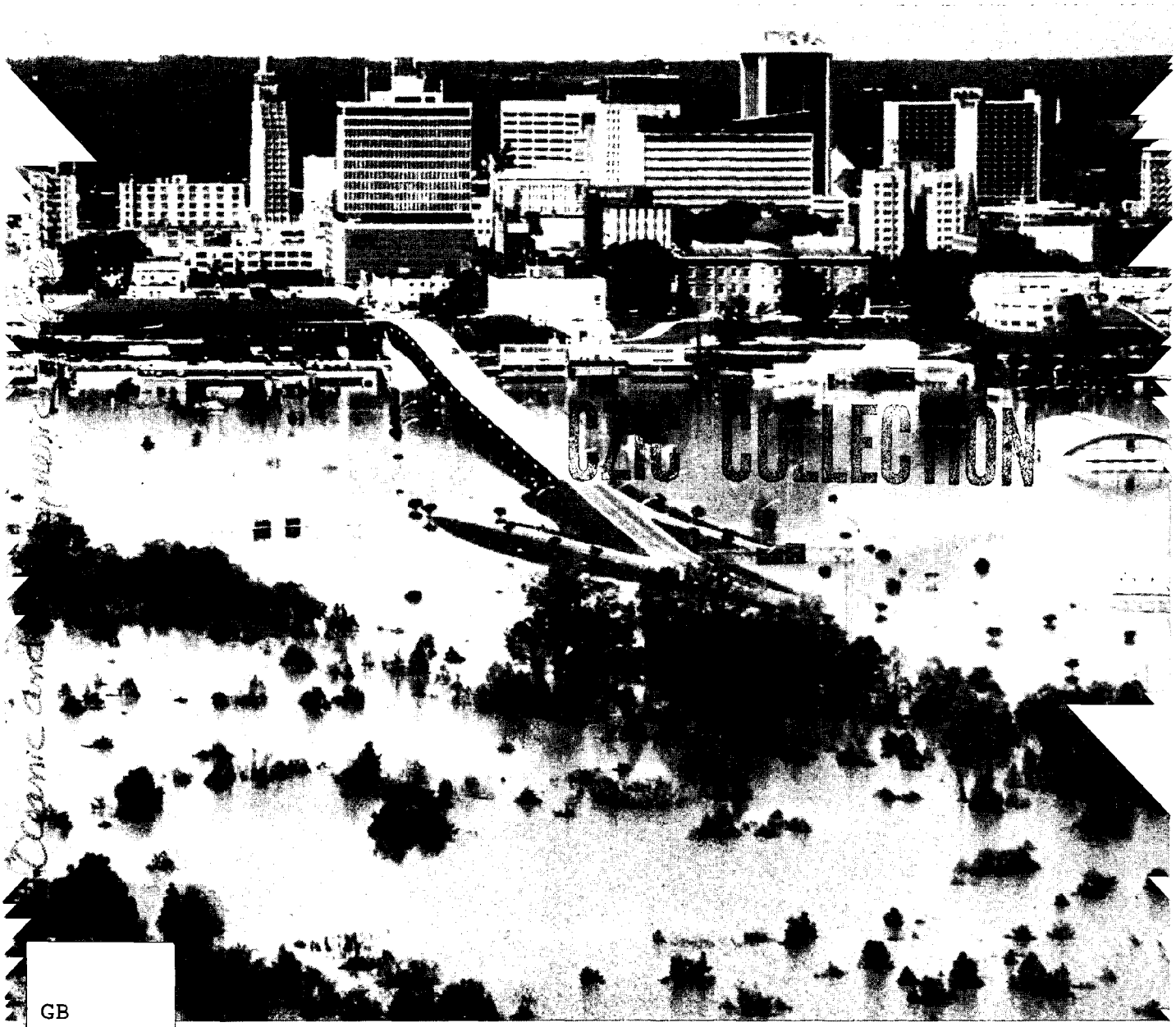
Natural Disaster Survey Report 80-2

The April '79 Floods of the Pearl and Tombigbee Rivers

April 1979

A Report to the Administrator



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NATURAL DISASTER SURVEY REPORT 80-2

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A REPORT TO THE ADMINISTRATOR

Rockville, Maryland
April 1980

U.S. DEPARTMENT OF COMMERCE
Philip M. Klutznick, Secretary

National Oceanic and Atmospheric Administration
Richard A. Frank, Administrator

FOREWORD

As recovery operations were underway in Mississippi and Alabama following the devastating flood of April 1979, a survey team of the National Oceanic and Atmospheric Administration (NOAA) was formed to assess the performance of the NOAA river and flood warning system. This report describes the meteorological and hydrological conditions associated with the flood, the data gathering and warning dissemination systems, public preparedness, and the findings and recommendations of the team.

The survey team thanks the many individuals who gave us their time and assistance. They include personnel of NOAA facilities and other Federal agencies contacted, local mayors, sheriffs and Civil Defense officials, National Guardsmen, and news media representatives. Their help and cooperation provided the information necessary to prepare this report and help improve the river and flood warning system.

The team would also like to extend their gratitude to the Clarion-Ledger and Jackson-Daily News for the cover photographs of downtown Jackson.

Donald P. Martineau
Acting Deputy Assistant
Administrator for Oceanic and
Atmospheric Services
National Oceanic and Atmospheric
Administration

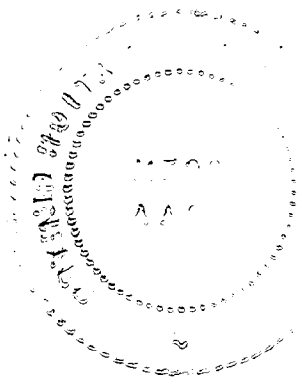


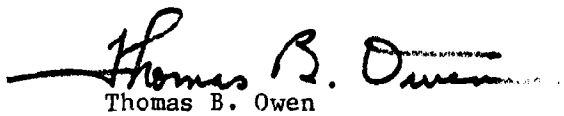
TABLE OF CONTENTS

PREFACE

On May 3, 1979, a disaster survey team was formed to review the NOAA river and flood warning system during the April 1979 floods of the Pearl River and Tombigbee River Basins in Mississippi and Alabama. The purpose of the review was to determine the effectiveness of the system and to recommend remedies where deficiencies were found. This report is a result of that survey.

The team was comprised of Donald P. Martineau, NOAA, Office of the Assistant Administrator for Oceanic and Atmospheric Services (OAS); Leo R. Beard, Consultant, Head of the Center for Research and Water Resources, University of Texas at Austin; John C. Davies, NOAA, Office of the Assistant Administrator, OAS; John C. Schaake, Jr., National Weather Service (NWS), Office of Hydrology; Glenn L. Audsley, NWS, Southern Region; Max White, NWS, Southern Region; Robert Hamilton, NWS, Meteorologist-in-Charge, Weather Service Forecast Office, St. Louis, Mo.; Don Kuehl, NWS, Hydrologist-in-Charge, River Forecast Center, Portland, Oreg.; John Guinan, NOAA, Office of Public Affairs; and Stanley Schneider, NOAA, National Environmental Satellite Service (NESS). Albert G. Holler, Jr., Corps of Engineers, South Atlantic Division, also accompanied the team during the field phase of the review.

At the outset, it was necessary to place limits on the extent of the survey because of time and the geographic size of the area affected by flooding. Three elements of the events were to be considered: the flash flooding at the headwaters of the Pearl, Noxubee, and Tombigbee Rivers; the flooding of the Pearl River in the Jackson area; and the flooding along the lower Pearl River, and the Noxubee, and Tombigbee Rivers. The preliminary field activities were completed on May 11, 1979. The activities focused on the Jackson area on May 8-9 with visits to the Jackson forecast office, the State and local Civil Defense Emergency Operations Centers, the mayor of Jackson and his staff, other Federal agencies, and the news media in the area. The team then divided into three smaller groups to visit other NWS facilities in Mississippi and Alabama, to contact local officials along the rivers, and to meet with the Corps of Engineers at the Mobile District Office. On July 23-24, a second visit was made by two team members to meet with local officials in the Jackson and Rankin County areas. After these initial surveys, the team was organized into task groups to analyze the functional areas of the river and flood forecast and warning system in order to determine as accurately as possible what had taken place. These analyses and the resulting findings and recommendations are the basis for this report.



Thomas B. Owen
Assistant Administrator for
Oceanic and Atmospheric Services
National Oceanic and Atmospheric
Administration

EXECUTIVE SUMMARY

The large tornado-breeding storm system that severely damaged Wichita Falls, Tex., and spread into Oklahoma on April 10, 1979, set off heavy rains as it moved into western Mississippi on Wednesday evening, April 11, and into Alabama the next morning. By Friday morning, April 13, the storm had deposited an areal rainfall average in excess of 12 inches over the upper Pearl Basin, with 15 and 20 inches reported in the east-central sectors of Mississippi. Flash floods occurred at many locations in Mississippi and Alabama, and later caused record flooding on the Noxubee, Tombigbee, Black Warrior, and Pearl Rivers. Flooding was occurring simultaneously in the entire area of the Lower Mississippi River Forecast Center, at Slidell, La., with the Yazoo, Leaf, Chickasawhay, and Big Black River systems experiencing maximum floods of record.

Both the Pearl River and Tombigbee River experienced record flood stages. The Pearl River at Jackson crested at 43.25 feet on April 17. The previous record crest was 37.2 feet in 1902. The Corps of Engineers (COE) has described the flood at Jackson as one with a likely occurrence of once in 500 to 1,000 years. Record flooding occurred on the Noxubee River at Macon, Mississippi, cresting on April 13 about 6 feet above the previous record set in 1951. Record flooding of less magnitude also occurred on the lower portions of the Tombigbee.

Preliminary estimates provided by Mississippi and Alabama State Officials placed total damages to crops, roads, bridges, and both public and private buildings in excess of $700 million. Nine deaths were associated with the flooding in the two states. In the Jackson area which was the hardest hit about 15,000 people were evacuated from their homes and an estimated $500 million in damages resulted from the flood. Farther downstream on the Pearl and Tombigbee Rivers, damages were less but still severe.

METEOROLOGICAL FORECASTS AND WARNINGS

Although severe local storms did occur during the heavy rainfall event, an extensive review of the severe thunderstorm and tornado warning programs was not conducted. Only those meteorological conditions directly related to the flood-producing rainfall were assessed by the survey team.

A review of the numerical guidance from the National Meteorological Center (NMC) of the National Weather Service (NWS) for the period preceding and during the heavy rainfall event indicates that the two numerical models used to provide guidance to the Weather Service Forecast Offices (WSFO's) in the affected area did not yield accurate prognoses. The present state-of-the-art is below the level required for consistently accurate watches and warnings for rainstorms of great intensity and magnitude. This storm was not an exception to the present "state-of-the-art". In Mississippi and Alabama, the forecasts prepared by Jackson and Birmingham Weather Service Forecast Offices (WSFO's), respectively, reflected the NMC guidance, which erroneously indicated too little precipitation over too small an area, along with too rapid eastward movement of the system. Thus, the extreme magnitude and the duration of the

rainfall were not anticipated prior to the event. Due to inaccuracy in previous guidance, both the Jackson and Birmingham WSFO's delayed issuance of initial flash flood watches until heavy rains were reported. Consequently, the initial flash flood watches were issued with less than desirable lead times. However, the issuance of flash flood warnings was good. Post analysis of the precipitation reports shows an excellent correlation between the areas of heavy rainfall and the counties warned. This is impressive because throughout the flood event WSFO Jackson was without its own radar owing to a lightning strike and was relying on reports from surrounding radar, data from satellites, and input from numerous precipitation networks.

RIVER AND FLOOD FORECASTS AND WARNINGS

Forecasts for Jackson are referenced to the stage heights measured at the river gage located on the US Highway 80 bridge. The gage is about 15 miles downstream from the Ross Barnett Reservoir. River stage heights for the Jackson forecast point are prepared by the WSFO rather than by the River Forecast Center (RFC) at Slidell, La. RFC Slidell routinely prepares inflow forecasts to the reservoir and Jackson is responsible for conversion of this information into forecasts for the gage at US Highway 80. This forecast point, unique to the Pearl River Basin, was assigned to Jackson because the stages at US Highway 80, south of the city, are controlled by the discharges from the Ross Barnett Reservoir. WSFO Jackson makes the forecasts on the basis of the reservoir release rates provided by the reservoir operator and a stage vs discharge rating curve.

The initial river forecast, issued on Thursday, April 12, by WSFO Jackson, called for near record levels on the Upper Pearl and a crest of 36 feet at Jackson for Friday and Saturday. The flood statements emphasized that the crest could go higher than 36.0 feet. When the thunderstorms moved out of the State later Friday morning, rainfall totals had about doubled from the previous day when the initial forecasts had been issued. On the basis of these later rainfall reports, RFC Slidell predicted an inflow of 120,000 cubic feet per second (cfs) into the Ross Barnett Reservoir and also prepared a stage guidance forecast for Jackson. The guidance forecast predicted that a crest of 38.5 to 39.5 feet would occur on Monday, April 16. This forecast was provided in person to the Mayor at the Jackson/Hinds Emergency Operations Center (EOC) on Friday morning by the Jackson Meteorologist-in-Charge (MIC).

NOAA Weather Radio (NWR) broadcasts and NOAA Weather Wire Service (NWWS) teletypewriter releases to the news media, radio, and television, informed the Jackson public, by noon Friday, that a record flood would occur and a 38.0-foot stage was not out of the question. Later forecast revisions indicated that (a) water would be in areas it had never been experienced before, (b) all indications pointed to a flood record proportions, and (c) it was entirely possible for stages of 39.5 to 40.0 feet to be reached by late Saturday. (At 6:00 p.m., on Saturday, the river height reached 39.7 feet.)

On Saturday morning, the RFC predicted a peak inflow of 180,000 cfs into the reservoir on the basis of information received from the U.S. Geological Survey

(USGS). USGS gages measured actual flows at the upstream stations totalling 123,000 cfs at this time. Using these gages, the USGS was projecting a peak inflow to the reservoir of 160,000 cfs. They advised the Ross Barnett Reservoir operator to expect this inflow on Sunday. Later Saturday afternoon, RFC Slidell issued a forecast for a 42.0 foot crest at Jackson on Monday, April 16. This stage was not issued by WSFO at that time. The forecasters considered that the levees would be topped on the east bank in Rankin County around Richland, Flowood, and Pearl City before that stage would be reached. The area would then become a storage space for water, thereby reducing the height of the river stage. Over topping, however, did not occur because the levees were built up by the local citizens and the COE. The final crest was not reached until April 17, and established a new record height of 43.25 feet.

In Jackson, warnings were given of a record flood event and accurate forecasts were made of the stages to be expected in the next 24-hours. However, the public was not served with accurate early forecasts of the magnitude and timing of the ultimate flood crest. Still, in the opinion of the survey team, the frequency of forecasts and river statements were more than adequate and the quality of the issuances were good considering the data and forecast procedures available. While the river statements did not give crest forecasts, neither did they always make it clear that the forecast stages issued for Jackson were not crest forecast.

HYDROLOGIC CONSIDERATIONS

The problems of river forecasting at Jackson are twofold. First, the operations of the Ross Barnett Reservoir must be considered, particularly, the schedule of future reservoir release rates, and second, the complex hydraulic system of the Pearl River through Jackson is complex due to levees and highway construction in the flood plain.

Reservoir Operations: Forecasts of inflow to the reservoir were produced by RFC Slidell and disseminated by WSFO Jackson. There was a substantial change in the peak inflow forecast from the Friday forecast of 120,000 cfs to the Saturday forecast of 180,000 cfs. Although there was no additional rain reported during the period between these forecasts, the reports from upstream USGS river gages indicated substantially larger runoff response. The actual peak inflow occurred near midnight Sunday and was about 162,000 cfs.

Coordination between the NWS, COE, and the reservoir operator was not sufficient for NWS to know the timing of future reservoir releases. Relationships with the reservoir operator were not strong because the operator normally receives inflow information from USGS. However, on Saturday afternoon the RFC forecast for a sustained 24-hour inflow of 180,000 cfs was relayed to him. The operator subsequently worked with COE in regulating the reservoir level and release rates. The maximum outflow was 125,000 cfs. The WSFO did not participate in the COE and reservoir operator strategy discussions for scheduling water releases; rather the forecasts were developed from the information passed to the WSFO by the operator. Therefore, NWS had only limited information on which to prepare forecasts of the magnitude and timing of the peak stage at the US Highway 80 gage.

The absence of a service hydrologist at Jackson during this flood episode also contributed to the coordination problem between NWS and reservoir operations. Normally, WSFO Jackson has a service hydrologist responsible for river forecasts and warnings; but the position has been vacant due to a university training assignment. As a result, the river forecasting responsiblities, during the flood, were assumed by the MIC and his Principal Assistant. The Warning and Preparedness Meteorologist at Jackson had been temporarily assigned to the river desk, but he was off-station attending a hydrology training session. A temporary replacement, sent from RFC Slidell, had little familiarity or experience with the Jackson forecast point, but did provide expert consulting service and served as an effective member of the staff.

While the survey team believes that the absence of the service hydrologist during the flood emergency was not a predominant factor affecting the quality of forecasts issued by the WSFO, the vacancy did impact the efficiency of operations. Not having a hydrologist resulted in the loss of coordination with Jackson officials, some pre-flood preparation of special and local forecast schemes, and the development of preparedness. Specifically, coordination with COE, USGS, and the reservoir operations was limited.

Forecast Operations: The complex hydraulic system through which the water passed in the Jackson area also contributed to the forecasts of the WSFO being lower than finally observed. The forecasts are based on flow rate curves which translate the river flow into stages. Three such curves were in existence. The WSFO had rating curves prepared by USGS that provided for stages of 36 feet with flows of 52,000 cfs as the maximum. At RFC Slidell, this rating curve was extrapolated on the basis of semi-log linear extension from a stage of 36 feet for 52,000 cfs to 42 feet for 163,000 cfs. The rating curves available to RFC Slidell and WSFO Jackson reflected conditions prior to the construction of the levee systems and highway bridges. The COE had developed a rating curve for the Federal Flood Insurance Administration. It took into account the levee and highway construction and gave a stage of 42.5 feet for a discharge at the US Highway 80 gage of 120,000 cfs, compared to the 40.5 feet on the Slidell extension. WSFO Jackson did not have the results from this most recent flood insurance study updated by COE. The study was completed in February 1977 but had not been published or relayed to NWS.

DISSEMINATION AND COMMUNITY RESPONSE

The key warnings to the City of Jackson were provided to the Mayor on Friday morning, April 13, at the Jackson/Hinds EOC. The Mayor and his department heads were briefed on the areal coverage of the heavy rainfall, the RFC Slidell's forecast for a reservoir inflow of 120,000 cfs with a corresponding crest stage of 38.5 to 39.5 feets, and that these projected figures represented a flood greater than any previously recorded.

Statements were isssued over NWR, NWWS, and the National Warning System (NAWAS). Most of the information on the flood situation went directly from the WSFO to the media and general public via NWWS, NWR, and by telephone. The

Civil Defense and disaster preparedness officials applied the information received from the WSFO to their local needs. The news media used the EOC as its primary source of flood information. Press releases made available by the EOC were based on information from the WSFO, as well as information from the COE, USGS, and the reservoir operator.

In general, the public forecast and warning statements were good and well-written. Most statements were rapidly and successfully disseminated despite a few teletypewriter problems. The NOAA-operated dissemination networks - NOAA Weather Radio and NOAA Weather Wire Service - functioned well and served as the principal channels for distribution of information to local officials and the general public. At three NWR sites some problems were encountered as a result of lightning strikes and other technical difficulties, however, these did not severely hamper total effectiveness. Both networks were augmented by NAWAS, local law enforecement communication circuits, mass media - radio and television, telephone, and volunteer amateur radio operators from the surrounding areas. On few occasions, telephone communications were extremely difficult due to the massive number of calls to and from the NWS offices. All telephone circuits were overloaded. Even unlisted numbers for data acquisition systems became known to the public and made access to these reporting locations by NWS more tedious and time consuming.

Many people were either not aware of their danger, or refused to believe the degree of danger. Many wanted to know specifically the degree of danger with respect to their location and property, which was beyond the ability and responsibility of WSFO Jackson and NWS.

Aerial photograph of Jackson, Miss., with Ross Barnett Reservoir in background.
(Photograph courtesy of Charlie Ridge, NWS, Southern Region)

Homes flooded in suburban Jackson, Miss. (Photograph courtesy of Charlie Ridge, NWS, Southern Region)

Aerial photograph of downtown Jackson and State Coliseum Fairgrounds.
(Photograph courtesy of Charlie Ridge, NWS, Southern Region)

Downtown Jackson, Miss. (Photograph courtesy of Charlie Ridge, NWS, Southern Region)

CHAPTER 1
GENERAL DESCRIPTION

The rainstorm that brought record flooding to the Mississippi and Alabama areas along the Pearl and Tombigbee Rivers (fig. 1.1) was closely associated with the storm system that struck the Wichita Falls, Tex., area the previous day. (See Natural Disaster Survey Report 80-1, Red River Valley Tornadoes of April 10, 1979.) The torrential rainfall caused flash flooding in the Chunnenugga Hills of Mississippi and Alabama, April 11-13, and later brought record flows to the river plains in both States, April 17-22.

Moist, warm air from the south being lifted over a weak, near stationary front generated the rain-producing thunderstorms that dumped 20 inches of rain in the headwaters region of the Pearl and Tombigbee Rivers, in the vicinity of Louisville, Miss. Most of the rain occurred between Wednesday, April 11, and Friday, April 13. During this period, thunderstorms continued to develop and redevelop over essentially the same area.

When the storm ended on Friday morning, at least 8 inches of rain had fallen over the upper Pearl Basin, with amounts of between 15 and 20 inches over most of Choctaw, Winston, and Oktibbeha Counties (fig. 1.2) in the east central part of Mississippi. Runoff potential at the start of this event was high owing to saturated soils and most streams were still near or above flood stage from the moderate flood of April 7-9. The Pearl River at Jackson was still at 28 feet or 10 feet above flood stage. Therefore, the rains beginning on April 11 caused flash flooding in numerous headwater areas in Mississippi and Alabama. At river forecast locations, record levels were produced in the Yazoo, Leaf, Chickasawhay, and Big Black, in addition to the 8 points in the Pearl and the 4 points in the Tombigbee basin. Selected values are shown on fig. 1.3.

At Jackson, Miss., the flood stage is 18 feet. The previous record flood in 1902 had a stage of 37.5 feet. The most recent prior record flood was 37.24 feet in December 1961. On April 17, 1979, the Pearl River crested at 43.25 feet - 25 feet above flood stage. Downstream at Monticello, the river crested at 34.50 feet on April 20 - about 2 feet above the previous record flood stage for that area. Further downstream, at Columbia, the crest reached 27.70 feet on April 22, surpassing the 1974 record by 0.56 foot. The Corps of Engineers has categorized the Pearl River flood as one with a likely occurrence of once in 500 to 1,000 years. In the Tombigbee River Basin, all the mainstream points below Columbus and the Noxubee, at Macon, exceeded their previous record levels.

Preliminary estimates provided by Mississippi and Alabama State officials placed total damages to crops, roads, bridges, and both public and private buildings in excess of $700 million. The Jackson area which was the hardest

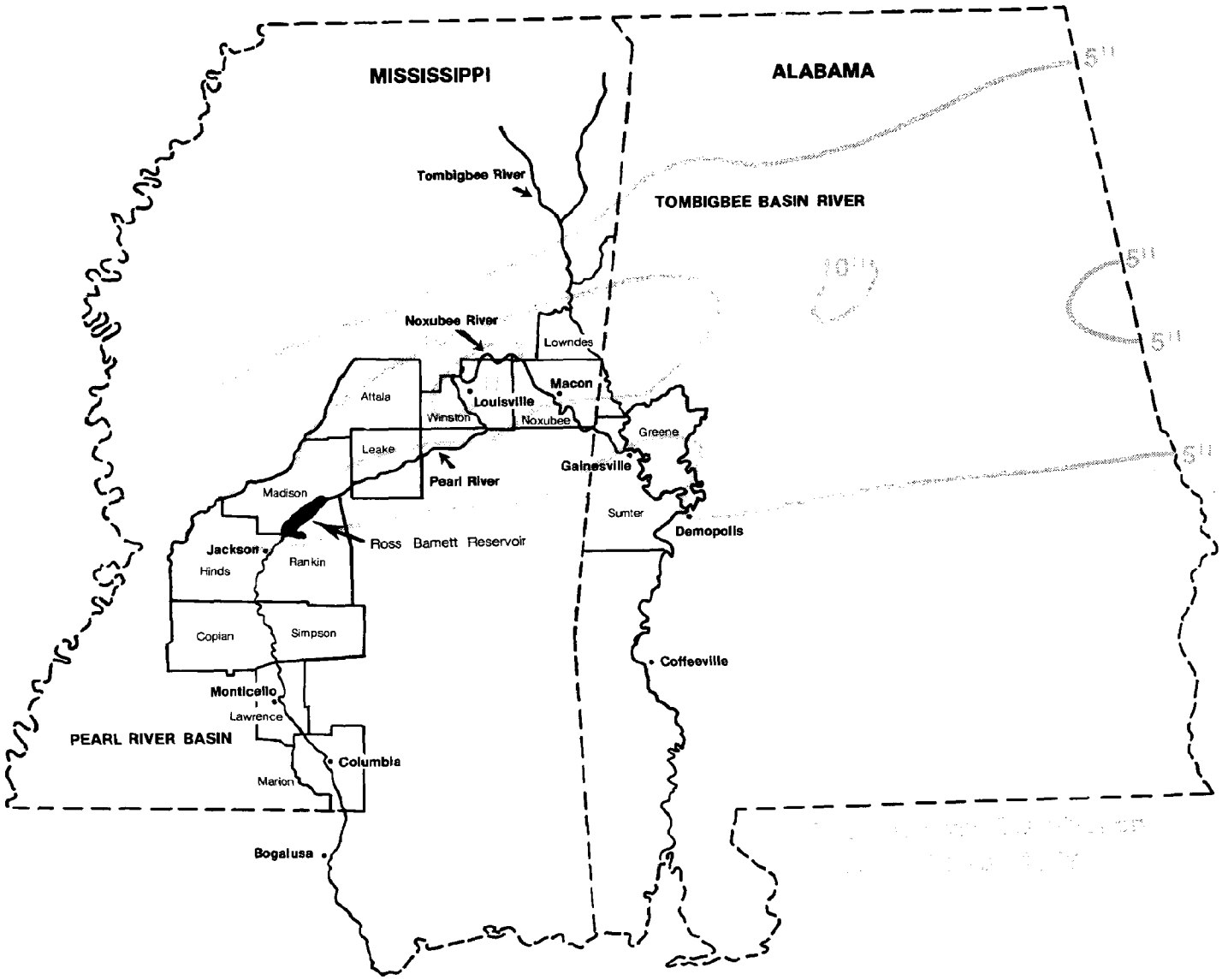


Figure 1.1 -- Total Rainfall Distribution for April 12-13, 1979.
Counties outlined were declared disaster areas.

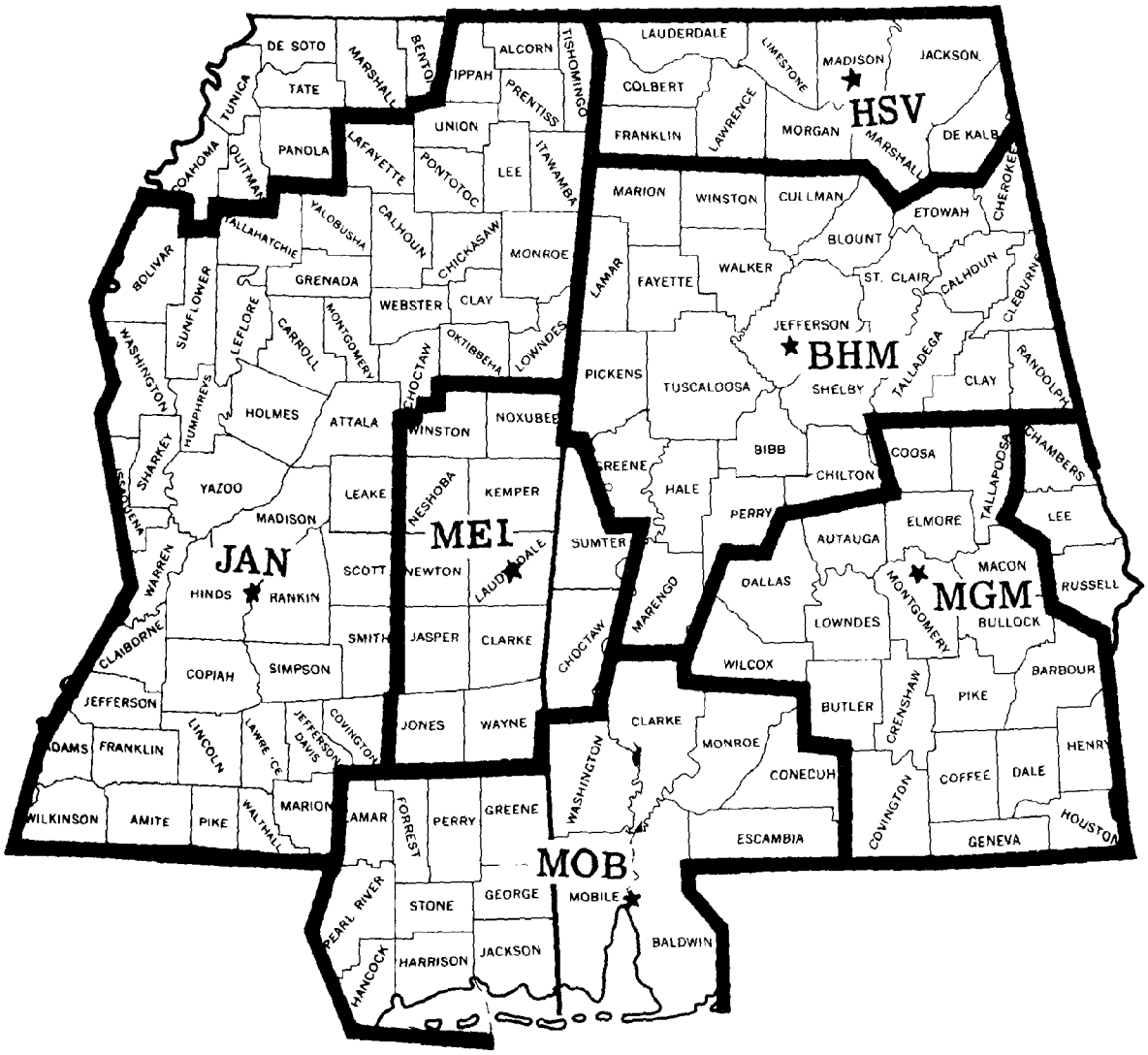


Figure 1.2 -- County Warning Areas for NWS Offices in Mississippi and Alabama.

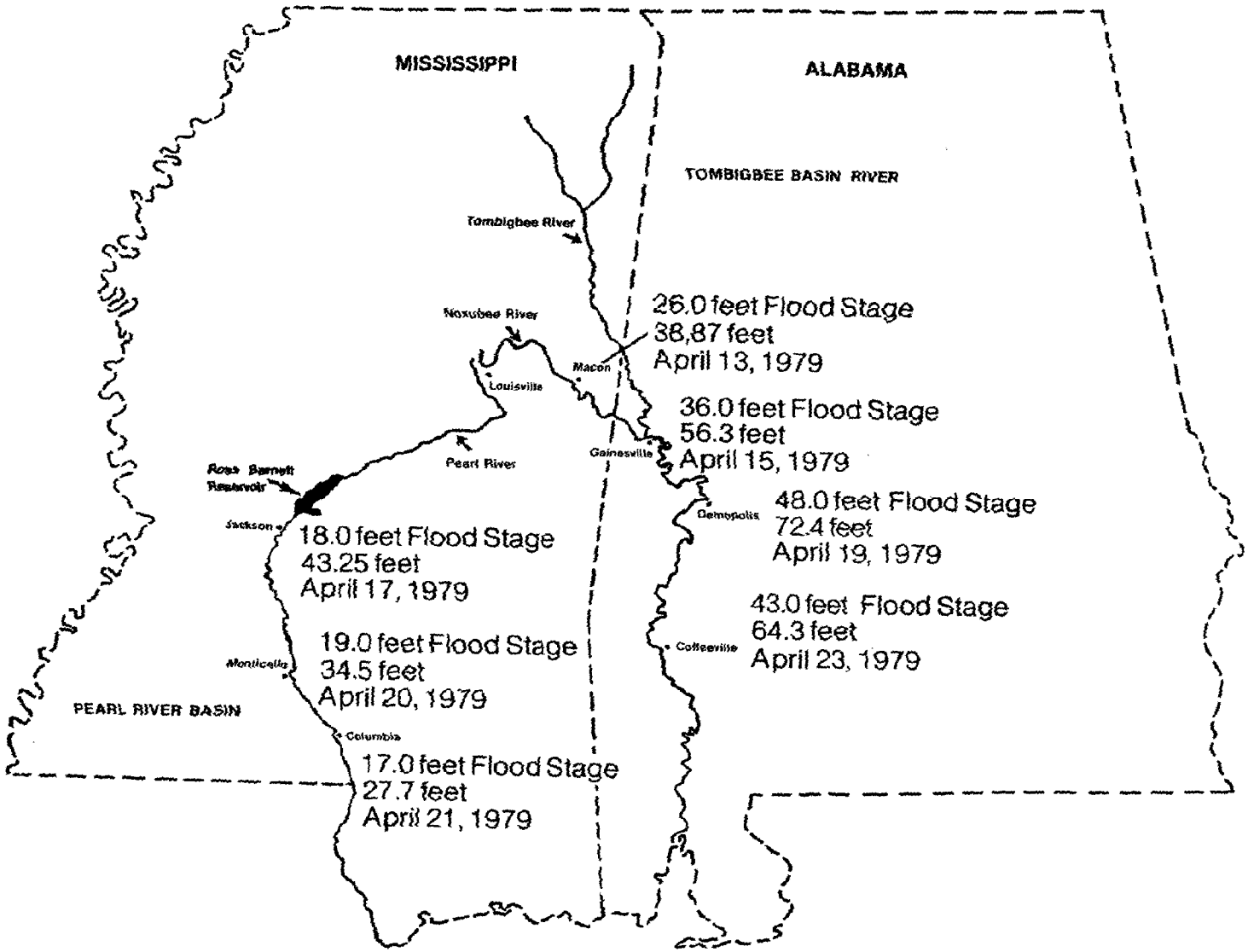


Figure 1.3 -- Record flood stages for the Pearl and Tombigbee Rivers.

hit about 15,000 people were evacuated from their homes and an estimated $500 million in damages resulted from the flood (fig 1.4). Farther downstream on the Pearl and Tombigbee Rivers, damages were less but still severe.

According to State Civil Defense officials, the floodwaters of the Pearl and Tombigbee Rivers resulted in four deaths in Mississsippi and five in Alabama. Three children drowned in the area of the Pearl's headwaters near Louisville, when they tried to leave their flooded home. The other death occurred in the Jackson area, when a child fell off of her porch into the water. The five deaths, in Alabama, were also attributed to drownings.

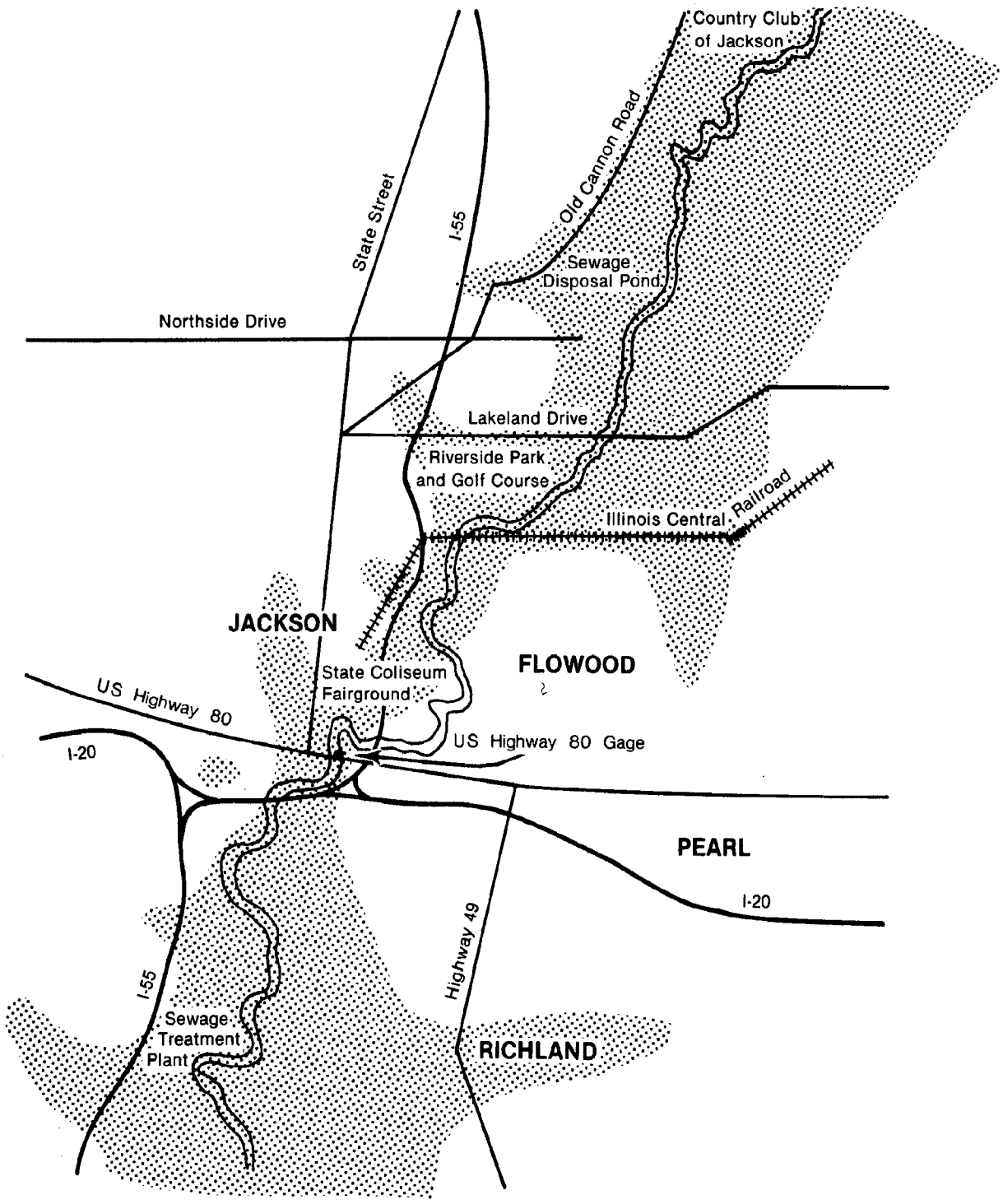


Figure 1.4 -- Map of the flooded areas in Jackson, Flowood, Pearl, and Richland.

CHAPTER 2
SIGNIFICANT METEOROLOGICAL CONDITIONS AND FORECASTS AND FLASH FLOOD WARNINGS

This chapter presents an analysis of the meteorological conditions and forecasts relevant to the flood-producing rainfall, including an assessment of the flash flood warning program. The survey team did not review extensively the severe thunderstorm and tornado warning program, although severe local storms did occur during the heavy rain event.

Appendix 2A provides a brief description of the organizational structure and levels of responsibility for the National Weather Service.

SIGNIFICANT METEOROLOGICAL CONDITIONS AND FORECASTS

SYNOPTIC SITUATION DISCUSSION

The tremendous rainstorm that fell on Mississippi and Alabama during the 48-hour period beginning 6:00 p.m. CST (all times in this report are Central Standard Time (CST)) April 11, 1979, resulted from interactions of different scales of atmospheric motion. During the preceding several days a major long-wave trough was becoming established over the western United States. This feature was perhaps the "driving force" behind all that followed. It induced a strong northward flux of low-level moisture from the Gulf of Mexico, caused continued southwesterly flow in the mid- and upper troposphere, and helped establish a good upper tropospheric diffluent pattern that favors the maintenance of convective storms. Ultimately, however, the heavy rainfall was a result of convective storms redeveloping upstream and moving over essentially the same location.

More than 48 hours before the onset of the heavy rain in Mississippi, a major trough had become established over the southwestern United States with a series of following short waves stretching back into the Pacific. Good southerly flow over a weak quasi-stationary front in the northern Gulf of Mexico through Texas was setting up conditions for the devastating tornado outbreak on the afternoon of April 10 and subsequent moderate to heavy rainfall in the central Plains. By 6:00 a.m., April 11 (fig. 2.1), a deep vertical low pressure center had formed and moved into southeastern Colorado with the associated surface front pushing through central Texas. Moderate to heavy precipitation was falling or developing from the central Plains eastward into the mid-Mississippi Valley.

By 6:00 p.m., April 11 (fig. 2.2) the situation was beginning to appear more ominous for the southeastern United States. The surface front had moved to central Arkansas and northeast Texas while showing definite signs of retardation in south Texas. An instability line with cloud tops of about 50,000 feet stretched from West Central Illinois through western Tennessee to southwest Louisiana and was pushing eastward about 30 knots. The high surface dewpoints in the low 70's were representative of the deep moist layer which

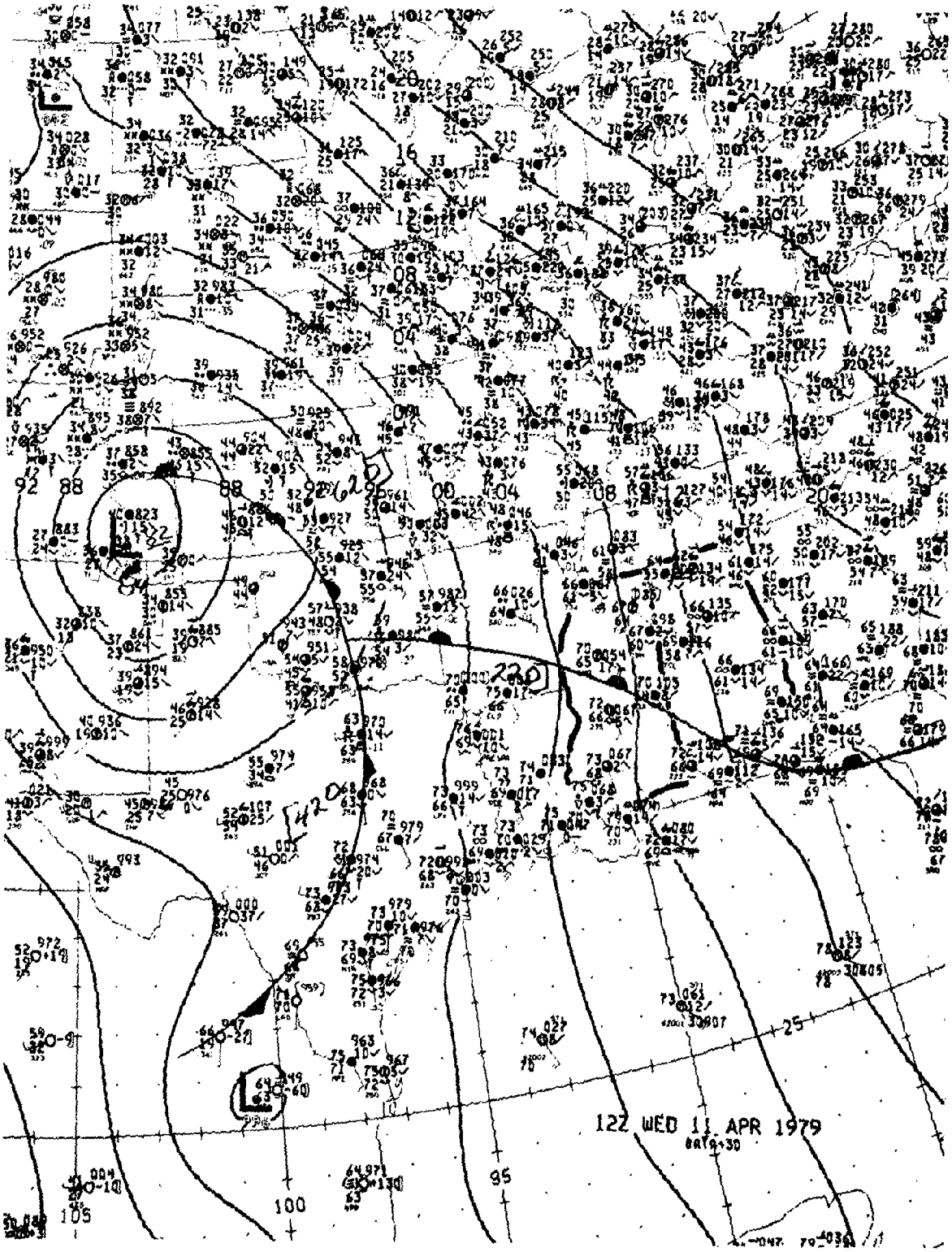


Figure 2.1 -- Surface weather analysis for Wednesday, April 11, 1979, at 6:00 a.m.

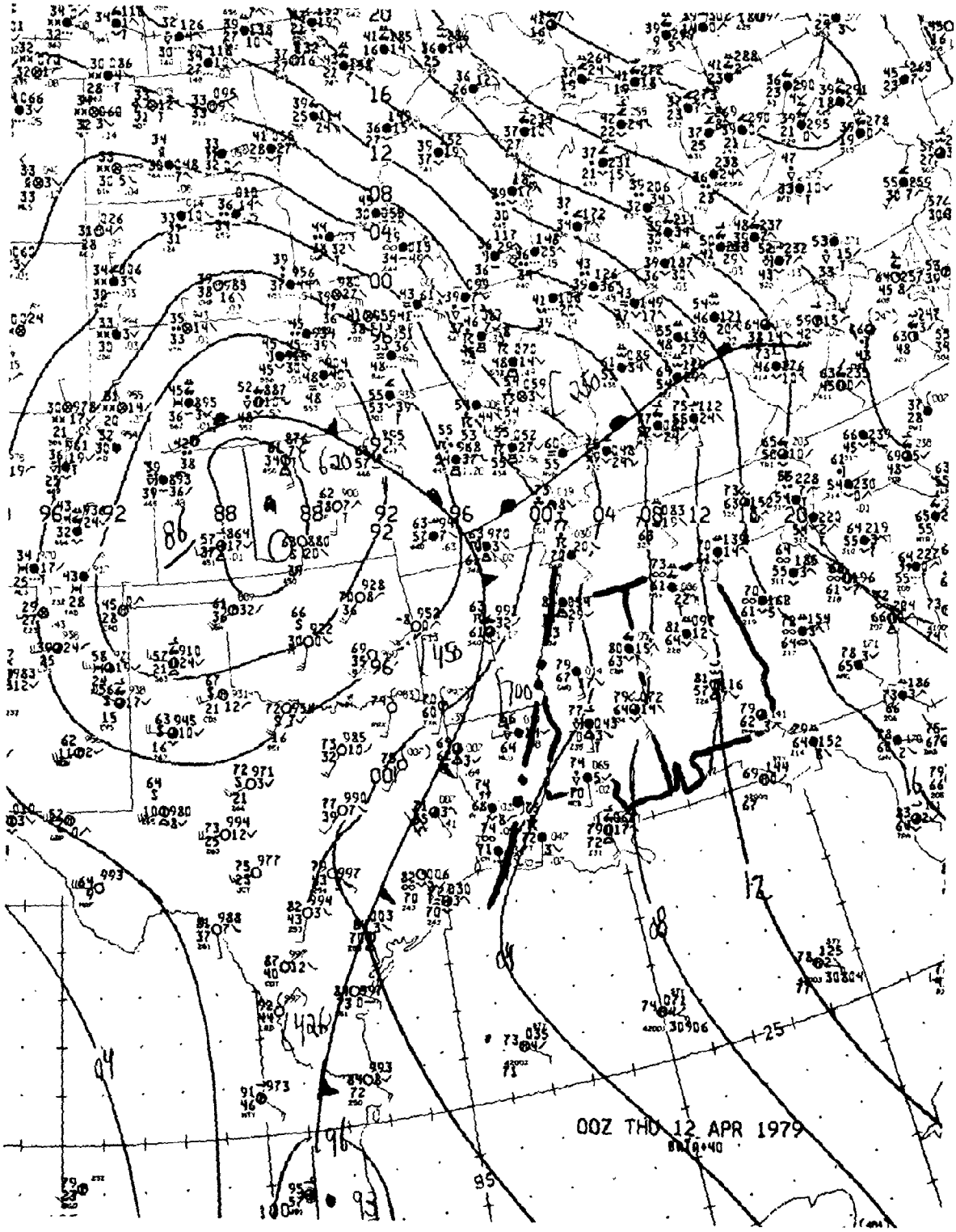


Figure 2.2 -- Surface weather analysis for Wednesday, April 11, 1979, at 6:00 p.m.

existed over southern Louisiana. Wind field calculations indicated enormous convergence at 850 mb and divergence at 250 mb with the centers over western Mississippi--a condition favorable for intense vertical motion and storm development. The enhanced infrared (IR) photo in figure 2.3 shows the location and intensity of this instability line.

During the night the instability line pushed slowly eastward across Tennessee and the northern portions of the Gulf States. By 6:00 a.m., April 12, the instability line extended from northeast Alabama to southwestern Mississippi, south of Jackson (fig. 2.4). By this time, Jackson had received nearly 6 inches of rainfall; the headwaters of the Pearl River had some reports of nearly 10 inches.

Within a couple of hours a strong surface boundary - strongly resembling a front - had become well established, as is shown by the 8:00 a.m. hourly surface data plot and sketch analysis (fig. 2.5a). Figure 2.5b shows this same area at 1:00 p.m., when temperature contrasts were approaching 20° F. The satellite photo for 7:30 a.m. (fig. 2.6) shows clearly that the southern edge of the major cloud mass nearly coincides with the surface data. Figure 2.7 is the automated radar analysis for this time and shows similar information. It is also extremely important to notice the redevelopment of convective cells upstream or over central and western Louisiana as these continued to develop and eventually moved over the same area that had received nearly 10 inches of rain the previous night. The southern edge of the cloud mass assumed frontal characteristics, and remained a strong, quasi-stationary boundary intercepting the flow of very moist unstable air from the Gulf of Mexico.

By 6:00 p.m., April 12, the instability line lies to the southeast of Jackson (fig 2.8) and continues to move slowly southward. At 850 mb, the flow gradually changed from strong southerly to northwesterly, effectively ending the precipitation. During the night, the last of the series of upper air short waves moved from eastern New Mexico to eastern Oklahoma and by 6:00 p.m., April 13, was pushing through the southern Appalachians.

GUIDANCE FROM THE NATIONAL METEOROLOGICAL CENTER

Numerical Guidance

A after-the-fact review of the numerical guidance available in the period preceding and during the heavy rainfall indicates that the two numerical models used (the Limited Area Fine Mesh (LFM) Model and the 7-Level Primative Equation (7LPE) Model) did not yield accurate prognoses. The Quantitative Precipitation Branch (QPB) forecasters at NMC later indicated that the "available numerical guidance was decidedly of a poorer than desirable quality and considerably below the skill level required for a manual or subjective interpretation of the events, as well as being well below the quality typically expected."

In general, both models made similar forecasts with similar errors, especially of the circulation. Much of this error was apparently related to a failure of the models to place correctly the deep occluded low-pressure system far enough

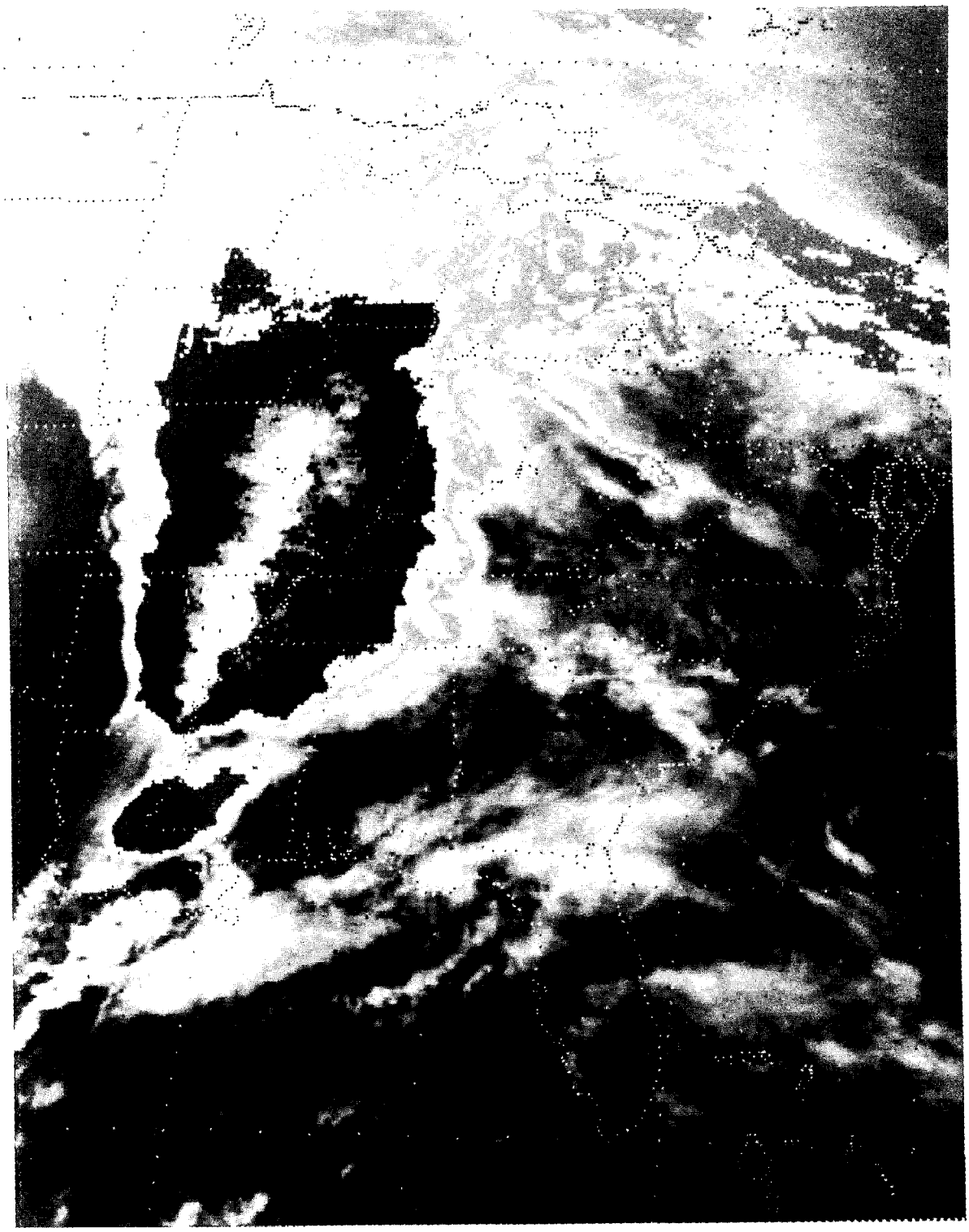


Figure 2.3 -- Enhanced Infrared (IR) Satellite photograph for April 11, 1979, at 6:00 p.m.

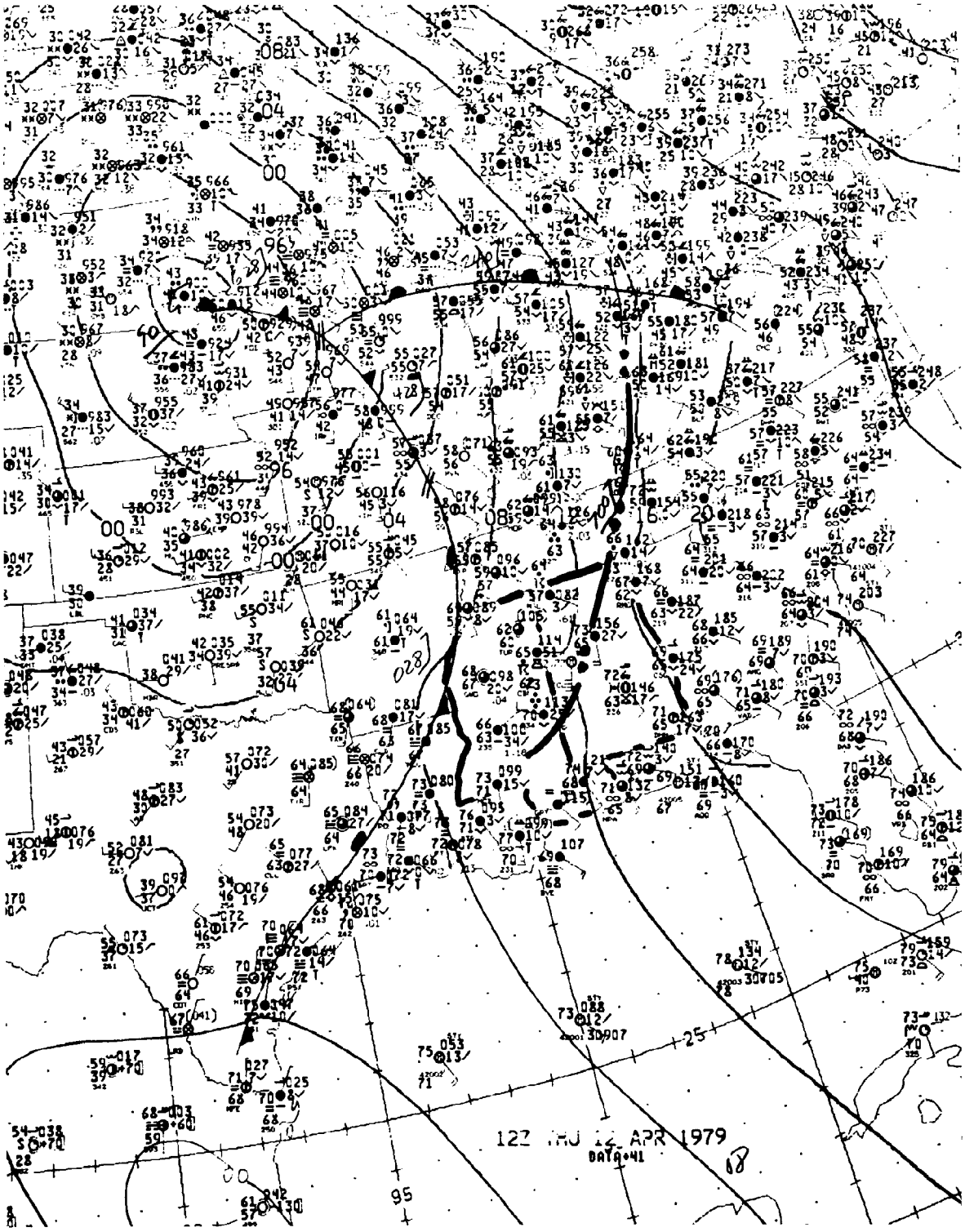


Figure 2.4 -- Surface weather analysis for Thursday, April 12, 1979, at 6:00 a.m.

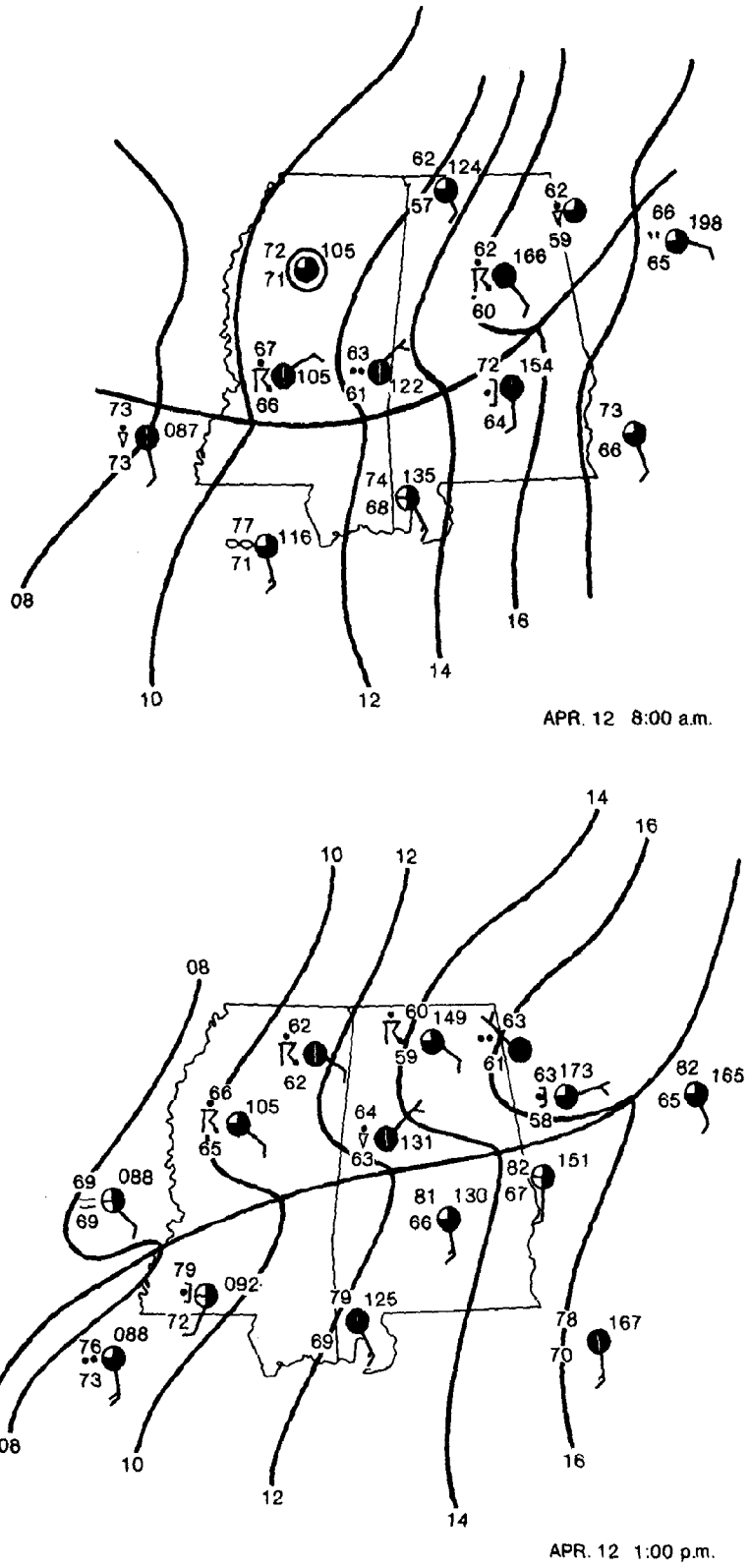


Figure 2.5 -- Surface data plot and sketch analysis for April 12, 1979, (a) 8:00 a.m. and (b) 1:00 p.m.

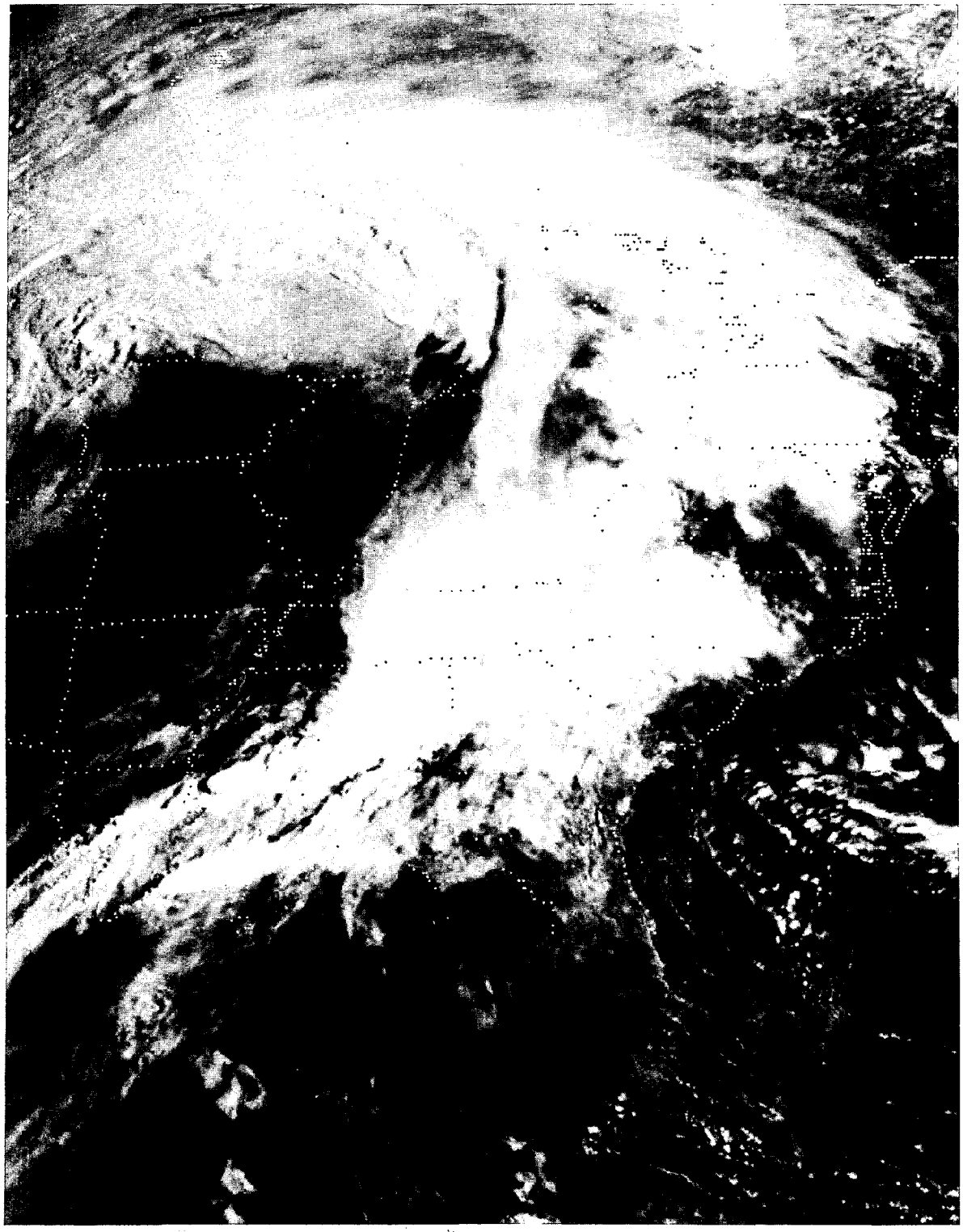


Figure 2.6 -- Visual Satellite photograph for April 12, 1979, at 7:30 a.m.

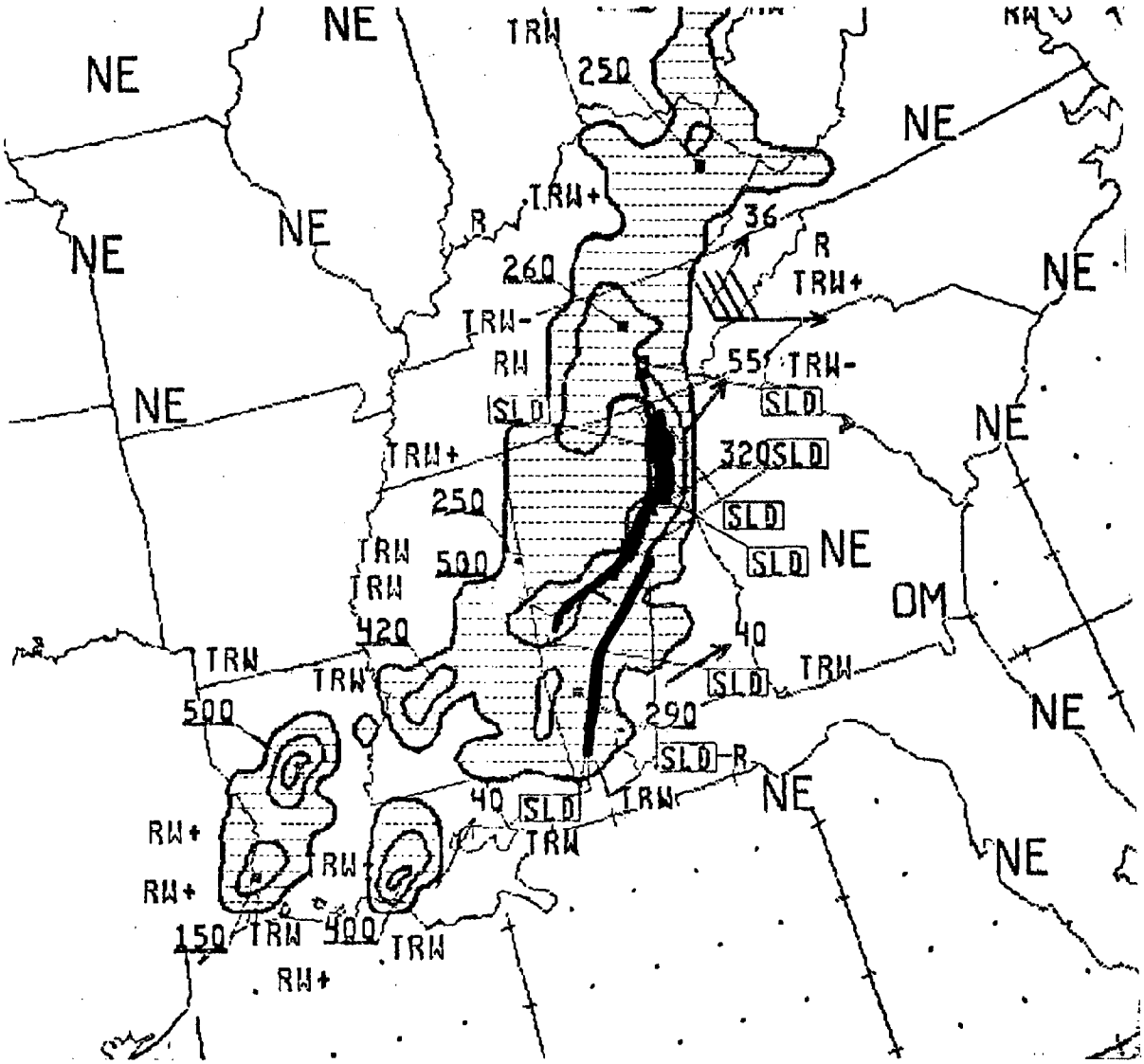


Figure 2.7 -- Automated Radar Chart for April 12, 1979, at 7:35 a.m.

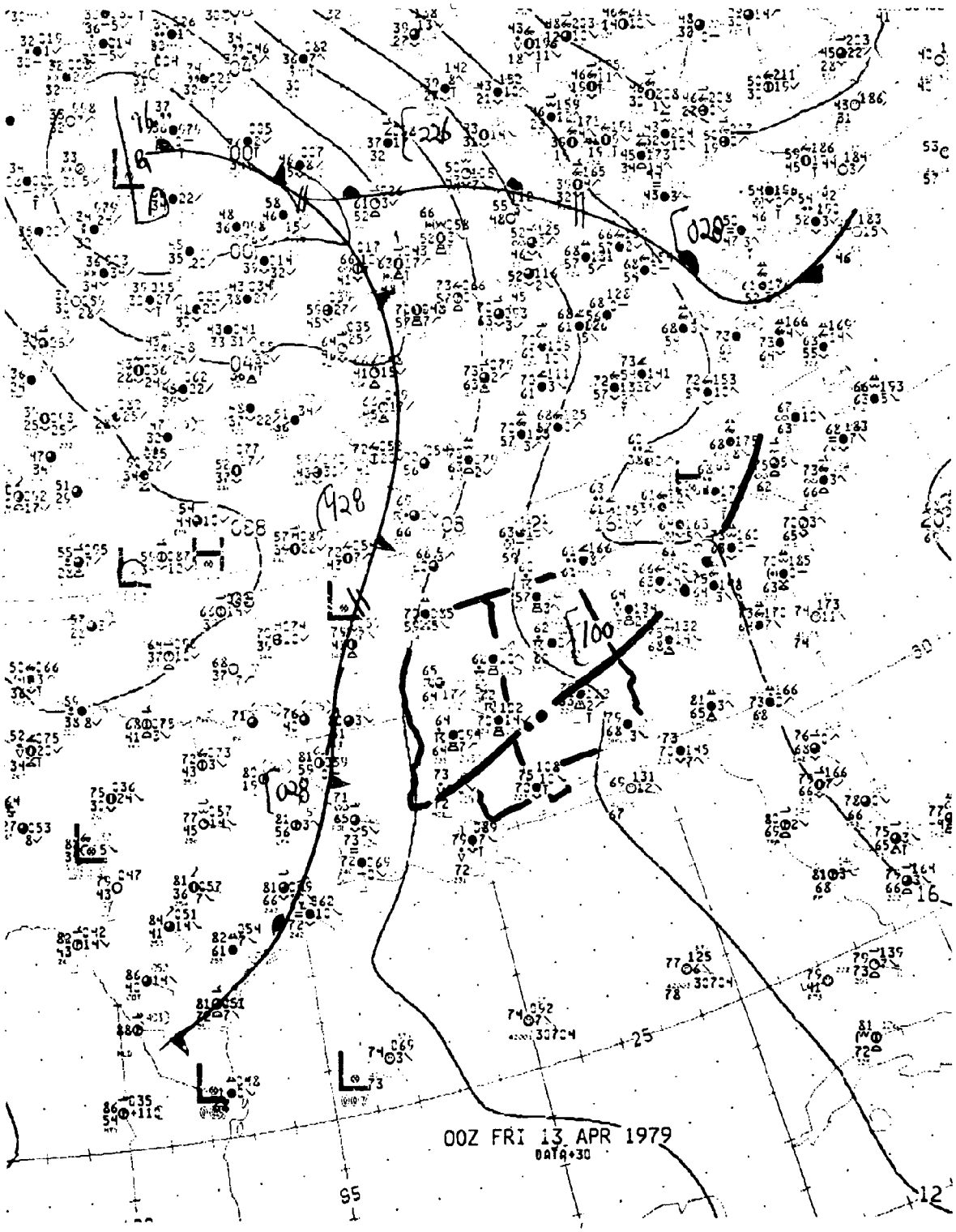


Figure 2.8 -- Surface weather analysis for Thursday, April 12, 1979, at 6:00 p.m.

north in the northern Plains. For example, at 6:00 p.m., Thursday, April 12, this low was centered over eastern North Dakota. The LFM 48-hour forecast valid at this time placed the center over northwest Missouri; the LFM 36-hour forecast valid at the same time placed the center in western Iowa.

The net effect of these errors in the Gulf States was to predict upper-air heights with far too low values, to predict a too rapid eastward movement of the frontal boundary, and to predict erroneously a tongue of dry air over the region that was to get the heaviest rainfall.

From the standpoint of precipitation forecasting, the most critical numerical forecasts were those verifying at 6:00 a.m., April 12; 6:00 p.m., April 12; and 6:00 a.m., April 13. The 36- and 48-hour LFM prognoses valid for these times displayed a 200-meter error in the 500 mb height over northern Mississippi. These large height errors in the longer range caused an implied erroneous frontal movement, distortion of the thermal field, displacement of moisture and therefore precipitation, and misleading implications concerning convective activity.

Even greater errors were noted on an earlier LFM model run that used the 6:00 a.m. data on Tuesday, April 10. The 24-hour prognosis contained a height error of more than 300 meters at 500 mb, produced a very erroneous jet level wind pattern, and incorrectly predicted a 4-inch plus rainfall area along the Mississippi-Alabama border for the 12 hours from 6:00 p.m., April 10 until 6:00 a.m., April 11. No rain fell during this period.

Objective statistical guidance giving probability of precipitation amounts is computed for each model run from various output fields. This guidance was slightly better than the explicit model precipitation forecast noted above, but was inconsistent and not very helpful to the QPB or WSFO forecaster.

Subjective Quantitative Precipitation Guidance

Before 6:00 a.m. each morning, the QPB duty forecaster prepares and issues a Quantitative Precipitation Forecast (QPF) for the 24-hour period ending at 6:00 a.m. the next day (this forecast termed Day 1), and a second QPF for the following 24 hours (Day 2). These forecasts are based on interpretations of the latest available upper-air data and numerical guidance and interpretations of the most recent surface, radar, and satellite data. Each afternoon, the QPF for the second 24-hour period (Day 2) is revised in accord with 6:00 a.m. upper-air data and numerical guidance. Forecasts are sent to the NWS offices on facsimile and teletypewriter.

At certain times during the day, the QPB forecaster considers what extremes of precipitation are likely to occur and whether they would exceed the Flash Flood Guidance values issued by the River Forecast Centers. The QPB then prepares the Excessive Rainfall Potential Outlook, an outline of the area(s) where excessive rainfall is likely to occur. This product is regularly issued at 2:00 a.m., 9:00 a.m., and 3:00 p.m., with all outlooks valid until 6:00 a.m. the following morning. During some portions of the day, the forecaster works toward improving previously issued forecasts and will either issue

special forecasts via the RAWARC (Radar Report and Warning Coordination) teletypewriter circuit or telephone them to pertinent WSFO's.

In general, during this heavy rainfall event, the 24-hour QPF's indicated a likelihood of heavy rainfall over the northern and central portions of the Gulf Coast States. Although these forecasts were in error in location and amount, each forecast did represent a substantial improvement over the numerical guidance, particularly the 24-hour periods ending at 6:00 a.m., April 13 and 14. For these days numerical prediction placed a consistent 3.00-inch maximum rainfall center over the West Virginia-Maryland-Pennsylvania region. The best of the subjective QPF's were the "Day 1's". These included a large 2.00-inch area through the lower and central Mississippi Valley for the 24 hours ending 6:00 a.m. on April 12, (fig. 2.9a). For April 13, it featured a 3.00-inch area in the northern portions of Mississippi and Alabama and southern Tennessee (Figure 2.9b). And for April 14, the Day 1 QPF showed a 4.00-inch maximum, mostly in northern Alabama (Figure 2.9c). The longer range QPF's (i.e., the updated Day 2's) clearly showed the effects of the numerical misguidance.

Largely because of the inability of the numerical QPF's to handle precipitation extremes, due to their grid size, modeling deficiencies, and data constraints, the preparation of Excessive Rainfall Potential Outlooks depends to a very large extent on the interpretation of current data. These outlooks were considerably more successful than the numerical QPF's in delineating the threat area and estimating the magnitude of rainfall. The area outlook issued at 9:00 a.m., April 11, about 9 hours before the onset of the rainfall in western Mississippi, included the northern third of Mississippi and indicated "precipitation amounts over three inches likely with isolated areas of five inches possible" (fig. 2.10a). At 2:00 p.m., the area issued was similar, but, unfortunately, reduced the excessive precipitation area over northern Mississippi (fig. 2.10b). However, at 8:50 p.m., April 11, a special discussion (operational forecast bulletin) was sent that included essentially all the heavy rain area and indicated 3 to 4 inches (fig. 2.10c).

At 2:00 a.m., April 12, the outlook for the 24-hour period ending at 6:00 a.m., April 13, included most of Mississippi, the northern half of Alabama, and the southern Appalachians and indicated that over 3 inches were likely (fig. 2.10d). At 9:00 a.m., this area was changed only slightly, but expected additional rainfall was increased to 5 inches (fig. 2.10e). By 2:00 p.m., the strength and stationary character of the instability line boundary, as well as the influence of the retarded surface front and a final upper-level impulse located over the Rockies, were recognized. This led to an outlook discussion which predicted additional amounts of 3 to 5 inches per 6 hours, with storm totals near 10 inches for the 24-hour period (fig. 2.10f).

On April 13, the 2:00 a.m. discussion included the northern Gulf States with 5 to 8 inches, which was too high. The 9:00 a.m. and 2:00 p.m. discussions correctly reduced the rainfall and moved it southeastward.

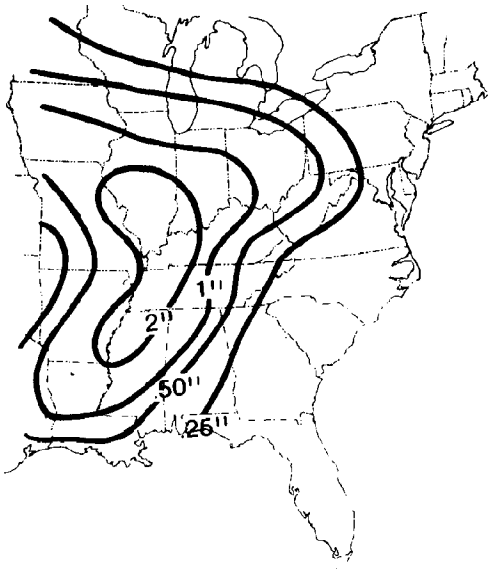


Figure 2.9a -- Day 1 Subjective QPF for 24 hours ending 6:00 a.m., April 12, 1979. Issued at 6:00 a.m., April 11, 1979.

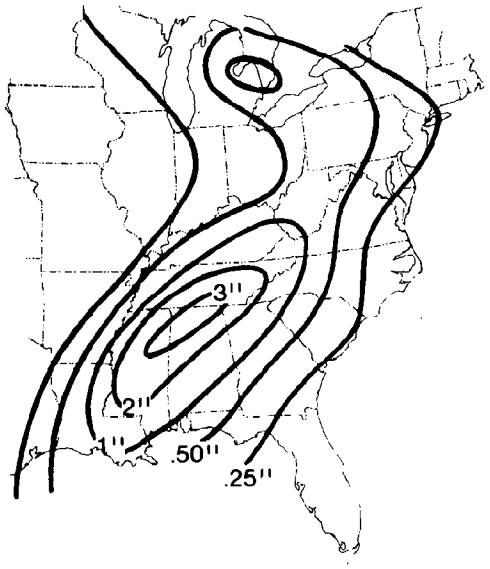


Figure 2.9b -- Day 1 Subjective QPF for 24 hours ending 6:00 a.m., April 13, 1979. Issued at 6:00 a.m., April 12, 1979.

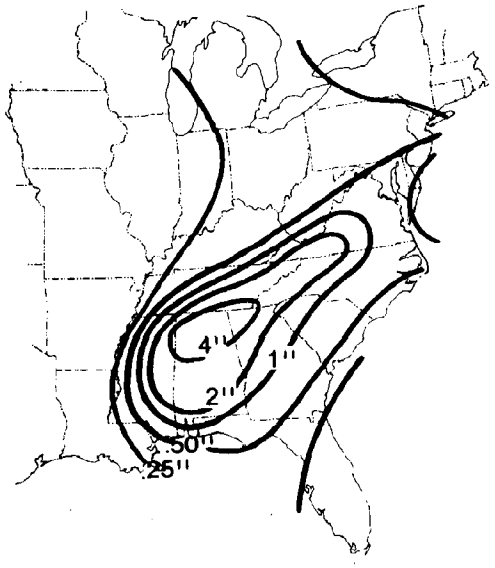


Figure 2.9c -- Day 1 Subjective QPF for 24 hours ending 6:00 a.m., April 14, 1979. Issued at 6:00 a.m., April 13, 1979.

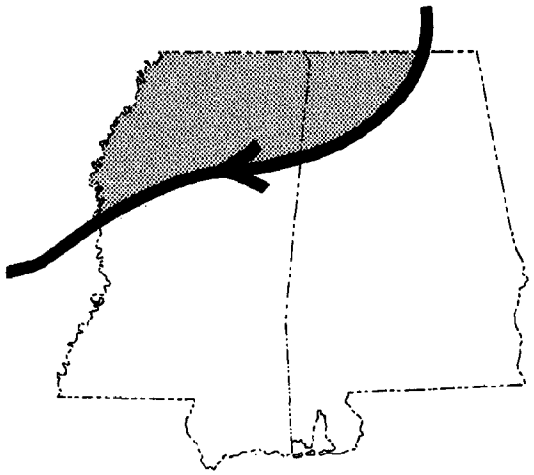


Figure 2.10a -- Excessive Rainfall Potential Outlook issued 9:00 a.m., April 11, 1979.

(Areas to the right of the line exceed Flash Flood Guidance)

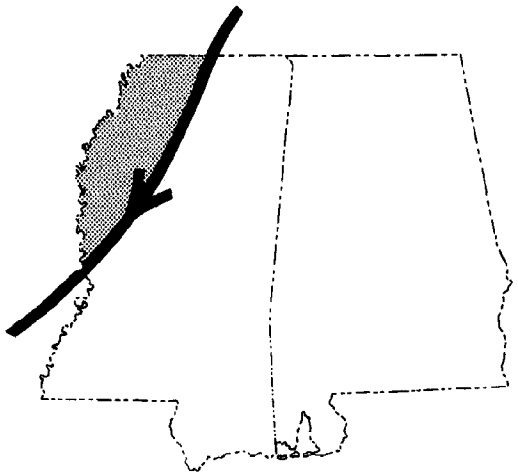


Figure 2.10b -- Excessive Rainfall Potential Outlook issued 2:00 p.m., April 11, 1979.

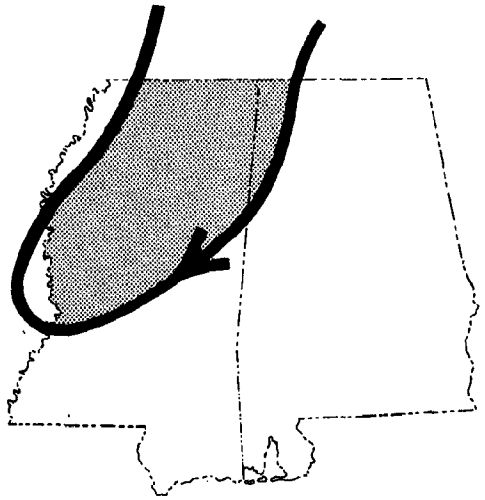


Figure 2.10c -- Excessive Rainfall Potential Outlook issued 8:50 p.m., April 11, 1979.

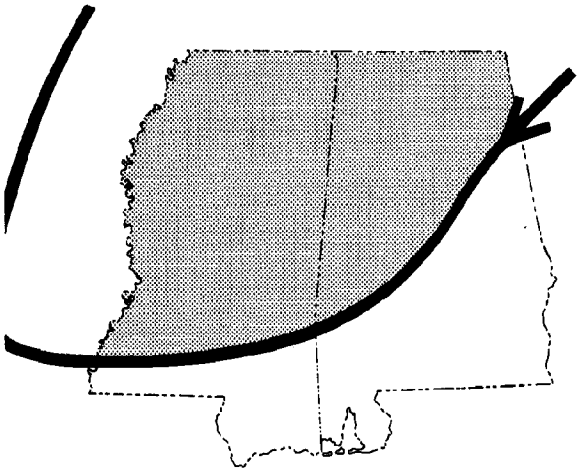


Figure 2.10d -- Excessive Rainfall Potential Outlook issued 2:00 a.m., April 12, 1979.

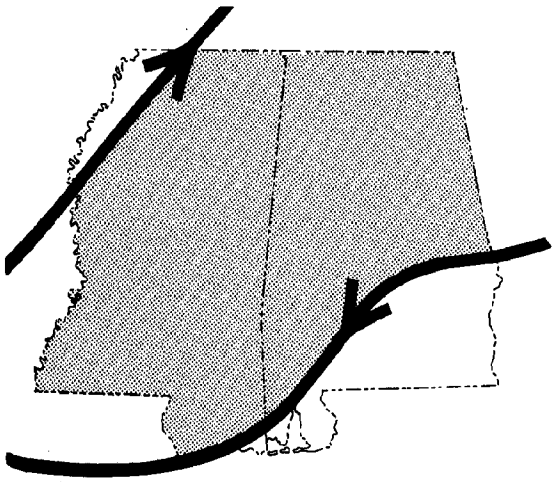


Figure 2.10e -- Excessive Rainfall Potential Outlook issued 9:00 a.m., April 12, 1979.

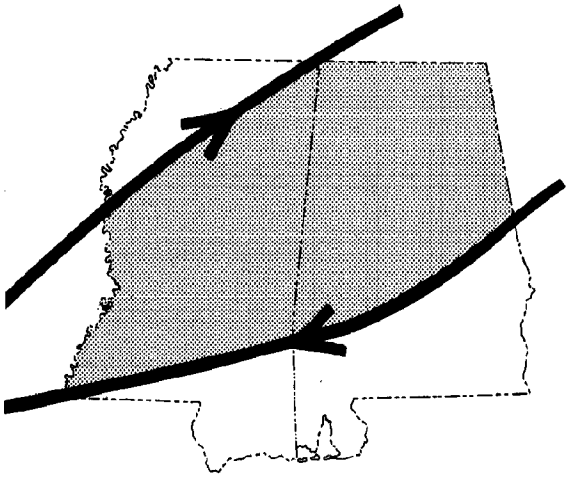


Figure 2.10f -- Excessive Rainfall Potential Outlook issued 2:00 p.m., April 12, 1979.

GUIDANCE AND FORECASTS FROM THE NATIONAL SEVERE STORMS FORECAST CENTER (NSSFC)

At 2:37 a.m., April 11, NSSFC provided an outlook for scattered severe thunderstorms for the 24-hour period beginning at 6:00 a.m. over a large area containing 12 States, including Mississippi and Alabama. The term, "scattered", as opposed to "isolated or few", is used when more numerous severe storms are expected.

At 5:00 a.m., April 11, NSSFC released a Severe Weather Statement for public distribution, noting that the weather was extremely dangerous and stating that the storms would have strong, possibly damaging winds, large hail, and possible tornadoes, and that very heavy rainfall was likely to produce flash flooding. When this statement was released, a tornado watch remained in effect for parts of Oklahoma, Arkansas, Texas, and Louisiana. NSSFC continued to issue tornado watch areas as the day went on and activity spread further east. Tornado Watch #77, valid from 5:15 p.m. to 11:00 p.m., April 11, included 64 counties in Mississippi. This watch was replaced, at 10:30 p.m. that evening by another which included a large part of central and eastern Mississippi and northwest Alabama.

The severe weather log at NSSFC for the 24-hour period covered by the 2:37 a.m. outlook listed 100 reports of wind damage, large hail, funnel clouds, or tornadoes. Severe local storms were reported in 11 States, including Mississippi and Alabama.

On Thursday, April 12th, the early morning outlook from NSSFC again called for scattered severe thunderstorms for all or portions of 14 States, including much of Mississippi and northwest Alabama. A severe weather statement went out again at 5:00 a.m., stressing the threat of severe weather and mentioning the potential for heavy rains in the outlook area. However, on the basis of the morning analyses, the convective outlook was revised at 9:00 a.m. to drop the expected coverage of severe thunderstorms from scattered to a few. The outlook noted that while "unstable air remains ahead of the surface system...pressure was rising over the frontal area" and "severe activity was not expected to be as intense as the last two days". Tornado watches were subsequently issued for parts of Louisiana, Mississippi, Alabama, and Georgia. Two of the four watch areas issued had severe activity during the valid period of the watch. The revised outlook was correct; only 23 severe storms were reported to NSSFC during the 24 hours ending at 6:00 a.m. on April 13.

On Friday, April 13, when the stagnant frontal system that had contributed to all the heavy rains finally began to move, severe activity again intensified in a fairly narrow zone from eastern Alabama through Georgia into South Carolina. The activity began about 9:30 a.m. and was over by 6:00 p.m., but, in this fairly short period, 46 severe storms, mostly wind damage or tornadoes, were reported. Twenty-nine of the 46 reports were in valid watch areas.

PUBLIC WEATHER FORECASTS AND WARNINGS

MISSISSIPPI

The forecasts issued by WSFO Jackson between early Wednesday, April 11, and early Thursday, April 12, reflected the NMC guidance in that they indicated a relatively short period of rainfall with the expected rapid movement of the frontal system through the State. As in the guidance, the extreme magnitude and the duration of the rainfall were not anticipated.

A summary of the precipitation forecasts contained in the zone forecasts for the area affected by the heaviest rainfall is contained in Appendix 2B.

In general, the forecasts were reasonably accurate for the first 12 to 24 hours, except for those issued early on Wednesday, April 11, and those issued early on Friday, April 13. The forecast, on April 11 did not reflect the magnitude and duration of the rainfall, while the forecast for the 13th held on to the precipitation too long.

Weather forecasts again became critical to the flood situation in the Jackson area early the following week of April 15, when record high river stages were threatening some of the levees. The forecaster paid particular attention to the wind forecasts, because wave action could have made the situation more critical. Further rainfall did not fall in the Pearl Basin until the flood crests were downstream.

The survey team reviewed warnings issued by WSFO Jackson and WSO Meridian between April 11 and April 13. During this period, WSFO Jackson, which has warning responsibility for 54 counties in the State, issued 29 severe thunderstorm warnings, 19 tornado warnings, 15 flash flood warnings, and 38 severe weather statements. WSO Meridian, with responsibility for 10 Mississippi and 2 Alabama counties, prepared 12 severe thunderstorm warnings, 3 tornado warnings, 9 flash flood warnings, and 9 severe weather statements. Almost without exception, the severe weather warnings were written well and disseminated rapidly.

ALABAMA

The survey team reviewed the State, Zone, and Agricultural forecasts issued by WSFO Birmingham. This review indicated that, as in the guidance available, the extended duration and extreme magnitude of the rainfall were not anticipated. Forecasts issued early on Wednesday, April 11, reflected a fairly rapid movement of the storm system through the State, and thunderstorms were expected earlier than they arrived. However, beginning with the zone forecasts issued late Wednesday morning, April 11, and continuing to Thursday afternoon, forecasts for the first 12 to 24 hours were reasonably accurate. By Thursday morning, April 12, forecasts on the end of the precipitation were good. Forecasts issued early Friday, April 13, again reflected the guidance in holding on to the precipitation too long, in these areas which had already received excessive rainfall.

A summary of forecast, as they pertained to precipitation, is located in Appendix 2C.

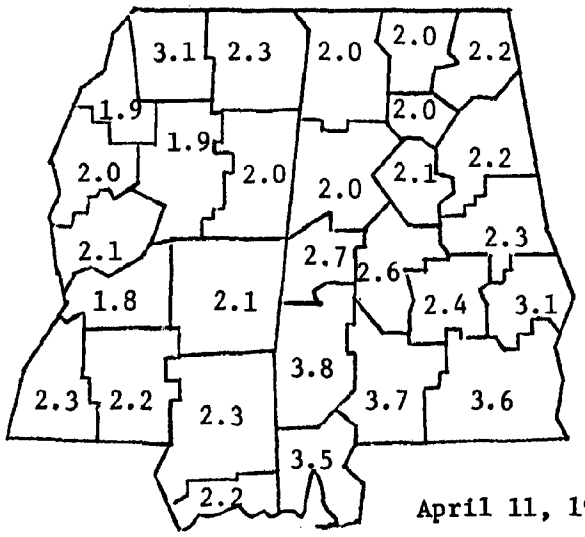
The team also reviewed the severe weather and flash flood warning logs and files issued by WSFO Birmingham. The first severe weather statement was issued at 11:30 p.m., Wednesday, April 11. The first severe thunderstorm warning was released at 3:15 a.m., April 12, followed by a tornado warning at 3:55 a.m. and a flash flood warning at 4:00 a.m. The last short-fused warning was issued at 11:00 a.m., Friday, April 13th. During the active thunderstorm period, the office issued 17 severe thunderstorm warnings, 11 tornado warnings, 13 flash flood warnings, and 32 statements on severe weather or flash flooding. The severe thunderstorm and tornado warnings were well-written and disseminated rapidly after preparation. The only possible problem noted occurred in a few warnings issued for a portion of a county, which may leave the users wondering if the warning applies to them. (This was evident in a tornado warning issued at 5:00 p.m., Thursday, April 12, for persons in Tuscaloosa, southern Jefferson, and Bibb Counties. A severe weather statement at 5:30 p.m. indicated that the tornado warning remained in effect for Bibb, Tuscaloosa, and extreme southern Jefferson Counties, evidently to try to make it clear that Birmingham, in Jefferson County, was not included).

FLASH FLOOD WARNINGS

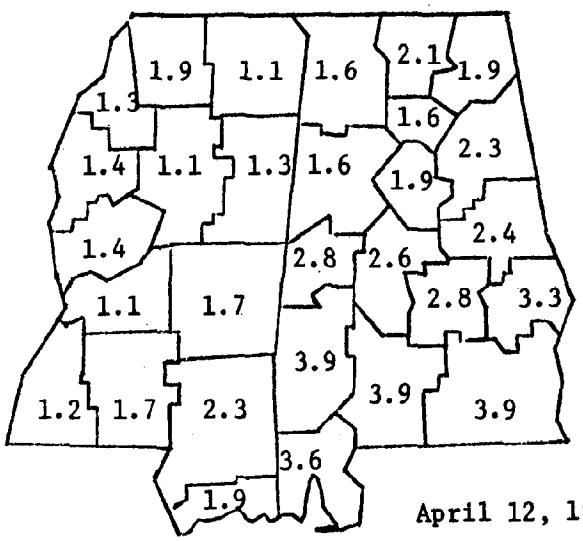
Flash floods are defined as those which follow the causative event within a few hours. The causative event is usually heavy precipitation, although it may be a dam break, ice action, melting snow, etc. The NWS Flash Flood Warning Program, is comprised of two main segments: the watch-warning approach and local flash flood warning systems. The watch-warning approach involves people at several forecast levels. First, the River Forecast Center, using the latest available hydrologic information, issues guidance values of precipitation necessary to produce flash flooding, usually a certain amount of rainfall in a 3-hour period. Using this information and available guidance from NMC, the WSFO issues flash flood watches if expected precipitation equals or exceeds the flash flood guidance figures. Flash flood warnings are issued by WSFO's or WSO's when reported or indicated rainfall equals or exceeds the guidance values or if flash flooding is reported. The local flash flood warning systems involve communities which have expressed an interest in a cooperative program that includes flash flood alarm systems, river stage and rainfall reporting networks, and NWS-devised forecast procedures. Local flash flood warning systems played no part during the flooding that affected Mississippi and Alabama from April 11-13, 1979. Local programs have not been established in the affected areas.

GUIDANCE FROM THE RIVER FORECAST CENTER

Flash flood guidance values (the amount of rainfall in 3 hours needed to produce flash flooding) were relatively low across Mississippi and Alabama on April 11, and decreased after the first of the rain had fallen (fig. 2.11). This information is prepared in the RFC's each morning, and was transmitted to the WSFO's as scheduled.

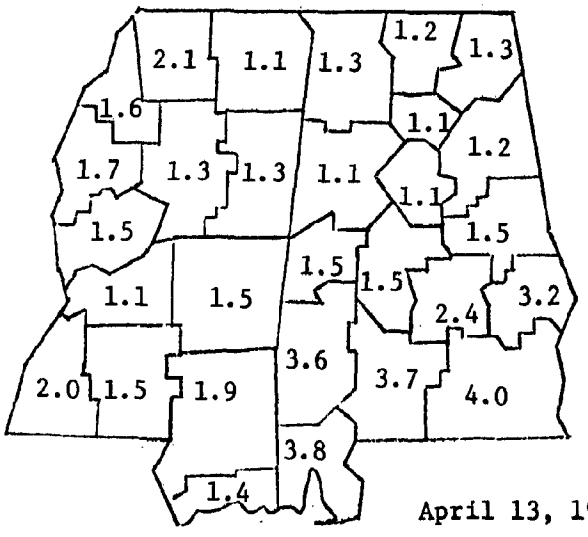


April 11, 1979



April 12, 1979

Figure 2.11 -- Flash Flood Guidance values by forecast zones for Mississippi and Alabama.



April 13, 1979

Mississippi

WSFO Jackson issued a flash flood watch at 10:00 p.m., Wednesday, April 11, for that portion of the State north of a Meridian-Vicksburg line (fig. 2.12). This watch was late since one flash flood warning had already been issued and others were required very shortly after the issuance of the watch. The flash flood guidance values from RFC Slidell and the Excessive Rainfall Potential Guidance from NMC at 9:00 a.m. supported the issuance of a watch for the northern third of the State. However, the withdrawal of the Excessive Rainfall Potential Guidance from northeast Mississippi in the 2:00 p.m. message did not help lend credibility to the guidance. The survey team understood from discussions with forecasters at WSFO Jackson that they had issued a flash flood watch the previous day, April 10, based on guidance, and absolutely no rain had fallen. This made them reluctant to issue another watch area without definite indications that it was justified. In any event, the reports of heavy rains in the early evening and the 8:50 p.m. excessive rainfall message from NMC indicated that the issued watch was justified. Shortly thereafter, WSFO Jackson received over 4 inches of rain in just over an hour and flash flooding was reported in the city.

WSFO Jackson and WSO Meridian issued flash flood warnings, as required, across central Mississippi from Wednesday night, April 11, through Friday morning, April 13. Warnings were usually issued for 2- to 4-hour periods and extended as necessary. With the continuing rains through the same area, some counties were under flash flood warnings for an extended period of time. Postanalysis of precipitation reports shows an excellent correlation between the areas of heavy rainfall and the counties warned. This correlation is impressive because WSFO Jackson was without its own radar owing to a lightning strike and was relying on reports from surrounding radar, data from satellites, and input from local and State officials and the spotter and cooperative networks.

Three deaths were reported to be associated with flash flooding in Louisville (Winston County) about 2:00 a.m., Thursday, April 12. Intense thunderstorms had been moving over this area for 2 to 3 hours, and WSO Meridian had issued and reissued severe thunderstorm warnings for the county. The flash flood watch and tornado watch were also in effect for Winston County at the reported time of the deaths. WSO Meridian issued a flash flood warning at 3:00 a.m., when they received reports of flooding.

WSFO Jackson issued a flash flood warning for Rankin County early on Sunday morning, April 15, based on the information from county officials that a levee had broken. Subsequent information indicated that it had not broken but was seeping and required strengthening. Under these circumstances, the situation was critical and this warning was justified.

Alabama

WSFO Birmingham recognized the potential for flash flooding in a severe weather statement issued at 3:20 a.m., Thursday, April 12, noting that very heavy rains and gusty winds would accompany thunderstorms for the next few

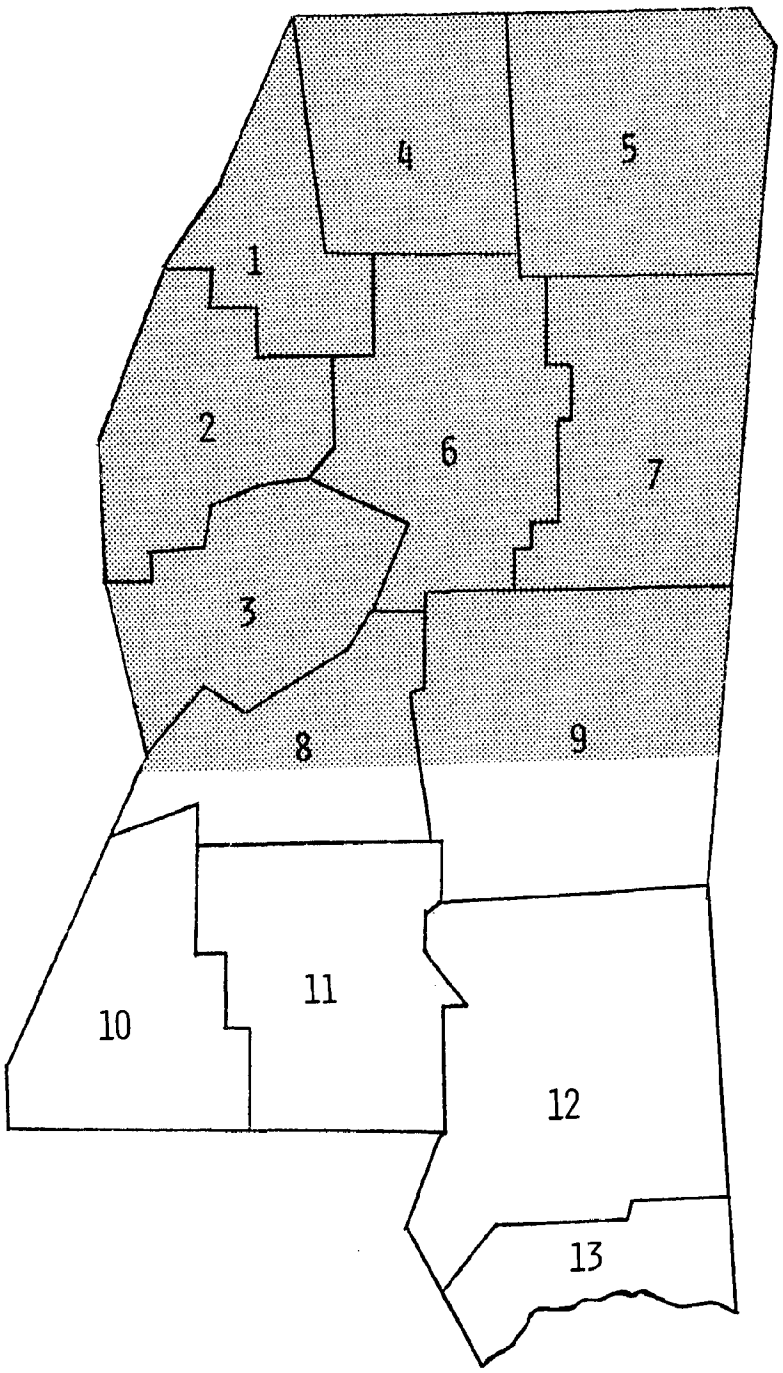


Figure 2.12 -- Flash Flood Watch area issued by WSFO Jackson at 10:00 p.m., Wednesday, April 11, 1979, for Mississippi.

hours through Lamar, Marion, and parts of Fayette Counties, in western Alabama. The statement stressed that flash flooding might result owing to the stationary nature of the line, and that flash flood warnings were in effect in the Mississippi counties on the Alabama border just to the west. At 4:00 a.m., the office issued a flash flood warning until 8:00 a.m. for Marion, Lamar, Pickens, Fayette, and Winston Counties of west-central Alabama. The State forecast issued 10 minutes later included a flash flood watch for the northwest portion of the State through the day. Zone forecasts at 5:00 a.m. redefined the area of the watch to include Zones 1, 2, 4, 5, 6, 8, and 9 (fig. 2.13). At 4:50 a.m., WSO Meridian issued a flash flood warning for Sumter County, just to the south of the counties warned by WSFO Birmingham. This warning remained in effect until 8:00 a.m. As heavy rains spread eastward, WSFO Birmingham continued to issue flash flood warnings, with the first warning for Birmingham and Jefferson County issued at 9:22 a.m., April 12. At 10:45 a.m., the Flash Flood Watch was continued into Thursday night and extended eastward to include Zones 3 and 7 in the northeast part of the State.

As the rains continued and reports were coming in of numerous small streams at bankfull or over in a belt entirely across the State, WSFO Birmingham continued to issue or extend flash flood warnings in the rainfall area. By late Thursday afternoon, April 12, WSO Montgomery also issued flash flood warnings for some of its counties.

At 4:10 p.m., Thursday, April 12, WSFO Birmingham extended the flash flood watch for the same area into Friday morning, and at 5:40 p.m. extended the watch area to include Zone 11 in the east-central section of the State. With small streams still full and rains continuing, WSFO Birmingham held the flash flood watch in effect and extended warnings in the same area through the night and into April 13.

As the thunderstorms finally began to move southeastward, warnings were allowed to expire and the flash flood watch was shifted with the activity. Warnings in WSFO Birmingham's area of responsibility ended at noon on Friday, April 13. A few brief heavy rains prompted flash flood warnings on Friday afternoon in WSO Montgomery's county responsibility area.

Tables 2.1 and 2.2 show the number of flash flood warnings (or extensions of warnings) issued for each county in Alabama and Mississippi and the number of hours each county was under such warnings.

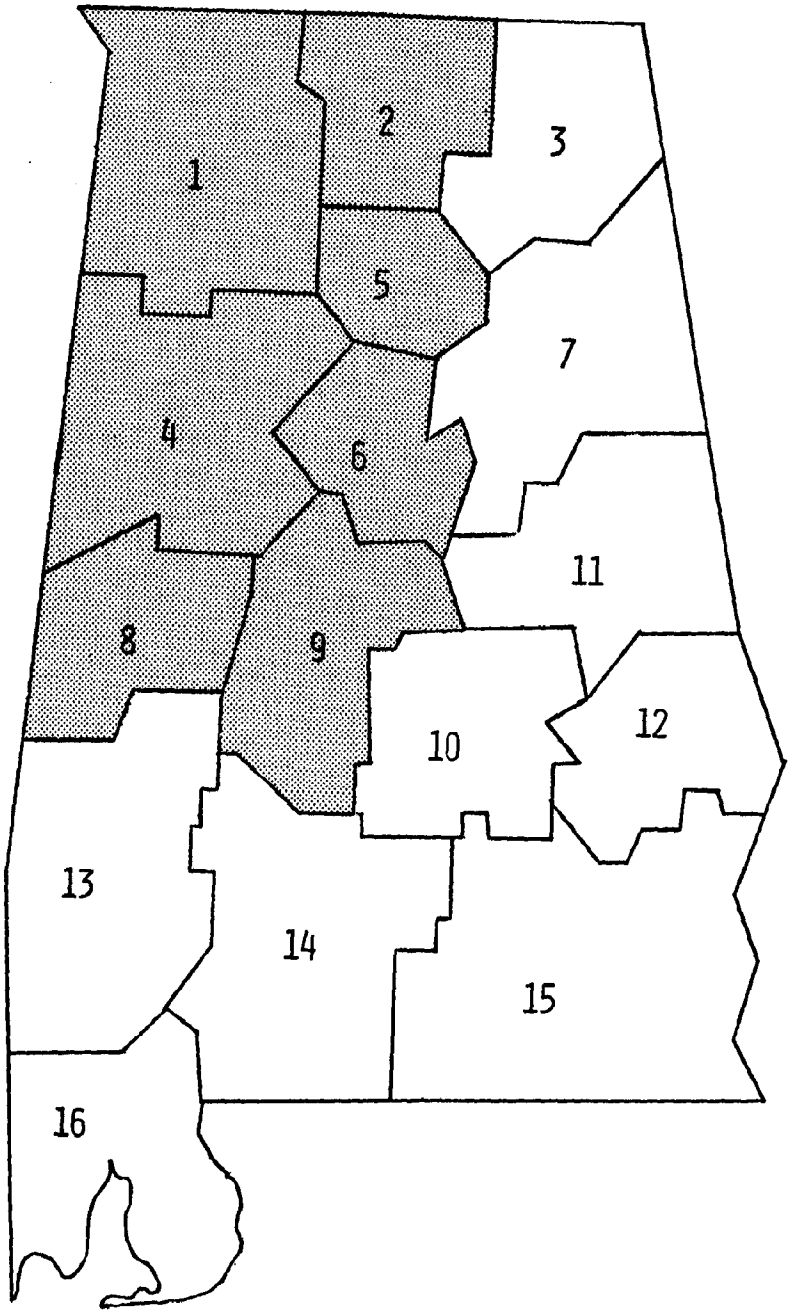


Figure 2.13 -- Flash Flood Watch area issued by WSFO Birmingham at 5:00 a.m., Thursday, April 12, 1979, for Alabama.

Mississippi

County	Warnings Issued	Minutes:Hours Under Warnings
Attala	9	24:30
Bolivar	1	2:15
Carroll	1	3:00
Chickasaw	1	3:00
Choctaw	8	23:30
Clay	4	11:40
Grenada	1	1:40
Hinds	5	13:18
Holmes	1	3:00
Humphreys	1	1:40
Itawamba	1	3:00
Kemper	7	14:40
Lauderdale	5	10:10
Leake	8	23:55
Lee	1	3:00
Leflore	1	1:40
Lowndes	6	16:30
Madison	8	21:55
Monroe	4	11:40
Montgomery	4	12:00
Neshoba	7	15:45
Newtom	3	8:10
Noxubee	6	15:25
Oktibbeha	8	22:30
Rankin	5	13:18
Scott	4	12:15
Webster	6	17:40
Winston	6	15:25
Yazoo	3	8:40

Table 2.1 -- Flash Flood Warnings (or extensions of warnings) issued for each county in Mississippi and the number of hours each county was under such warnings.

Alabama

County	Warnings Issued	Minutes:Hours Under Warnings
Autauga	3	8:45
Bibb	6	23:38
Blount	3	8:25
Calhoun	5	19:20
Chilton	4	15:30
Cherokee	2	7:40
Choctaw	1	2:15
Clay	5	19:20
Cleburne	5	19:20
Coosa	5	15:55
Cullman	3	7:55
Dallas	1	2:45
Elmore	3	8:45
Etowah	2	7:40
Fayette	8	27:15
Greene	8	28:57
Hale	5	18:45
Jefferson	7	26:10
Lamar	5	15:00
Marion	2	7:40
Perry	5	18:45
Pickens	8	30:00
Randolph	5	19:20
Shelby	7	26:05
St. Clair	6	23:55
Sumter	5	12:25
Talladega	6	23:50
Tallapoosa	5	15:25
Tuscaloosa	8	29:05
Walker	6	20:30
Winston	3	8:55

Table 2.2 -- Flash Flood Warnings (or extensions of warnings) issued for each county in Alabama and the number of hours each county was under such warnings.

FINDINGS AND RECOMMENDATIONS

FINDING 2.1

Despite the extremely heavy workload conditions, all offices issued very timely and meaningful flash flood warnings. Warnings from Jackson were especially impressive, in view of the fact that they had lost their radar early in the storm.

FINDING 2.2

NMC guidance, both numerical and subjective, was poor in predicting the magnitude and duration of the precipitation over Mississippi and Alabama, April 11-13, 1979. This translated directly into less-than-desirable lead time on the initial flash flood watches. It is recognized, however, that accurate forecasting of precipitation amounts from convective activity is not now within the state-of-the-art and that the models performed poorly on a broad scale during this series of forecasts.

RECOMMENDATION 2.2

NWS should thoroughly review the forecast errors in this series of prognoses and pursue methods to overcome such model shortcomings.

FINDING 2.3

Field offices in Mississippi and Alabama used information from radar, satellite, cooperative and spotter networks, and State and local officials to issue timely warnings, well-confined geographically, of the flooding threat. However, the procedures which have evolved in the flash flood warning program (e.g., short-period warnings that were reissued again and again for the same area) may have made it more difficult for them to convey adequately their information.

RECOMMENDATION 2.3

Review the procedures and terminology used in the flash flood warning program to ensure that procedures do not hinder the clear communication of flood threat.

FINDING 2.4

Both WSFO Jackson and WSFO Birmingham delayed issuance of initial flash flood watches until heavy rains were reported. In each instance, some positive guidance was provided by the excessive rainfall potential outlook.

RECOMMENDATION 2.4

Re-emphasize to all warning offices, and in public education materials, that watch areas should be issued for lower probabilities of occurrence than warnings and that a certain number of watch areas will not verify.

FINDING 2.5

Forecasters expressed their concern that this event did not fit the popular concept of a flash flood. Both the staff and public feel that flash flood implies short-period phenomena with rapid rise and rapid fall.

RECOMMENDATION 2.5

NWS should review flash flood definitions and consider different terminology, such as "small stream and urban flood warning" to describe this type of flood threat.

CHAPTER 3
FLOOD FORECASTS AND WARNINGS

The NWS Flood Forecast System is designed to predict flooding on larger streams or rivers where the time or rise is long enough to allow an orderly process of data collection and analysis to yield specific river stage forecasts. Flood warnings usually indicate the stage, location, and time of flooding along a river. The time between the issuance of a flood warning and the crest may be several hours to several days. These lead times permit evacuation of people and actions to reduce property damage.

This chapter reviews how the system functioned. The first section covers the specific offices involved; the second presents the forecasts and warnings issued, including an assessment of them; the third discusses hydrologic issues affecting the accuracy and timeliness of the forecasts; and the final section presents findings and recommendations.

SPECIFIC FIELD OFFICES INVOLVED

In the two river basins covered by this report, two RFC's, two WSFO's, and three WSO's had operational responsibility. Areas of responsibility for the WSFO's are shown in fig. 1.2; for the RFC's, in fig. 3.1.

The Lower Mississippi RFC (LMRFC) at Slidell La., prepared the river forecast guidance for the Pearl River. Their entire area includes the main stem of the Mississippi River below Cairo, Ill., plus streams and forecast points in Louisiana, Mississippi, and most of Tennessee and Arkansas. This area contains 206 river forecast points, most of which were experiencing major rises during April 11-15. Four of the river systems, in addition to the Pearl, were experiencing maximum floods of record.

The LMRFC has a staff of eight, including seven hydrologists. Beginning on the evening of April 12, RFC was manned 24 hours per day for the period of the emergency. Staffing was four on the day shift and one each on the night shifts (afternoon and midnight). To assist WSFO Jackson, a hydrologist from the RFC was sent on temporary duty to Jackson on April 12. Although this was essential to the overall operations of NWS, it reduced the operational capabilities of the RFC at a critical time.

WSFO Jackson, Miss., has responsibility for all the rivers in the Mississippi, including the entire Pearl River and portions of the Tombigbee River above Pickensville. The WSO's at Meridian, Miss., and Mobile, Ala., have county area of responsibility for sections of the Pearl River. Because the Jackson gage at US Highway 80 is 15 miles downstream of the Ross Barnett Reservoir and is directly affected by the water release rates from the reservoir, the preparation and issuance of stage forecasts for the Jackson forecast point was the responsibility of WSFO Jackson.

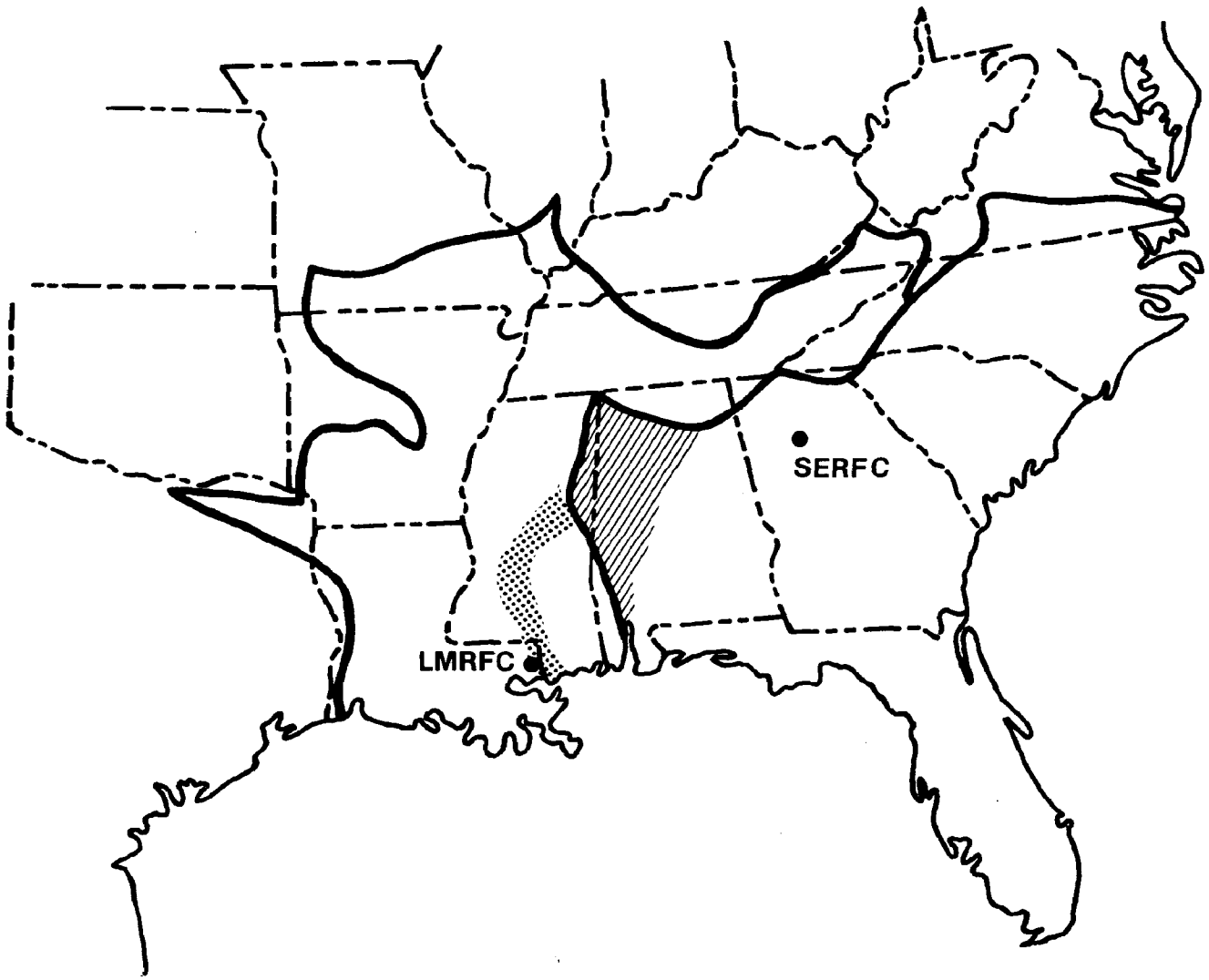


Figure 3.1 -- Areas of responsibility for the Lower Mississippi River Forecast Center (LMRFC) and the Southeast River Forecast Center (SERFC). The dotted area shows the Pearl River Basin; the hatched area shows the Tombigbee River Basin.

Procedures used at Jackson call for daily contact with the Reservoir operator to determine the amount of water to be released in the next 24 hours. These water release rates are referenced on a rating table to derive the stage at the gage for the next 12-24 hours. It was believed by regional management that the additional time delay that would result if the RFC were to prepare the forecasts was not in the best public interest.

Normally, WSFO Jackson has a Service Hydrologist responsible for river forecasts and warnings, but the position had been vacant since the prior summer, because the incumbent was assigned university training. As a result, the Meteorologist-in-Charge (MIC) and the Principal Assistant assumed the river forecasting responsibilities during the period of the flood. WSFO Jackson does not have a Hydrologic Technician on the staff. The Warning and Preparedness Meteorologist at the WSFO, who had been temporarily assigned by the MIC to the river desk, was off-station attending a hydrology training session at the time of the flood. A temporary replacement of the service hydrologist sent from the LMRFC Slidell had little experience or familiarity with the Jackson forecast point, but he did provide expert consulting service and became an effective member of the office staff during his stay.

The Southeast River Forecast Center (SERFC) at Atlanta, Ga., has the entire Tombigbee as a part of its total forecast guidance area, which also includes all rivers and tributaries entering the Atlantic and Gulf of Mexico from North Carolina to and including Mobile Bay, Ala. This area includes 205 forecast points, most of which were in flood or experiencing major rises.

SERFC has a staff of nine, including eight hydrologists. RFC was manned 24 hours per day for the period of the emergency. Staffing was five on the day shift and two and one for the respective night shifts.

WSFO Birmingham, Ala., has responsibility for the entire Tombigbee except the portion in Mississippi. WSO's at Montgomery and Mobile, Ala., and Meridian, Miss., had county area of responsibility for parts of the Tombigbee River.

The staff pattern of WSFO Birmingham provides for a Service Hydrologist, who was on duty during the flood period. The Service Hydrologist performed the hydrologic operations, with help from the WSFO staff.

RIVER SITUATION AND FLOOD FORECASTS AND WARNINGS

Flooding was occurring simultaneously in the entire area of the LMRFC with the Yazoo, Chickasawhay, and Big Black River systems experiencing maximum floods of record. During this period, operation of floodways to prevent flooding at New Orleans was a major concern.

Many streams in the Pearl River Basin were receding on April 11 from a storm on April 7-9, with numerous streams not yet having receded to below flood stage. The record storm of April 11-13 affected watersheds whose rivers were running high from a previous storm and produced new record high stages at many sites. The Corps of Engineers (COE) estimated that many streams reached levels which would occur on the average once in 500 to 1,000 years.

Tabulations of the forecasts issued in each basin are presented in Appendix 3A. A summary of typical forecast bulletins and river statements is given in Appendix 3B.

Pearl River Basin - Headwater Tributaries

Storm and River Response. All the upstream tributaries of the Pearl Basin (Upper Pearl at Edinburg and Carthage, Yockanookany at Ofahoma, and Tuscolometa at Walnut Grove) (fig. 3.2) were near or over flood stage on the morning of April 11, receding from the runoff of the storm of April 7-9. The April 11-13 storm had maximum rainfall along a west-southwest line from Louisville to Pickens. The greatest amounts were observed in the headwaters of the Pearl River above Carthage. The storm's central amount of over 20 inches fell in the Louisville area (fig. 1.1). To the south of a Jackson-Meridian line, rainfall amounts decreased sharply to generally less than 3 inches.

The headwater tributaries of the Pearl received two periods of significant rainfall. The first period of extremely intense rainfall was between 10:00 p.m., April 11, and 2:00 a.m., April 12. As a result, the rivers at Edinburg, Carthage, Ofahoma, and Walnut Grove responded rapidly (by 7:00 a.m., April 12), to the very intense rain, nearly cresting on the 12th and early on the 13th. Because of the great intensity of the rainfall, the streams' initial responses were unusually fast -- within 6 to 12 hours of the rain event. The second, more prolonged rain period during the daylight and evening of April 12 produced rainfall about 50 percent greater that the first period, causing the rivers to renew or continue the rise to the final crest on the 14th.

The Pearl River exceeded its previous record gage heights by 3.4 feet at Edinburg and 4.2 feet at Carthage. Figure 3.3 and 3.4 shows the observed stages and the crest forecasts for the headwater tributary forecast points. Figure 3.5 shows the temporal rainfall patterns at Jackson and Meridian to illustrate the widely varying behavior of the rainfall intensity and spatial distribution.

Forecasts Issued and Assessment. The first reports of excessive rainfall from the initial intense period were received by 7:00 a.m., April 12. Forecasts based on this information were issued at 10:00 a.m., April 12, and called for crests within 0.5 foot of the maximum stages of record at Edinburg and Ofahoma. Subsequent forecast revisions on the 13th and 14th following the greater amounts of rain from the second part of the storm increased these forecasts with at least 12 hours of advance warning.

The 10:00 a.m., April 12, Ofahoma forecast called for significant rises of 5 to 7 feet. This forecast was revised that evening at 7:30 p.m., and verified within 2.6 feet. The 11:00 a.m., April 13, forecast was within 1.1 feet of the final crest, which occurred at 2:00 a.m. on the 15th. These were the best forecasts that could be made with the type of limited data available. Nevertheless, their issuance was delayed due to the lack of automated reports and they tended to be low because of inadequate rainfall intensity data.

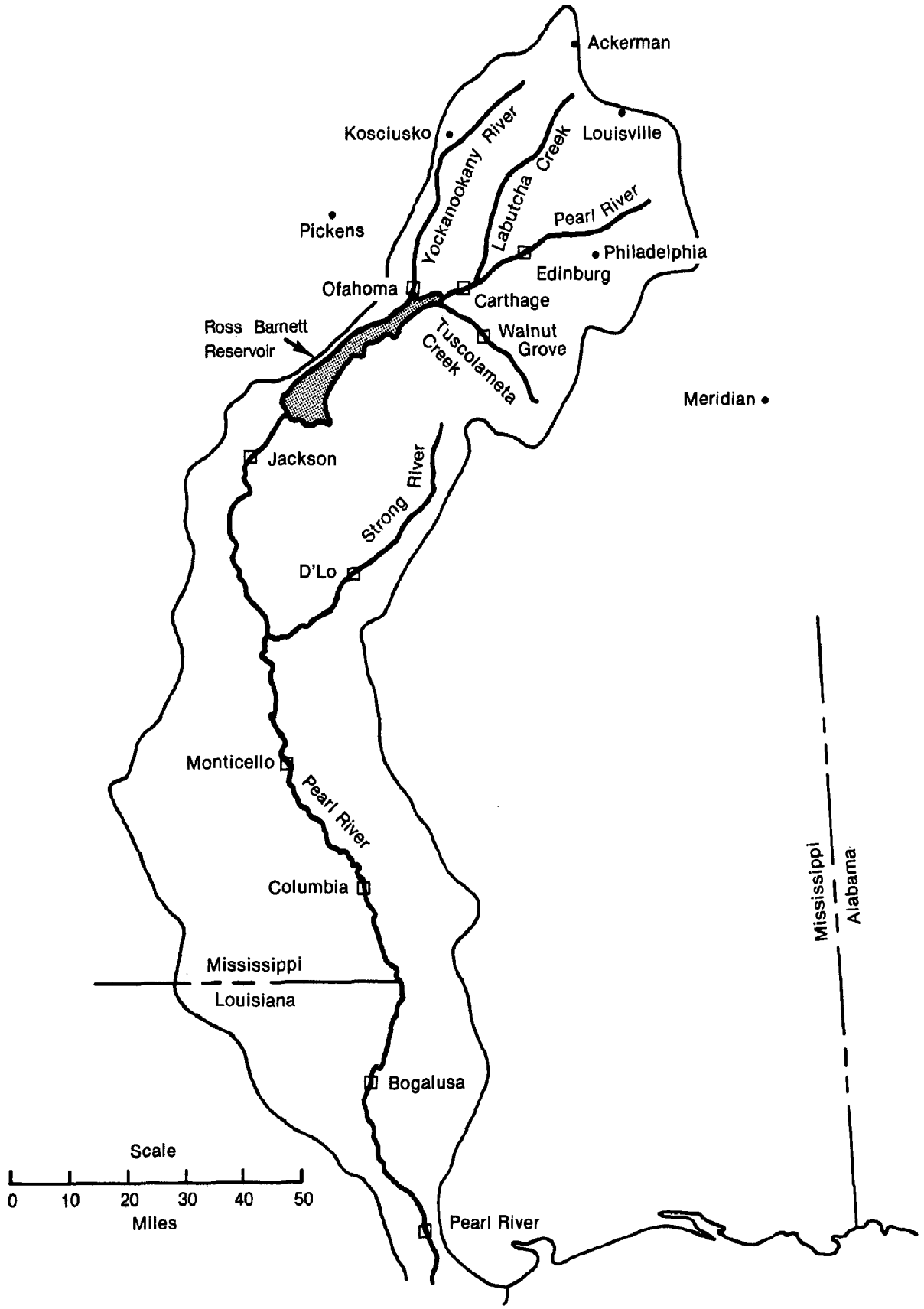


Figure 3.2 -- Pearl River Basin in Mississippi.

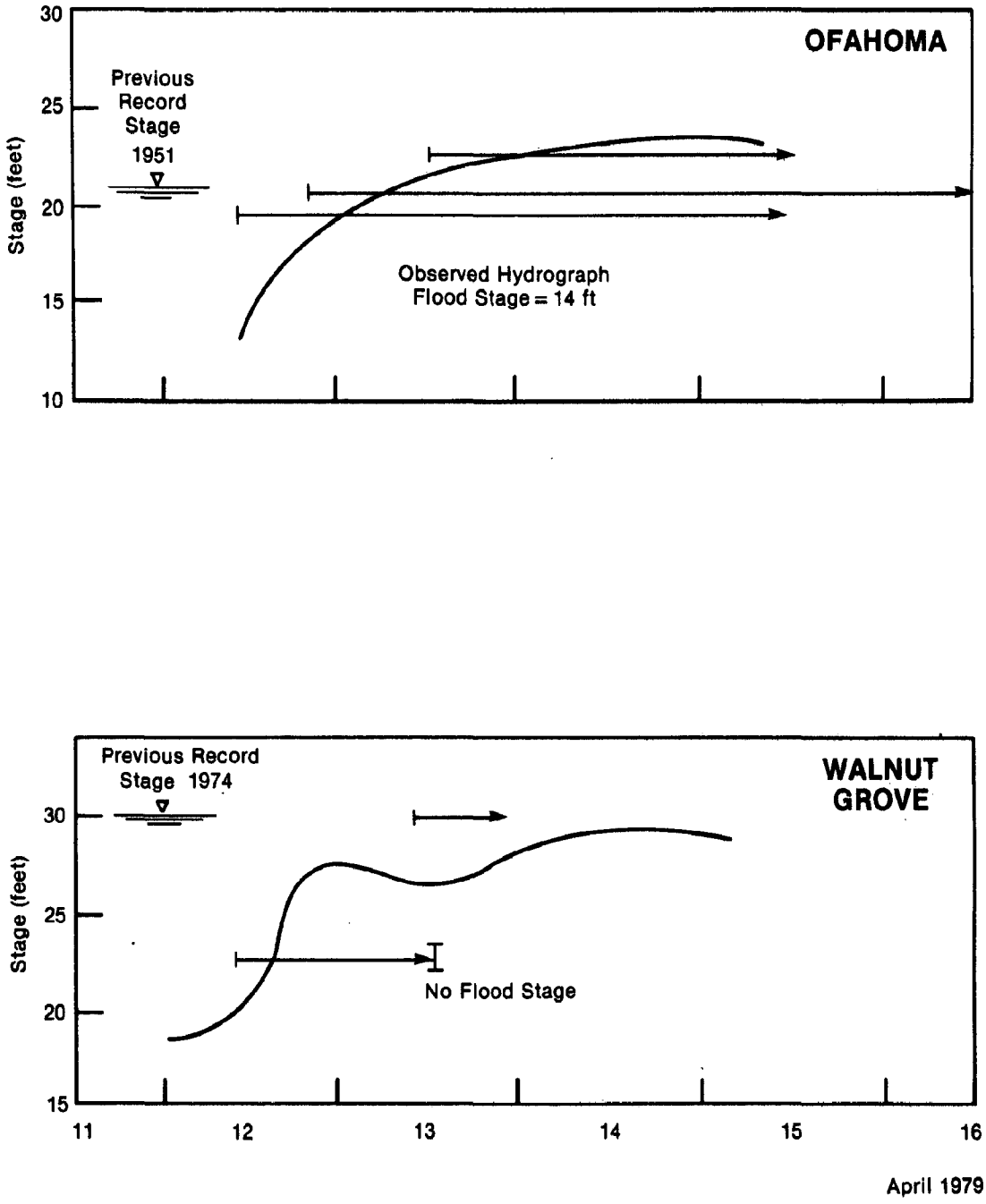


Figure 3.3 -- Comparison of crest forecasts and observed stages for Ofahoma and Walnut Grove in the headwaters of the Pearl River above Jackson, Miss. Arrows extend from time of forecast to time and stage forecasted.

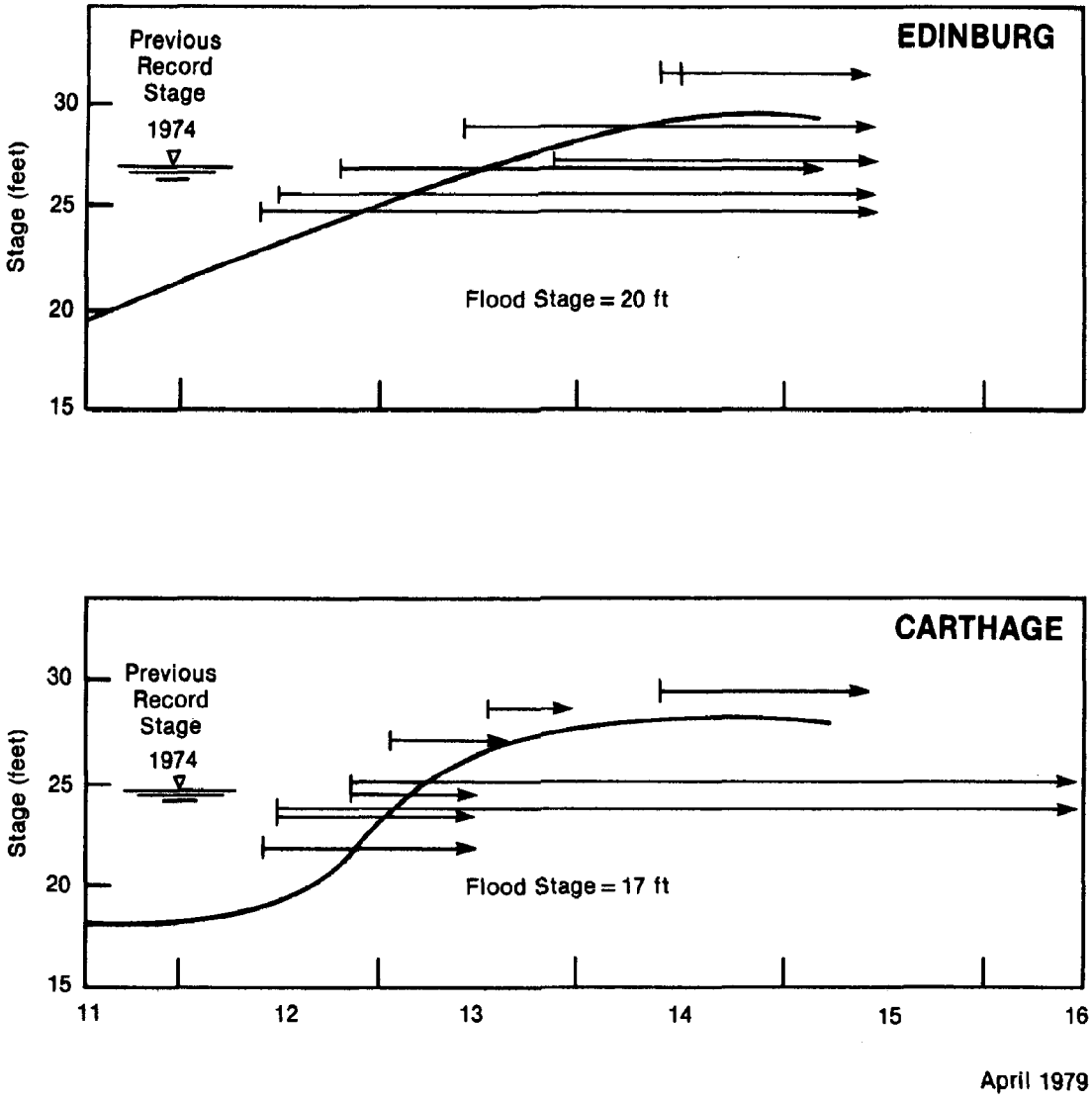


Figure 3.4 -- Comparison of crest forecasts and observed stages for Edinburg and Carthage in the headwaters of the Pearl River above Jackson, Miss. Arrows extend from time of forecast to time and stage forecasted.

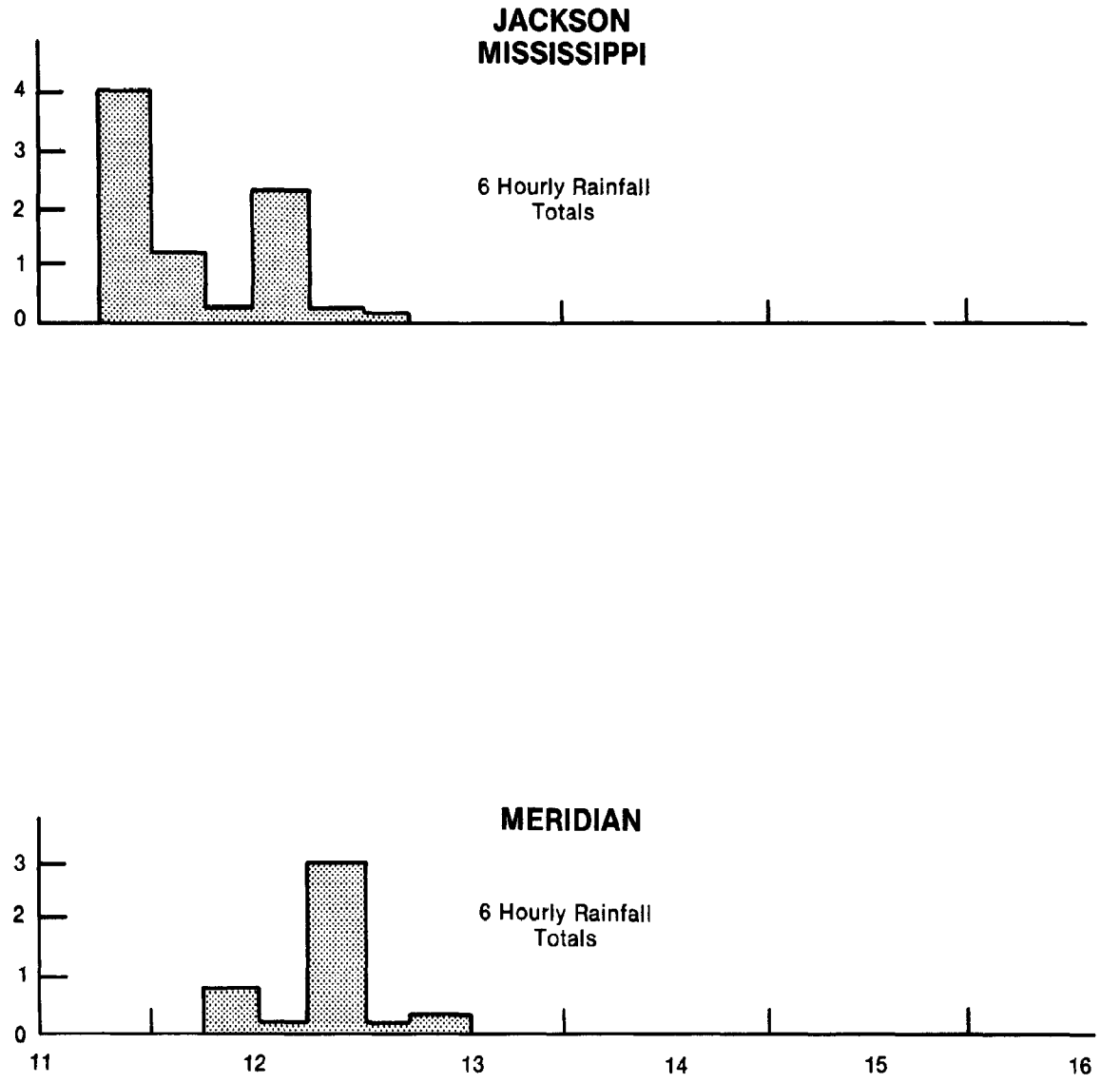


Figure 3.5 -- Intensity and spatial distribution of rainfall for Jackson and Meridian, Miss.

At Walnut Grove, the Tuscolameta River rose for 9 hours (10:00 a.m. - 7:00 p.m., April 12) at a rate of about 1 foot per hour. The 9:00 a.m., April 12, forecast was low and provided little forecast lead time. This was undoubtedly due to the fact that the magnitude and intensity of the rainfall during the early hours of the 12th was under-estimated on the basis of the reports available. However, later forecasts were good and provided 24-hour forecast crests for small watersheds based on more accurate estimates of the intensity of rain.

The effect of under-estimation of the rainfall intensity is also evident in the early forecast for the Strong River at D'Lo, where the 10:00 a.m., April 12, prediction was low. Later revisions on the 13th overforecast the crest. The overforecast was probably due to extrapolation of the Walnut Grove rainfall into the Strong Basin, when in fact the heavy rainfall fell only in the very headwaters of the Strong watershed. Better definition of the rainfall intensity and area location by the reporting network would have prevented this vacillation of the forecast. The final revision of the forecast on the 14th, however, provided an accurate 24-hour lead time to the crest.

Pearl River Basin - Ross Barnett Reservoir

The headwater tributaries of the Upper Pearl River flow directly into the Ross Barnett Reservoir. The reservoir is operated by the Pearl River Valley Water Suppy District for water supply and recreation.

Reservoir Inflow. Inflow into the reservoir was high on Wednesday, April 11. As a result, the reservoir was being evacuated through releases of 15,000 to 20,000 cubic feet per second (cfs) which produced a Jackson gage height 10 feet above flood stage. On the evening of the 11th and into the morning hours of the 12th, the inflow resulting from the previous week's storm was supplemented by intense rainfall on the reservoir and the runoff into local tributaries. The combination of these sources of inflow produced an initial peak inflow to the reservoir of 60,000 cfs. (The reservoir inflow and outflow values are estimated and are subject to uncertainty of ±10% to 20%.) The inflow then receded to 40,000 cfs by the afternoon of the 13th before the first upstream flow from the storm of the 11th to 12th began to arrive at the dam. The inflow then rose steadily for over 48 hours to a broad peak late on the 15th. Inflow recession began early on the 16th and fell steadily for over 7 days. Figure 3.6 shows the inflow hydrograph for the Ross Barnett Reservoir.

Forecasts Issued and Assessment. Friday morning, April 13, before the 11:00 a.m. forecast was issued, the MIC and Service Hydrologist visited the Jackson/Hinds EOC. While there they received a forecast from the LMRFC at Slidell for reservoir inflow of 120,000 cfs (along with a crest of 38.5 to 39.5 feet at the US Highway 80 for Monday, April 16). They passed this information to the Mayor and other Jackson officials. On April 14, the NWS revised the inflow forecast to reflect additional streamflow data and called for a peak inflow of 180,000 cfs to occur early Monday, April 16th. Also on

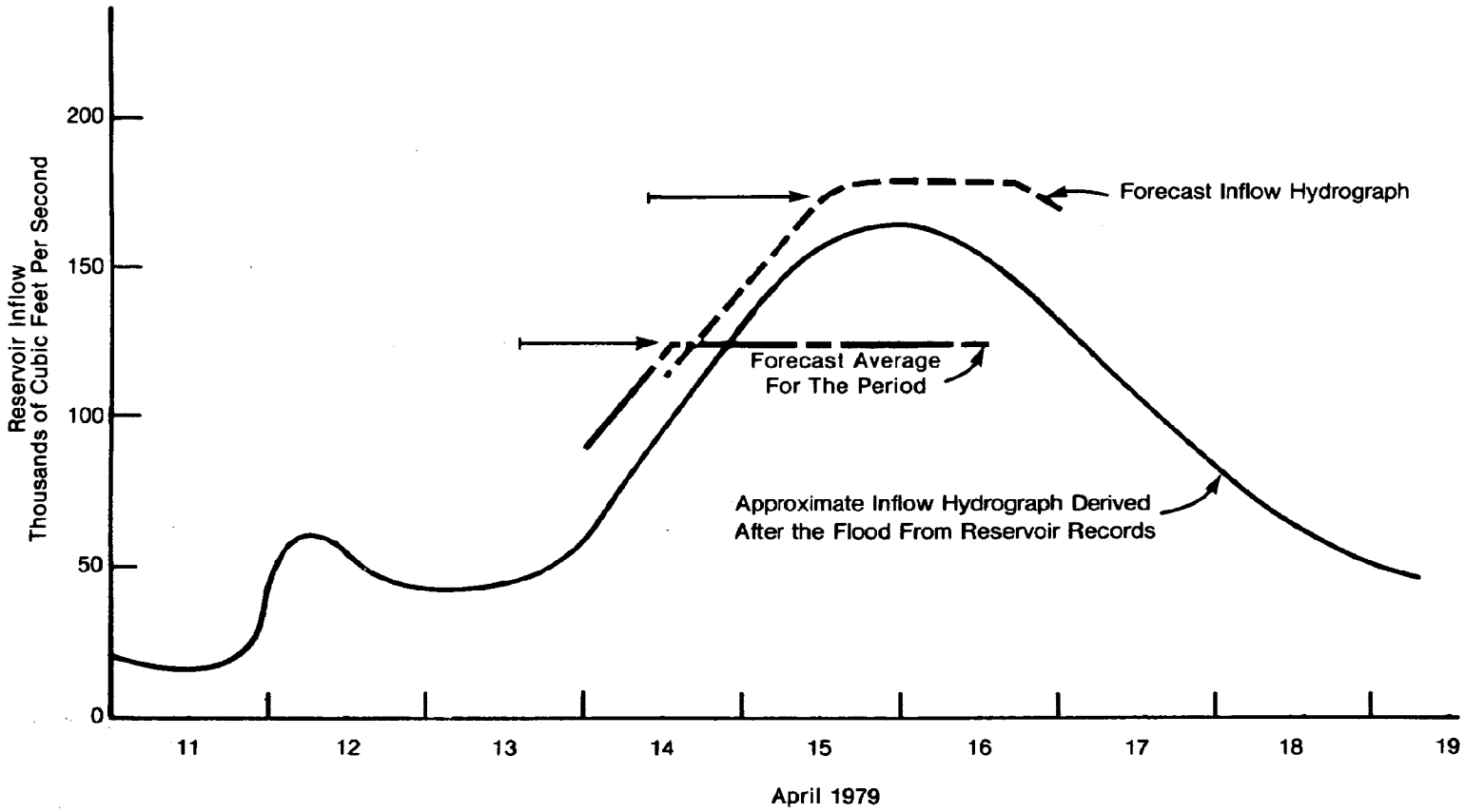


Figure 3.6 -- RFC forecasts of inflow to the Ross Barnett Reservoir. Arrows extend from time of forecast to time and stage forecasted.

the 14th, the USGS advised the Ross Barnett Reservoir operator to expect a peak inflow of 160,000 cfs to reach the reservoir on April 15. Their projection was based on streamflow measurements upstream from the reservoir.

The peak inflow of about 162,000 cfs did not reach the Ross Barnett Reservoir until near midnight, Sunday, April 15. Thus, the NWS revised forecast of April 14, although not unreasonable, was too high on rate and later in timing. The USGS April 14th projection appears to be closer on both the rate and timing of the peak inflow.

Pearl River Basin - Ross Barnett Reservoir to Jackson US Highway 80 Gage.

Outflow from the Ross Barnett Reservoir is controlled by the reservoir operator and is maintained by manually operated gates. The outflow largely determines the stage of the Pearl River as measured at the US Highway 80 gage. The gage site is 15 miles downstream from the reservoir where the highway crosses the river (See fig. 1.4).

River Situation. To evacuate water remaining in the reservoir from the flood of April 7-9, the reservoir level was being lowered by releases of 15,000 to 20,000 cfs the evening of April 11th. This amount of outflow was producing gage heights at the US Highway 80 gage of 27 to 28 feet. This stage is 10 feet above the flood stage of 18 feet. As the heavy local inflows began to arrive at the reservoir, during the early morning hours of April 12, the reservoir releases were increased gradually. By evening the releases reached 50,000 cfs and were maintained at the level throughout the night. During the day of April 13, the releases were steadily increased and reached 100,000 cfs by midnight. The outflow was held at this level until the afternoon of April 14 and increased to about 120,000 cfs. The releases were held at 120,000 cfs ± 5% until 2:00 a.m., April 17. Reservoir inflow, level, and releases are presented in fig 3.5.

Because of the storage effect in the river reach between the reservoir and the US Highway 80 gage, the river rose at a rate considerabley less than would be indicated by a direct application of the dam's discharge to the gage height-discharge relationship (rating table). The gage height rose at an average rate of 4 feet per day from 10:00 p.m., on April 11, to noon on the 15th (14 hours after the reservoir outflow was stabalized at about 120,000 cfs).

Forecasts Issued and Assessment. Flood statements and forecasts for the Jackson US Highway 80 gage were issued periodically - a statement averaging once every four hours - for a period of 6 days. Fig. 3.7 shows forecasts of river stages at the US Highway 80 gage.

At 12:00 p.m., April 12, before the storm rainfall had stopped, the forecast called for a 36-foot flood stage. Included in the forecast was the comment "...There is a very strong potential for more heavy rain...This could make the river at Jackson go even higher on Saturday..." The forecast stage of 36 feet was the highest experienced since the building of Ross Barnett and the levees

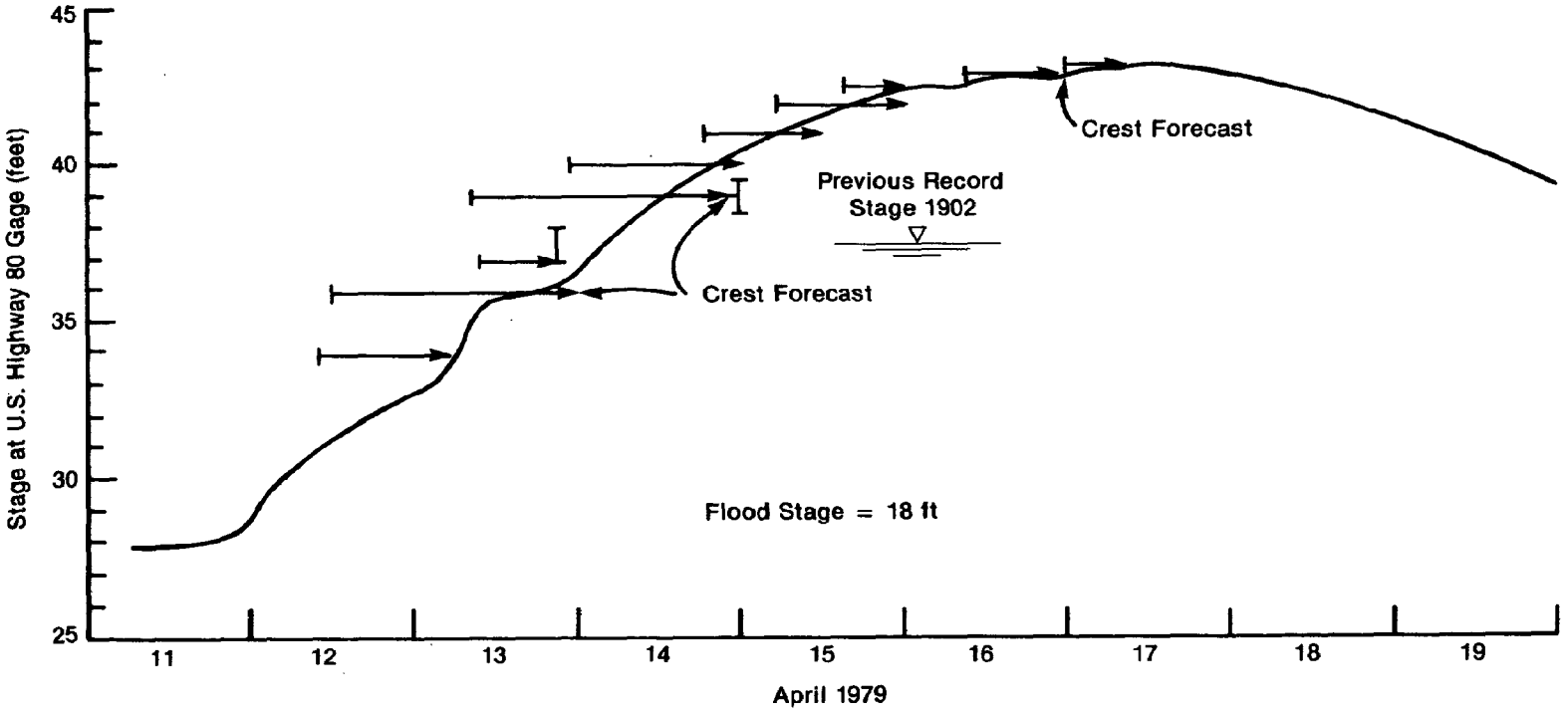


Figure 3.7 -- Forecasts of river stages at US Highway 80. Arrows extend from time of forecast to time and stage forecasted.

on both the Jackson and Rankin County sides of the river upstream of the US Highway 80 gage. It was also at the upper limit of the USGS rating table available in the RFC and WSFO.

Friday morning, April 13, while the MIC and service hydrologist were at the Jackson/Hinds EOC, they briefed the Mayor and Jackson officials on a forecast of a crest of 38.5 to 39.5 feet to occur Monday, April 16. This forecast was produced by the RFC and considered the inflow forecast of 120,000 cfs; the moderating effects of the reservoir storage; and the overbank storage between the reservoir and US Highway 80 gage. Based on this information from the RFC, the WSFO forecasters at 11:10 a.m., April 13, issued a statement forecasting 37 feet for April 14th, with "38 feet not out of the question." The forecasters took into account that the levee system on the east bank of Rankin County - around Richland, Flowood, and Pearl City - would be overtopped before the 38.5 to 39.5 feet height would be reached. The area would then become a storage space for the water and, thereby, reduce the river's stage.

As early as Friday afternoon, and continuing all during Saturday, April 14, statements repeatedly emphasized the record magnitude of the flood and the fact that the expected flood would "put water where it's never been before." The WSFO statements reiterated the uncertainty of the forecast situation and admonished the public to "assess their situation carefully and take appropriate precautionary measure." By 8:45 p.m., Friday evening, the statements which accompanied the 39.5 to 40.0 foot revised forecast said, "...All indications point to a flood of record..." Later statements stressed "...Flood of this magnitude has never been experienced before..." The maximum historical flood stage, which occurred on March 31, 1902, was 37.5 feet.

Forecasts issued by WSFO Jackson clearly called for a major flood and generally gave 24-hour lead times until late Saturday evening, when gage heights reached 40 feet. From Saturday evening, April 14, until Sunday noon, the river reached the predicted stage about 12 hours after the forecast was issued. Except for 3 forecasts issued by the WSFO (on the 12th and 16th), neither the magnitude of the crest stage at US Highway 80 nor the crest time were stated.

Pearl River Basin - Below Jackson

River Situation. Because of the lack of significantly heavy rainfall below Jackson, most of the river response in this region was caused by water flowing downstream from the area north of Jackson. The Strong River, at D'Lo, is the only major tributary below Jackson. As a reflection of the storage and delaying effects of the Ross Barnett Reservoir and the downstream channel reaches, the river at the downstream forecast points rose much more slowly. River peaks occurred at Monticello (1:00 p.m., April 20), Columbia (11:00 p.m., April 21, Bogalusa (1:00 a.m., April 24), and Pearl River (3:00 a.m., April 26). Reported crests were from 6.0 to 15.5 feet above flood stage and 0.4 to 2.3 feet above previous maximum of record.

Forecasts Issued and Assessment. Forecasts were issued for Monticello, Columbia, Bogalusa, and Pearl River several times a day beginning Thursday,

April 12, and through the time of the crest. Revisions were infrequent. Forecasts issued on the mornings of the 12th and the 13th were low. However, after the upstream situation became apparent and starting with the 10:25 a.m., forecast, April 14, the forecasts were excellent if not outstanding (fig. 3.8). The deviations for crests and lead times were Monticello (+0.4 feet, 6 days), Columbia (+0.3 feet, 7 days), Bogalusa (-1.3 feet, 10 days), and Pearl River (-1.3 feet, 12 days). Subsequent revisions improved the deviations at Bogalusa and Pearl River.

Tombigbee River Basin - Above Aberdeen

River Situation. Figure 3.9 shows a map of the Tombigbee River Basin. Figure 3.10 shows example forecasts for points in the Tombigbee River Basin. Headwater streams above Amory (Old Town Creek at Tupelo, Miss., East Fork at Fulton, and Bigbee) responded to the very intense 2- to 3- hour rainfall reported at 7:00 a.m., April 12, and crested early on the 13th. Subsequent rainfall was much less intense and only delayed the falling side of the hydrograph. Amory and Aberdeen, the downstream stations on the main Tombigbee, crested at 1:00 p.m., Saturday, April 14, and 8:00 p.m., Sunday, April 15, respectively, reflecting the upstream peak flows.

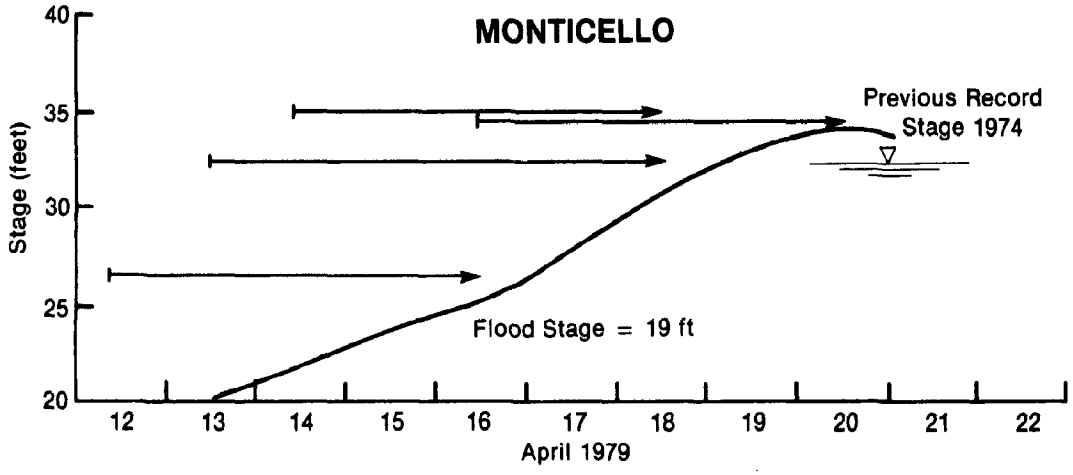
Forecasts Issued and Assessment. Crest range predictions for the four points were good-to-excellent with the forecasts issued at or prior to 3:00 p.m., April 12, verifying within 0.8 feet, while Aberdeen was within 1.3 feet. The Aberdeen crest forecast was revised on Friday, April 13, at 10:30 a.m., to within 0.2 feet, 58 hours before the actual crest.

Tombigbee River Basin - Aberdeen to Columbus

River Situation. South of Aberdeen the intense rain continued for most of the 13th and produced higher and later crests. The main rainfall area extended eastward from the headwaters of the Noxubee between Columbus and Pickensville to Tuscaloosa. There are indications that in this area the rainfall about 7:00 a.m., April 12, was nearly double that which fell before that time. Initial reports indicated maximum, total point rainfall of 15 inches. A field survey later revised this value to 20 inches. The tributaries in this area Tibbee at Tibbee and Luxapalila at Columbus) responded with crest stages early on the 14th.

The Battahatchee River, which enters the Tombigbee in the area of Aberdeen, was north of the isohyetal maximum area and received its most intense rain before 7:00 a.m., on the 12th. No reports were recieved from either of the two river stations near Aberdeen and Kolola Springs.

Forecasts Issued and Assessment. As a result of the timing of the heaviest rainfall during the 24 hours ending at 7:00 a.m., the 13th, the crest forecasts issued on the 12th predicted above-flood stages, but they were low. However, the river forecasts issued 8 to 19 hours before the crest and based on Friday's 7:00 a.m., river and rainfall all verified within 1.4 feet.



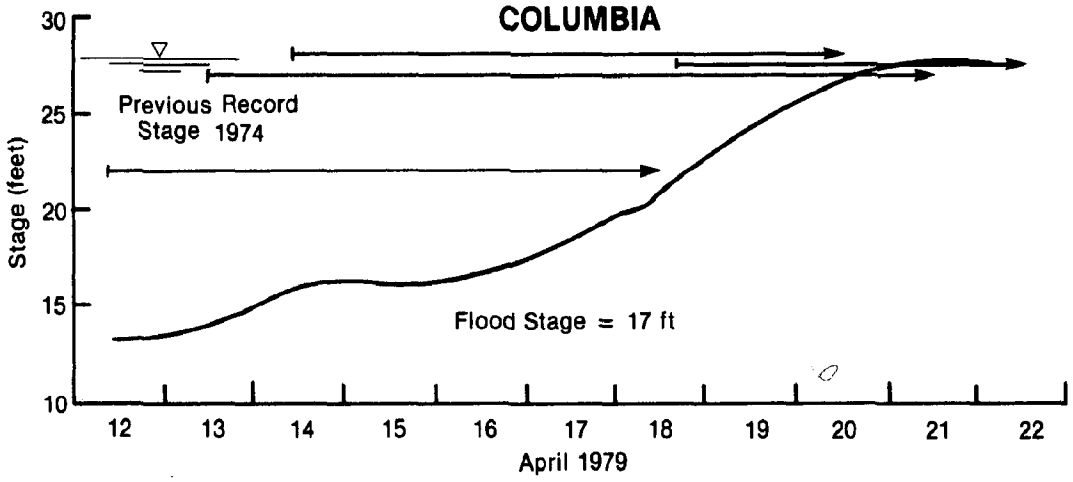


Figure 3.8 -- Comparison of crest forecasts and observed stages for Monticello and Columbia on the Pearl River below Jackson. Arrows extend from time of forecast to time and stage forecasted.

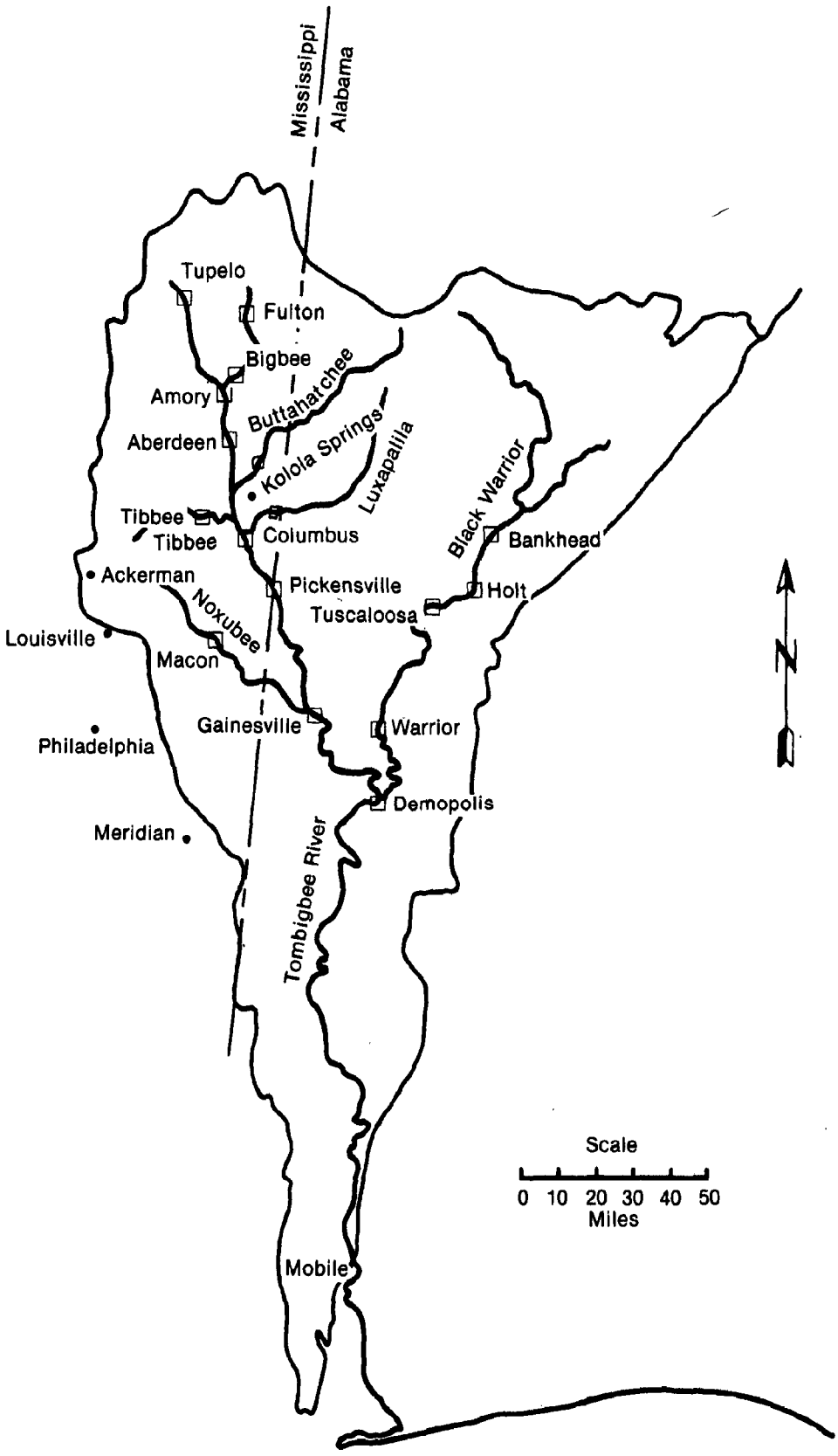


Figure 3.9 -- Map of the Tombigbee River Basin in Alabama and Mississippi.

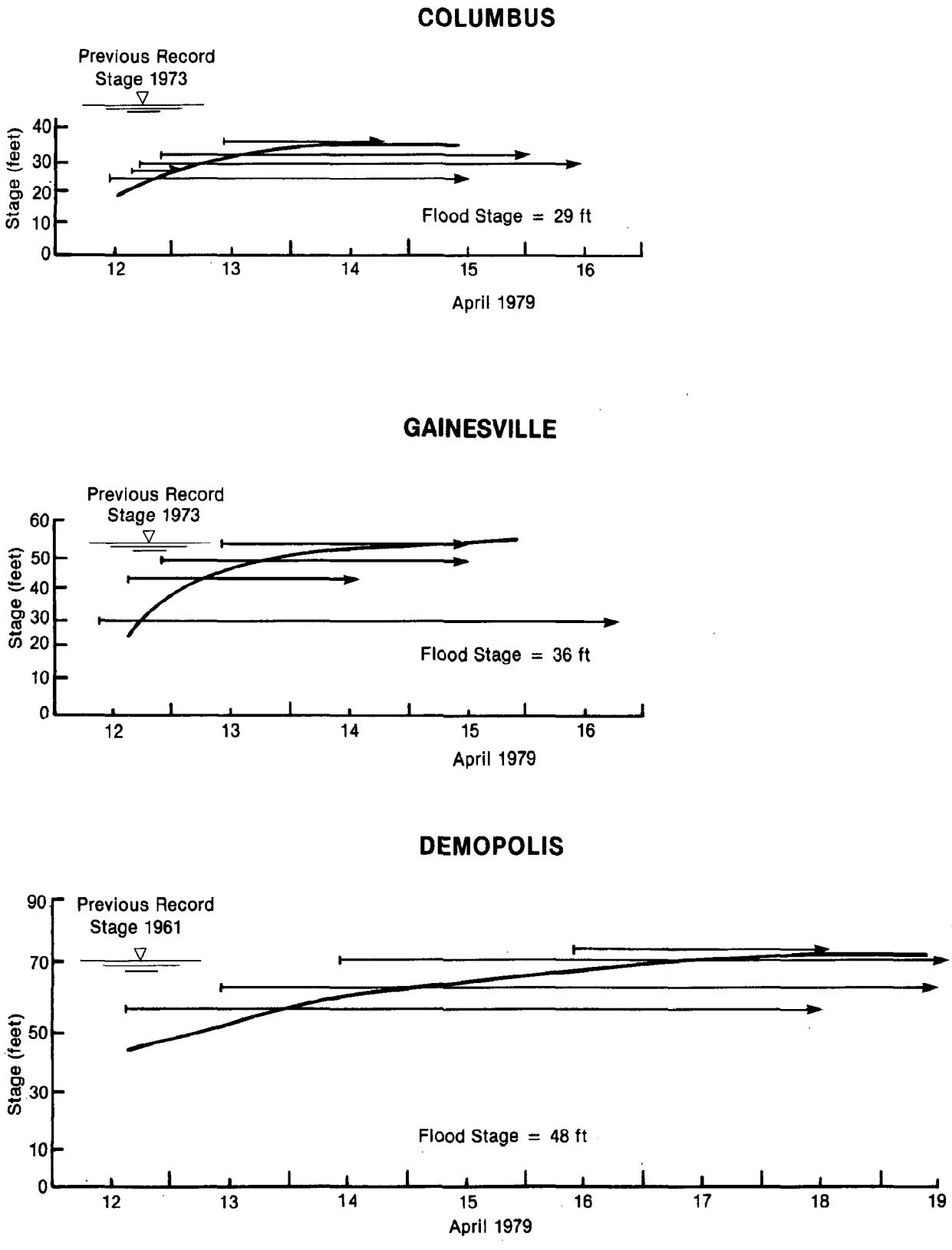


Figure 3.10 -- Comparison of crest forecasts and observed stages for Columbus, Gainesville, and Demopolis on the Tombigbee River. Arrows extend from time of forecast to time and stage forecasted.

Although no reports for the Buttahatchee were received, advisory forecasts were issued at 9:30 a.m., April 12. Verification of these forecasts was not possible due to the lack of these reports.

Tombigbee River Basin - Columbus to Demopolis

River Situation. The points at Columbus, Pickensville, and Gainesville along the Tombigbee responded very rapidly to the initial rain and continued to rise as a result of the more intense rain during daylight on the 13th. The two upstream points crested mid day on the 14th, whereas Gainesville, the downstream point, crested on the 15th.

Forecasts Issued and Assessment. After the end of the intense precipitation, crest predictions were good on Friday, at 10:30 a.m. Columbus verified within -0.4 foot and 26 hours in advance of the crest; Pickensville within 1.0 foot and 20 hours in advance. The Gainesville crest prediction at 10:30 a.m., Friday, was 1.8 feet low with 52 hours advance warning and was revised at 10:00 a.m., Saturday, to within 1.3 feet of the crest (20.3 feet above flood stage) (fig. 3.9).

The rise on the Black Warrior, which joins the Tombigbee at Demopolis, was influenced by water releases from a series of locks and dams just above Bankhead. As a result, the changes in the stages at Bankhead, Holt, and Tuscaloosa were reflective of operational decisions that are only partially related to the natural flow. Therefore, the predictions for these stations gave less than adequate warning, being low in the early rise and high as the rise approached the crest.

The forecast point at Warrior, a significant distance downstream from Tuscaloosa, has a reasonable component of natural inflow which permitted reasonable predictions of the crest to be issued as early at 10:30 a.m., on the 13th - with 1.6 feet of the actual crest and more than 2 days before the crest.

Tombigbee River Basin - Demopolis to Mobile

Forecast points in the lower Tombigbee were outside the significant precipitation area, and most of the rise occurred as the crest moved downstream. Predictions of the crest stages were issued daily. Demopolis crested more than 24 feet above flood stage and 1.3 feet above the previous maximum record (fig 3.10).

Forecasts for these downstream points were of high quality. The forecasts issued on the 14th provided advance warning within 1.8 feet more than 5 days before the crest.

HYDROLOGIC CONSIDERATIONS

Definition of Rainfall Event

Throughout this report the description of the rainfall event is based on all data collected and analyzed since the event. With this information, plus the actual river response, reasonable definition of the rainfall event is possible. However, it must be remembered that at forecast time, information on areal extent, quantity, and timing of the rainfall event was sketchy, and subject to considerable uncertainty.

Extremely high precipitation reports of this type presented several difficulties to the analyst. First, it could have been an erroneous value. Unless verified by other reports or observations, it must be suspect; if in error and used as input to a simulation model it would produce a disastrous overforecast. Second, if a judgement were made that the extreme report was valid and it was the highest amount that fell, there was uncertainty of the extent of rainfall of this intensity (or of greater intensity if the report did not sample the storm center). Third, the intensity of a rainfall event (duration of rainfall of a given amount) had a critical impact on the watershed response. Four inches in 1 hour would have produced in the order of three times as much direct runoff (major effect on peak stage) as 4 inches in 12 hours.

When initial rainfall reports from the upper Pearl River Basin began to come in at 7:00 a.m., April 12, the WSFO forecasters and RFC hydrologists were faced with the issue concerning the validity of these precipitation amounts. The reported total rainfall at Louisville (9.35 inches) was nearly double that of the closest station (Ackerman, 4.84 inches) and nearly four times more than other surrounding stations (Philadelphia, 2.27 inches).

In the headwater region of the Pearl River Basin, two distinct and significant rainfalls occurred. During the late evening of April 11, and into the early morning hours of the 12th, extremely intense rain fell onto the Louisville area. Most of the 9.35 inches of total rainfall reported to WSFO Jackson, the morning of April 12th, fell in the 4 short hours between 10:00 p.m. and 2:00 a.m. In contrast to the initial rainfall, which was heavy and short-lived, the secondary rainfall was prolonged and moderate in intensity. The continuous precipitation of the 12th resulted in rainfall totals 50 percent greater than the 7:00 a.m. total. In response to these two periods of rainfall, the headwater tributaries of the Pearl rose to an initial crest late on the 12th and early 13th, and a renewed or continued rise to a final crest on the 14th.

Reservoir Inflow

Forecasts of inflow to the Ross Barnett Reservoir were prepared by LMRFC and based on current upstream river observations and the forecast of future flow at these points. Initial forecasts were based mainly on the predicted flows at the upstream gages, which in turn were a result of simulation of each

stream's response to the estimated watershed rainfall. Later, as the upstream points were nearing or had reached their crest, the inflow forecasts were refined. Relative timing of the runoff peaks from the several upstream subbasins was extremely critical in determination of peak reservoir inflow. Therefore, in this case it was especially vital to have knowledge of the quantity and time distribution of the precipitation in each subbasin.

Reservoir Releases

During most of the rise of the Pearl in Jackson, the major factor affecting the river channel originated with the discharges of the Ross Barnett Reservoir. Foreknowledge of the details of the strategy for releases from the dam was necessary to compute stage forecasts downstream at the US Highway 80 gage. NWS operating procedures did not encourage the reservoir operator to work directly with hydrologists at RFC Slidell to investigate the sensitivity of reservoir operations to inflow forecasts.

The reservoir operator normally receives inflow information from the USGS and uses this information to determine the release. On Saturday, April 14, the operator had two values for forecast inflow. One was the USGS inflow of 160,000 cfs and the other the RFC forecast of 180,000 cfs. With this information the operator consulted COE concerning the uncertainty regarding the volume and timing of the ultimate inflow and his need to protect the structure. The operator subsequently worked with COE in regulating the reservoir level and water releases. The maximum outflow of 125,000 cfs was set after consultation with COE. WSFO Jackson did not participate in the COE and reservoir operator strategy discussions for scheduling water releases; rather the forecasts were developed from the information passed to NWS by the reservoir operator. As such, the reservoir operator was unable to provide NWS with release schedules for more than 12 to 18 hours in advance in the early part of the rise.

Starting on Sunday, longer term release schedules were available when the stated intent was to hold the outflow to near 120,000 cfs to pass the flood. On the basis of this advance notification, WSFO Jackson issued forecasts for the US Highway 80 gage that were generally 18 to 24 hours in advance.

Rating Tables

Successful conversion of computed flow at a river gage to river elevations (stages) at the gage (or the reverse -- stage to flow) is accomplished by a rating table or curve. At most of their gaging stations, USGS maintains rating tables based on measurements made during recent historical flow events. Beyond recent current flood levels, the relationship must be extended by theoretical means. During this flood, many stations had stages well above the existing rating table limits and the situation necessitated the extrapolation of the tables beyond historical levels.

Three rating curves (tables) for the US Highway 80 gage were used. The WSFO had a rating curve prepared by the USGS that provided for stages of 36 feet with flows of 52,000 cfs as the maximum. At RFC Slidell, the curve was an

extrapolated version based on a semi-log extension from a stage of 36 feet for 52,000 cfs to 42 feet for 163,000 cfs. The COE had a more recent rating curve, which they had developed for the Federal Flood Insurance Administration. The rating curves available to RFC Slidell and WSFO Jackson reflected conditions prior to the construction of the levee systems and highway bridges in the Jackson area. COE's rating curve took into account the levee and highway construction. As a result, for river flow at the US Highway 80 gage of 120,000 cfs, COE's rating curve gave a stage of 42.5 feet, while the Slidell extension gave a stage of 40.5 feet. The WSFO did not have the results from the COE's most recent flood insurance study. The study was completed in February 1977 but had not been published. The difference in the COE rating curve as compared to the NWS/USGS version is about 0.5 foot at 50,000 cfs, 2 feet at 110,000cfs, and 3 feet at 180,000 cfs. On the basis of the USGS revised rating curve subsequent to the flood, it appears that the COE extension during the flood was about correct. (See fig. 3.11).

Effects of Levees

In general, levees are not constructed to the height of the maximum flow ever expected. Physical constraints of the site, cost-to-benefit ratios, and the public demands determine the final levee height. However, when a flood exceeds levee design capacities, three possible things can occur: 1) The levee may be flanked or overtopped, 2) the levee height may be increased by temporary measures such as sandbagging, or 3) the levee might be breached because of structural failure.

The levees at Jackson were constructed in 1967, on both sides of the Pearl River. On the east bank across Jackson, the levee around Flowood held with the assistance of sandbagging by local citizens and COE. On the west bank, around a portion of downtown Jackson, the levees were built to the same elevation as at Flowood; however, on Saturday, the area was flooded as a result of (1) heavy local inflow from creeks into the leveed area, (2) water backing up through sewers and drains, and (3) flanking of the levee. The performance of the levee system and uncertainty about its possible failure under the onslaught of a record-size flood complicated the stage forecasts. Several times during the flood period, false information was passed to WSFO Jackson that the levee around Flowood had weakened and was about to fail. The risk of levee failure was influential in the statements and forecasts issued for the US Highway 80 forecast point.

Hydraulics of the Pearl River at Jackson

The river reach between the reservoir and US Highway 80 is very flat and tends to function as a natural lake, storing water and smoothing out fluctuations in the flow (discharge from Ross Barnett). (See fig 3.12 to compare the shape of the dam release hydrograph with the hydrograh of streamflow leavings this reach at US Highway 80.)

Because the reach is very flat, the slope of the water surface had to be steeper than the slope of the normal stream in order to pass the flood. This increased water surface slope caused not only extreme flooding in northeast

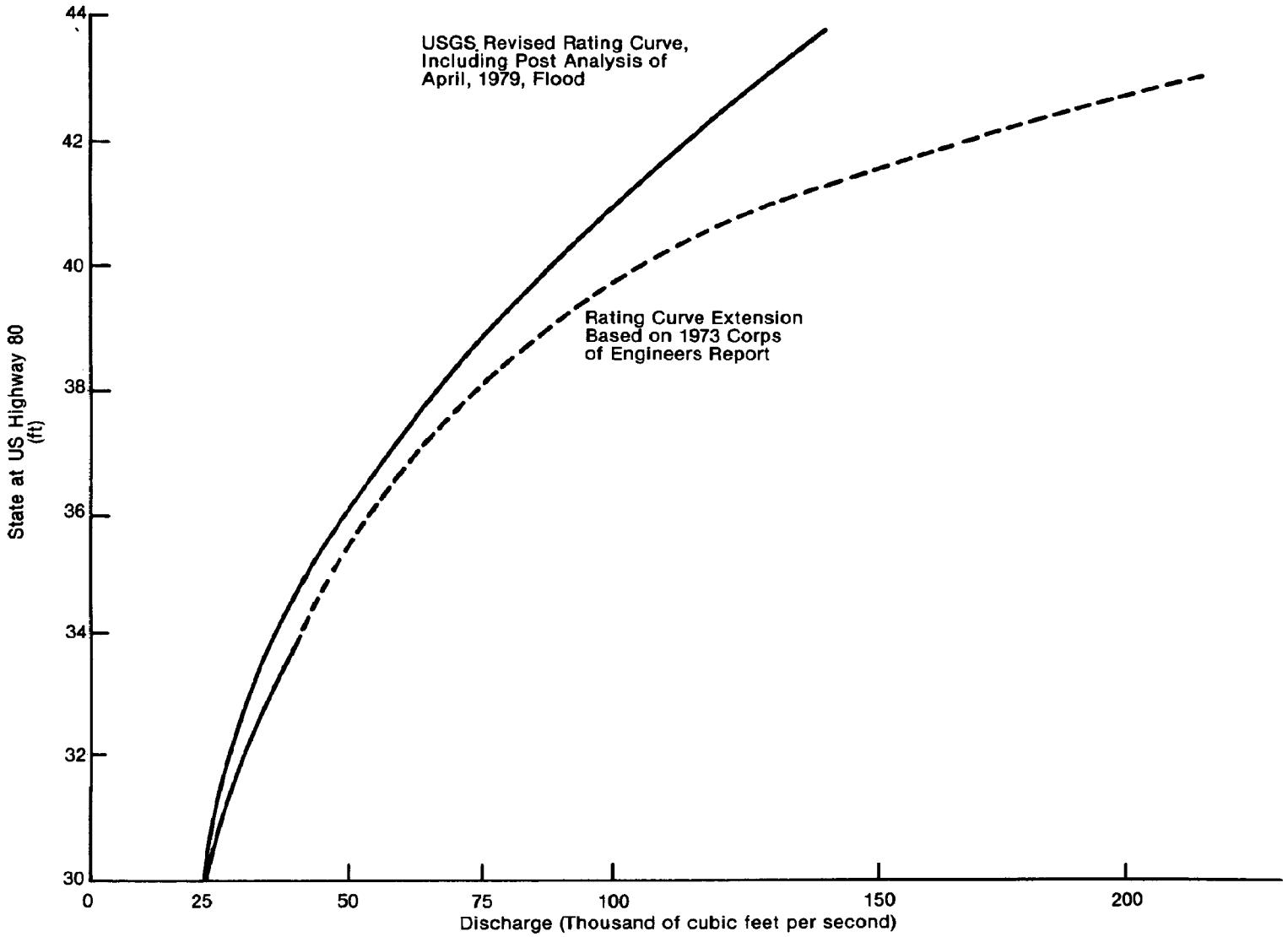


Figure 3.11 -- Rating curves of discharge vs stage for US Highway 80.

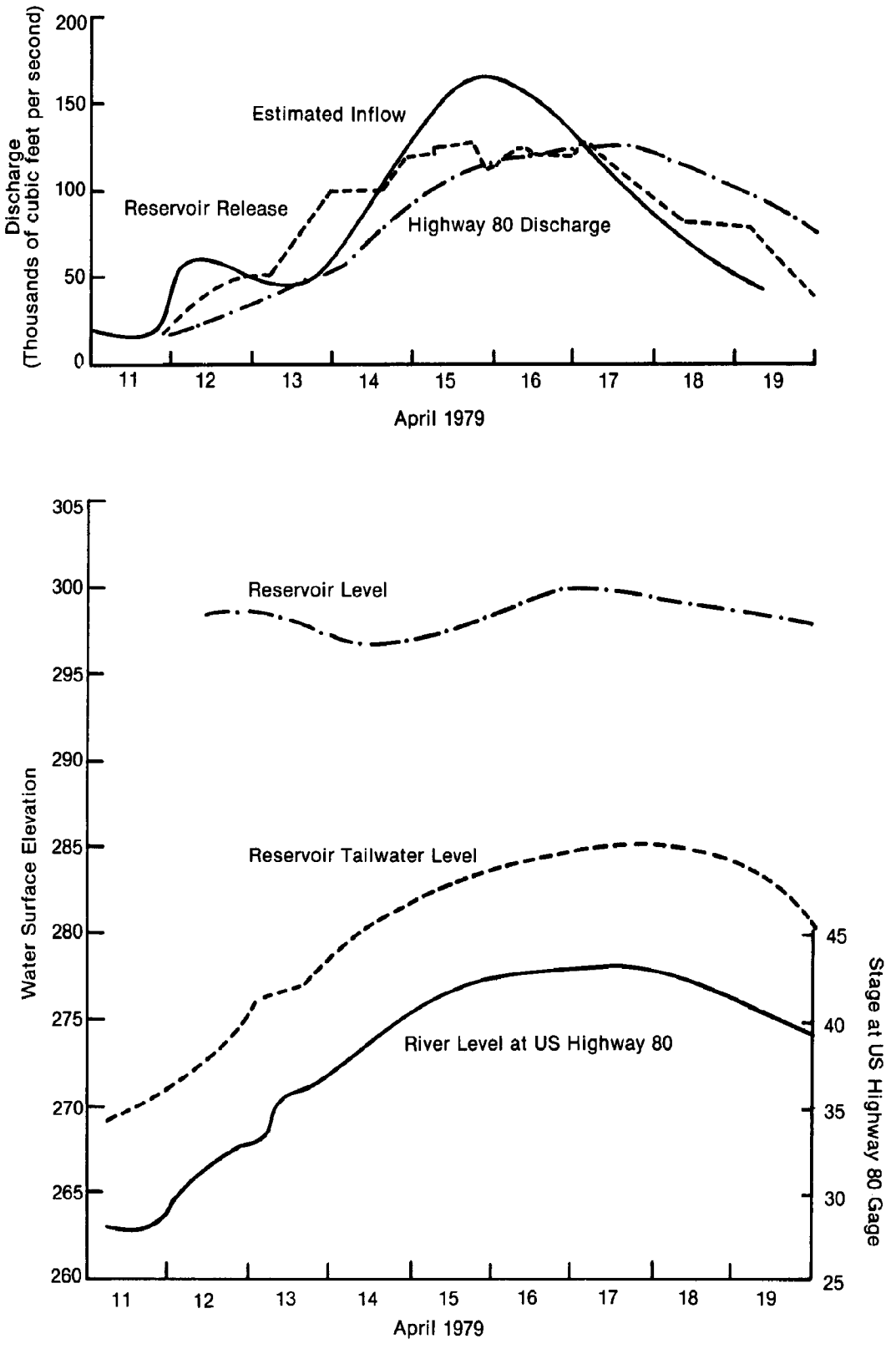


Figure 3.12 -- Ross Barnett Reservoir and Pearl River hydrographs for April 11-19, 1979.

Jackson, but also a more complicated hydraulic condition than is accounted for by the forecast procedures normally used by Jackson. Presence of the levees and other encroachments on the flood plains added to the complexity of the situation. The hydraulics of the routing of the water through Jackson to the US Highway 80 gage is not amenable to subjective and manual techniques.

FINDINGS AND RECOMMENDATIONS

Finding 3.1

Flood forecasts for the Tombigbee, Pearl upstream tributaries, and Pearl below Jackson were good to excellent (mostly within one to three feet).

Finding 3.2

At Jackson an adequate warning was given of a record flood event and accurate forecasts were made of the stages to be expected in the next 12 to 24 hours. But the public was not served with an accurate early forecast of the magnitude and timing of the flood crest.

To make such a forecast, the expected schedule of future releases from Ross Barnett Reservoir until April 17 would have been needed together with better information on how high the river would rise in response to the predicted releases.

Recommendation 3.2

Develop working relationships with the reservoir operator so that more adequate future release schedules can be known during flood periods. Given a planned response to an inflow forecast of any given volume and time distribution, simulation techniques should be used by the RFC to improve the quality of downstream stage forecasts.
Develop a more adequate forecast model of the complex hydraulic system including the Ross Barnett Reservoir and the river reach between the Ross Barnett Dam and US Highway 80.

Because of the complexity of the forecast problem at the US Highway 80, assign forecast responsibility for flood forecasts to LMRFC.

Finding 3.3

To have given the NWS a definitive schedule of future reservoir releases, the reservoir operator would have needed from the NWS forecasts of the inflows. The inflow forecasts made by the LMRFC were as accurate as the available rainfall data, streamflow data, and existing forecast techniques would permit. Additional accuracy could be achieved with additional rain gages, better RFC access to radar and satellite data, and by improving the forecast update procedures that take into account the observed streamflow data.

Recommendation 3.3

The NWS should continue present efforts to improve the use of radar and satellite data in RFC forecasts. In addition, network improvements should be made in accordance with recommendation 4.1. Improved methods should be developed for adjusting forecast models using observed streamflow data.

Finding 3.4

There was some confusion within the general public in the interpretation of the forecasts issued by WSFO Jackson. In some cases, despite narrative qualification, forecasts were acted upon as if they were the final crest expected. Wording of the statements was not consistently clear on this point.

Recommendation 3.4

All river and/or flood forecasts and statements should clearly differentiate between crest forecasts (highest gage height and time expected) and a predicted river height for a given time in the future. Each of these types of forecasts are valid and in fact may be desirable to include in one forecast statement. However, under flood conditions the crest forecast is probably the most useful. During flood conditions, it may be necessary to include the words "This is not a crest forecast" in case of a predicted gage height for given time.

Finding 3.5

Integration of the Service Hydrologist into the WSFO operation at Birmingham was ideal. He was used as focal point for the hydrologic program, using his expertise to assist the MIC to manage the program while the routine operations of the hydrologic program were carried on by other staff personnel. The results of this arrangement were evident in the high level of coordination and liaison with reservoir operators, outside agencies, and community emergency personnel. The adequacy of the documentation of the reporting network stations, forecast points, and flood prone areas indicated that the Service Hydrologist was used in the proper manner.

Recommendation 3.5

Structure the operation at all WSFO's to take full advantage of the Service Hydrologist's expertise and allow him time to maintain a high level of coordination with outside agencies and to operate an efficient, well-documented hydrologic program at the WSFO.

Finding 3.6

At WSFO Jackson the absence of the Service Hydrologist or Hydrologic Technician during the flood emergency contributed to limited or inadequate coordination with the COE, the USGS, and the reservoir operator; and to loss to the NWS of important information developed by the COE on river hydraulics and levee capacity to withstand overtopping.

Recommendation 3.6

In the case of planned vacancies for key personnel such as the Service Hydrologist or the Warnings and Preparedness Meteorologist, have adequate

provision for backup. At the national level, develop improved mechanisms for interagency sharing of detailed river and flood plain information.

Finding 3.7

There was inadequate documentation of the river station sites and the effects of various flood levels on the surrounding areas, particularily at Jackson. The contrast between the use of the Service Hydrologist at Jackson and Birmingham, as discussed in (4) above, in part contributed to this condition.

Recommendation 3.7

The WSFO and RFC should have available adequate and up-to-date documentation on each river reporting and river forecast site. Report on River Gage Station (WS Form E-19) is a good starting point for such documentation.

Finding 3.8

Quantitative Precipitation Forecasts (QPF) prior and during the flood-producing storm severely underestimated the rainfall intensities as well as the areal extent of the storm.

Recommendation 3.8

The importance of improved QPF's cannot be over-emphasized. Present efforts should continue to improve the state of the art of QPF forecasting, incorporating radar, satellite, and gaged rainfall data.

Finding 3.9

The large area of major flooding and severe weather created an excessive workload on the RFC's and WSFO's. There was not adequate hydrologic staffing to deliver forecast service up to the level of the state of the art for the magnitude of the event encountered. At the WSFO's there was not adequate hydrologic expertise for around-the-clock coordination with local officials throughout the large area affected. At the RFC's the night shifts were staffed with only one or two hydrologists which was not sufficient to properly analyze the incoming data and perform forecast computations. During the most critical period, a hydrologist from the LMRFC was sent to WSFO Jackson to act as Service Hydrologist. Although this reduced the capacity of the LMRFC it was the best way to use the available hydrologic staff. The survey team recognizes that staff deficiencies are not unique to the stations involved with this flood. The hydrologic staffing at the WSFO's and RFC's in the area are typical of the entire NWS.

Recommendation 3.9

The NWS should give serious consideration to improving hydrologic services during major and extensive flood events. Some of the specific measures that should be considered are:

a. Allocate additional qualified hydrologic personnel at WSFO's;

b. Develop a program for sending experienced hydrologists from other offices to flood areas on a temporary basis;

c. Provide additional automation to reduce the workload for data handling, analysis, and forecast preparation; and

d. Develop computer graphics information displays to expedite forecaster understanding of the current situation.

CHAPTER 4
DATA ACQUISITION AND INTERNAL COMMUNICATIONS

Before the National Weather Service (NWS) can provide forecasts and warnings of impending weather situations, the existing weather conditions must be determined and recorded. To gather these vital data, NWS relies on various observation systems, programs, and network configurations. Numerous and various kinds of observations provided the data used in the meteorological and hydrological forecasts and warnings. This chapter discusses the effectiveness of the systems that provided these data and the communication channels over which they moved.

DATA ACQUISITION

METEOROLOGICAL SURFACE AND UPPER AIR-OBSERVATIONS

Networks of about 300 surface and 70 upper air reporting stations over the contiguous United States and adjacent waters provide the data used in the basic meteorological analyses and forecasts prepared by the National Meteorological Center (NMC). The surface network provides data used for surface analyses every 3 hours. No significant deficiencies were reported in the surface data network, which, for synoptic-scale purposes, is fairly dense. The upper-air network provides observations twice daily, for input, with the surface data for the synoptic (broad) scale numerical weather prediction models that form the basis of the NMC guidance products.

Missing data or irregularities are critical in the network of upper-air stations, and some of these did occurr. At 6:00 a.m., Thursday, April 12, the upper air observation for El Paso, Tex., reached the circuits with an incorrect station identifier--one assigned to Tucson, Ariz. This error was discovered at NMC, but not before it had already been used in the Limited Fine Mesh (LFM) Model. The error was corrected for the run of the 7-Level Primitive Equation (7LPE) Model, and a message sent to the field offices warning of a spurious vorticity maximum which may have affected the LFM forecasts. At the same data time, 6:00 a.m., April 12, the upper-air observation for Jackson, Miss., was missed owing to equipment outage caused by the lightning strike at that station late the previous evening. The electronic technicians at WSFO Jackson repaired the equipment as rapidly as possible, and it was ready for the 6:00 p.m. observation. The effect of one missing observation is difficult to assess, but in this case, it certainly affected the analysis of mean relative humidity and atmospheric stability, both important conditions for thunderstorm and rainfall prediction.

The lightning strike also damaged some surface-observing equipment at WSFO Jackson. The hygrothermometer, used to measure dewpoint temperature, and the wind-measuring equipment, were put out of commission, but repaired very shortly after the lightning strike. The rotating beam ceilometer, used to measure cloud bases, was inoperative until Friday, April 13.

RADAR OBSERVATIONS AND DERIVED PRODUCTS

Observations

When severe thunderstorms moved into Mississippi on Wednesday evening, April 11, the basic radar network covering Mississippi and Alabama was operational. Network radars at Little Rock, Ark.; Millington, Tenn. (outside Memphis); Jackson, Miss.; Slidell, La.; and Centreville, Ala., were all operating and contributing data to their warning offices. Local warning radars in Meridian, Miss.; Huntsville, Ala.; and Baton Rouge, La., were also operational. While the National Severe Storms Forecast Center was issuing tornado watches for Mississippi and Tennessee, WSFOs Jackson and Memphis were issuing local storm warnings on the basis of radar information. The area affected was well within the storm detection and hydrologic range (75-100 nautical miles) of 10-centimeter (cm) network radars at Jackson, Miss., and Centreville, Ala., and a 5-cm local warning radar (LWR) at Meridian, Miss. However, the area was beyond the effective hydrologic range of the next-closest radars at Slidell, La.; Memphis, Tenn.; and Little Rock, Ark.

By 10:30 p.m., April 11, WSFO Jackson had issued 11 tornado warnings, 11 severe thunderstorm warnings, and 1 flash flood warning, many of them on the basis of radar information. Shortly after 10:30 p.m., in the middle of a scheduled hourly radar observation, lightning struck the radome of the Jackson radar. The office had switched over to emergency power earlier in the evening following a brief flicker in the commercial power. The lightning strike damaged the alternator on the emergency power generator, knocked out several essential parts of the radar, and damaged other pieces of equipment. The radar at WSFO Jackson was out of action for the rest of the severe thunderstorm and rainfall event. With the assistance of surrounding radar offices, some as far away as Baton Rouge and Shreveport, La., and Huntsville, Ala., Jackson continued to function as the primary warning office for the State of Mississippi. Forecasters in Jackson were very appreciative of the support given them.

The Weather Bureau Radar Remote (WBRR), a device for receiving facsimile images from other radar stations, was also knocked out by the lightning strike and was out of service, awaiting parts, at the time of the survey.

Fortunately, the Forecast office did not lose commercial power. The telephone lines, National Warning System (NAWAS) lines, and other communications equipment returned to normal. The staff plotted radar information received over the Radar Reports and Warning Coordination (RAWARC) teletypewriter circuit and by telephone and was able to handle the warning functions, despite the increased workload and obstacles to effective operation caused by the loss of radar. Telephone communications between the offices made up for occasional losses of observations to normal transmission circuits (RAWARC).

WSFO Jackson transferred responsibility for network radar coverage, listing WSO Meridian as its primary alternate. WSFO Jackson first believed that the

outage would be only 1 to 4 hours. However, many components of the radar were damaged, and it was not until Thursday afternoon that the radar was fit for even limited operation.

During the night of April 11, Meridian was short staffed and hard pressed to maintain both routine forecast and warning responsibilities, in addition to encoding and transmitting radar observations. For a small office with a staff of seven, including an electronics technician, WSO Meridian did a creditable job in the 35 hours following the lightning strike at Jackson, taking 30 hourly observations and transmitting 28. Two observations were not transmitted because of severe weather warnings being issued. The team considers this remarkable, because the office simply was not staffed for a sustained period of radar responsibility, in addition to handling the warnings and data collection function in its county responsibility area. On the whole, Meridian's radar observations clearly defined the heavy rain threat.

An examination of the radar logs of the network stations involved and a review of the RAWARC circuit output indicate adequate radar coverage during this severe weather and heavy rainfall event.

Manually Digitized Radar

One product derived from radar observations each hour is the coded list of Manually Digitized Radar (MDR) values. These values, encoded for a grid made up of squares about 22 nautical miles on a side, are the maximum intensity radar returns for each square. The maximum values are used in estimating potential for severe thunderstorms and in estimating rainfall rates. They are also used in the automated radar map, which is plotted and transmitted by NMC for use in the NWS offices.

Data were available from the Jackson radar until 10:30 p.m., April 11. About the time of the lightning strike rain began in earnest at the WSFO. Hourly MDR data for Jackson's area showed estimated rainfall maxima for a 2- or 3-hour period (before the outage) of up to 3 $\frac{1}{2}$-inches with a 50 percent probability. The WSFO staff recognized the flash flood threat and issued a warning at 10:40 p.m., for counties around Jackson.

First radar observations at Meridian during this storm were logged at 7:30 p.m., April 11. By 2:30 a.m., April 12, the 4-hour total of MDR values (a total of 16) was sufficient for an estimate of a 50 percent chance of 4 $\frac{1}{2}$ inches in the grid square that included Louisville. At 3:30 a.m., Meridian warned this area, basing the warning largely on radar data. MDR did not indicate it rained 10 inches at Louisville by 6:00 a.m., but did indicate a high probability of more than 5 inches of rain. This was sufficient for warning action.

SATELLITE IMAGERY AND DERIVED PRODUCTS

NOAA's operational East Coast satellite during the April 11-13 rainfall was SMS-1. It was stationed 37,500 kilometers over the Equator at 75° W. Imagery from the satellite was transmitted every half hour to WSFO Birmingham and WSFO

Jackson from the NESS Satellite Field Service Station (SFSS) at Kansas City. WSFO Birmingham received the imagery with no breaks in reception. At WSFO Jackson, a 2-hour outage was experienced following the lightning strike. Both visible and thermal infrared (IR) imagery are transmitted during daylight; only the IR imagery is available at night.

The Kansas City SFSS prepared Satellite Interpretation Messages (SIM's) every 6 hours for transmission to the WSFO's over RAWARC. The storms in the Mississippi-Alabama region were mentioned in every SIM released between noon, April 11, and 6:00 p.m., April 13. The SIM's gave direction and speed-of-line movement while pointing out areas of strongest convective activity. In addition, during this period, six consultation calls were logged between meteorologists at the SFSS and the WSFO Birmingham; eight calls were logged between the SFSS and the WSFO Jackson.

SFSS also requested QPE's from the NESS Synoptic Analysis Branch (SAB) at the World Weather Building in Camp Springs, Md., for relay to the WSFO's. The technique provided half-hourly or hourly rainfall estimates for county areas using specially enhanced GOES thermal IR imagery together with high-resolution visible images, if available. NESS made 139 QPE determinations during the storm event: 71 for counties in Mississippi and 68 for counties in Alabama. These estimates were hand delivered to NMC's QPB and relayed by telephone from SAB to the Kansas City SFSS and then to the WSFO's in Jackson and/or Birmingham. The estimates were generally in the hands of the WSFO staff about 60 minutes after the satellite viewed the scene.

Figure 4.1 shows an isohyetal map of satellite derived rainfall estimates for the 48-hour period ending 6:00 a.m., April 13.

During the period 4:30 to 5:30 p.m., April 11, truncated or unusable satellite data were reported to the Kansas City SFSS by WSFO's in Indiana, Texas, and Alabama. This was due to a high bit-error rate in the data stream transmitted from the satellite to the antennas at Wallops, Va. This data loss delayed the start of QPE until 5:45 p.m.

Problems with gridding resulted in nontransmission of QPE over northwestern and southwestern Mississippi for the period 7:30 to 8:30 p.m., April 11. Gridding had been a problem at NESS since a forced changeover from GOES-2 to SMS-1 on January 26, 1979. SMS-1 had a non-circular orbit and a subpoint oscillation that could not always be adequately handled by the computer programs which automatically implant the gridding. The replacement of SMS-1 by SMS-2, on April 19, together with new techniques of navigation have since negated these gridding errors. In any case, gridding errors only aborted QPE for the one-hour period on April 11, with subsequent estimates unaffected. SFSS Kansas City and WSFO Jackson indicated that their operations were not affected significantly by the errors.

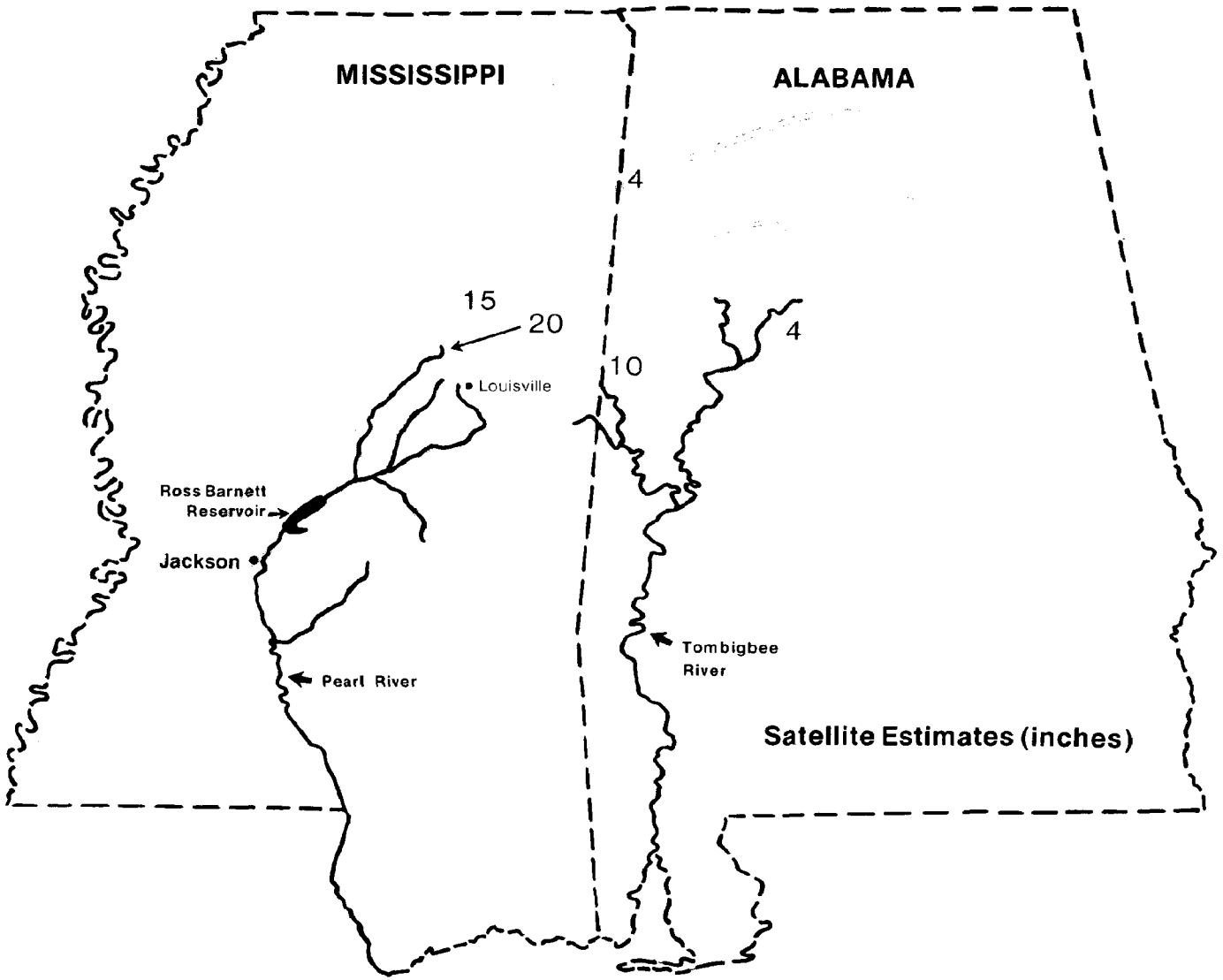


Figure 4.1 -- Satellite derived rainfall estimates for Mississippi and Alabama for the 48 hours ending 6:00 a.m., April 13, 1979.

HYDROLOGIC REPORTING NETWORK

Mississippi

The NWS Hydrologic Reporting Network in Mississippi has been set up to measure and report once daily, at 7:00 a.m., when minimum stage or rainfall criteria are met. This network comprises 34 river stage and lake elevation reporting locations (fig. 4.2) -- actually 36 reports, because two locations have both manual and automatic observations -- and about 100 rainfall reporting points (fig. 4.3). In addition, COE receives daily stage and rainfall reports, on a radionet, from four reservoirs and three river reporting points. These reports are called into WSFO Jackson and relayed by telephone to RFC Slidell. Jackson also receives rainfall reports from the "a" network of climatological stations within the State and routinely collects rainfall reports from the State agricultural network.

Nineteen of the 36 river gages in the NWS network are automated and can be interrogated by telephone. Seven of these stations also have automatic readout of tipping-bucket rain gages. There is one other automatic rain gage, at Liberty, in southwest Mississippi. All the other rainfall reports and the other 17 river stage reports are made manually by cooperative observers who then telephone reports to a specified NWS office, usually the office with county warning responsibility. Thus, WSFO Jackson collects most of the Mississippi river and rainfall reports, with a lesser number being collected by WSFO Memphis and WSO's Meridian and Mobile. Reports are then sent by telephone or over the RAWARC teletypewriter circuits(s) to RFC's in Slidell or Atlanta.

During the period of heavy rainfall and flooding, the network operated as designed. Considering the outage of some telephone lines, the extent of rainfall, and the extreme overload of RAWARC, a remarkable number of reports were received at the RFC's within 2 hours of observation time. By 8:20 a.m., Thursday, April 12, 33 river stage reports, 2 discharge measurements, and 51 rainfall reports had been sent on the RAWARC circuits of the RFC's from WSFO's Jackson and Memphis and WSO's Meridian and Mobile.

By 7:20 a.m., April 13, WSFO Jackson had placed on the circuit 34 rainfall reports and 24 stage reports. An additional 20 rainfall reports and 8 more stage reports followed an hour later. More problems with telephone outages were noted by this time, and one critical report-- the additional 10.25 inches of rain at Louisville on top of their previous 24-hour total of 9.35 inches-- was sent by an amateur radio operator. It is impossible to determine the times that late reports were sent to the RFC's, but it is the practice at WSFO Jackson to relay all reports by telephone as they arrive.

Both RFC's visited indicated that additional reports (1:00 p.m. and 7:00 p.m.) would have been useful during the period of heavy rain. Some concern was expressed by WSFO Jackson, which sent an appeal through the news media at 5:20 p.m., Thursday, April 12, for additional reports from cooperative observers.

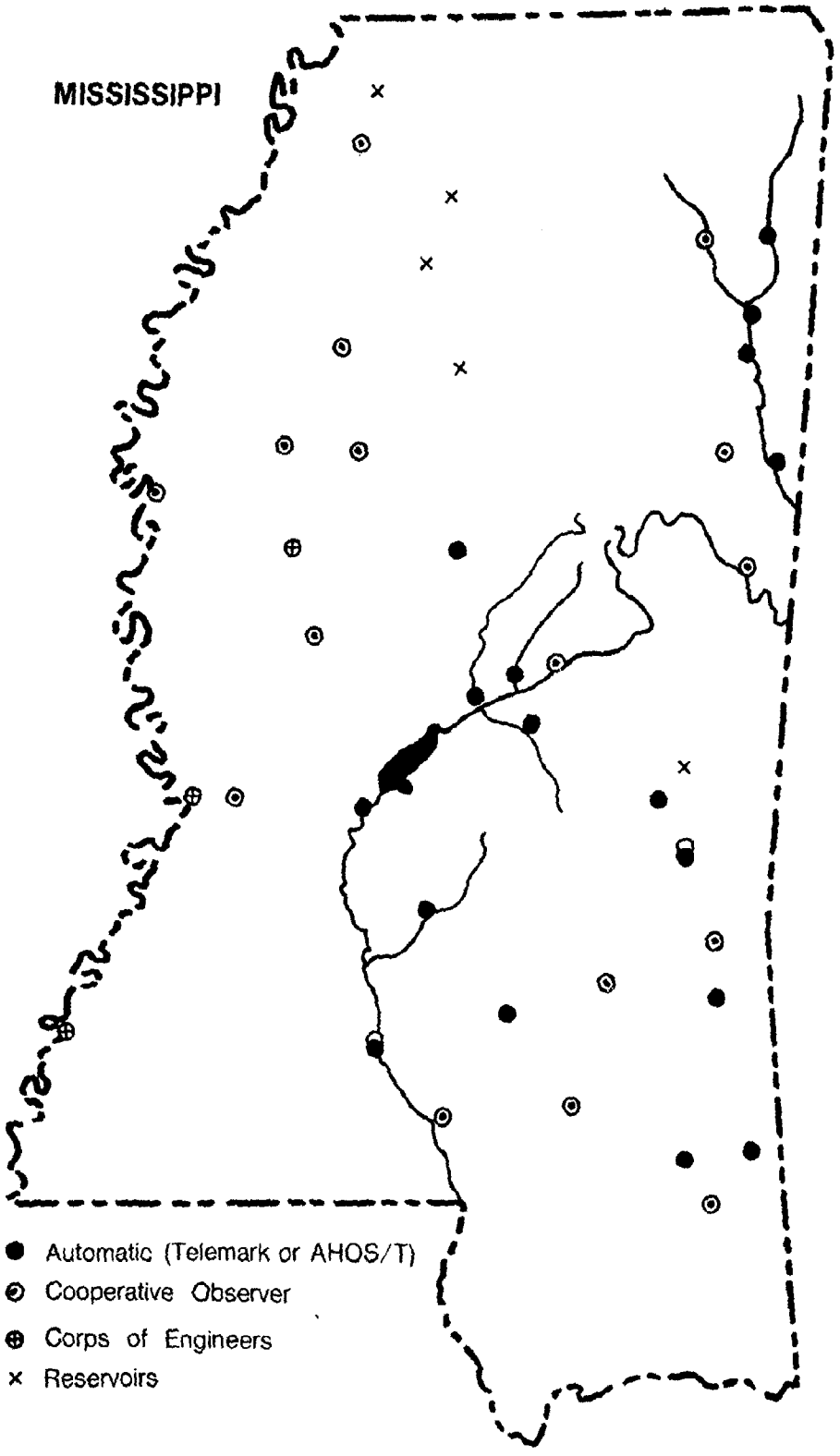


Figure 4.2 -- River Stage and Lake Elevation network for Mississippi.

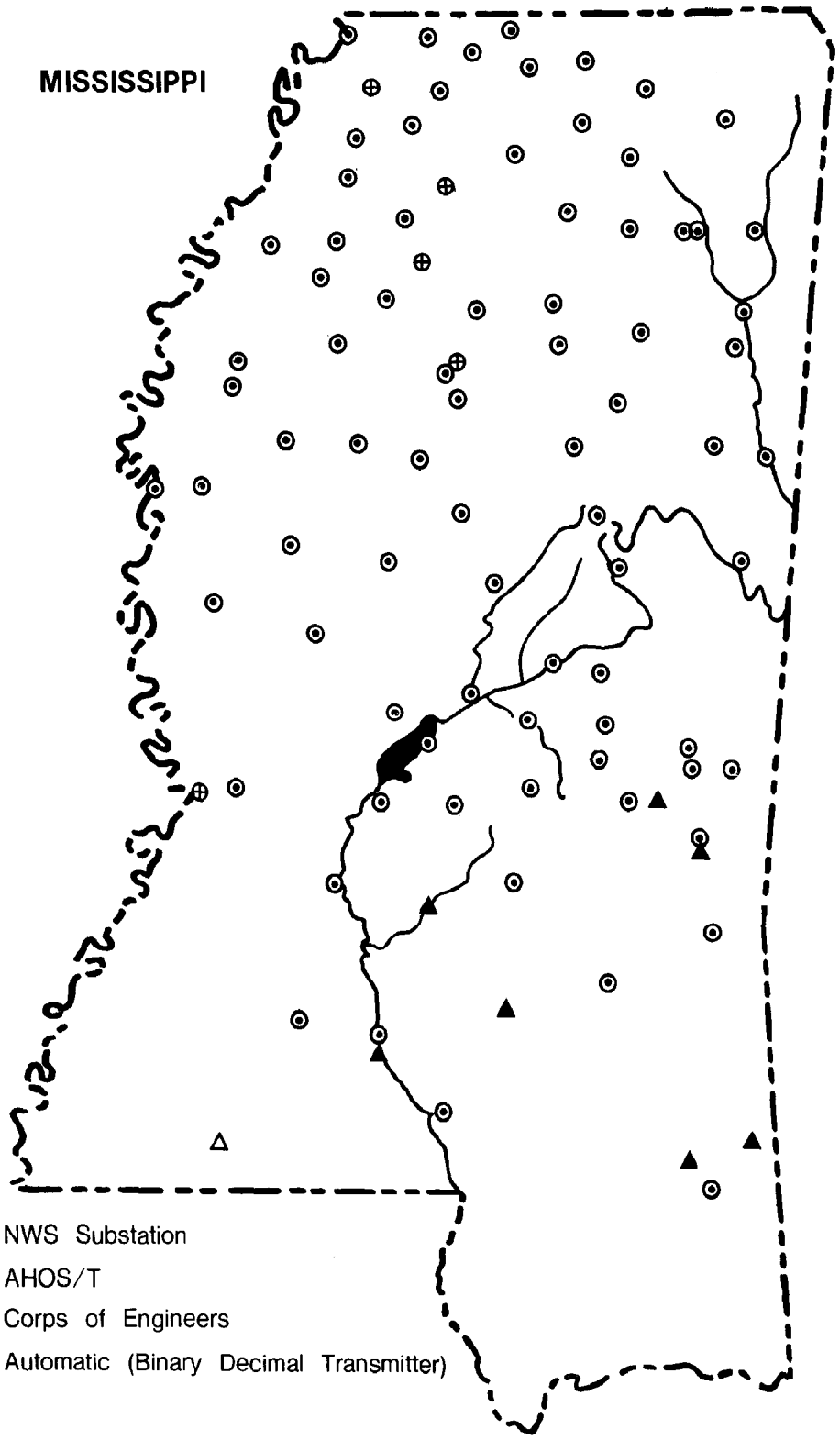


Figure 4.3 -- Daily Rainfall Reporting stations for Mississippi.

Some of the staff at Jackson thought this resulted in additional reports, but a check of the logs indicates that nearly all the extra reports received that day arrived before the appeal.

In the Upper Pearl Basin, three of the four river gages are automated. The fourth, at Edinburg, is read manually, as is the precipitation gage at that station. This station did not report at 7:00 a.m., Thursday, April 12, but did call in a river stage that evening. The following morning, delayed stage and rainfall reports for Thursday morning were given, along with the Friday readings. The team was unable to determine the reason the call was not made Thursday morning. From Friday until the flood crest on the Pearl River had passed on downstream, readings of all automatic gages were made every 2 to 3 hours.

Telephone lines caused continous problems. The stage reading for Walnut Grove, on the Upper Pearl, was missing intermittently, because of malfunctioning telephone lines for several hours before the crest. It became serviceable for the crest, then was inoperative for over 24 hours. In Jackson, it became apparent that too many people had the telephone number for the US Highway 80 river gage, and the number had to be changed. When telephone lines to the Ross Barnett Reservoir went out, amateur radio operators stepped in. They also set up operations for data relay between the US Highway 80 gage and the WSFO.

The Automated Data Acquisition System (ADAS) at WSO Athens, Ga., was inoperative during the rainfall and flood event. This system is used to interrogate automatically the Automated Hydrologic Observing System/Telephone (AHOS/T) stations and disseminate the information. Without this equipment, the WSFO's involved had to call each AHOS/T station for the report. This created an added workload, but was not considered a significant factor in the data acquisition.

Alabama

The basic hydrologic observing network in Alabama comprises 37 river stage and lake elevation reporting stations (fig. 4.4) and about 100 rainfall reporting stations (fig. 4.5). Unlike the network in Mississippi, this network reports on criteria, with the basic observation taken at 7:00 a.m. each day. Supplementary observations are taken and reported at 1:00 and 7:00 p.m. The duty hydrologist at WSFO Birmingham reported that the network in Alabama functioned as designed, with the following exceptions: (a) The AHOS/T rainfall station at Pickensville was inoperative, and even when operating had not been reliable; (b) a misunderstanding arose over a stage reported at Oliver Lock and Dam (Tuscaloosa) -- the upper gage reading was mistaken for the lower gage readings, which led to confusion and the need to revise a forecast; and (c) telephone lines to the area of heaviest rainfall went out and reports from Reform and Aliceville were delayed. The RFC in Atlanta reported that only 7 of 15 reports were received from the Upper Tombigbee in Mississippi the evening of April 12. This agrees with the data received in WSFO Jackson and WSO Meridian for that evening.

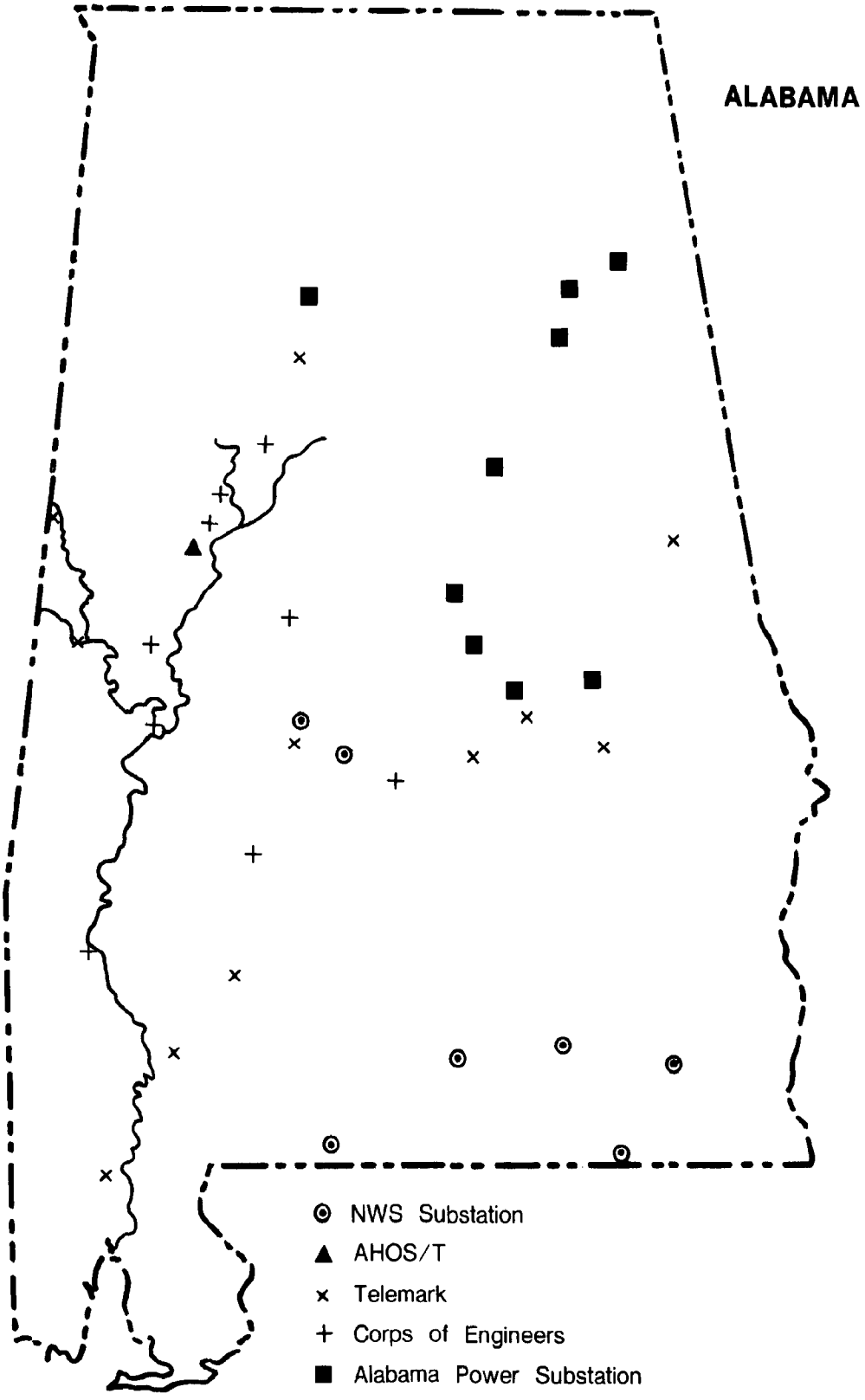


Figure 4.4 -- River Stage and Lake Elevation network for Alabama.

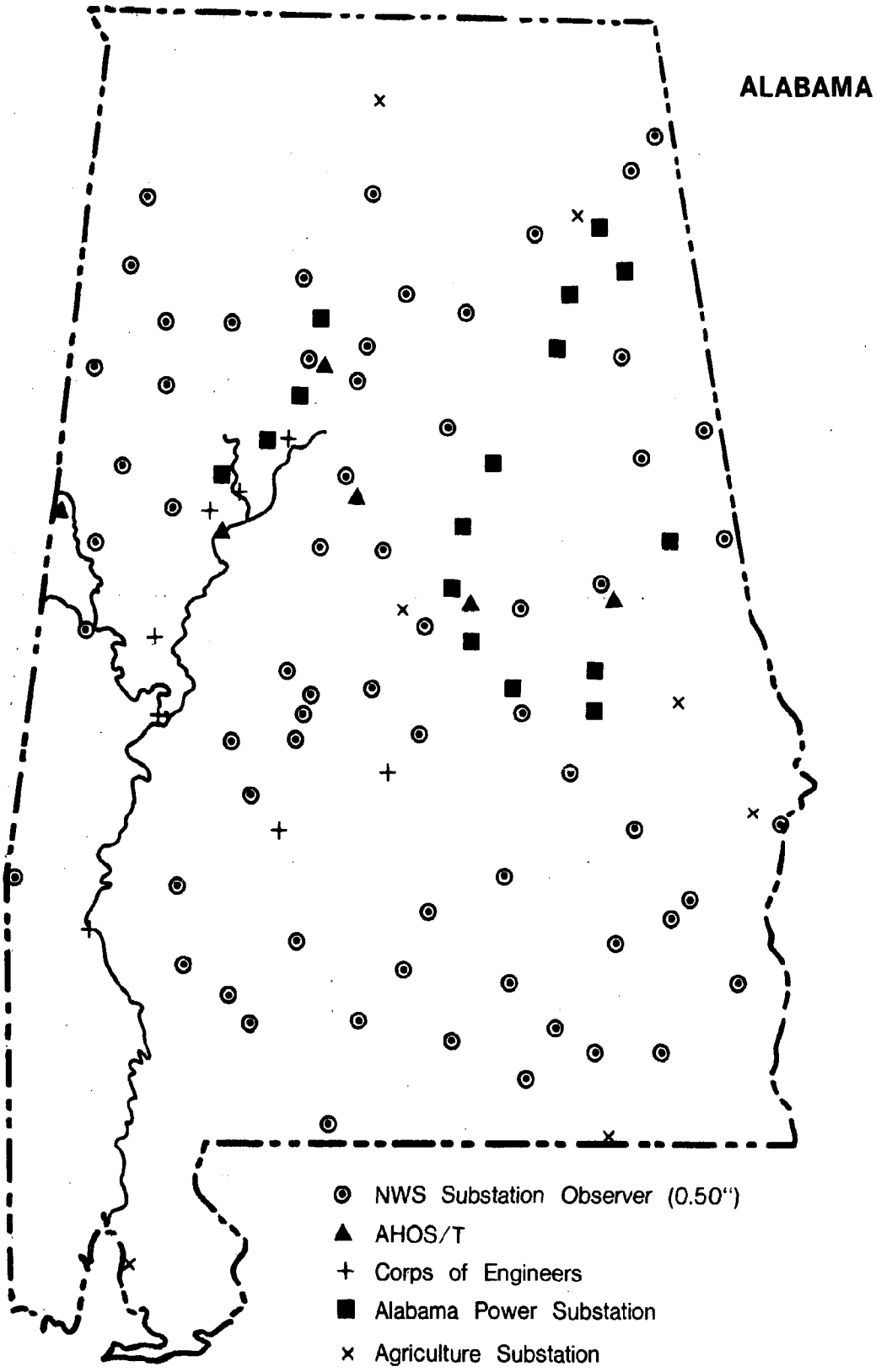


Figure 4.5 -- Daily Rainfall Reporting stations for Alabama.

INTERNAL COMMUNICATIONS

Three basic systems - facsimile, telephone, and teletypewriter - provided NWS field offices with the internal communications to make the warning system function. No problems were noted with the facsimile system, which provides the field offices with graphic material from NMC. However, the field offices had some problems with the telephone and portions of the teletypewriter systems.

As noted earlier, commercial and FTS (Federal Telecommunications System) telephone lines were less than perfect in the areas of heaviest rainfall. WSO Meridian, with warning responsibilities for two Alabama counties, has a hotline to WSFO Birmingham and can contact that office much easier than it can its own WSFO in Jackson. Commercial telephone is the only telephone link between WSFO Jackson and WSMO Millington, Tenn., which covers part of Jackson's warning area. Calls on these systems were very time consuming and frustrating.

No problems were noted with the basic Service A and Service C teletypewriter circuits. The RAWARC circuit was a different story. One forecaster referred to RAWARC as a "real jungle". The survey team agrees. This circuit (Circuit 23421, which serves most of Alabama, Mississippi, and six other southern States) was extremely overloaded. Hundreds of separate messages were sent on this circuit April 11-13. Many of these were broken, some just before finishing, and had to be restarted. Some of the traffic was low priority; some of it should not have been on the circuit at all. Some messages were sent in lengthy columnar format, to prevent having to prepare one message for RAWARC and one for weather wire; but, when one of these messages has to be restarted, it only compounds the circuit overload.

FINDINGS AND RECOMMENDATIONS

FINDING 4.1

The Hydrologic reporting networks in Alabama and Mississippi functioned essentially as expected. But sufficient reports were not available to adequately define the areal and temporal distribution of the rainfall event in the headwaters of the Pearl and Tombigbee. This was the main cause of uncertainty in forecasts for the headwaters and in forecasts of the inflow to the Ross Barnett Reservoir. An additional 6 to 12 hours of lead times could have been obtained with an automated data network.

Following the Black Hills and Agnes disasters, the Office of Hydrology, with cooperation of the RFC's, developed a proposed national automated reporting network, which was considered adequate for hydrologic purposes. (See Natural Disaster Survey Report 72-1 (Black Hills), Finding and Recommendation 1; Natural Disaster Survey Report 73-1 (Agnes), page 29, paragraph 5.)

RECOMMENDATION 4.1

This network should be completed.

FINDING 4.2

Amateur radio operators provided valuable assistance to the Jackson Forecast Office by relaying information on river or rainfall data from flooded areas of the Upper Pearl and also in the immediate Jackson area.

RECOMMENDATION 4.2

They should be commended for their assistance and urged to continue their backup support in such emergencies.

FINDING 4.3

The RAWARC teletypewriter circuit serving Mississippi, Alabama, and six other southern States, was overloaded with traffic during this severe weather and heavy rainfall event.

RECOMMENDATION 4.3

During severe weather and flood situations, NSSFC should continually review RAWARC traffic for violations and enforce existing rules.

FINDING 4.4

The Automated Data Acquisition System (ADAS) at WSO Athens was inoperative so that each station had to be called individually from the responsible forecast office.

RECOMMENDATION 4.4

NWS should review its experiences with ADAS and establish a reliable automatic data acquisition system to produce timely data for operational use.

FINDING 4.5

A lightning strike shortly after 10:30 p.m., April 11, disabled the Jackson network radar, emergency power generator, and other equipment. The radar was inoperative throughout the rest of the heavy rain and thunderstorm period. This outage increased the station workload significantly in both WSFO Jackson and WSO Meridian.

RECOMMENDATION 4.5

Review techniques for lightning protection to ensure that damage from such strikes is minimized.

FINDING 4.6

Satellite QPE's were transferred on a timely basis to WSFO Jackson and WSFO Birmingham during April 11-13, 1979. WSFO's used QPE's in issuing flash flood warnings and statements. The estimates were not available to WSO Meridian or the RFC's in Atlanta and Slidell. Isohyetal maps of satellite-derived vs rainfall measurements show excellent agreement as to both shape of isohyets and total accumulation of rainfall.

RECOMMENDATION 4.6

QPE data should be transmitted in such a manner as to assure widest possible dissemination (i.e., to WSO's and RFC's as well as WSFO's) in the shortest possible time. Develop digital satellite QPE isohyets and techniques so they can be used operationally in stage forecasts issued by RFC's.

FINDING 4.7

Warning coordination functions were hampered, because of the necessity of using either commercial or FTS telephone systems, which performed poorly during critical times.

RECOMMENDATION 4.7

Wherever possible, hotlines should be established to make coordination and communications between offices more efficient and reliable.

CHAPTER 5

WARNING DISSEMINATION, COMMUNITY PREPAREDNESS, AND PUBLIC RESPONSE

WARNING DISSEMINATION

Throughout the rain and flooding, WSFO Jackson alone issued more than 200 statements and warnings. As noted in previous chapters, WSFO Birmingham as well as the WSO's in Meridian and Mobile also issued numerous statements and warnings. The principal channels for disseminating information to local officials and the public were the NOAA Weather Wire Service and the NOAA Weather Radio. Augmenting these systems were the National Warning System; local law enforcement communications circuits; and the press, radio, and television. The following describes the effectiveness of these channels in disseminating the NWS river and flood forecasts and warnings.

NOAA WEATHER RADIO

NOAA Weather Radio (NWR) provides around-the-clock broadcasts of the latest weather information from NWS offices. During severe weather, the routine broadcasts are interrupted for warning messages. Specially designed weather warning receivers also can be activated to indicate an emergency. The exact number of NWR receivers in use in the flood disaster areas is unknown and could not be determined by the disaster survey team. However, a nationwide retail chain of radio and electronic supplies estimated that its stores in the Jackson area sold about 3,000 NWR receivers during the past 3 years. In addition, a Jackson CATV company with more than 12,000 subscribers carries the NWR as audio as does a Pearl, Miss., CATV with more than 1,500 subscribers.

The NWR system within Mississippi and Alabama responsible for broadcasting watches, warnings, and statements includes 10 transmitter sites (fig. 5.1). All NWR programing for Mississippi, except at Meridian (by WSO Meridian) and Gulfport (by WSO Mobile, Ala.), comes from WSFO Jackson. The reception area from the Jackson, Ackerman, Bude, and Columbia transmitters includes most of the Pearl and Tombigbee River Basins affected by floods.

In the initial period of inclement weather as the storm passed across Mississippi, the NWR system suffered several outages. A lightning strike at WSFO Jackson on Wednesday night, April 11, disrupted NWR broadcasts from all three of its broadcast consoles for a 2- to 5-minute period. No warnings were issued during this brief period. The lightning strike knocked out about half of the playback decks in the three NWR consoles; however, service was restored and continued, by using the remaining operational decks. At the Ackerman transmitter, an apparent lightning strike disabled the system from near midnight on the same evening until 11:00 p.m., the following day, April 12. This outage was during a critical period when tornado and flash flood watches were in effect. Although it hampered dissemination, WSO Meridian ascertained that warnings were being received in Winston County from the NOAA Weather Wire Service and over the law enforcement teletypewriter system. A blown fuse

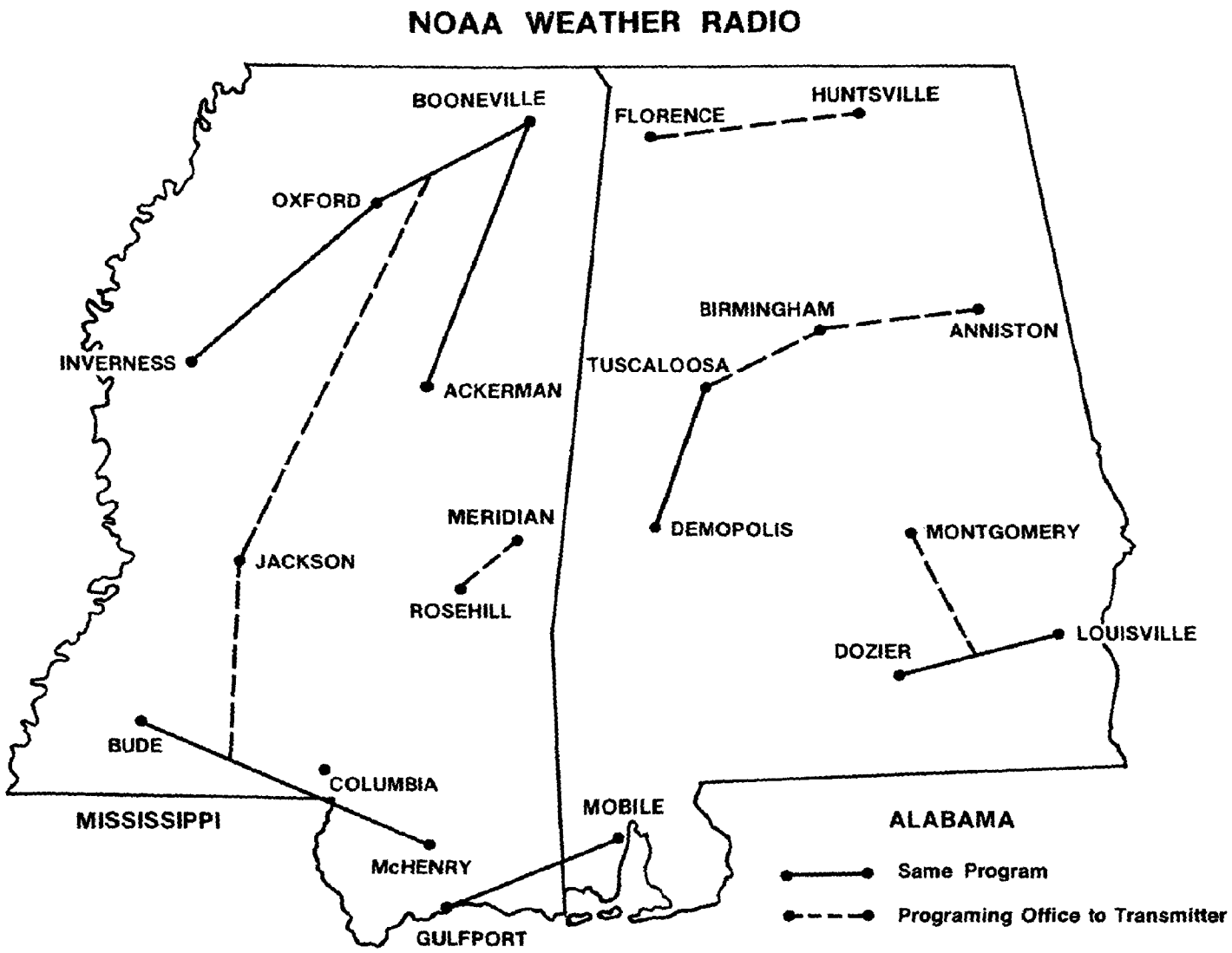


Figure 5.1 -- Map of NOAA Weather Radio sites in Mississippi and Alabama.

caused 23-hour loss of the Ackerman transmitter. Several factors caused the prolonged delay in restoring service: (1) No personnel are at the tower site from midnight to 6:00 a.m.; (2) maintenance personnel had to be contacted to determine and repair the problem; and (3) the transmitter is on a platform at the 790-foot level of the tower, which cannot be climbed in bad weather or whenever other maintenance personnel are working on the tower.

The storms or flooding did not interrupt NWR transmissions from the Bude site. The low-powered "shadow" unit at Columbia was not in service owing to technical problems. The local Civil Defense purchased and maintains this transmitter.

All watches, warnings, and statements during the inclement weather and flooding were broadcast over the NWR system within 15 minutes after issuance except from those transmitters that had outages. NWR was the only means of routine communication between the WSFO Jackson and some EOC's in the smaller communities along the Pearl River and provided an effective source of information to them. One community official indicated that the broadcast cycle times were too long and it was difficult to extract information they needed to support local flood operations. In cases where cycle times for the information were too long, disaster officials relied primarily on direct telephone contact with WSFO Jackson personnel. The three TV stations in Jackson visitied by the survey team had NWR receivers, as did four of the five radio stations and the daily morning newspaper. The system provided broad dissemination.

NOAA WEATHER WIRE SERVICE (NWWS)

The NOAA Weather Wire Service (NWWS) is a teletypewriter channel that provides hard copy of all warning information issued by NWS and is intended primarily for the news media; however, it is available to anyone paying for the teletypewriter equipment rental and local line charges. Many radio and television stations serving the Jackson-Columbus-Louisville-Columbia areas subscribe. About 115 television, radio, cable TV, Civil Defense, and law enforcement outlets in Mississippi subscribe to NWWS. The Jackson area alone has 25 NWWS subscribers.

NWWS operated continuously except for a 3-hour period (5:00-8:00 p.m.) on Monday, April 16, when water in the basement caused a power outage at the telephone company building in Jackson. WSO Meridian was able to provide some backup, and the backlog of information at WSFO Jackson was transmitted as soon as service was restored. The media were able to obtain information for evening news/weather programs from NWR.

NATIONAL WARNING SYSTEM (NAWAS)

The National Warning System (NAWAS) is a telephone hotline system operated nationally by the Federal Emergency Management Agency (FEMA). It is used to disseminate warning information to local officials and supplies storm reports

to NWS warning offices. There were no known failures of the NAWAS system during the flood event. All watches, warnings, and other necessary information were promptly disseminated.

TELEPHONE

Communication by telephone was a problem during the flood, primarily for the Jackson area. All telephone circuits were overloaded. In addition, the general public learned unlisted and restricted office numbers for WSFO Jackson. This hampered communication and dissemination of warnings to and from the media and and disaster officials.

The public recorder telephones that provided local forecasts and warning information performed as designed; however, dissemination of warnings to individuals on a one-on-one basis had very limited utility.

Needs and desires for more information by the media, disaster officials, and the public finally resulted in a Special Weather Statement by WSFO Jackson at 2:45 p.m., April 12. The statement sought the media's assistance in urging the public not to call NWS.

By the time the crisis eased in the Upper Pearl Basin and in Jackson, the telphone situation was improving. Telephone contact between WSFO Jackson and the media, disaster officials, and city officials at locations on the lower Pearl River was made with little difficulty.

LAW ENFORCEMENT COMMUNICATIONS

The Mississippi Highway Patrol Law Enforcement Teletypewriter System (LETS) is used to distribute NWS warnings across the State as the Highway Patrol deems appropriate. This network is a high-speed, partially computer-driven teletypewriter communications system reaching into nearly every law enforcement and State Police office in Mississippi. During the period April 11-16, WSFO Jackson and WSO Meridian warnings were transmitted over this network with drops in Louisville, Columbus, and Columbia. Most releases were transmitted within minutes. With the outage of the Ackerman NWR transmitter, Louisville (Winston County) officials received warnings by NWWS and from local law enforcement officials on their communications system by relay from the Mississippi Highway Patrol.

NEWS MEDIA

Throughout the flooded area the primary sources of information for most people were the radio and local disaster officials. Radio stations aired information as soon as it was received. All but one of the stations contacted by the disaster survey team had NWWS and/or NWR. All of the TV stations had NWWS. In addition, the press and radio/TV stations received briefings at the EOC that incorporated information received from WSFO Jackson. The EOC served as an information center. The news media, however, made no visits to the WSFO to obtain additional information.

Although the Mayor and local press were critical of the performance of WSFO Jackson, one Jackson newspaper concluded from its own review of the NWS forecasts and warnings that adequate and timely warnings were given. The Natural Hazards Research and Applications Information Center of the University of Colorado also made a survey of the Pearl River flood at Jackson and concluded that the criticism of inadequate warning appeared to be unfounded. Contacts with management of radio and TV stations in the Jackson area further indicated that the media considered that NWS did the best it could with the resources available.

COMMUNITY PREPAREDNESS

For many years, NWS has had a disaster preparedness program that is carried out in cooperation with authorities at local, county, and State levels and with other Federal agencies. The purpose of the program is to develop preparedness planning with communities and to enlist and train citizens as observers of severe weather conditions. The NWS is responsible for providing the forecasts and warnings of river and flood conditions and other natural disasters to these community officials, who in turn are responsible for the interpretation and use of this information to respond to specific local situations.

In the flood area, the primary community preparedness efforts had been directed toward the threats of tornadoes and flash floods. However, as result of efforts of NWS to work with communities, the survey team noted that well-developed working relationships had been established between the WSFO Jackson and the Civil Defense Directors and staffs of the localities affected by the flood. As recently as January 1979, WSFO Jackson and the Jackson/Hinds EOC had worked well together during the flood on the Pearl River that reached a crest of 37 feet at Jackson.

PRE-FLOOD PLANNING

An element of the community preparedness program is to help localities develop plans to respond to weather-related disasters. WSFO Jackson developed a formal flood preparedness plan for the city of Jackson in July 1974. It was undertaken in conjunction with an On-Site Assistance Program conducted by NWS at that time and stated that rainfall in excess of 10 inches in the headwater basin of the Pearl River would necessitate opening the flood gates at the Ross Barnett Reservoir to 50,000 cfs, which would cause a near-record flood on the Pearl. If 100,000 cfs or more were released, the plan noted that a river stage in excess of 40 feet could result and top the levee system around Jackson. This would create a flood with widespread damage.

The 1974 survey has not been updated. A copy of the original survey was available at WSFO Jackson, but according to interviews of the staff at that office and with local officials, the document was not used. The recently completed flood insurance study also was not available to either WSFO Jackson nor RFC Slidell, as noted earlier in chapter 3 concerning the flood forecasts and warnings.

As part of their communications preparedness planning, NWS offices also maintain telephone checklists that are used to alert local officials of severe weather and flash flood situations. Calls normally are logged on these lists, but WSFO Jackson did not maintain such a log, because of the intensity of the workload.

WSFO Jackson did have an established emergency communications system through the Jackson Repeater Organization, which was particularly effective during this flood. The organization set up emergency communications and provided that office with critical rainfall and river information. As many as 20 volunteers operated at one time at WSFO. About 130 volunteers participated in support of the total flood disaster operation. Some came from as far away as Tupelo and Senatobia, Miss.

COMMUNITY WARNINGS

According to press accounts, State of Mississippi Civil Defense officials reported that the flooding on the Pearl River and streams caused more than 25,000 residents to leave their homes. About 17,000 were from the Jackson area alone; another 6,000 evacuated their homes in Marion County farther downstream. Nearly 1,000 Alabama residents fled their homes along the Tombigbee.

Initial flood warnings to the City of Jackson were given to the Mayor and other city officials on Friday morning, April 13, at the Jackson/Hinds EOC. They were informed of the widespread heavy rainfall at the headwaters of the Pearl River. The city officials also were notified of the forecast by RFC Slidell for an inflow to the Ross Barnett Reservoir of 120,000 cfs and a crest of 38.5 to 39.5 feet for Monday, April 16. This forecast was based on rainfall reports received by 10:00 a.m. on Friday the 13th. Officials were advised that the prediction represented a flood of record, meaning a record high flood. Based on this information, the Mayor declared a state of emergency. That same afternoon, April 13, COE advised the Mayor that the river stage at US Highway 80 would rise to about 42 feet, but it was stated that this forecast was not official.

The Mayor subsequently criticized NWS and COE for the inaccuracy of the information. The Jackson/Hinds disaster preparedness officials indicated to the survey team that they believe more property could have been saved had the crest been predicted by Saturday morning, April 14. At that time, WSFO Jackson was forecasting 39.5 to 40 feet, and increased it to 41.5 feet by 10:00 p.m on the evening of the 14th.

The officials from communities on the east side of the Pearl River in Rankin County never felt they had received a crest forecast. Farther downstream on the Pearl and Tombigbee Rivers, local officials attributed large savings to the NWS warnings. On April 13, residents along the lower Pearl River were warned to move cattle and equipment from low-lying areas. At Monticello, Miss., they had 2 days' warning to build levees and evacuate areas. The predicted crest forecast was used by the National Guard and Civil Defense

officials to determine the areas to be affected. On April 17, at Columbia, Miss., a crest was forecast to reach the city on April 22. With this warning and subsequent continuous interaction with WSFO Jackson, evacuation was initiated. The use of river forecast information has been officially estimated to have contributed to a $3 million savings to the citizens of Columbus in Lowndes County.

The translation of river stage levels to local topography posed a problem for some officials, as well as the public. The river stage levels are reported in feet above an arbitrary reference level. COE and other mapping agencies use mean sea-level contours. The translation of the forecast stages to topographic levels was the basis for the local communities' determining the areas for evacuation and the construction of levees. In addition, stages upstream from the US Highway 80 gage increased by about 6 inches to a foot in elevation per mile, which was not recognized by those concerned with fighting the flood.

The locations of river gage points for which stages were reported and forecasts provided also were a matter of concern for several communities. In the Jackson area both public officials and citizens expressed the need for a gage closer to the Ross Barnett Reservoir, because of differences found between the height of the water in northeast Jackson and that at the gage at US Highway 80 about 10 to 15 miles from the reservoir. There was difficulty correlating the heights, particularly with the damming effects of Highway 25. Similarly, at Monticello, Miss., it was felt that a gage upstream near Georgetown, Miss., would have been useful as an indication of the conditions progressing down the Pearl River. That area previously had had a gage. Delays in obtaining river stage levels were experienced in at least one community as a result of reporting procedures. Most of this information, however, was obtained locally by the resourcefulness of officials, but delays of several hours were experienced in acquiring information from observers, processing it through the NWS system, and reporting back to local officials.

PUBLIC RESPONSE

The public response to the NWS forecast and warning services during the flooding in Mississippi and Alabama was favorable, except in Jackson. Along the Tombigbee the forecasts were accurate and timely. In Macon, Miss., the Civil Defense Director based the evacuation of a large area on the south side of town on Flash Flood Warnings and radar information received from WSO Meridian. Most of the evacuation was completed before the heavy rains moved into the area. A major contributing factor to the responsiveness of the people was their experience from previous flooding. In Pearl and Flowood, there was some doubt about the forecasts; some people were away for the Easter weekend, and others simply did not want to be disturbed. On the Lower Pearl, where longer lead time and more accurate forecasts were available based on data from the Jackson area, doubts also existed. Many residents of Monticello and Columbia found the flood forecasts hard to believe because, in their minds, the Jackson forecast was "missed". But, as the water rose and forecasts began verifying, protective action was taken and property damage was minimized.

Many people were either not aware of their danger or refused to believe the degree of danger. Not all who listened were even able to perceive the danger adequately. The stormy weather cleared from the area late in the week. It was Easter weekend. Many were shopping and did not realize fully the danger of the rising river. To get the warning information, people in the affected areas would have had to listen to NWR, regular TV news, or radio. Many wanted to know the degree of danger with respect to their location and property, such as a certain block of a certain street. This degree of warning is beyond the WSFO's and NWS's ability. Flood forecasts could not be made for each individual location in the city. Such detail was the responsibility of local authorities. The people of Jackson did not comprehend the magnitude of the flood nor visualize where the water was going to be from the information issued by the WSFO Jackson.

The people in the flooded section of northeast Jackson, in particular, could not relate the river stage observations and forecasts for the gage located 10 to 15 miles south of them on Highway 80 to the water effects they were experiencing. Typical of the comments from the people in the Jackson area as reported in the local press were the following:

> "We just heard it come over the television. We didn't see any water rising, so none of us really took it that seriously. People just aren't going to believe it until they see the water."
>
> "The police came around telling us we'd be flooded, but we didn't really believe them. We kept thinking it wouldn't happen to us. We never thought it would be flooded. Neither did anyone else."
>
> "I could have saved almost everything if they had notified us how high it was going to get."

The terminology used in bulletins and flood forecasts probably contributed additional confusion to the public. Very few were aware of the meaning of phrases such as "flood of record, record flood, and flood plain." Some people took the forecast of successive increases in the river stages at Jackson to mean new crests. A review of the statements and forecasts from WSFO Jackson indicates that there is merit to the claim that stage forecasts could have been interpreted as crest forecasts. Specifically, on April 15 it was noted that the inflow into the Ross Barnett Reservoir was expected to peak that afternoon and the river was to rise several hours after the peak was reached. A press release issued from the Jackson/Hinds EOC, dated 3:00 p.m., Sunday, April 15, 1979, noted, "The crest of this flood is now expected to be at 42.5 feet, and it should reach this level at midnight tonight". The Pearl River crested at Jackson on during the afternoon of April 17 with a crest of 43.25 feet.

North of Jackson, all officials and residents interviewed were aware of NWS warnings of heavy rain well in advance of the flooding, but many were amazed at the amount of rainfall. The warnings were received despite temporary

interruption of some lines of communication. Methods of communication used included the State Law Enforcement System, NAWAS, commercial telephone, NWWS, and NWR.

Downstream from Jackson, along the lower Pearl, there was no criticism of the NWS warning system, although some persons admitted that they were initially dubious of the flood forecasts. As it soon became evident from the flooding at Jackson, the forecasts were accurate; Jackson suffered a record flood, and because of information from NWS, the lower Pearl was prepared as the crest moved downstream.

Nearly all criticism of NWS and other Federal agencies originated in Jackson. It came from community leaders, some of the media, and a number of residents. The most severe criticism concerned the lack of a single source and conflicting information from various sources. In summary, the survey team found that NWS was and is highly regarded for its severe weather and flood warning systems both upstream and downstream from Jackson. This applied to both the Pearl and Tombigbee River areas.

FINDINGS AND RECOMMENDATIONS

FINDING 5.1

The local disaster preparedness officials contacted by the survey team stated that the personnel at WSFO Jackson performed as best they could for an event of the magnitude encountered. A similar consensus was obtained from the staffs of radio and television stations contacted in the area.

FINDING 5.2

The criticisms of the federal agencies voiced locally and nationally by Jackson public officials about the lack of coordination and the inconsistency of information were substantiated in general.

RECOMMENDATION 5.2

NWS should work with the Federal Emergency Management Agency and other federal agencies and develop better procedures for assuring coordinated responses to public officials. Particular efforts should be made to establish strengthened relationships with the U.S. Geological Survey and the Corps of Engineers.

FINDING 5.3

Warning dissemination systems used by NWS--NWR, NWWS, and NAWAS--provided flood warning information to local officials and the media in a timely manner. Where outages in one system did occur, other systems were able to provide backup. Except for NWR and limited telephone contact, dissemination to the public was through the news media.

RECOMMENDATION 5.3

Although the number of users of NWR in the area of the flood is unknown, a stronger effort should be made by NWS to familiarize the public with this system and promote its use.

FINDING 5.4

Communication by telephone was a major problem in the Jackson area throughout the flood, but for other locales along the lower Pearl River and the Tombigbee River it served as an effective means of exchanging information between local officials and the WSFO's. No logs were maintained of important telephone conversations at WSFO Jackson.

RECOMMENDATION 5.4

Dedicated telephone lines should be established between WSFO Jackson and the State of Mississippi and local EOC's to ensure direct access to WSFO during

disaster situations. The field office also should maintain a convenient supply of telephone forms with data, time, party spoken to, and a brief indication of the action taken.

FINDING 5.5

The major source of river and flood information for the media and public in the Jackson area was the Jackson/Hinds EOC, which issued press releases based on information received from WSFO Jackson and other sources. No meteorological/hydrologic expertise was available at the EOC to assist in the interpretation of NWS issued forecasts and warnings to aid local officials and the public in their planning.

RECOMMENDATION 5.5

The survey team recognizes the limitations of current manning levels at the NWS field facilities, especially in times of major disasters. However, consideration should be given to making available expertise to selected EOC's for discussion and explanation of stage forecasts and conditions contained in NWS releases.

FINDING 5.6

Preflood planning for the Jackson/Hinds area had addressed the case of major flooding from heavy rainfall in the headwater basin of the Pearl River. However, the documentation was nearly five years old and no reference was made to its use during the flood by NWS or community officials.

RECOMMENDATION 5.6

NWS in collaboration with FEMA, other federal agencies, and local preparedness officials should revise existing planning documentation as a result of the experience and information derived from the April 1979 flood.

FINDING 5.7

Persons living in Northwest Jackson found it difficult or impossible to relate the US Highway 80 gage height forecasts to their area because of the extreme slope of the river during periods of high outflow from the reservoir.

RECOMMENDATION 5.7

Install a gage in the area of Northeast Jackson to which forecasts can be referenced during periods of high outflow.

APPENDIX 2A

ORGANIZATIONAL STRUCTURE AND LEVELS OF RESPONSIBILITY

The National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA), through a system of national centers and field forecast and service offices, provides general weather forecasts and warnings for the United States. NWS also performs and manages the river and flood forecasting functions of NOAA. Input and assistance to NWS in carrying out these functions are provided by other elements of NOAA, such as the National Environmental Satellite Service (NESS) and the Environmental Data and Information Service (EDIS).

NATIONAL CENTERS

The National Meteorological Center (NMC) in Camp Springs, Md., is responsible for producing a variety of broad-scale analyses and forecasts for use by NWS field offices. Graphic and alphanumeric forecast guidance, based to a large extent on computerized forecast models and covering periods ranging from a few hours to several days in advance, is transmitted through various channels to the field offices.

Several products prepared and issued by NMC provide guidance for forecasting precipitation amounts. Unmodified numerical model forecasts of precipitation for 12-hour periods out to 48 hours are available twice daily. At NMC's Quantitative Precipitation Branch (QPB), forecasters consider the numerical forecast and other data, and produce 24-hour subjective quantitative precipitation forecast that are sent in map and coded form to field offices. In addition, an "Excessive Rainfall Potential Outlook" for the next 24 hours is issued whenever organized weather systems are expected to produce excessive rainfall within the United States. This outlook is followed during the day by narrative updates that amplify and modify the original forecasts. It should be empahsized that the accurate forecasting of extremely heavy precipitation amounts from convective activity remains beyond the state-of-the-art.

Further guidance for heavy rain forecasts is provided by an automated statistical-numerical procedure that yields, twice daily, a probability distribution of rainfall accumulations, for 6- and 24-hour periods, at specific cities.

The River Forecast Center (RFC) function in the hydrologic program is, in a manner, analogous to the function in the NWS meteorological program. The RFC prepares numerical river and flood forecasts and flash flood guidance in response to the program needs in each State by the Weather Service Forecast Office (WSFO). The RFC is responsible for preparing daily stage forecasts, as well as flood warnings and forecasts for key points on the main stem and major tributaries of a river system. Other RFC responsibilities include the technical lead in preparation of community flash flood warning systems and advice to WSFO's on flash flood potential.

Numerical models are used to simulate the response of watersheds to rainfall and other meteorological variables. Development of the specific procedure to each forecast point is accomplished by adapting and optimizing the coefficients of the generalized watershed simulation model (NWS RIver Forecast System - NWSRFS). Historical data supplied by EDIS are used in this process. Current observed data input required by the models is supplied by the WSFO data collection program. Forecasts of future meteorological conditions are provided by the WSFO with guidance supplied by NMC.

Additional observations of current meteorological conditions are provided by radar and satellite. Radar observations in the form of Manually Digitized Radar (MDR) supplement the ground observations of rainfall with qualitative indications of the areal extent and intensity of rainfall. Satellite data also provides the RFC with estimates of rainfall amounts and intensities. However, this program of satellite data interpretation is still experimental.

The National Severe Storms Forecast Center (NSSFC) in Kansas City, Mo., issues guidance to the field forecast and service offices in the form of scheduled outlooks of convective activity, generallly in the 18- to 30-hour time frame. These outlooks, which are sent out in both graphic and word form, indicate the expected threat of severe local storms, defined as being those producing large hail, tornadoes, or damaging winds. NSSFC also issues, for dissemination directly to the public, short-range forecasts, termed "Watch Areas" of severe thunderstorm and/or tornado activity. NSSFC also releases special public notices when it expects especially numerous or violent severe storms. NSSFC is not charged with preparing rainfall guidance.

FIELD FORECAST AND SERVICE OFFICES

Weather Service Forecast Offices (WSFO's) are responsible for warnings and forecasts for States, or in some cases large portions of States. Forecast responsibility extends from the immediate future to several days in advance and encompasses a broad range of meteorological phenomena including severe weather; agricultural, aviation, and marine weather; and forestry and air pollution meteorology. WSFO's interpret and modify NMC and NSSFC guidance for their areas of responsibility and provide, in turn, the main field forecast support and guidance to local Weather Service Offices (WSO's). This is accomplished by using regional expertise along with local data, obtained after NMC forecast preparation, to update and tailor forecasts and warnings for thw WSFO area. Through Satellite Field Services Stations (SFSS's), NESS provides WSFO's with interpretations of satellite imagery and, when possible, quantitative estimates of rainfall by county areas.

The WSFO is the lead office in each State with the final responsibility for issuing river and flood forecasts for the State. Guidance for flood warnings and numerical forecasts of river and flood stages are prepared by the RFC. Before dissemination of forecasts or warnings received from an RFC, these forecasts must be appraised for consistency with the latest reports and information available at the WSFO. The WSFO bears full reponsibilitiy for contacting the RFC to discuss revisions or adaption of forecast to local conditions.

WSFO's also manage the rainfall and river reporting networks, which supply the data needed to prepare specific numerical forecast and issue statements and warnings. Data collected by the WSFO is transmitted to the RFC and other agencies involved in water management and project operation.

Many WSFO have a Service Hydrologist who serves as staff assistant to the MIC in managing the hydrologic program for the station and the State. Some State WSFO's in other NWS regions also have a Hydrologic Technician who assists in the hydrologic program by being directly involved in the collection and dissemination of data and preparation of routine river statements. In off-peak periods the Technician helps the Service Hydrologist manage the reporting network by making field inspections and documentating the forecast and observation sites.

The WSFO meteorologists are responsible for issuing all flash flood watches, and warnings for their county area of responsibility. Guidance to the meteorologists is supplied by the RFC and the Service Hydrologist. General narrative river forecast and warning statements are issued by WSFO for all areas of the State. WSFO has final public dissemination of the river forecast and warnings for their county area of responsibility. In other county areas, WSO's have dissemination responsibility.

Weather Service Offices (WSO's) provide the most direct link to the public. These offices are responsible for preparing and disseminating of weather and flash flood warnings to designated counties in their areas of responsibility. In most cases, they also prepare local forecasts for the city in which they are located. WSO's uses guidance from higher forecast echelons, such as the WSFO's and National Centers, along with local observations and expertise.

Each WSO is also charged with local disseminations of all river forecasts and warnings. The meteorological staff carries on this function. Some WSO's also have the assigned duty to collect data from observers, automated networks, and project owners for transmission to the WSFO and RFC.

WSFO's also function as a WSO's, in that they prepare local forecasts and have county responsibility areas for preparing and disseminating warnings.

APPENDIX 2B

Summary of the precipitation forecasts - Mississippi

Wednesday
April 11

4:20 a.m. - likelihood or chance of showers and thunderstorms during the day, then diminishing tonight with decreasing cloudiness forecast for Thursday. The forecast also incorporated the severe thundestorm guidance from NSSFC by noting that thunderstorms would be occasionally or possibly heavy. (Probability of Precipitation (POP's)): today 40%-60%, tonight 30%-50%)

10:40 a.m. - forecasts became more specific about the timing of the showers and thunderstorms that were expected to move into the western sections during the afternoon and into the east during the night. Mentioned potential for severe thunderstorms. Decreasing cloudiness forecast for Thursday. (POP's: this afternoon 60%, tonight 70%)

4:20 p.m. - rain and heavy thunderstorms tonight with a few thunderstorms possibly severe. Chance for some showers on Thursday and continuing in the northern zones into Thursday night. (POP's: tonight 90%, Thursday 20%-30%, Thursday night 20% northern zones)

10:45 p.m. - Flash Flood Watch tonight and Thursday morning. Periods of rain and heavy thunderstorms through Thursday morning then a chance of thunderstorms Thursday afternoon diminishing Thursday night and Friday. (POP's): rest of the night 90%, Thursday 50%)

Thursday
April 12

4:40 a.m - Flash Flood Watch today. Showers and thunderstorms to diminish during the afternoon and end tonight. Decreasing cloudiness Friday. (POP's: northern zones for today 80%, tonight 20%; southern zones decreasing to 40% this afternoon and 20% tonight)

10:45 a.m. - Flash Flood Watch continued for this afternoon. Showers and thunderstorms today and tonight diminishing on Friday. (POP's: decreasing to 50% Friday)

4:20 p.m. - Flash Flood Watch tonight. Thunderstorms, a few possibly severe, tonight and diminishing during the day Friday. (POP's: eastern zones, tonight and Friday 80% decreasing to 30% Friday night; western zones, decreasing to 50% Friday)

Friday
April 13

12:30 a.m - Flash Flood Watch until 6 a.m. Rain and thunderstorms occasionally heavy this morning diminishing this afternoon. Mostly fair tonight and Saturday. (POP's: decreasing to 50% this afternoon)

4:20 a.m. - Flash Flood Watch continues today. Rain and thunderstorms occasionally heavy, diminishing late today. Decreasing cloudiness late tonight becoming mostly sunny by Saturday afternoon. (POP's: today 80%, tonight 20%)

10:40 a.m. - Flash Flood Watch continues in eastern zones for today with rain and thunderstorms diminishing during the afternoon and ending tonight. For western zones chance for showers this afternoon, ending tonight. Mostly fair on Saturday. (POP's: eastern zones, decreasing to 30% tonight; western zones, 40% this afternoon, 20% tonight)

4:20 p.m. - No precipitation forecast. Decreasing cloudiness this evening becoming fair tonight through the weekend.

APPENDIX 2C

Summary of precipitation forecasts - Alabama.

Wednesday
April 11

4:10 a.m. - Scattered thunderstorms today... Thunderstorms possibly severe during the afternoon north and west portions spreading over the State tonight. Decreasing cloudiness from the southwest Thursday. (Probability of Precipitation (POP's)): for today, 40%-50% in east-central and southeast, increasing from 30%-40% in the north and west for the forenoon to 70%-80% in the afternoon)

5:45 a.m. - Agricultural forecast - scattered thunderstorms today with heavier thunderstorms moving into the west and north this afternoon and spreading over the State and early Thursday. Thirty-six-hour rainfall amounts 1 to 2 inches. Outlook for Friday chance of showers.

10:45 a.m. - (POP's lowered for afternoon to 30%-40% in west and north, increased, for Wednesday night to 80%-90% in west, north, and east-central. POP's for Thursday still 30% or less)

4:10 p.m. - Thunderstorms locally severe north and west portions tonight gradually ending from the northwest Thursday and Thursday night. Mostly sunny and mild Friday. (POP's: for tonight, 100% northwest, 90% northeast, central and rest of west. For Thursday, range from 50% northwest to 80% in southeast)

5:45 p.m. - Agricultural forecast - Showers and thunderstorms, some possibly severe, should occur tonight and end Thursday. Rainfall amounts one-half to 1 inch with local amounts in excess of 1 $\frac{1}{2}$ inches.

Thursday
April 12

4:10 a.m. - Tornado watch until 8 a.m. northwest, Flash Flood Watch nortwest portion today... some possibly severe thunderstorms wit heavy rain northwest portion. Showers and thunderstorms today and tonight, otherwise scattered showers and a few thunderstorms across the State through Friday morning. Decreasing clouds Friday afternoon. (POP's: Thursday, 80%-90% through north half, 50% in south; Thursday night 80%-90% in north, 50%-60% in central and south; Friday 20% in central, 40%-50% elsewhere)

5:45 a.m. - Agricultural forecast - Flash Flood Watch northwest and west central today... rain locally heavy today and possibly severe thunderstorms. Thunderstorms continuing tonight and ending early Friday. Thirty-six-hour rainfall amounts 1 to 2 inches with some amounts to 4 inches. Outlook Saturday through Monday partly cloudy.

Noon - Flash Flood Watch north and west-central this afternoon and tonight. Showers and locally severe thunderstorms more numerous north and west this afternoon and tonight. Thunderstorms ending west and north Friday, but increasing southeast. (POP's: afternoon, 100% in north, 90% in west-central, 30%-50% in east-central and south; tonight 90%-90% in north and west-central, 50%-70% east-central and south)

4:10 p.m. - Tornado Watch until 8 p.m., Flash Flood Watch north and west-central for tonight and Friday. Showers and locally severe thunderstorms tonight and Friday and over the southeast portion Friday night. Clearing from the west Friday night and Saturday. (POP's: for tonight, 100% north and central, 70% southwest, 30% southwest; Friday 80%-90%)

5:45 p.m. - Agricultural forecast - showers and thunderstorms will develop southeastward tonight and end from the west Friday. Amounts averaging near 2 inches, but locally more than 5 inches.

Friday
April 13

4:10 a.m. - Flash Flood Warning north-central till 8 a.m., Flash Flood Watch north and west-central today. Showers and locally heavy severe thunderstorms today more numerous north half. Heavy rain at times. Gradual clearing from the west late tonight with scattered thunderstorms south and east. Saturday partly sunny. (POP's: today, 100% north and central, 40%-70% south; tonight 30% north and west, 40% southeast)

5:45 a.m. - Agricultural forecast - Flash Flood Watch northern counties with Flash Flood Warning north-central. Thunderstorms continuing today and still a chance tonight. Thirty-six-hour rainfall amounts 4 to 6 inches north to near 1 inch south.

APPENDIX 3A

FORECAST TABULATIONS FOR THE PEARL RIVER

FORECASTS ISSUED -- PEARL RIVER

Station (FS) (Prev. Record)	Last Report Date/Time	Last Report GH (feet)	FORECAST Date/Time	FORECAST Statement	Final Crest
EDINBURG (20)	11/AM 20.0				
(26.7 - 1974)	12/1000 23.1	25.0	15		
	12/1130 -	26.0	15		
	12/1840 -	27.0	15/AM		
	13/0115 25.5	27.0	13/AM		
	13/1110 26.2	29.0	15		
	13/1330 26.9	29.0	15		
	13/1930 -	27-28	15		
	14/1025 29.6	31.5	14		
	14/1220 -	31.5	15	Correction on date	
	15/0245 -			Crested	14/1630
	15/0630 29.5			Crested	30.06
CARTHAGE (17)	11/AM 18.3				
(24.5 - 1974)	12/1000 19.1	22.0	13		
	12/1130 -	23.5	13	Double Crest	
		24.0	16		
	12/1930 22.2	24.5	13	Double Crest	
		25.0	16		
	13/0100 -	27.0	13/AM		
	13/1100 27.2	27.0	16		
	13/1330 27.7	28.5	13/PM		
	14/1025 28.1	29.5	15		
	15/0245 28.5	29.5	15/AM		14/2300
	15/0630 28.4			Falling	28.74
KOSCIUSKO (none)	12/1000 -	23.0	12/PM		
	13/1100 -			Near Crest	13
	13/1730 -	23-25	13/2300		23.06
OFAHOMA (14)	11/AM 11.17				
(20.3 - 1951)	12/1000 12.8	19.5	15		
	12/1130 -	18.5	12/1800	Double Crest	
		20.0	15/AM		
	12/1930 18.2	19.5	12/PM	Double Crest	
		20-21	16/AM		
	13/0100 20.6	21.5	13/AM		
	13/1110 20.9	22.5	15		
	13/1330 21.1	22.5	15		
	14/1025 22.2	24.0	15		
	15/0245 23.6	24.0	15		14/2300
	15/0630 23.2			Falling	23.27

Station (FS) (Prev. Record)	Date/Time	Last Report	Forecast GH (feet)	Date/Time	Statement	Final Crest
WALNUT GROVE	11/AM	21.3				
(No FS)	12/1000	19.4	22-23	13		
(30.2 - 1974)	12/1930	26.9	28.0	13/0000		
	13/1110	27.0	30.0	13.2300		
	14/1025	29.6			Near Crest	
	15/0245	-			Crested	14/0600
	15/0630	29.1E			Falling	29.77
D'LO (10)	12/1000	5.9	9-10	13		
	13/1225	10.5	27-28	13/2400		
	14/1025	18.3	20	14/PM		16/AM
	15/AM	20.9			Near Crest	20.5
JACKSON (18) (37.5 - 1902)	12/1000	31.1	34.0	13/0600	Add'l rains will cause upward revisions.	
	12/1130	31.1	34.0	13/0600	May go higher Saturday.	
	12/1210	31.3	36.0	14	Forecast crest could go higher than 36.	
	12/1930	31.9	36	13/PM	Crest	
	13/AM		385-395	16	Crest forecast given to city officials at EOC.	
	13/1110	35.4	37.0	13/2000	Forecasts are for a record flood. Will put water in places it hasn't been before. 38' not out of question.	
	13/2045	36.3	37.8-38.2	14/AM	All indications point to a flood of record. Higher stages will occur in Northeast Jackson.	
			39.5-40.0	14/PM		
	14/0555	37.6	38.2	14/1200		
			39.5-40.5	14/2400		
	14/0820	38.3	39.5-40	14/2400	Higher than ever before.	
	14/1025	38.3	39.5	14/2400	A flood of record - a situation which has never occurred before. Higher stages are occurring in NE Jackson closer to dam.	
			40	15/0300		
	14/1135	38.8	39.5	14/2000		
			40.0	15/AM		
	14/1540	39.3	39.5	14/1800		
			40.0	14/2400	Could go higher Sunday.	
	14/1900	39.8	41.0	15		
	14/2200	40.2	41.5	15	Flood of this magnitude has never been experienced before.	

Station (FS) (Prev. Record)	Forecast Date/Time	Last Report	GH (feet)	Date/Time	Statement	Final Crest
JACKSON (cont'd)	15/0245	40.7	41.5	15/1200	Flood of this magnitude has never been experienced before.	
	15/0500	41.0	41.5-42		Ross Barnett Dam NOT breaking.	
	15/0620	41.2	42.0	15/PM	Inflow of Ross Barnett Reservoir nearing its peak -- conditions may begin to stabilize in the reservoir by 15 PM.	
	15/0815	41.4	42.0	15/PM		
	15/1000	41.6	42.0		Inflow to Reservoir expected to peak this afternoon.	
	15/1045	41.6	42.0		Record Flood. The river is expected to rise several hours after the peak is reached.	
	15/1500	42.0	42.5	15/PM		
	15/1615	42.1	42.5		Rate of rise is slowing. Gradual rise expected thru this evening.	
	15/2130	42.3	42.5-42.7	16/AM	River still rising -- will continue into Monday morning.	
	16/0630	42.6	42.6-42.8		Up 0.2 in 12 hours.	
	16/0945	42.7	42.7-42.8		Peak later today (16 PM)	
	16/1225	42.8	43.0	16/2200	River continues to creep up.	
	16/1600	42.8	42.9-43.1		Peak tonight or tomorrow.	
	16/2015	42.9	43.0-43.1		Peak later tonight or early Tuesday. High crest to hold for some time. Fluctuations of 0.2' can be expected.	
	17/0010	43.0	43.1-43.2		Peak early this morning.	
	17/0605	43.1	43.2		May be near peak. Some decrease by tonight or tomorrow.	
	17/0915	43.2	-		Continue very high for some time.	
	17/1215	43.2	43.3	17/PM		
MONTICELLO (19) (32.3 - 1974)	12/0900	19.5	26.5	16		
	13/1225	20.2	32.5			
	14/1025	21.6	35.0	18/AM		
	15/1000	23.5	35.0	19/AM		
	15/2130	24.5	35.0	19/PM		
	16/0945	25.0	34.5	20		
	16/2130	-	34.5	20		

Station (FS) (Prev. Record)	Date/Time	Last Report	GH (feet)	Forecast Date/Time	Forecast Statement	Final Crest
MONTICELLO (cont'd)	17/1020	27.5	34.5	20		
	17/2030	29.0	34.5	20		
	18/0600	30.4	34.5	20		
	18/1230	29.8	35.0	20		
	18/1610	31.3	34.5	21		
	18/2130	31.7	34.5	21		
	19/0630	32.5	34.5	21		
	19/1030	33.0	34.5	21		
	19/1445	33.0	34.5	21		20/1300
	20/0600	34.1	34.5	21		34.50
	20/0930	34.1			Near Crest	
COLUMBIA (17) (27.3 - 1974)	12/0900	13.2	22.0	18		
	13/1225	14.0	27.0	21		
	14/1025	15.8	28.0	20		
	15/1000	15.9	28.0	21		
	16/0945	17.0	27.5	22		
	16/2130	-	27.5	22		
	17/1020	18.3	27.5	22		
	17/2030	19.4	27.5	22		
	18/0600	20.0	28.0	22		
	18/1230	20.6	28.0	22		
	18/1610	21.7	27.5	22		
	18/2130	22.5	27.5	23		
	19/0630	23.6	27.5	23		
	19/1030	24.0	27.5	23		
	19/1445	24.2	27.5	23		
	20/0600	25.9	27.5	23		
	20/1530	26.8	29.0	22/AM		
	21/0600	27.7	29.0	22/AM		21/2300
	22/1000	27.6			Near Crest	27.70
BOGALUSA (15) (22.1 - 1974)	12/0900	18.9	20.5	20		
	13/1030	18.8	22.0	23		
	14/AM	18.7	22.0	22		
	15/AM	18.8E	22.0	23		
	16/AM	18.9	21.5	24		
	17/1130	19.1	21.5	24		
	18/AM	19.3	21.5	25		
	19/AM	19.5	21.5	25		
	20/0930	19.7	22.0	24/PM		
	20/1430	-	22.5	24/AM		
	21/AM	20.3	22.5	24/AM		
	22/AM	21.6	22.5	24/AM		
	22/2300	22.5	23.0	23/PM		

Station (FS) (Prev. Record)	Date/Time	Last Report	GH (feet)	Forecast Date/Time	Statement	Final Crest
BOGALUSA	23/AM	22.8	Nr 23	23/PM		
(cont'd)	23/1300	-	23.3	23/1800	thru 23/2200	24/0100
	24/AM	23.3	At crest - little change for 36 hours.			23.23
	25/AM	22.9	Falling.			
PEARL RIVER (12)	12/0900	14.1	16	22		
(18.6 - 1921)	13/1030	13.8	18	25		
	14/AM	13.6	18	24		
	15/AM	13.4	18	25		
	16/AM	13.2	17	26		
	17/1130	13.2	17	26		
	18/AM	13.2	17	27		
	19/AM	13.5	17	27		
	20/0930	13.8	17.5	26/AM		
	21/AM	14.3	17.5	26/AM		
	22/AM	15.0	18.0	26/AM		
	22/1730	15.5	18.0	26		
	22/2300	16.1	18.5	25		
	23/AM	16.7	18.5	24/PM		
	24/AM	18.1	18.5	24/PM	Little change (36-48 hours)	
	25/AM	19.2	Near Crest		Little change (24-48 hours)	26/0300
	26/AM	19.3	At Crest		Little change (18-24 hours)	19.25

APPENDIX 3A

FORECAST TABULATIONS FOR THE TOMBIGBEE RIVER

FORECASTS ISSUED -- TOMBIGBEE RIVER

Station (FS) (Prev. Record)	Date/Time	Last Report	Forecast CH (feet)	Date/Time	Statement	Final Crest
TUPELO (21)	12/0930	24.3	24-25	This evening		
(27.1 - 1973)	12/1100		25.5	This evening		
	12/1500		nr 25.5	This evening		12/1900
			nr 26.0	Tonight		25.5
	13/1030	23.6			Falling	
FULTON (16)	12/0930	14.2	nr 18.0	13/PM		
(25.8 - 1955)	12/1100		NC			
	12/1500	16.4	nr 18.0	13/1200		
	12/2130	17.8	20-21	13		
	13/1030	18.8	nr 20.0	13/PM		13/0800
	14/1000	18.1			Falling	18.8
BIGBEE (14)	12/0930	-			No forecast	
(27.4 - 1973)	12/2130	-	nr 19.0	16		
	13/1030	-	nr 20.0	14/PM		
	14/1000	17.7	nr 20.0	14/PM	Highest reported	18.2
AMORY (20)	12/0930	17.2	26.0	13		
(33.5 - 1892)	12/1500	20.3	26.0	13		
	12/2130	21.3	26-27	14/AM		
	13/1030	24.0	27.0	14/AM		14/1300
	14/1000	26.0			Near crest this AM	26.1
	15/1000	25.4			Falling	
ABERDEEN (34)	12/0930	21.0	34.0	14/PM		
(45.0 - 1973)	12/1100		36.0	14/PM		
	12/1500		36.0	14/PM		
	21/2130	25.7	38.0	15		
	13/1030	29.4	37.5	15/PM		
	14/1000	34.5	37.5	15/PM		15/2000
	15/1000	36.9	37.5	Today		37.3
	16/0915	36.8			Falling	
ABERDEEN (13)						
(Buttahatchee R.)	12/0930	NR	14	16		
(23.5 - 1973)	12/1500	NR	16	15		
	12/2130	NR	18	15/AM		
	13/1030	NR	19	14/PM		
	14/1000	NR	Nr 19	14/PM		
	15/1000	NR			Falling	No repor

Station (FS) (Prev. Record)	Date/Time	Last Report	Forecast GH (feet)	Date/Time	Statement	Final Crest
KOLOLA SPRINGS	12/0930	NR			No forecast	
(12)	12/1100	NR	13-14	16		
	12/1500	NR	14-15	16		
	12/2130	NR	16-17	15/PM		
	13/1030	NR	17	15		
	14/1000	NR	17	15		
	15/1000	NR			Near crest	
	16/0915	NR			Falling	No reports
TIBBEE (23)	12/0930	19.0	24-25	14		
(32.3 - 1973)	12/1500	-	25	15/AM		
	12/2130	23.4	26-27	14		
	13/1030	26.7	28	14		
	14/1000	-	28	14		
	14/1400	29.1	nr 30	Late Today	Highest Observed	29.1
	15/1000	29.1			Falling	
COLUMBUS (no FS)	12/0930	15.2	21-22	13/PM		
(Luxapalila Cr.)	12/1100	-	23	12/PM		
(28.3 - 1975)	12/1500	-	26-27	12/PM		
	12/2130	25.0	nr 31	14		
	13/1030	-	nr 31	14		
	13/1200	-	nr 32	14		
	13/1730	33.0*	35-36	14/AM		
	13/1930	31.9	32	14/AM		14/0500
	14/1000	31.9			Near crest this morning.	32.4
COLUMBUS (29)	12/0930	16.5			No forecast	
(Main Stem	12/1100	-	24.25	15		
Tombigbee)	12/1500	22.4	27.0	Tonight		
(42.2 - 1973)	12/1700	-	29.0	16		
	12/2130	24.9	32-33	15/PM		
	13/1030	31.1	nr 36	14/PM		14/1300
	14/1000	35.4	nr 36	Late today		35.6
	15/1000	35.0			Falling	
PICKENSVILLE (130)	12/0930	122.9	131	17		
	12/1100	-	133	17		
	12/1500	128.3	nr 137	14		
	12/2130	134.4	140	13/PM		

* Probably main Tombigbee report -- forecast corrected before release by the Civil Defense.

Station (FS) (Prev. Record)	Date/Time	Last Report	GH (feet)	Forecast Date/Time	Forecast Statement	Final Crest
PICKENSVILLE (cont'd)	13/1030	141.0	nr 144	17		
	14/1000	143.0	nr 144	17		
	15/1000	142.9	nr 144	17		14/0800
	16/0915	143.0			At crest	143.0
MACON (26) (34.0 - 1892)	12/0930	19.5	24	13/PM		
	12/1100	21.5	31	12/evening		
	12/1500	-	32	12/evening		
	12/2130	-	34-35	13/PM		
	13/1030	37.7	44	13/PM#		13/1830
	13/1200	38.3	39-40	13/PM		38.87
	14/1000	37.8			Falling	
GAINESVILLE (36) (54.2 - 1973)	12/0930	-	30	16/PM		
	12/1500	26.4	nr 43	14		
	12/2130	39.2	nr 49	15		
	13/1030	46.2	nr 54.5	15		
	14/1000	52.2	nr 55	15		15/1400
	15/1000	55.8	nr 56.5	today		56.7
BLACK WARRIOR RIVER						
BANKHEAD (189) (194.9 - 1977)	12/1500	187.9	188	12/PM		
	12/2130	189.0	189-190	13/0100		
	13/1030	190.2	190.5-191	13/1300		13/1000
	13/1200	193.8	195-196	13/PM		197.1*
	14/1000	190.5			Falling	
HOLT (140) (152.3 - 1970)	12/1500	130.4	136	14/PM		
	12/2130	146.3	153	12/2300		
	13/1030	154.4	nr 158	13/PM		13/1000
	13/1200	159.9	161-162	13/evening		160.1*
	14/1000	153.3			Falling	
TUSCALOOSA (47) (66.7 - 1961)	12/1500	25.2	46	13/AM		
	12/2130	55.2	63-64	13/1200		
	13/0330	62.0	65-66	13		
	13/1030	62.5	67	This evening		13/1200
	13/1200	67.3	68-69	This evening		65.7
	14/1000	63.1			Falling	

Forecast result of a rating table being exceeded -- corrected by the 1200 revision.

* From COE

Station (FS) (Prev. Record	Date/Time	Last Report	GH (feet)	Forecast Date/Time	Forecast Statement	Final Crest
WARRIOR (30)	12/1500	22.1	32	15		
(50.1 - 1961)	13/1030	32.6	46	15		
	14/1000	37.7	nr 49	16		
	15/1000	44.1	nr 49	16		16/0700
	16/1000	47.0			Near crest this AM	47.0
	17/1000	46.7			Falling	
TOMBIGBEE RIVER						
DEMOPOLIS (48)	12/1500	42.4	55-56	18		
(71.0 - 1961)	13/1030	50.5	nr 66	19		
	14/1000	59.8	nr 71	19		
	15/1000	63.9	nr 71	19		
	16/0915	67.3	nr 74	18		
	17/1000	70.8	nr 74	18/PM		19/0700
	18/1000	72.2	73-74	Tonight		72.3
	19/0930	72.3			Falling	
COFFEEVILLE	12/1500	48.6	48-49	14		
(No FS)	13/1030	47.9	62	23		
(64.2 - 1961)	14/1000	48.6	65	23		
	15/1000	49.1	65	23		
	16/0915	50.7	65	23		
	17/1000	53.2	65	23		
	18/1000	56.6	65	23		
	19/0930	59.2	68	22		
	20/0915	61.7	68	22		23/UNK
	21/1000	63.3	68	22		64.6*
	22/0930	64.1	64.5	Today		
MOBILE RIVER						
BARRY STEAM	13/1200	13.9	15	28		
PLANT (No FS)	14/1500	NR	16.5	28		
	15/1000	NR	16.5	28		
	16/0915	11.0	16.5	28		
	17/1000	10.7	16.5	28		
	18/1000	-	16.5	28		
	19/0930	11.1	18	28		
	20/1000	12.0	18	28		
	21/1000	13.3	18	28		
	22/0930	14.5	18	28		
	23/0900	15.6	18	26		

* From COE

Station (FS) (Prev. Record)	Date/Time	Last Report	GH (feet)	Forecast Date/Time	Forecast Statement	Final Crest
BARRY STEAM	24/0915	16.9	17-18	26		
PLANT (Cont'd)	25/0940	17.4	18	26		26/1000
	26/0915	17.6	18	Today		17.6
	27/0930	16.7			Falling	
SARALAND (4)	12/1500	NR	4.0	17		
	14/1530	NR	7.5	30		
	15/1000	NR	7.5	30		
	16/1000	NR	7.5	30		
	17/1000	NR	7.5	30		
	18/1000	2.3	7.5	30		
	19/0930	2.4	8.5	28		
	20/0930		8.5	28		
	21/1000		8.5	28		
	22/0930	5.3	8.5	28		
	23/0900	6.5	8.5	26		
	24/0915	7.3	8.5	26		
	25/0940	7.6	8.0	26		26/
	26/0915	7.8	8.0	Today		7.8
	27/0930	7.0			Falling	

APPENDIX 3B

SUMMARY OF BULLETINS AND FORECASTS

Following is a brief summary of some of the Bulletins and Forecasts issued by the WSFO-Jackson during the flood of 1979.

11:30 AM Thu — Flood Warning for Upper Pearl River Basin. Three foot rise to 34 ft forecast for Pearl at Jackson on Friday morning (13th) with additional rise by Saturday.

12:10 PM Thu — Pearl in Jackson 31.3 ft, revised crest forecast of 36 ft issued for Saturday.

"There is a very strong potential for more heavy rains. Thunderstorms are expected to redevelop over the area late this afternoon or tonight, adding more water to the already flooded area. This could make the river at Jackson go even higher than 36 ft (on Saturday)."

"All interests along the Pearl and its tributaries are urged to take immediate action to move property and livestock to higher ground. If you live in an area that will be affected by this high stage, you should make plans to move to higher ground or get a boat."

7:30 PM Thu — Due to additional 5-7 inches of rain during the day Thursday, the 36 ft crest for Jackson on Saturday moved up to Friday afternoon.

"If additional rains occur, crests will likely be revised upward again."

"Backwater flooding begins on portions of Town Creek when the (Pearl) stage exceeds 32 ft, and on Purple Creek, Hanging Moss Creek, and White Oak Creek (all in Northeast Jackson) water begins backing up between 32 and 34 feet."

9:00 AM Fri — 24-hour rainfall amounts received, making 10-20 inches total rainfall over Pearl Basin during past 48 hours.

11:10 AM Fri — "A Flood Warning is in effect for the Upper Pearl Basin including the Jackson area. Forecasts are for a record flood."

"The river (at Jackson) should reach 37.0 ft late tonight and 37.5 ft by Saturday mornings. An additional rise seems possible, with a reading of 38 ft by Sunday not out of the question."

"Immediate action should be taken by people who would be

affected by this record stage."

11:10 AM Fri (continued) "The current forecast will put water in places it hasn't ever been before."

"Jackson residents should realize that this record stage makes the forecast very difficult. To some extent we are dealing with an unknown quantity, since there is no way to determine the exact extent of a record flood."

"Jackson area residents should also be aware that many of the smaller creeks that drain into the Pearl will also experience backwater flooding. Residents along those creeks should assess their situation carefully."

2:00 PM Fri "Remember, this is a very dangerous situation. Water levels of record dimensions are likely, and past experience may not give you the proper idea of just how much water will be accumulating during the next couple of days. Dont take chances."

4:45 PM Fri "Record stages have been set at Edinburg and Carthage as the extremely heavy rains of the last few days move downstream. This has created a serious situation for cities and towns downstream, including Jackson..."

"The current forecast for Jackson will put water in areas where it has never been before. Jackson area residents should be aware that many of the smaller creeks and streams that drain into the Pearl may experience backwater flooding and be prepared for that possibility."

"Remember, this is a very dangerous situation. Water levels of record dimensions are likely, and past experience may not give the proper idea of just how much water will be accumulating during the next couple of days. Don't take chances."

8:45 PM Fri "A flood of record is occurring on the Upper Pearl above Jackson, and is moving downstream toward Jackson tonight."

"All indications continue to point to a flood of record all up and down the river, including Jackson."

"The (river) stages referred to in this message are for the Highway 80 bridge in south Jackson. It is emphasized that higher stages will occur earlier in Northeast Jackson.

"We must reemphasize that this is a flood of record and that to a certain degree we are dealing with an unknown quantity, because we have no previous experience in dealing with a flood of this magnitude."

8:45 PM Fri (continued) "At the Highway 80 bridge, the river is expected to continue rising during the night, to 37.8 to 38.2 ft by Saturday morning. Again, higher stages will occur in Northeast Jackson earlier tonight."

"Based on the inflow into the upper reservoir, it is entirely possible that the river at Jackson will approach 39.5 to 40.0 ft, possibly as early as Saturday evening."

5:55 AM Sat "At 5.28 AM...the Pearl River gage at Jackson read 37.6 ft. This is a new record for the Pearl at Jackson...surpassing the previous stage of 37.5 ft set on Mar 31, 1902."

8:20 AM Sat "At 8 AM this morning the Pearl River gage on Highway 80 read 38.3 ft. At the present rate, a stage of 39.5 to 40.0 ft could occur as early as tonight."

"Residents should keep in mind that this is higher than the river has ever been before. Water will show up in places it has never been before."

11:35 AM Sat "The flood waters have already reached many homes and businesses. The situation is very serious, and no one should take it lightly."

"As the water keeps rising, more and more streets and highways will become impassable due to the high water."

3:40 PM Sat "Flood waters continue to rise, inundating homes and businesses along the river and around many of the smaller creeks that normally drain into the Pearl. Up to 500 homes have been evacuated in Northeast Jackson alone, and many commerical establishments and industrial firms have been affected. Many streets have also been closed due to the rising water."

"The river should reach 39.5 ft by 6PM tonight and close to 40.0 ft around midnight. Based on the amount of water still to come into the Reservoir, the river at Jackson could go even higher late tonight and Sunday."

7:00 PM Sat "A flood warning is continued for the Pearl River as flood waters continue to rise, especially in the Jackson area."

"At Jackson, the river has been rising steadily all day today and at 7 PM had reached 39.8 ft on the gage at the Highway 80 bridge in South Jackson...A stage of 41 ft may be reached by Sunday."

"Most of the evacuations in Jackson have been completed."

GLOSSARY OF ABBREVIATIONS

ADAS	Automated Data Acquisition System
AHOS/T	Automated Hydrologic Observing System/Telephone
CFS	Cubic feet per second
CM	Centimeter
COE	Corps of Engineers
CST	Central Standard Time
EDIS	Environmental Data and Information Service
EOC	Emergency Operations Center
FEMA	Federal Emergency Management Agency
FTS	Federal Telecommunications System
IR	Infrared
LETS	Law Enforcement Teletypewriter System
LFM	Limited Area Fine Mesh
LMRFC	Lower Mississippi River Forecast Center
LWR	Local Warning Radar
MDR	Manually Digitized Radar
MIC	Meteorologist-in-Charge
NAWAS	National Warning System
NESS	National Environmental Satellite Service
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NSSFC	National Severe Storms Forecast Center
NWR	NOAA Weather Radio
NWS	National Weather Service
NWSRFS	National Weather Service River Forecast System
NWWS	NOAA Weather Wire Service
QPB	Quantitative Precipitation Branch
QPE	Quantitative Precipitation Estimates
QPF	Quantitative Precipitation Forecasts
RAWARC	Radar Reports and Warning Coordination
RFC	River Forecast Center
SAB	Synoptic Analysis Branch
SERFC	Southeast River Forecast Center
SFSS	Satellite Field Service Station
SIM	Satellite Interpretation Message
USGS	United States Geological Survey
WBRR	Weather Bureau Radar Remote
WSFO	Weather Service Forecast Office
WSO	Weather Service Office
7LPE	7-Level Primitive Equation

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