet, right in the middle of the forecast range, but also added that "THE MODERATION OCCURRING IS ONLY TEMPORARY..." and a "SECONDARY CREST BETWEEN 23 AND 25 FEET TONIGHT" was expected. The river rose to 22.8 feet by 2200 EDT. With the additional information from the town of Rapidan, the warning was again updated to a forecast of near 30 feet Wednesday morning, June 28. The river indeed continued rising overnight to its June 28 record crest of 30.40 feet.

The first River Flood Warning for the Rappahannock River was issued at 1615 EDT June 27, for the downriver locations of Remington and Fredericksburg. At the time of the warning, the river level was 12.4 feet at Remington (2.6 feet below flood stage), and below 10 feet at Fredericksburg (at least 8 feet below flood stage). Initial crest forecasts were 18 to 20 feet at both locations; by early Wednesday morning at Remington and late Wednesday morning at Fredericksburg. By 2200 June 27, the Remington gage exceeded flood stage (15.02 feet). The gage at Fredericksburg apparently surpassed flood stage around midday June 28.

Crests were initially under forecast somewhat at Remington and Fredericksburg, partly due to the gage failure on the Rapidan at Culpeper. However, forecasts were adjusted upward to 22 - 23 feet at 0300 June 28, and to 25 - 27 feet by 0545 EDT June 28.

III. Flash Flood Operations in Sterling's Forecast Area, but outside the CWA

The other major flooding event occurred during the late evening of June 28 and early morning of June 29 from the southern foothills of Pittsylvania, Franklin, and Henry county northward to the southern Shenandoah Valley. Four deaths were attributed to the devastating flooding, with another death a result of a dam break on June 23. Short-fused warnings and river flood warnings were issued by the NWSO in Blacksburg, VA, with zone forecasts and flash flood watches issued by Sterling.

Two flash flood watches were issued for this region. The second issuance began at 0441 EDT June 27th and continued uninterrupted until 2000 July 1. The most devastating flooding was occurred under two areas of thunderstorms, one developing southward from Rockbridge County Virginia to near the North Carolina border; the other developing northward in the North Carolina piedmont. Both areas contained torrential rains. The two areas merged at around 2230 EDT June 28 over northeast Rockingham County North Carolina, then drifted slowly north into southern Virginia over the next several hours.

The synoptic explanation issued at 2108 EDT June 28 highlighted "...SERIOUS LIFE-THREATENING FLOOD SITUATION SETTING UP IN SW VA..." and hinted at a possible cell merger: "...LAST [SATL] IMG SHOWS SWD DVLPMT OF CELLS OVER PITTS/HALIFAX/HENRY CO WITH NWD MOVMT OF CELLS IN NC (WHICH ERLYR PRODUCED 1/4TRW+ AT CAE SC)...UH OH!"

The updated zone forecasts, issued at 2145 EDT, for the most affected counties included enhanced wording as well, with the mention of "TORRENTIAL RAINS CAUSING SERIOUS FLASH FLOODING" in the text. Finally, the flash flood watch extension, issued at 2210 EDT, included further details of the merger, including the possibility of "...AN ADDITIONAL 2 TO 4 INCHES OF RAIN IN PITTSYLVANIA...PATRICK...AND HENRY COUNTIES..." In fact, the Blacksburg WSR-88D estimated over 6 inches along the Pittsylvania/Franklin County line, and between 4 and 6 inches in southeastern Henry County, in a three-hour period ending at 0025 EDT June 29.

IV. Conclusions

The NWS Forecast Office in Sterling, teamed with the NEXRAD Weather Service Office in Blacksburg, provided exemplary service to Virginians up and down the Blue Ridge. The quality of service rivaled that provided during the Superstorm of March 13, 1995 - enough to warrant praise from Virginia Gov. George Allen.

APPENDIX A.

FLASH FLOOD WATCHES

(A): Central/Northern Shenandoah Valley: intermittent watches were in effect beginning at 0425 EDT Friday, June 23, until 2000 EDT Saturday, July 1.

(B): Southwestern Virginia portion of WBC zone forecast area: initial issuance: 0947 EDT Saturday, June 24...expiration 2300 EDT Saturday, June 24. second issuance 0441 EDT Tuesday, June 27...continuous until 2000 EDT Saturday, July 1.

(C): Flood Watch for the Northern Neck region of Virginia and the Maryland counties along the western shore of the Chesapeake Bay: 1415 EDT Saturday, June 24 through 0500 EDT Sunday, June 25.

Notes on Flash Flood Watch area (A):

1. Initial issuance valid through 0400 EDT Saturday, June 24.
2. Re-issuance at 0511 EDT Sunday, June 25th, valid until 2000 EDT.
3. Re-issuance for only the Potomac Highlands of Maryland and West Virginia, and the extreme northern Shenandoah Valley, from 2000 EDT/June 25 until 0400 EDT/June 26.
4. Re-issuance for same areas as in (3), adding additional counties through the central Shenandoah, at 2019 EDT/June 26. Counties affected by June 27 floods ADDED were:

GREENE, WARREN, RAPPAHANNOCK, MADISON, SHENANDOAH, FAUQUIER, and FREDERICK(VA)

Counties affected by the June 27 floods NOT INCLUDED were:

CULPEPER, ORANGE, LOUISA, FLUVANNA.

Expiration time: 0400/June 27.

5. Re-issuance for entire western third of Virginia, including all of the above counties, at 0441 EDT/June 27. There was an objective "window" without a watch of 41 minutes; however, for "real world" verification (used to calculate lead times), the 2019 EDT/June 26 FFA was used.
6. Counties removed from the FFA at 2158 EDT/June 27 (initially issued at 0441 EDT/June 27),

LOUISA, FAUQUIER, RAPPAHANNOCK, CULPEPER, MADISON, ORANGE,
SPOTSYLVANIA.

Note: these counties were reinstated at 348 AM Friday, June 30.

APPENDIX B

FLASH FLOOD WARNING LOG

STIME = Start time of warning

XTIME = End time of warning

V (Y/N) = Verification (Yes or No)

VTIME = Verification Time (- denotes ongoing event; + indicates
that event continues beyond this time)

Flash Flooding June 23 through June 30, 1995

WARNINGS

<u>DATE</u>	<u>LOCATION</u>	<u>ST</u>	<u>STIME</u>	<u>XTIME</u>	<u>V(Y/N)</u>	<u>VTIME</u>
0623	S AUGUSTA	VA	0000	0300	Y	-0000+
0624	E PRINCE GEORGES	MD	1341	1745	Y	-1341+
0624	ANNE ARUNDEL	MD	1341	1745	Y	-1345+
0624	CALVERT	MD	1341	1745	?	
0625	SW/WC RAPPAHANNOCK	VA	0042	0300	?	
0625	GRANT	WV	1626	1830	?	
0625	NW HARDY	WV	1626	1830	Y	1800+
0625E	GRANT	WV	1756	2000	?	
0625E	NW HARDY	WV	1756	2000	Y	1800+
0625	ALLEGANY	MD	1841	2045	N	
0625	GREENE	VA	2248	0045	N	
0625	W ORANGE	VA	2248	0045	N	
0625	NE ALBEMARLE	VA	2248	0045	Y	2330+
0625	MADISON	VA	2248	0045	N	
0625E	ALBEMARLE	VA	2359	0200	Y	-2359+
0625	NELSON	VA	2359	0200	?	
0626	AUGUSTA	VA	1226	1430	Y	1230+
0626E	AUGUSTA	VA	1433	1630	Y	-1433+
0626	FAUQUIER	VA	1719	1915	Y	-1719+
0626	ALLEGANY	MD	2032	2230	Y	2040+
0627	MADISON	VA	0434	0630	Y	0630+
0627	ORANGE	VA	0553	0900	Y	0630+
0627	RAPPAHANNOCK	VA	0553	0900	Y	0830+
0627	W FAUQUIER	VA	0553	0900	Y	0830+
0627	WARREN	VA	0553	0900	Y	0830+
0627E	MADISON	VA	0553	0900	Y	0630+
0627	NW CULPEPER	VA	0810	1115	Y	0900+
0627E	ORANGE	VA	0910	1215	Y	-0910+

0627E	W RAPPAHANNOCK	VA	0910	1215	Y	-0910+
0627E	WARREN	VA	0910	1215	Y	-0910+
0627E	MADISON	VA	0910	1215	Y	-0910+
0627	SW FREDERICK	VA	0910	1215	Y	0930+
0627E	CULPEPER	VA	1210	1500	Y	-1210+
0627E	ORANGE	VA	1210	1500	Y	-1210+
0627E	RAPPAHANNOCK	VA	1210	1500	Y	-1210+
0627E	WARREN	VA	1210	1500	Y	-1210+
0627E	FREDERICK	VA	1210	1500	Y	-1210
0627E	MADISON	VA	1210	1500	Y	-1210+
0627	GREENE	VA	1406	1600	Y	-1406+
0627E	MADISON	VA	1500	1700	Y	-1500+
0627E	GREENE	VA	1601	1800	Y	-1601+
0627E	MADISON	VA	1705	1800	Y	-1705+
0627	SHENANDOAH	VA	2010	2200	Y	2100+
0627	W ALBEMARLE	VA	2132	0000	Y	UNKN
0627	NELSON	VA	2132	0000	Y	UNKN
0628E	W ALBEMARLE	VA	0009	0100	Y	-0009+
0628E	NELSON	VA	0009	0100	Y	UNKN
0628	AUGUSTA	VA	0435	0730	Y	UNKN
0628E	AUGUSTA	VA	0731	1030	Y	-0731+
0628	ROCKINGHAM	VA	0731	1030	?	
0629	ORANGE	VA	1753	2000	?	
0629	E CULPEPER	VA	1821	2015	?	
0630	ALLEGANY	MD	1248	1445	Y	-1248+
0630	ALLEGANY	MD	1647	1845	Y	1657+
0630	MADISON	VA	1902	1945	?	

Flash Flood Statements

The number of Flash Flood Statements issued by WSFO WBC, by date:

June 23	0
June 24	0
June 25	4
June 26	2
June 27	13
June 28	4
June 29	2
June 30	2

APPENDIX C

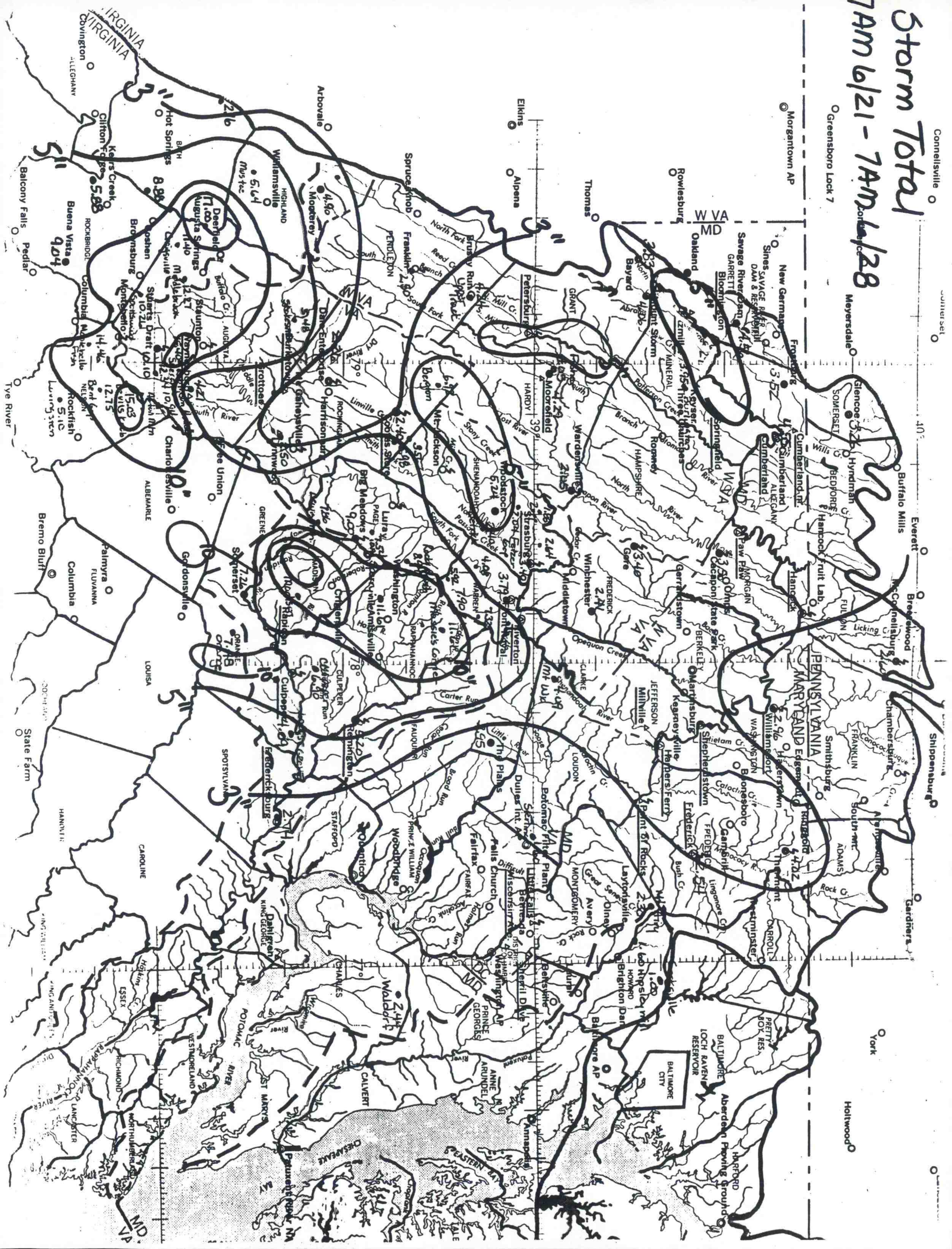
Precipitation Observations:

1. Hand plotted map of rainfall through June 27
2. List of all rainfall reports from official observers

(Note: higher amounts came from unofficial sources indicating as much as 20 inches in southern Madison County. These reports seem consistent with observation to radar ratios used)

Storm Total

7AM 6/21 - 7AM 6/28



RAINFALL TOTALS

<u>LOCATION</u>	<u>7AM 6/21 - 7AM 6/28 RAINFALL</u>	<u>7AM 6/27 - 7AM 6/28 RAINFALL</u>	<u>DATA SOURCE</u>
Glencoe PA	3.26	0.91	Coop Observer
McConnellsburg PA	2.60	----	LARC
Bayard WV	3.83	0.70	Coop Observer
Brandywine WV	----	0.65	Coop Observer
Fisher WV	4.05	1.63	Coop Observer
Moorefield WV	----	1.85	Coop Observer
Petersburg WV	----	0.15	Coop Observer
Romney WV	----	1.60	Coop Observer
Sugar Grove WV	----	0.35	Coop Observer
Wardensville WV	2.05	0.52	Coop Observer
Cacapon WV	3.50	0.30	Coop Observer
Burlington WV	3.95	1.96	Coop Observer
Upper Tract WV	4.24	----	Coop Observer
Mount Storm WV	4.06	1.21	DCP
Pinto WV	3.29	2.11	DCP
Franklin WV	2.50	0.80	LARC
Moorefield WV	4.29	1.51	LARC
Great Cacapon WV	3.30	2.20	LARC
Piedmont WV	----	5.77	Mineral Co EOC
Round Top WV	1.76	0.20	IFLOWS
Sleepy Creek WV	2.12	0.20	IFLOWS
Cumberland MD	4.55	0.65	Coop Observer
Frederick MD	2.54	0.10	Coop Observer
Damascus MD	----	0.09	Coop Observer
Frostburg MD	3.52	1.82	Coop Observer
Savage River Dam MD	4.56	3.37	Coop Observer
Smithsburg MD	----	0.06	Coop Observer
Waldorf MD	2.44	0.06	Coop Observer
Williamsport MD	2.96	0.24	Coop Observer
Thurmont MD	4.02	0.74	Coop Observer
Oakland MD	----	0.03	Coop Observer
Mt Airy/Damascus MD	2.30	0.12	LARC
Dale Enterprise VA	2.26	0.66	Coop Observer
Craigsville VA	----	1.42	Coop Observer
Fredericksburg VA	2.74	0.40	Coop Observer
Front Royal VA	3.79	0.90	Coop Observer
Locust Grove VA	4.09	0.03	Coop Observer

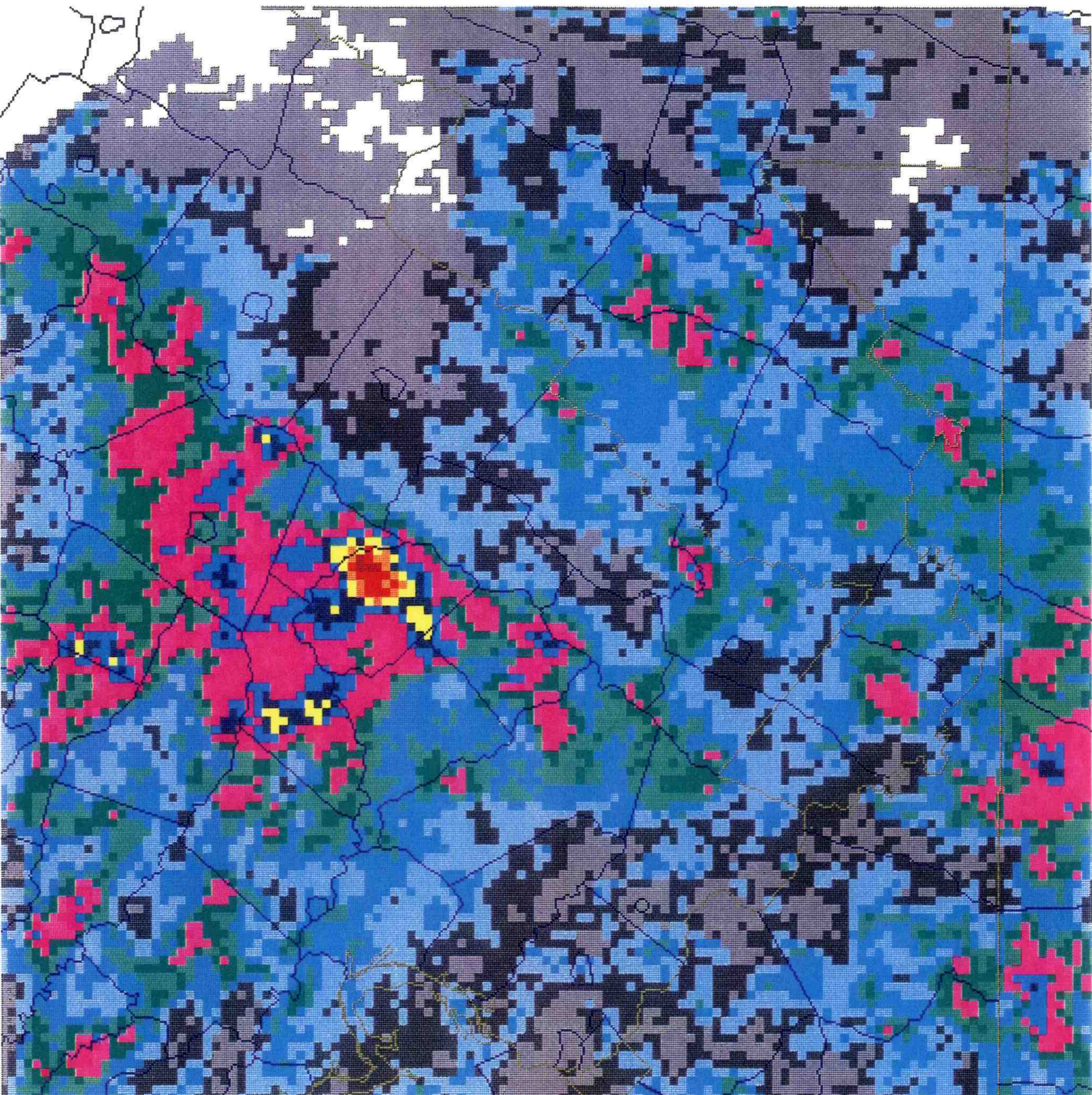
Near Berryville VA	4.09	0.53	Coop Observer
Orange VA	7.48	0.27	Coop Observer
Somerset VA	7.26	0.39	Coop Observer
Sperryville VA	11.61	1.16	Coop Observer
Staunton VA	----	2.67	Coop Observer
The Plains VA	2.95	0.31	Coop Observer
Vienna VA	----	0.28	Coop Observer
Waynesboro VA	4.21	1.00	Coop Observer
Winchester VA	2.41	0.12	Coop Observer
Massies Corner VA	11.61	0.30	Coop Observer
Sterling VA	1.60	0.17	WSFO LWX
Gore VA	3.40	2.20	LARC
Stuarts Draft VA	10.10	6.20	LARC
Lynwood VA	2.50	1.50	LARC
Big Meadows VA	9.00	5.00	LARC
Mathiews Arms VA	7.90	6.10	LARC
Culpeper VA	6.90	5.20	LARC
Remington VA	5.20	3.70	LARC
Lovingston VA	5.10	0.76	IFLOWS
Montebello Fish VA	14.46	3.20	IFLOWS
Brent Gap VA	12.75	3.96	IFLOWS
Devils Knob VA	15.03	5.44	IFLOWS
Afton Mountain VA	10.94	3.50	IFLOWS
Toms Branch VA	15.92	3.20	IFLOWS
Sherando VA	12.34	2.51	IFLOWS
Robinson Hollow VA	15.40	2.28	IFLOWS
Spottswood VA	10.26	1.08	IFLOWS
Middlebrook VA	12.27	1.00	IFLOWS
Stoney Creek VA	9.76	0.60	IFLOWS
Stokesville VA	5.48	0.80	IFLOWS
Craigsville VA	11.40	2.68	IFLOWS
Mustoe VA	5.64	0.28	IFLOWS
Monterey VA	4.90	0.00	IFLOWS
Lewis Mtn Camp VA	7.86	2.64	IFLOWS
Ida VA	7.54	2.24	IFLOWS
Skyland VA	6.08	1.80	IFLOWS
Rocky Branch VA	8.94	3.24	IFLOWS
Cootes Store VA	5.98	0.96	IFLOWS
Bergton VA	6.92	2.56	IFLOWS
Long Run Road VA	11.11	1.68	IFLOWS
Dundore Mtn VA	6.88	2.12	IFLOWS
Briery Branch VA	1.96	1.00	IFLOWS
Swift Run VA	5.72	1.24	IFLOWS
Camp Roosevelt VA	6.17	3.49	IFLOWS
Detrick VA	2.40	1.20	IFLOWS
Smith Ck/Cn VA	3.56	0.72	IFLOWS

Jerome Gap VA	3.60	1.24	IFLOWS
Woodstock VA	5.24	3.24	IFLOWS
Fetzer Gap VA	2.04	1.68	IFLOWS
Zepp VA	1.80	0.12	IFLOWS
Tumbling Run VA	2.64	0.72	IFLOWS
Strasburg VA	3.40	0.88	IFLOWS
Hogback Mtn VA	5.92	2.44	IFLOWS
Limeton VA	4.08	1.44	IFLOWS
Chester Gap VA	7.34	1.48	IFLOWS
Manassas Gap VA	5.26	0.88	IFLOWS
Browntown VA	7.13	3.38	IFLOWS

APPENDIX D

WSR-88D Storm Precipitation Products:

1. Storm Total Precipitation Map through June 27
2. Same map as (1) but zoomed in on Madison County
Highway 29 is also on this map.
3. One Hour Precipitation Map for afternoon on June 27
4. Three Hour Precipitation Map for afternoon on June 27



07/31/95 20:28
 STM PRECIP 80 STP
 124 NM 1.1 NM RES
 06/28/95 03:07
 RDA:XLWX 38/58/30N
 369 FT 77/28/40W
 MAX= 13.0 IN
 MODE A / 21
 CNTR 247DEG 49NM
 BEG=06/21/95 16:14
 END=06/28/95 03:09



MAG=2X FL= 1 COM=1

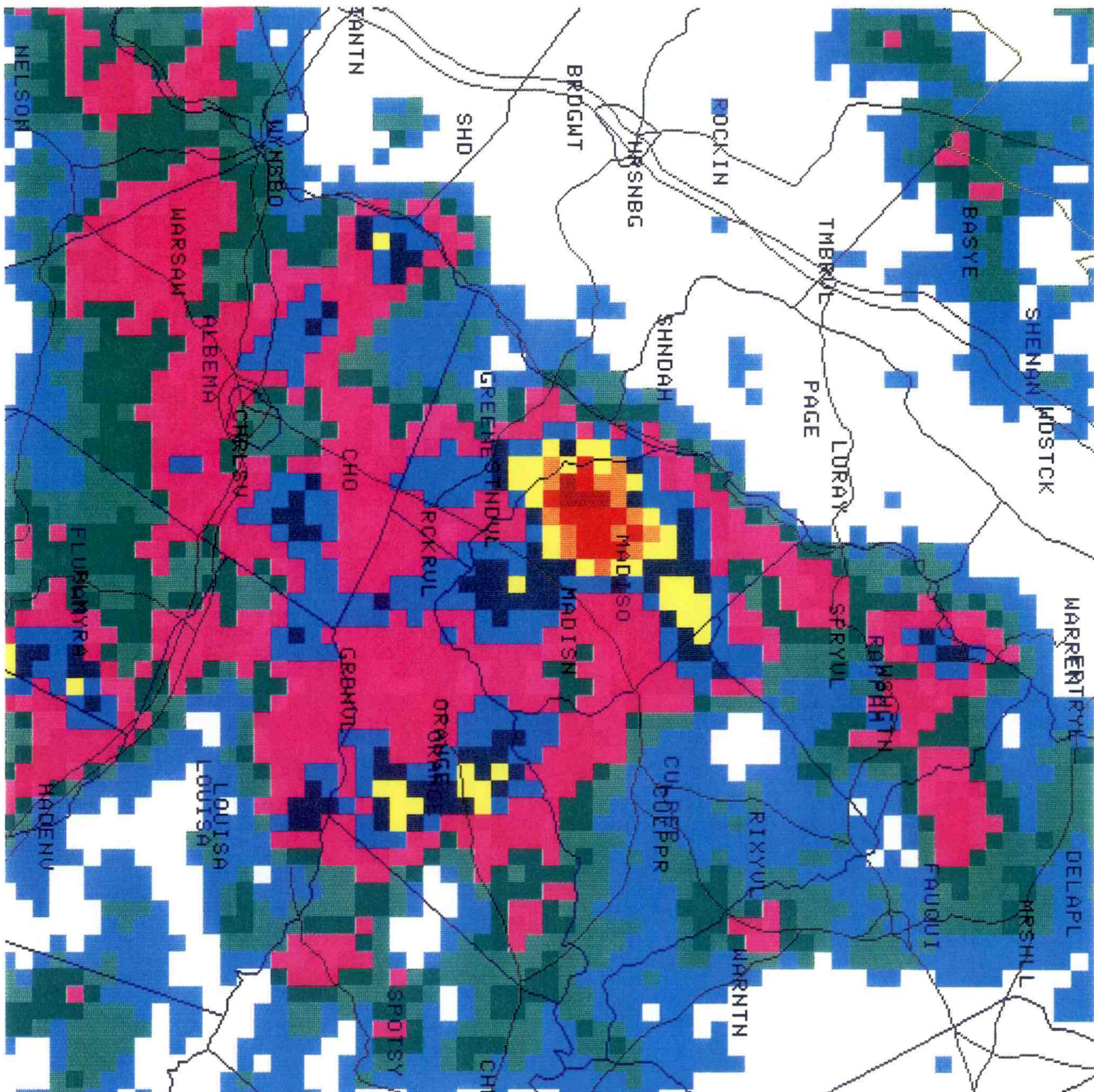
A/R (RDA) 231 DEG
 56 NM
 QUEUE EMPTY
 31/2027 ARCHIVE
 UNIT 1 READ DONE
 HARDCOPY
 HARDCOPY REQUEST
 ACCEPTED

07/31/95 20:30
 STM PRECIP 80 STP
 124 NM 1.1 NM RES
 06/28/95 03:07
 RDA:KLWX 38/58/30N
 369 FT 77/28/40M
 MAX= 13.0 IN
 MODE A / 21
 CNTR 224DEG 57NM
 BEG=06/21/95 16:14
 END=06/28/95 03:09

ND
 >0.0 IN



MAG=4X FL= 4 COM=1



A/R (RDA) 231 DEG
 QUEUE EMPTY 56 NM
 31/2027 ARCHIVE
 UNIT 1 READ DONE
 HARDCOPY
 HARDCOPY REQUEST
 ACCEPTED

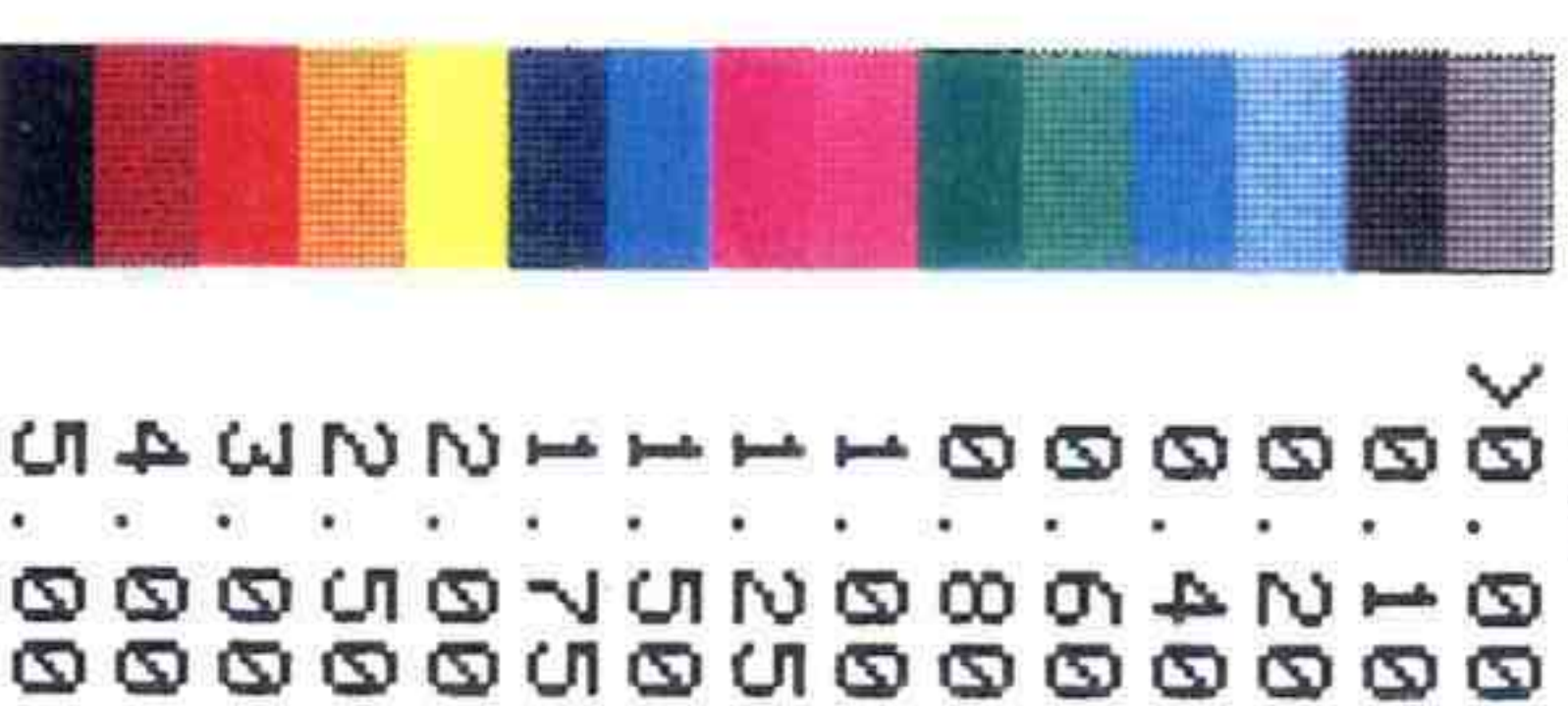
PAGE

07/31/95 19:06
1-HR PRECIP 78 OHP
124 NM 1.1 NM RES
06/27/95 17:09
RDA: KLWX 38/58/30N
369 FT 77/28/40W

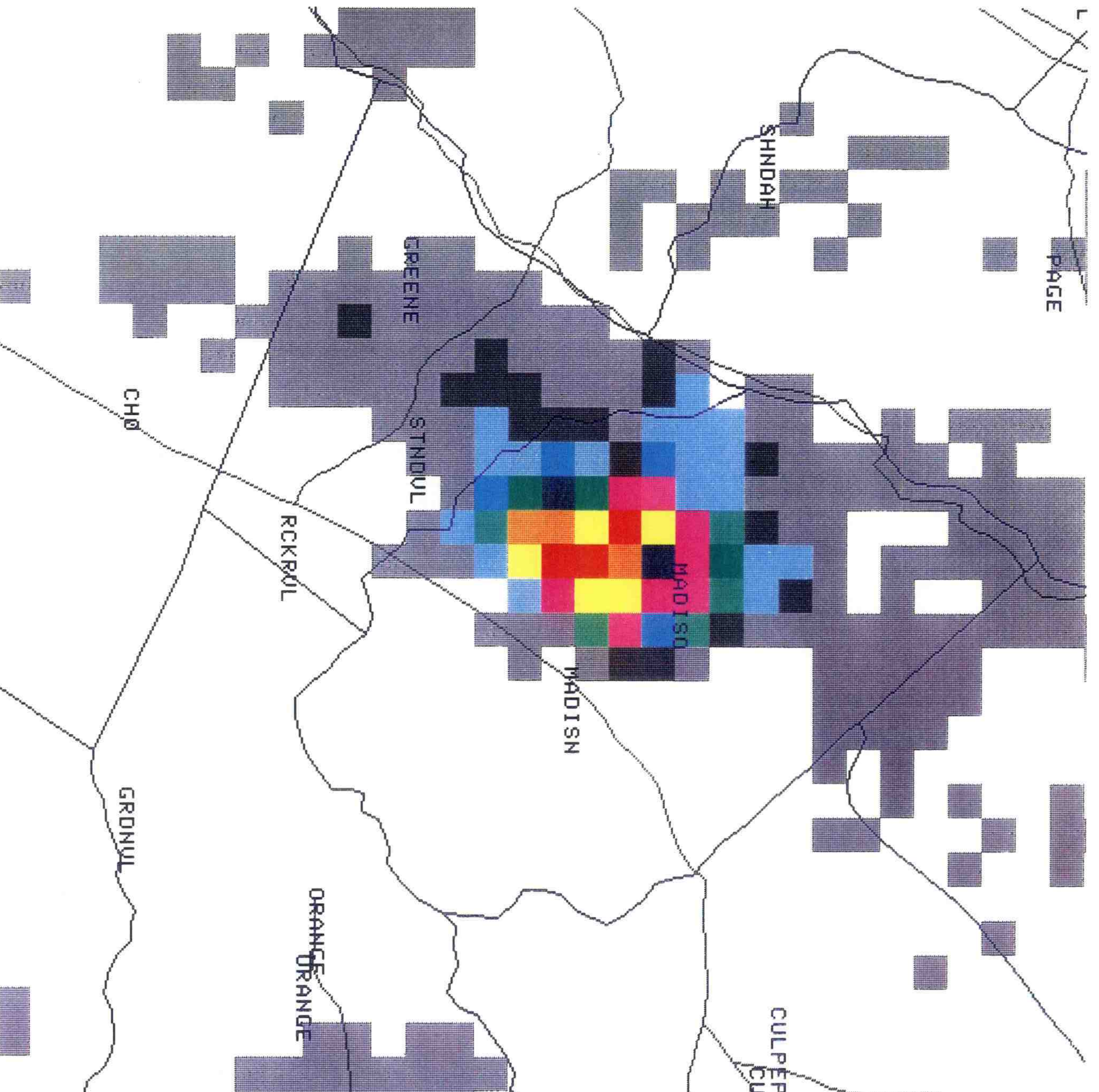
MODE A / 21
CNTR 227DEG 56NM
MAX= 3.2 IN
END=06/27/95 17:12

ND

>0.00 IN

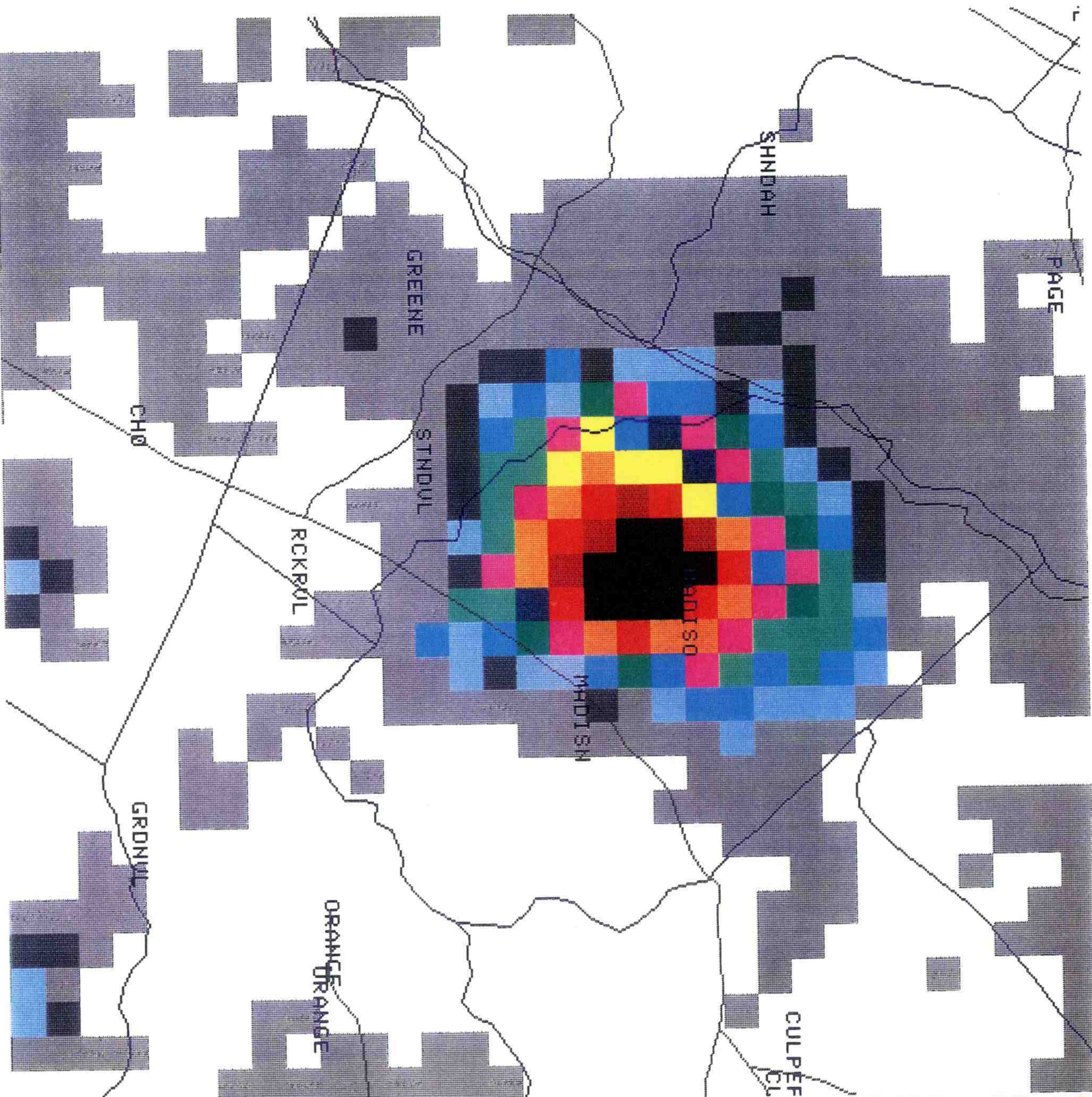


MAG=8X FL= 1 COM=1



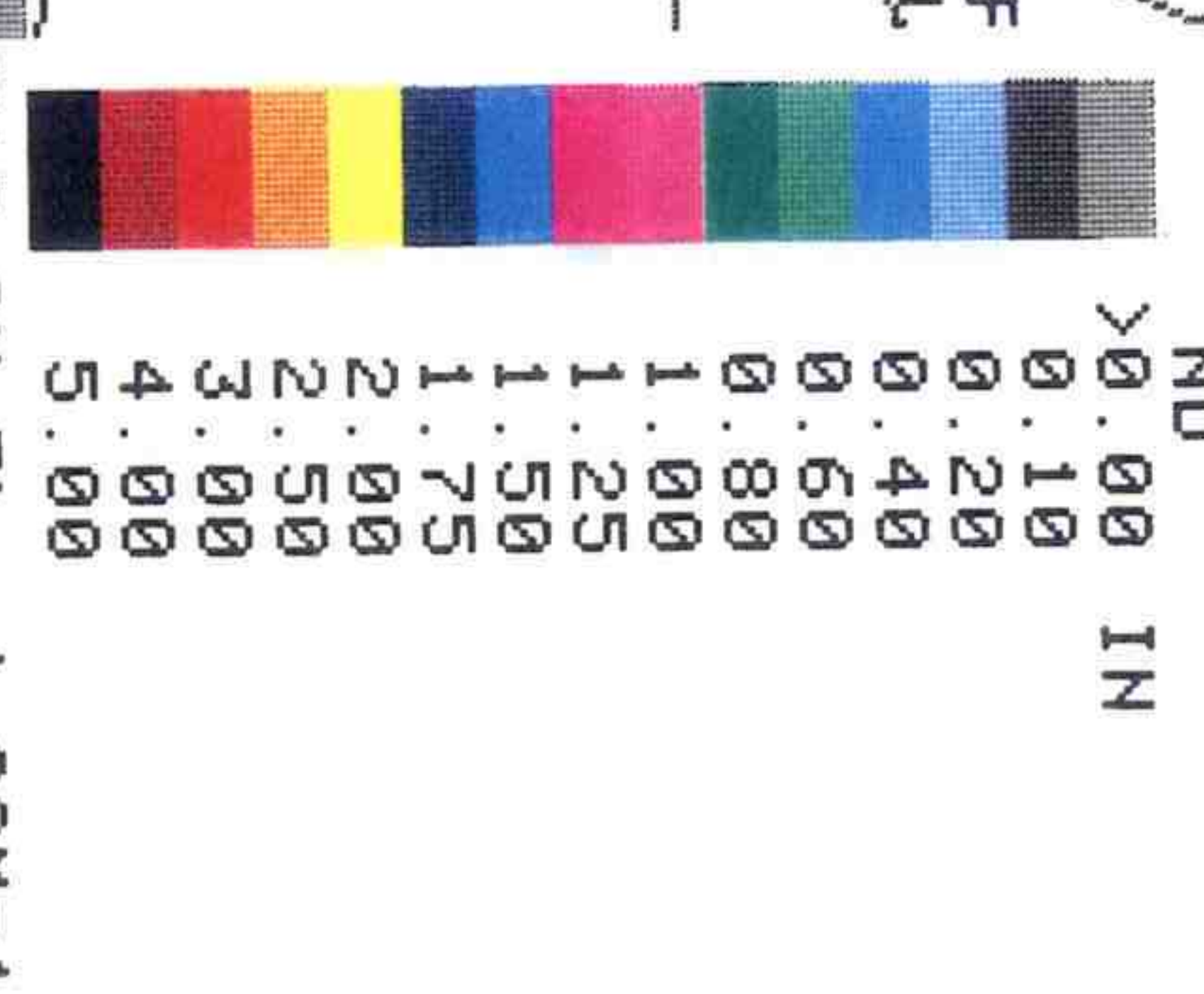
A/R (RDA) 229 DEG
54 NM
Q15 R 1854 R
PROD RCVD: U RPS
KLWX 1854 .54 3.5
31/1859 ARCHIVE
UNIT 1 READ DONE
HARDCOPY
HARDCOPY REQUEST
ACCEPTED

PAGE



07/31/95 19:04
3-HR PRECIP 79 THP
124 NM 1.1 NM RES
06/27/95 17:09
RDA: KLWX 38/58/30N
369 FT 77/28/40W

MODE A / 21
CNTR 227DEG 56NM
MAX= 6.0 IN
END=06/27/95 17:00



MAG=8X FL= 1 COM=1

A/R (RDA) 229 DEG
015 CR 1845 54 NM
PROD RCUD: 0 RPS
KLWX 1854 .54 2.5
31/1859 ARCHIVE
UNIT 1 READ DONE
HARDCOPY
HARDCOPY REQUEST
ACCEPTED

APPENDIX E

Aftermath of Flooding:
Pictures along the Rapidan



Picture 1: Rebuilding Federal Highway 29 where it crosses the Rapidan between Madison and Greene Counties.



Picture 2: USGS streamgage on Rapidan River in Greene County after flood waters washed it off its foundation.



Picture 3: Caboose in the town of Rapidan damaged by flooding. Flood waters were over the top of it.

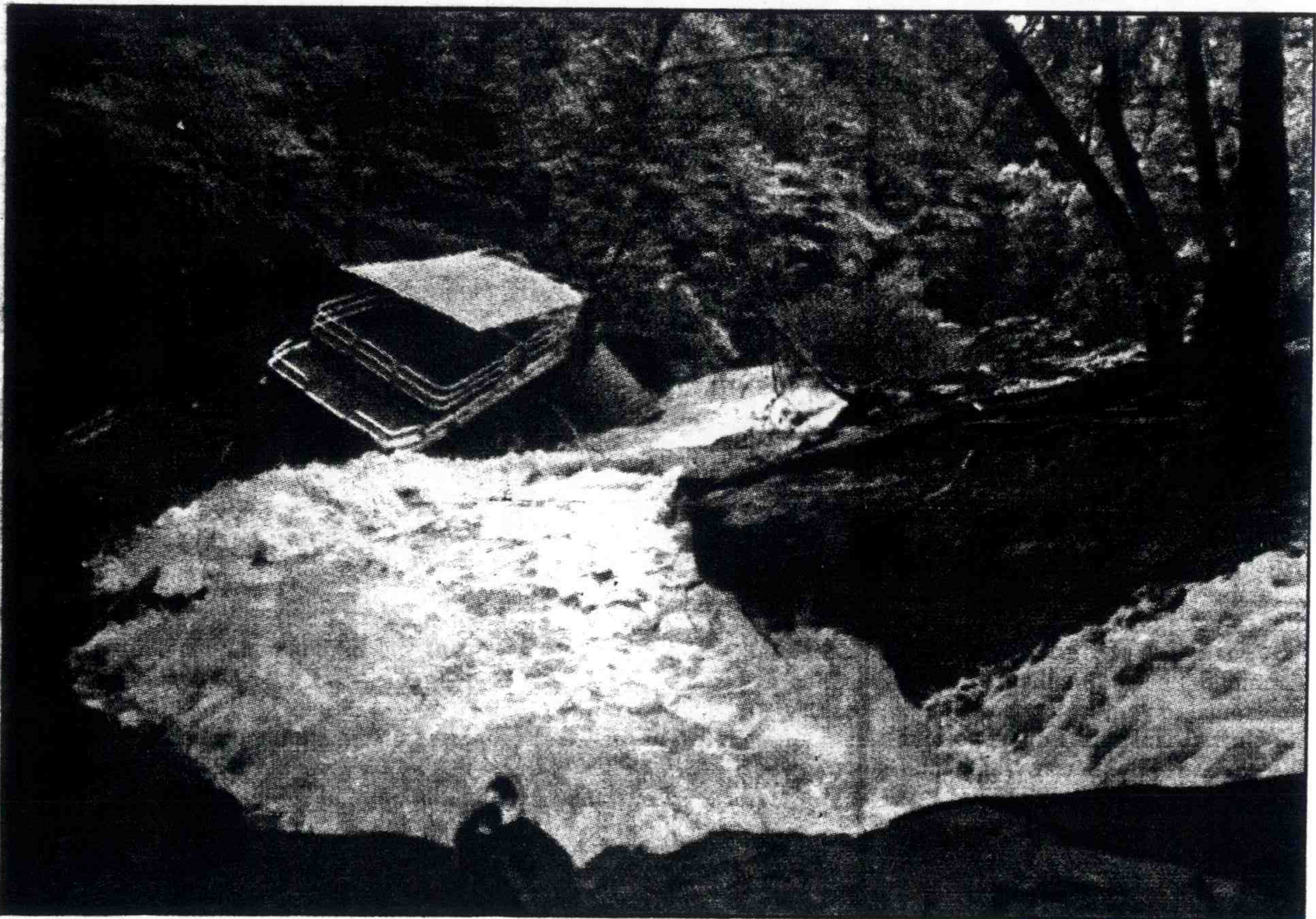


Picture 4: NWS telemeter gage and USGS streamgage on the Rapidan River 8 miles south of Culpeper. Record flood crest at this point reached 30.40 feet.



The Daily Progress / Leslie Close

With flood waters of the Rapidan River having subsided, Virginia Department of Transportation employees survey damage to the U.S. 29 bridge that connects Greene County and Madison County.



The Daily Progress / Leslie Close

A pontoon boat lies wrecked on the rocky banks of waters pouring from Izac Lake, a 60-acre body of water at Shenandoah Crossing Resort and Country Club in Loudoun County near Gordonsville.

APPENDIX F

1. Example Flash Flood Warning during height of event highlighting the "life threatening" situation
2. Example Flash Flood Statements
 - a. Early on the 27th
 - b. Mid-day as the seriousness of the event grew

Example Flash Flood Warning

ZCZC
WBCFFWWBC
TTAA00 KWBC 271900
VAC113-272100-

BULLETIN - EBS ACTIVATION REQUESTED
FLASH FLOOD WARNING
NATIONAL WEATHER SERVICE WASHINGTON DC
259 PM EDT TUE JUN 27 1995

THE NATIONAL WEATHER SERVICE IN WASHINGTON HAS ISSUED A
FLASH FLOOD WARNING EFFECTIVE UNTIL 500 PM EDT
FOR PEOPLE IN THE FOLLOWING LOCATION...

IN WEST CENTRAL VIRGINIA

...MADISON COUNTY

AT 300 PM DOPPLER RADAR SHOWED A STATIONARY AND VERY PERSISTENT
THUNDERSTORM WITH TORRENTIAL RAINS CENTERED IN SOUTHWEST MADISON
COUNTY. THE THUNDERSTORM HAS RESULTED IN VERY SERIOUS FLOODING IN
THE COUNTY WITH RESCUE AND EVACUATION ATTEMPTS ONGOING.

THIS IS A LIFE THREATENING SITUATION AND PEOPLE IN MADISON
COUNTY...PRIMARILY THE SOUTHWEST PART...SHOULD SEEK HIGHER GROUND
AWAY FROM STREAMS AND OTHER FLOOD PRONE AREAS. UNDER NO
CIRCUMSTANCES SHOULD ANYONE ATTEMPT TO DRIVE IN FLOODED AREAS.

A FLASH FLOOD WARNING MEANS THAT FLOODING IS OCCURRING OR IS
IMMINENT. MOST FLASH FLOOD DEATHS OCCUR IN AUTOMOBILES. DO NOT
ATTEMPT TO CROSS BRIDGES...DIPS...OR LOW SPOTS IF WATER COVERS THE
ROADWAY. NEVER TRY TO CROSS A FLOWING STREAM...EVEN A SMALL
ONE...ON FOOT. TO ESCAPE RISING WATER MOVE UP TO HIGHER GROUND.

NNNN

Example Flash Flood Statement

ZCZC

WBCFFSWBC

TTAA00 KWBC 271026

VAZ026>031-038>042-050>053-055>056-MDZ003>004-009-WVZ050>053-055-271300-

FLASH FLOOD STATEMENT

NATIONAL WEATHER SERVICE WASHINGTON DC

620 AM EDT TUE JUN 27 1995

...FLASH FLOOD WARNINGS ARE IN EFFECT UNTIL 9 AM EDT FOR THE FOLLOWING VIRGINIA COUNTIES: ORANGE...RAPPAHANNOCK...FAUQUIER...WARREN...MADISON

...FLASH FLOOD WATCH IS IN EFFECT FOR VIRGINIA...MARYLAND...AND THE EASTERN WEST VIRGINIA PANHANDLE FROM FOOTHILLS OF THE BLUE RIDGE WEST...UNTIL 10 PM THIS EVENING...

NATIONAL WEATHER SERVICE DOPPLER RADAR INDICATES A PERSISTENT AREA OF HEAVY SHOWERS AND THUNDERSTORMS OVER NORTHERN VIRGINIA...THE EXTREME EASTERN WEST VIRGINIA PANHANDLE AND PORTIONS OF THE MARYLAND PANHANDLE NEAR THE BLUE RIDGE. THE RAIN AREA IS NEARLY STATIONARY WITH INDIVIDUAL RAIN ELEMENTS MOVING NORTH AT 10 TO 15 MPH.

RAINFALL REPORTS FROM COOPERATIVE OBSERVERS AND AUTOMATED RAIN GAGES INDICATED THAT 1.5 TO 2.0 INCHES OF RAIN HAS FALLEN SINCE MIDNIGHT. LOCALLY HIGHER AMOUNTS CLOSER TO 3.0 INCHES ARE ESTIMATED TO HAVE FALLEN NEAR THE BLUE RIDGE.

A POLLING OF COUNTY SHERIFFS OFFICES INDICATED THE FOLLOWING CONDITIONS THROUGH 615 AM:

- MADISON COUNTY VA...FLOODING WAS IN PROGRESS. DOPPLER RADAR INDICATED THAT THE WORST AREA IS ACROSS THE SOUTHERN HALF OF THE COUNTY.

- RAPPAHANNOCK COUNTY VA...THERE WAS A REPORT THAT A STREAM MAY BE OUT OF ITS BANK ALONG ROUTE 729. POLICE ARE CHECKING. THERE WAS A REPORT OF STANDING WATER ON ROUTE 211 NEAR MASSIES CORNER.

- WARREN COUNTY VA...LOW WATER BRIDGE NEAR BENTONVILLE ALREADY HAD WATER ON IT FROM RAIN MONDAY. POLICE EXPECT THAT THE BRIDGE IS INUNDATED THIS MORNING. HEAVY RAIN IN PROGRESS.

- ORANGE COUNTY VA...ONE CAR WAS TRAPPED IN 3 FT OF WATER ON ROUTE 20. THE MONKEY CREEK NEAR ROUTE 669 WAS OUT OF ITS BANK.

ADDITIONAL FLOODING AND FLASH FLOODING IS IMMINENT IN THESE AREAS. MOTORISTS ARE URGED TO USE EXTREME CAUTION IF YOU MUST TRAVEL THROUGH THESE COUNTIES...AND BE PREPARED FOR BLOCKED ROADS IN LOW LYING AREAS...STREAMS AND CREEKS OVERFLOWING THEIR BANKS AND INUNDATED LOW WATER BRIDGES.

PERSONS IN FLOOD PRONE AREAS SHOULD BE PREPARED TO EVACUATE TO HIGH GROUND SHOULD FLOODING BEGIN IN YOUR AREA. STAY TUNE TO NOAA WEATHER RADIO AND THE LOCAL MEDIA FOR ADDITIONAL BULLETINS.

NNNN

Example Flash Flood Statement

ZCZC

WBCFFSWBC

TTAA00 KWBC 271711

VAZ021-025>031-037>042-049>051-056-MDZ002>004-WVZ048>055-272100-

FLASH FLOOD STATEMENT

NATIONAL WEATHER SERVICE WASHINGTON DC

115 PM EDT TUE JUN 27 1995

...FLOODING RAINS ARE CONTINUING OVER PARTS OF VIRGINIA...

A FLASH FLOOD WARNING REMAINS IN EFFECT UNTIL 300 PM EDT FOR CULPEPER...ORANGE...RAPPAHANNOCK...WARREN...FREDERICK...AND MADISON COUNTIES IN VIRGINIA.

A FLASH FLOOD WATCH REMAINS IN EFFECT THROUGH 10 PM EDT TONIGHT FOR A LARGE PORTION OF WESTERN VIRGINIA...THE EASTERN PANHANDLE OF WEST VIRGINIA...AND WESTERN MARYLAND.

SHOWERS AND THUNDERSTORMS...SOME WITH FLOODING RAIN CONTINUED IN THE WARNING AREA THIS AFTERNOON. MADISON COUNTY VIRGINIA IN PARTICULAR HAS EXPERIENCED WIDESPREAD FLOODING WITH RAINFALL TOTALS EXCEEDING 8 INCHES REPORTED AT MASSIES CORNER EARLIER THIS MORNING. AS OF 115 PM RADAR SHOWED A NEARLY STATIONARY THUNDERSTORM CONTINUING OVER MADISON COUNTY. THIS THUNDERSTORM HAS AFFECTED THE COUNTY SINCE EARLY THIS MORNING WITH RADAR PRECIPITATION ESTIMATES OF 2 TO 3 INCHES PER HOUR.

THIS IS AN ESPECIALLY DANGEROUS SITUATION IN MADISON COUNTY AND RESIDENTS SHOULD AVOID FLOOD PRONE AREAS AS WELL AS STREAM BEDS AND OTHER LOW LYING AREAS. SEEK HIGHER GROUND AND NEVER ATTEMPT TO DRIVE ACROSS FLOODED ROADWAYS.

RADAR ALSO SHOWED NUMEROUS SHOWERS AND A FEW THUNDERSTORMS CONTINUING OVER MUCH OF WESTERN MARYLAND...EASTERN WEST VIRGINIA...AND NORTHERN AND CENTRAL VIRGINIA. PEOPLE IN THE WATCH AREA SHOULD CONTINUE TO MONITOR LATER STATEMENTS OR WARNINGS FROM THE NATIONAL WEATHER SERVICE THROUGH THE AFTERNOON.

NNNN