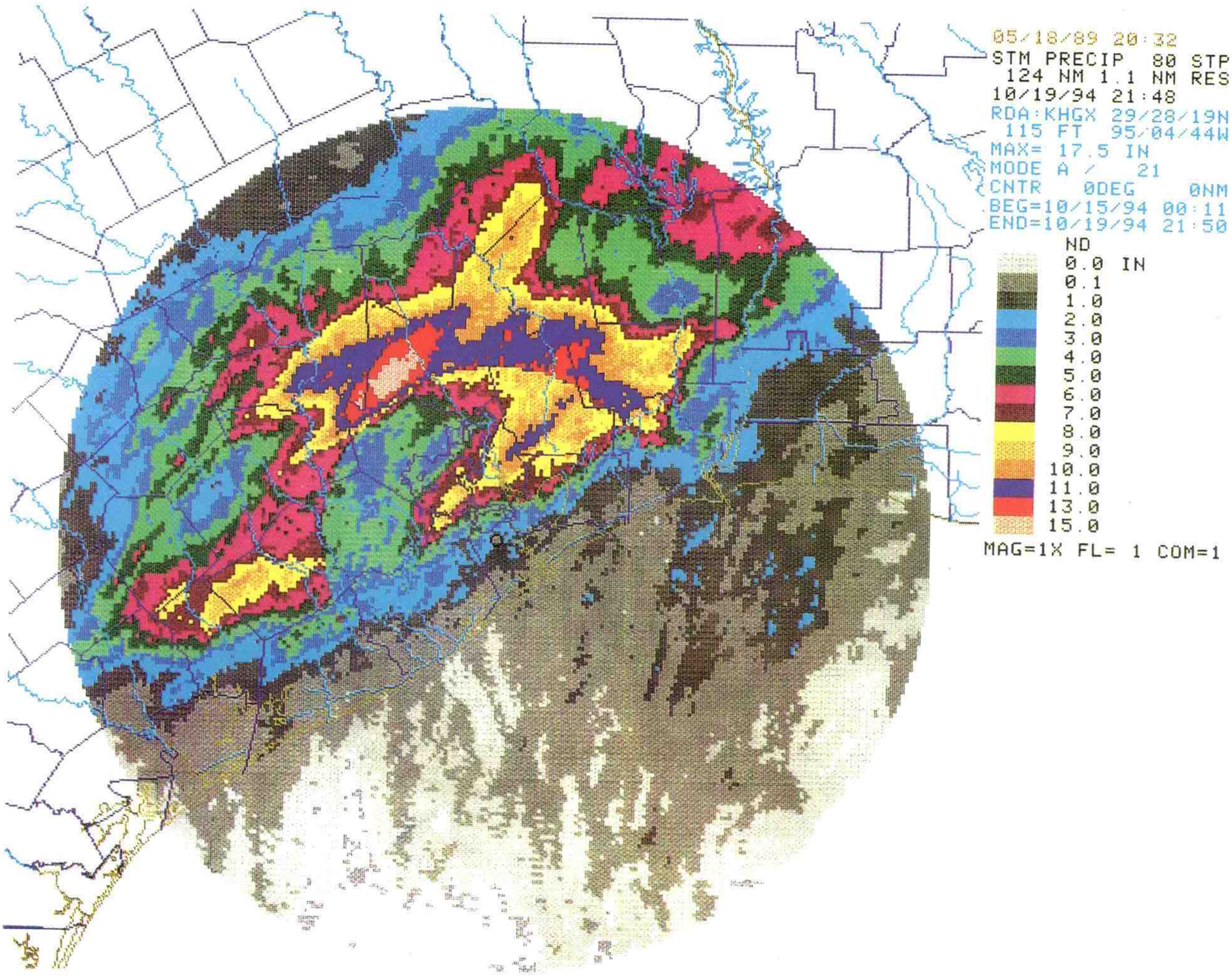
Natural Disaster Survey Report

Southeast Texas Tropical Mid-Latitude Rainfall and Flood Event

October 1994



U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service, Southern Region
Fort Worth, Texas

January 1995

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Southeast Texas Tropical Mid-Latitude Rainfall and Flood Event

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National Weather Service
Dr. Elbert W. Friday, Jr., Assistant Administrator

National Weather Service, Southern Region
Harry S. Hassel, Director

PREFACE

Perhaps to the casual observer it would seem that "unusual" weather events are occurring routinely, and if so, is there not an oxymoron somewhere in this? After all, was it not just recently that we were all relieved to be free of "The Flood of the Century", that great Upper Mississippi River flood of the summer of 1993? And then just last July 4 Tropical Storm Alberto brought more than twenty inches of rain to parts of southwest Georgia, southeastern Alabama, and the Florida panhandle, with resulting flooding beyond local residents' memories. Now has come this extreme rain and flood event in southeast Texas, with rainfalls approaching thirty inches in two days, and flooding to match.

Our **immediate** concern is not to place these events in their appropriate perspective concerning climate and frequencies—that is important and soon needs to be done—but to quickly align our services to the present-day needs of the impacted public we are serving, and to function better within our organizational framework to meet those user needs. That is why the Survey Team was assembled and charged with submitting this report.

I would like to thank the Survey Team for its rapid call-to-duty and energetic approach to the job at hand. The report faithfully traces the spirit of professional objectivity established by the many such surveys conducted previously, and we plan to place into practice as many of the report's recommendations as possible.

Harry S. Hassel
November 1994

FOREWORD

This report on the October 1994 heavy rain and severe flooding in southeast Texas is predicated largely upon a week of personal interviews with the officials at several NWS offices which dealt directly with the event as it unfolded, and the officials from several agencies outside the NWS which also dealt directly with the event while discharging their own particular agencies' missions.

The team is grateful to the following NWS officials, and their staffs, for the courtesies extended during the visitation and interview phase of the survey, and for their attentive assistance, when requested, during the logistical planning for the survey.

WGRFC Fort Worth — HIC Dave Morris
NWSFO Austin/San Antonio — MIC Al Dreumont
NWSO Houston/Galveston — MIC Bill Read

Likewise the following agencies were gracious in receiving the Survey Team and their cooperation is sincerely appreciated.

Lake Control Unit, Ft. Worth District, USCE, Ft. Worth, TX
Harris County Flood Control District, Houston, TX
San Jacinto River Authority, Conroe, TX

The Team recognizes that not every NWS office which had concerns and involvement with this event was visited, and that other external agencies could have also been included in the visitation phase. Unfortunately, practical considerations of time made an exhaustive visitation schedule impossible.

We hope the findings and recommendations of this survey will serve as a guide post to a better service. It is not unreasonable that during this time of such rapid and all-embracing change within the NWS, we take occasional pause to check that we're still on the highway to **positive** change that we set out to travel!

The Survey Team

DTS:jbm

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ACRONYMS

ABRFC	Arkansas-Red Basin River Forecast Center
AFOS	Automation of Field Operations and Services
ALERT	Automated Local Evaluation in Real Time
API	Antecedent Precipitation Index
ASOS	Automated Surface Observing System
AWIPS	Advanced Weather Interactive Processing System
CDT	Central Daylight Time
CFS	Cubic Feet per Second
CIAMS	Cooperative Institute for Applied Meteorological Studies
COMET	Cooperative Program for Operational Meteorology, Education, and Training
CWA	County Warning Area
DOD	Department Of Defense
EOC	Emergency Operations Center
HAS	Hydrometeorological Analysis and Support
HCFCD	Harris County Flood Control District
HIC	Hydrologist-in-Charge
HSA	Hydrologic Service Area
IFP	Interactive Forecast Program
LCRA	Lower Colorado River Authority
LCU	Lake Control Unit
LMRFC	Lower Mississippi River Forecast Center
MAR	Modernization and Associated Restructuring
MIC	Meteorologist-in-Charge
NAS	National Advanced System (brand name)
NAWAS	NAtional WArning System
NCDC	National Climatic Data Center
NEXRAD	NEXt Generation RADar
NGVD	National Geodetic Vertical Datum
NIDS	NEXRAD Information Dissemination Service
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NWR	NOAA Weather Radio
NWS	National Weather Service
NWSFO	NEXRAD Weather Service Forecast Office
NWSO	NEXRAD Weather Service Office
NWSRFS	National Weather Service River Forecast System
NWWS	NOAA Weather Wire Service
OSF	Operational Support Facility
PUP	Principal User Processor
QPF	Quantitative Precipitation Forecast
RDA	Radar Data Acquisition
RFC	River Forecast Center

RJE	**Remote Job Entry**
RPG	**Radar Product Generator**
SJRA	**San Jacinto River Authority**
SRH	**Southern Region Headquarters**
TLETS	**Texas Law Enforcement Telecommunications System**
UCP	**Unit Control Position**
USCE	**United States (Army) Corps of Engineers**
USGS	**United States Geological Survey**
VAD	**Velocity Azimuth Display**
VME	**Versa Module Eurocard**
WCM	**Warning and Coordination Meteorologist**
WFO	**Weather Forecast Office**
WGRFC	**West Gulf River Forecast Office**
WSFO	**Weather Service Forecast Office**
WSO	**Weather Service Office**
WSR-88D	**Weather Surveillance Radar - 1988 Doppler**

THE SOUTHERN REGION SURVEY TEAM

Following a severe weather event, such as heavy rain and extreme flooding, a survey team may be assembled by the NWS Regional Director to evaluate the effectiveness of the Region's programs in dealing with the event and providing service consistent with the mission of the National Weather Service. Following is the team that was assembled for this October 1994 event in southeast Texas.

TEAM MEMBERS

Leader, **David T. Smith**, Regional Hydrologist, Southern Region Headquarters, Ft. Worth, TX 817-334-2674 (W/SR2)

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*Visited NWSO Houston/Galveston Only

EXECUTIVE SUMMARY

An October 1994 tropical mid-latitude rainfall event of unusual proportion occurred over a 30 to 35 county area of southeast Texas resulting in catastrophic flooding. The intense rainfalls, which totaled over 25 inches in several closed isohyetal centers and more than eight inches over much of the affected area, caused terrific problems as drainage capabilities, both natural and man-made, were overcome by the copious downpours. Resulting runoff quickly gathered into classic river floods, especially over the San Jacinto, Lower Trinity, and Lower Brazos Valleys, and to a somewhat lesser extent over another half-dozen Texas rivers.

The triggering rainfalls commenced during late afternoon on Sunday, October 16, and continued for about 60 hours all together, moving only slightly within this interval from an initially affected area of about a dozen Texas counties to the final affected area of around 35 counties. The death toll, which easily could have been greater, has been determined at eighteen, half of which were vehicle-related.

The meteorological situation Sunday revealed a weak warm front lying indistinctly in southeast Texas, with considerably above normal low level moisture, and a deep trough to the west furnishing significant energy impulses. A likely contributing factor to the eventual severity of the flooding was Hurricane Rosa, an eastern Pacific storm which had moved quickly from the Mexican Pacific coast northeastward over southern Texas 36 to 48 hours prior, leaving one to four inches of antecedent rainfall over southeast Texas, and possibly trailing wakes of mid and upper level moisture.

The Regional Director of Southern Region, NWS, requested the formation of a Regional Survey Team at the conclusion of the episode. This included the explosive rains of the first 48-60 hours and subsequent record-setting floods which persisted for about a week, until Monday, October 24. His charge to the team was to focus on examining the internal coordination and cooperation among involved NWS offices and the level of service provided to the agency's external users.

A four-person Southern Region Survey Team was identified by noon, October 21, and the team assembled in Fort Worth at Southern Region Headquarters on Monday morning, October 24. The team spent the balance of the week interviewing officials at a number of affected NWS offices across the state, as well as officials of several agencies external to NWS who were involved in the event and depended upon NWS for services.

The Survey Team's findings indicated that NWS products and services to external users were generally considered at least adequate and often better; no outstanding complaints were voiced, and examples of exemplary service were pointed out. The internal coordination and cooperation among the various NWS offices involved with this event was commendable considering the agency's transition process which is affecting its people, technology, and organizational structure.

One theme found throughout the survey, however, was that an earlier recognition and explicit identification of an impending **significant** hydrometeorological event, even by 6 to 12 hours, would likely have resulted in more effective overall services, both internal and external to NWS.

As a final indication of the extreme nature of this rain and flood event, it is to be noted that preliminary estimates by the U.S. Geological Survey place the maximum flood discharge of the San Jacinto River below Lake Houston at about 1.6 times the 100-year-frequency flood flow. That agency's direct measurement there, of 354,000 cubic feet per second, is believed to be the greatest single river flow ever **directly measured** in the state of Texas. (It is true that greater discharges have occurred in the past; none of those were determined by direct measurement.)

SECTION 0

PRELIMINARY METEOROLOGICAL SYNOPSIS

A broad longwave trough was positioned over the Rocky Mountain states and the west, with south to southwest upper atmospheric flow across Texas. Hurricane Rosa, an eastern Pacific storm, moved rapidly northward across Mexico and eastern Texas October 14-15, and was only peripherally associated with the heavy rain synoptic situation. However, the remains of Rosa outlined a tropical plume of mid and high level moisture extending from the eastern Pacific north to eastern Texas. The presence of such a tropical moisture plume has been previously linked with flash flood producing rains by Scofield and others, and is discussed in the Cooperative Program for Operational Meteorology, Education, and Training (COMET) heavy rain module.

A very weak front moved northward from the Gulf of Mexico on Saturday and became nearly stationary on Sunday, extending roughly from Austin to College Station and Galveston. As the powerful low in the Rockies ejected energy disturbances northeastward behind the remains of Rosa, rain developed along this front. The lift associated with the frontal boundary, combined with moisture provided by strong southeast surface flow from the Gulf of Mexico, and the tropical plume from the south, produced a focusing mesoscale boundary for the subsequent torrential rainfall.

Many of the meteorological characteristics long associated with disastrous flood events were present: precipitable water was close to 200% of normal across east Texas, a strong moist and unstable low level inflow, a tropical moisture plume, strong upper level difluence, and a mesoscale focusing mechanism (first, a weak warm front, then a mesoscale outflow boundary). The synoptic situation included a deep trough over the Rockies with weak, subtle short waves rotating through the base of the trough. While the deep trough suggested a Maddox defined synoptic type flood event, forecasters at NWSFO Austin/San Antonio and NWSO Houston/Galveston generally agreed that the resulting situation most closely resembled a Maddox mesohigh type event.

NWSO Houston/Galveston's WSR-88D products vividly showed strong low level inflow (on the VAD Wind Profile the 2,000 to 3,000 foot level winds were 50+ knots!) from the Gulf of Mexico to the southeast intersecting the mesoscale outflow boundary. The resultant convection produced widespread 20 to 30 inch rains in two days across parts of southeast Texas, resulting in 18 deaths and disaster declarations for 35 Texas counties.

SECTION 1

U. S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT - LAKE CONTROL UNIT (LCU)
FORT WORTH, TEXAS

DISCUSSION — Fort Worth District's Lake Control Unit (LCU) is located in the Federal Building on Taylor Street in downtown Fort Worth. For nearly twenty years the LCU and the West Gulf River Forecast Center (WGRFC) were "collocated" in adjacent offices on the building's tenth floor. A very close working relationship between the two offices was a consequence of their proximity and shared mission-related interests. The primary responsibilities of the LCU include monitoring ongoing weather conditions, routinely collecting hydrometeorological data and reservoir conditions from the District's 27 reservoirs in Texas, and determining operations at those reservoirs in order that they furnish optimum flood control and protection for all interests affected by those reservoir operations.

LCU personnel were interviewed by the Survey Team on Monday, October 24.

FINDINGS AND RECOMMENDATIONS

Finding 1.1 — The WGRFC, along with the NWSFO Dallas/Fort Worth, moved into new quarters in north Fort Worth, about 7 miles distant from the Federal Building in November 1993. The former collocation of WGRFC and LCU made coordination and data sharing easy. Corps personnel would "drop in" to the WGRFC, and also to the WSFO, to look at mapped data or radar products. Discussions on different types of forecasts, both meteorological and hydrological, were direct, person to person. Of particular interest to the LCU were WGRFC-developed rainfall maps, inflow forecasts to District reservoirs, and downstream forecasts of river conditions which were affected by reservoir operations. In addition, staffs of both the NWS offices and the District knew each other personally. As changes in NWS programs occurred, LCU staff members were notified directly. Physical separation of the offices, brought about by the NWS offices' move, has resulted in a need to establish effective new coordination procedures.

Recommendation 1.1 — Because coordination with the LCU is mutually beneficial to both agencies, an effort should be made to re-establish the once close working relationship between the LCU and WGRFC. An annual meeting, at least, in which personnel from both offices discuss mutual concerns should take place. Forecast products, data collections, means of inter-office communications, organizational changes, and operating rules should be reviewed during these meetings. Renewal of personal contacts and amicable working relationships should be an encouraged goal.

Finding 1.2 — The District's project office at Sam Rayburn Reservoir, a reservoir in southeast Texas on the Neches River affected by these October rains, requested staffing by the LCU at 1:00 AM Monday morning, October 17, and a LCU staff member went to the LCU office at that time. NWS was not made aware of this.

Recommendation 1.2 — When hydrometeorological conditions at a District project mandate extra staffing of the LCU, WGRFC should be made aware of this in order to plan and respond appropriately.

Finding 1.3 — The District's LCU does not presently have access to NWS Doppler radar (WSR-88D) data.

Recommendation 1.3 — WGRFC and LCU should develop a long-range plan for the provision of eventual WGRFC-derived stage III-mosaicked WSR-88D data to the LCU. In the meantime, the District should be encouraged to subscribe to the NEXRAD Information Dissemination Service (NIDS).

Finding 1.4 — The District's LCU, as well as its Public Affairs Office, received many phone inquiries regarding river forecasts during these October floods. Forecasting river stages is a function of NWS, not the District, so the District was not able to respond directly to these inquiries, but made many referrals to the NWS. Understandably, NWS lines were often tied-up during this stressful time.

Recommendation 1.4 — NWS forecasts for flooding rivers should be made available to the District as soon as possible so these forecasts, appropriately identified as NWS products, may be used in answering phone inquiries.

Concluding Discussion — NWS Modernization and Associated Restructuring (MAR) plans called without exception for a collocation of all NWS RFCs with their WFO counterparts. Definite advantages will stem from this. It is also true that other traditional collocations in certain instances have been sundered as the MAR plan has been carried out, and there are some disadvantages to these. This WGRFC-LCU collocation sundering is such an example, and the agencies affected must in all cases attempt to take a pro-active role in minimizing disadvantages accruing from these diminished working relationships.

SECTION 2

NWS WEST GULF RIVER FORECAST CENTER (WGRFC)
FORT WORTH, TEXAS

DISCUSSION — The West Gulf River Forecast Center (WGRFC) in Fort Worth, Texas is the sole RFC responsible for forecasting rivers in the area affected by these October rains. The RFC's total forecast area in Texas is shown in Appendix C. WGRFC also has forecast area in New Mexico and Colorado, and parts of the Rio Grande drainage lie in Mexico. Its forecast area is explicitly defined as comprising all drainage between and including the Rio Grande eastward to and including the Sabine River. The WGRFC staff, recently increased in preparation for modernized RFC operations, is listed in Appendix A. Its total present staff of 14 is only one position shy of its fully-modernized complement of 15.

The State of Texas' Lower Colorado River Authority (LCRA) purchased four (Pre-AWIPS) workstations for the WGRFC, which were delivered in December 1993. These workstations provide capability for operating the NWSRFS's new Interactive Forecast Program (IFP) and will later provide capability for mosaicking NWS and DOD WSR-88D rainfall estimations and providing these estimations into the WGRFC river forecasting process. However, the mosaicking process is not yet a developed WGRFC capability. The WGRFC does have IFP operational capability, but has not completed a full transition to the NWSRFS Sacramento model, hence several river basins contain non-calibrated, "regional" parameters. Consequently, the IFP, which is being set up to use the Sacramento model, will give differing results for river systems forecasted through the traditional API/NWSRFS "batch mode" processing on the remote job entry (RJE) NAS 9000 system (physically located in Suitland, MD). Nonetheless, while the NAS 9000 RJE batch-mode of preparing river forecasts was the primary method used by WGRFC on some rivers during these October floods, the IFP, executed on the WGRFC in-house workstations, was available for at least limited types of applications on all rivers, and would have afforded advantages in speed and flexibility of forecasting operations.

The WGRFC was visited by the Survey Team on Monday, October 24, and again on Tuesday, October 25. RFC staff were interviewed by the team on Tuesday.

FINDINGS AND RECOMMENDATIONS

Finding 2.1 — Two HAS forecasters departed Fort Worth Monday morning, October 17, for a familiarization trip through Louisiana and were not available through the week for the flood event. The Senior HAS forecaster worked normal duty hours during the week. The HAS function at WGRFC is not yet fully operational and is still considered to be in a developmental mode.

Recommendation 2.1 — Familiarization trips to other offices and the field are important and provide opportunities to share information and methods, as well as helping to become

acquainted with the RFC area. However, such trips should be secondary to operations during a flood emergency such as this one. The WGRFC HAS functions should be incorporated more into the office operations, providing WSR-88D rainfall estimations to the extent possible, and coordination with WFO forecasters concerning amount and duration of additional rainfall. Close interaction between HAS forecasters and hydrologists at WGRFC should be encouraged.

Finding 2.2 — The WGRFC, although working extended hours Monday and Tuesday, October 17-18, did not go to full 24-hour operation until Wednesday, October 19. See Appendix B. In addition, a total of 233 hours of (extra) overtime or compensatory time were worked by the WGRFC staff during this flood event. However, hours of extra time by the individuals on the staff varied from 4 to 46, most occurring in the 7-day period October 17-23.

Recommendation 2.2 — It must be recognized early that when a major flood situation exists or is developing, a decision for 24-hour staffing by the RFC must be made quickly. Once the need for 24-hour staffing is evident, a schedule for working in that mode which more evenly distributes the at-work demand on staff members should be implemented. When individuals work in excess of 12-hours per day (average) for nearly a week, fatigue impairs needed critical judgement capability.

Finding 2.3 — No quantitative precipitation forecast (QPF) support was sought, nor offered, from involved NWSFOs during this heavy rain event. Special Excessive Rainfall Potential Outlooks from NMC (see Appendix P) called for heavy rains to continue past Sunday evening. Several WGRFC stage forecasts, especially for the severely impacted San Jacinto River Basin, were deficient through the rainfall duration period. See Appendix M.

Recommendation 2.3 — Limited use of QPF has been proven beneficial to river forecasts in numerous situations in the past. With the HAS forecasters as a vehicle, WFOs in critical flood situations should be encouraged to provide short time scale (less than 24 hours) QPF for hydrologists to use in QPF-included contingency forecasts. Operational hydrologic forecasters should also consider such QPF when issuing flood forecasts that will be affected appreciably by continued heavy rain. The San Jacinto River forecasts in this instance present just such a case. A qualifier statement should be included with such forecasts when rainfall is continuing, and prompt updates of such forecasts should be issued as data become available.

Finding 2.4 — The WGRFC was reluctant in some cases to use the IFP capability during this flooding event due to problems with transfer of observed data to the IFP and also because some regional parameters used to initialize the IFP capability yet require basin-specific calibrations for optimum forecasting capability. (To be fair, it is also true the IFP was used as the primary mode of developing river forecasts on some of the flooded rivers, especially the Trinity and Neches Rivers.)

Recommendation 2.4 — Continue calibration of basin parameters as quickly as possible, and ensure to the extent practical that IFP-to-database linkages are operationally sound, so the IFP can be used to full forecast advantage as soon as possible. Adequate river forecasts, especially for a river basin like the San Jacinto, will only be made by using IFP capability. Traditional batch-mode RJE operations will rarely provide adequate forecasts for the San Jacinto River Basin, and other rapidly responding ones, during heavy rain episodes like this October event.

Finding 2.5 — WGRFC did not notify the NMC Senior Duty Meteorologist nor the Office of Hydrology's Operations and Data Systems Group for the purpose of having a critical flood day declared for WGRFC RJE operations at the NAS 9000 Computer Operations Facility. (NMC's RJE service to WGRFC was acceptable throughout the forecast period. However, not declaring a critical flood day was taking an unnecessary risk.)

Recommendation 2.5 — The HIC or his designate upon assessing that a potential critical flood situation either exists or is imminent, and that needed river forecasts are essential to saving lives and property, should notify the NMC and Office of Hydrology as instructed in the Office of Hydrology's manual *Organized Operational Panic System*, dated February 23, 1994.

Finding 2.6 — The list of river forecasts issued by WGRFC to its Hydrologic Service Areas (HSA), Appendix K, indicates that prior to Wednesday the composite forecast product, furnishing **all** the river basin forecasts for a HSA, was sent, rather than sending individual river basin forecasts. Even though Appendix K shows that frequently telephone calls were soon placed to the HSA conveying the individual basin forecasts, hard copy individual basin forecasts should also be provided as quickly as possible. Holding river basin forecasts until the composite product can be assembled frequently delays getting vital forecasts to the HSA.

Recommendation 2.6 — During periods of severe flooding and especially when conditions are changing rapidly, the RFC should send individual river basin forecasts to the appropriate HSA as quickly as possible. Composite products are better suited to the routine, non-extreme, river situations.

Finding 2.7 — Data from the San Bernard River is limited to manual, one reading a day stage. No rainfall in real time is available for the Lower Neches basin, including Sour Lake. This limits the effectiveness and accuracy of WGRFC forecasts.

Recommendation 2.7 — An effort should be made by the appropriate Service Hydrologist to improve data collection in these basins.

Finding 2.8 — WGRFC frequently issues forecasts of the following sort: "River to rise to flood stage tomorrow", or "River to rise to bankfull by Friday", or "River to rise to near 5 feet Wednesday". None of these types of forecasts identify a crest nor do they, in some cases, provide information beyond 24 hours, or at best 2 or 3 days. These forecasts provide insufficient information to the user.

Recommendation 2.8 — It is understood that ongoing rains, or crests more than a few days into the future introduce added forecast risk. Nonetheless, additional forecast information beyond the next 24 hours, or even the next 2 days, is important. In addition, some information of expected rise is needed, even if the crest is still in the "distant future".

Where crests are expected to occur within the next 4 to 5 days, those crest forecasts should be provided. Where the rivers are expected to continue rising through the next 4 to 5 days, forecasts for those rises should be provided. WGRFC should conform with this recommendation now; and the recommendation is also intended to be consistent with modernized RFC operations, when numeric time-series of stage forecasts will normally be issued.

CONCLUDING DISCUSSION — The Survey Team's observation is that the WGRFC was operating largely in a reactive versus a true forecast mode, especially during the early half of this flooding episode. This is understandable, given the extreme rainfalls, the many problems with reliable and sufficient data, a staff in modernization transition, and the normal chaos always attending events of this sort. Nonetheless, the Survey Team also believes that having a third shift (24-hour staffing), a critical flood day declaration, QPF-based contingency forecasts, HAS forecasters' evaluation of ongoing rainfall, near-term QPF, and a more operational IFP could have contributed to placing WGRFC in a considerably more pro-active mode. A commendable dedication to duty was demonstrated by the WGRFC staff.

SECTION 3

NWS AUSTIN/SAN ANTONIO NEXRAD WEATHER FORECAST SERVICE OFFICE NEW BRAUNFELS, TEXAS

DISCUSSION — This office, formerly WSFO San Antonio and located in San Antonio, moved to its present location in New Braunfels, Texas during June 1994. The staff adequately reflects the traditional area management system. See Appendix A. NWSFO Austin/San Antonio still has formal watch and forecast responsibility for all of south Texas, including NWSO Houston/Galveston's County Warning Area (CWA), although the latter office is assuming more and more duties as NWS modernization continues. Prior to January 1993, WSFO San Antonio had Hydrologic Service Area (HSA) responsibility commensurate with its entire forecast area, i.e. all of south Texas. The NWSFO's HSA was significantly reduced in size when NWSO Houston/Galveston took over full HSA responsibility for an area commensurate with its county warning area on January 5, 1993. With the redefined HSA, NWSFO Austin/San Antonio now issues river warnings, forecasts, and statements for drainages only eastward to and including the Colorado River drainage, while NWSO Houston/Galveston's HSA includes all southeast Texas drainages east of the Colorado River. See Appendix C. Only the easternmost part of the NWSFO Austin/San Antonio HSA was affected by the torrential rains and extreme flooding during this October episode.

The Survey Team made a visit to NWSFO Austin/San Antonio on Wednesday, October 26, interviewing the MIC, Service Hydrologist, and a few other members of the staff.

FINDINGS AND RECOMMENDATIONS

Finding 3.1 — In general, forecasts issued by NWSFO Austin/San Antonio were good. Heavy rainfall was forecasted, but only maximum amounts in the four to six inch range were discussed, rather than the 20 to 30 inch maximums received. No Flash Flood Watch was issued until 4:10 AM CDT Monday, October 17, after the truly heavy precipitation event was well underway. See Appendix H. However, forecasters at the NWSFO were concerned midday Sunday that ingredients for a **major** rainstorm were coming into place. The inability to geographically pin-point the position of a weak warm front in southeastern Texas caused forecasts for that part of the state to be understated, i.e. the most at-risk counties could not be clearly differentiated.

Recommendation 3.1 — Relatively sparse realtime surface data reporting networks continue to make locating vital mesoscale meteorological features difficult. NWS should spearhead a lobbying effort for a Texas data mesonet. Such a network would greatly augment ASOS data. The additional data would not only greatly assist meteorological forecasters, but provide much needed ground truth to support the application of WSR-88D data, especially precipitation estimates, into NWS models.

Finding 3.2 — NWSFO Austin/San Antonio forecasters pointed out that they had very little upper air data from Mexico available for their own analyses throughout this event. The lack of data was also felt as Hurricane Rosa moved across south Texas from Mexico two days prior to Sunday's onset of torrential rains. In fact, from October 14 through 17, only the 14/0000Z upper air data from Mexico's west coast was available. In lieu of this data, the NWSFO forecasters had to rely extensively upon satellite information.

Recommendation 3.2 — Delivery of Mexican upper air network data to NWS forecast offices (especially along the southern tier of states) is a requirement for their complete forecast analyses. Whether failure of consistent delivery is due to incomplete data acquisition at the source or due to late dissemination to and/or within NWS needs to be determined, and appropriate remedial actions initiated.

Finding 3.31 — It is agreed that this October rain episode, with rainfalls approaching 30 inches in some closed isohyetal centers, was extreme. On the other hand, rainfalls on the order of 15 inches are not terribly rare in south Texas for October. Forecasters were aware of impending conditions which could result in very heavy rainfalls. The earlier passage of eastern Pacific Hurricane Rosa at mid and upper levels over south Texas, with the associated rainfall, is a case in point. Also, temporary saturation of the surface soil mantle by rains Friday, probably Rosa induced, and the approaching low pressure system from the west placed the area in greater jeopardy for a flood than may have been realized.

Finding 3.32 — The National Meteorological Center's (NMC) Hydrometeorological Prediction Center issued an Excessive Rainfall Potential Outlook (see Appendix P) at 5 PM (CDT) Sunday, October 16, assessing the situation in southeast Texas and calling for the distinct likelihood of rainfalls in excess of five inches within 12 hours.

Recommendation 3.3 — Hydrometeorological conditions stated above should be sufficient to prompt discussions between WFO forecasters and RFC HAS forecasters in the modernized NWS operations. Such discussions should become routine from now on between the WGRFC HAS forecasters and WFO Forecasters when such conditions exist. Agreement between the WFOs and HAS forecasters as to impending rainstorms of significance will enable RFCs to enter flooding episodes in a pro-active rather than a reactive mode.

Finding 3.4 — WGRFC may not have the most recent rendering of all E-19s (NOAA/NWS Reports on River-Gage Stations) in NWSFO Austin/San Antonio's HSA.

Recommendation 3.4 — Copies of all updated E-19s should be sent to WGRFC, SRH, and the Office of Hydrology, whether by hard copy or electronically. To enhance a spirit of cooperation and coordination, distribution of copies to appropriate USGS Districts, USCE Districts, and State River Authorities should be considered.

CONCLUDING DISCUSSION — NWSFO Austin/San Antonio's approach to this heavy rainfall episode was appropriate and consistent with traditional NWS procedure. The addition of new technologies into the WFOs and the presence of HAS forecasters in RFCs should bring into sharper focus—between the two offices—the impending likelihood of significant rains. At the same time, objective studies and reviews of local climatologies coupled with the improved technologies should in the future provide NWS forecasters with a greater sense of confidence in calling for the imminent onset of unusually heavy rains and serious flooding.

SECTION 4

NWS HOUSTON/GALVESTON NEXRAD WEATHER SERVICE OFFICE DICKINSON, TEXAS

DISCUSSION — This office was formerly located in Alvin, Texas but moved to its present location in autumn 1991. Houston WSO became one of the earliest NWSOs in the NWS when the WSR-88D was installed as one of the first deployed by NWS. Staffing of the NWSO during the October episode was as shown in Appendix A. As seen, the staff includes a Service Hydrologist, and NWSO Houston/Galveston has had full HSA responsibility for its area since January 5, 1993. See Appendix C. The most intense, heaviest rains and the most devastating flooding occurred within the NWSO's HSA during this event. The rains commenced Sunday afternoon and by very late Sunday it was evident a major rainstorm was in progress. The MIC and WCM were both scheduled to travel Monday morning, but both canceled their travel plans realizing the work load at the NWSO was going to be significant. This certainly proved to be the case. Appendix O shows the flash flood and flood products put out by the office. Ninety-six such products were issued, including 48 flash flood warnings and statements. Sixty-four of the 96 flash flood and flood products were issued during the initial 48 hours of the episode. Due to recent staff turnover and vacancies, only two forecasters were fully trained on WSR-88D operations, in addition to the MIC, SOO, WCM, Service Hydrologist, and Marine Focal Point/Forecaster.

The Survey Team visited NWSO Houston/Galveston on Thursday and Friday, October 27-28, interviewing the MIC, WCM, and Service Hydrologist.

FINDINGS AND RECOMMENDATIONS

Finding 4.1 — There was some question about correlation between NWSO Houston/Galveston's CWA and HSA which was causing some confusion during river forecast issuances.

Recommendation 4.1 — Any unresolved issues concerning HSAs among NWSFOs/NWSOs in WGRFC's forecast area need to be addressed by SRH.

Finding 4.2 — A number of data problems surfaced during the flood event. Numerous automated gages failed. In particular, the San Jacinto River Authority's ALERT system was not reporting and the Harris County Flood Control District's 70-gage ALERT network contained some bad data as well as numerous gages not reporting.

Recommendation 4.2 — Despite the apparent abundance of automated gages throughout much of southeast Texas, and especially within the metropolitan Houston area, efforts should be made to establish back-up observers for vital emergency observations, especially at critical river forecast gaging sites.

Finding 4.3 — A disagreement between NWSO Houston/Galveston and WGRFC concerning flood stage exists on at least one river forecast point on the San Jacinto River (East Fork at Cleveland).

Recommendation 4.3 — It is essential that all conflicts on flood stages between the WGRFC and the NWSFOs/NWSOs it serves be resolved as soon as possible.

Finding 4.4 — A number of river forecast points in the NWSO's HSA do not have flood stages established. This makes it difficult to relate current and forecast river stages to necessary preparedness action. Also, a number of E-19s for the NWSO Houston/Galveston HSA filed at WGRFC are more than ten years old.

Recommendation 4.4 — The Service Hydrologist should make an effort to establish flood stages at forecast points through normal NWS procedures including coordination with other local, state, and federal agencies. A "call-to-action" statement should accompany forecasts issued to the public. Updates of E-19s older than 10 years from the present date should be accomplished and copies sent to the WGRFC, SRH, and Office of Hydrology, whether by hard copy or electronically. To enhance a spirit of cooperation and coordination, distribution of copies to appropriate USGS, USCE, and river authorities is an encouraged option.

Finding 4.5 — The Galveston District of the U.S. Army Corps of Engineers evidently did not receive all the products they needed despite being on NWWS. The District phoned in to NWSO Houston/Galveston and asked that products be read to them.

Recommendation 4.5 — NWSO Houston/Galveston should provide a list of recommended products to Galveston District and encourage them to contact Contel and have them added to their NWWS collection. In addition the communication network between the USCE districts of Southwestern Division and WGRFC needs to be reviewed for reliability of NWS product delivery to all the districts, including Galveston.

Finding 4.6 — NWSO Houston/Galveston is not in direct receipt of Cooperative Observer reports for rainfall and rivers, but depends on the routine AFOS transmission of those collections from NWSFO Austin/San Antonio, which collects those observations via the Automated Touch Tone Data Collection computer. This results in delayed receipt of this vital data to NWSO Houston/Galveston.

Recommendation 4.6 — NWSO Houston/Galveston should be the collecting office for Cooperative Observer data in their HSA via their own Automated Touch Tone Data Collection computer. SRH should provide this to them as soon as possible.

Finding 4.7 — At the present time the NWSO can dial in to the Harris County Flood Control District's (HCFCD) ALERT data collection. Efforts to effect a base-station direct receipt of the HCFCD's ALERT data have thus far been unsuccessful.

Recommendation 4.7 — Establishing a true base-station direct receipt of the HCFCD's ALERT data should be a priority project for NWSO Houston/Galveston. Any needed assistance should be funded by SRH. In addition, back-up dial in capability should be maintained by WGRFC, including the collection of ALERT data from the San Jacinto River Authority, via the HCFCD's data base.

Finding 4.8 — A number of product and warning dissemination problems were evident, some of them beyond direct NWS control. Included were the following:

(a) The Texas Law Enforcement Telecommunications System (TLETS) is overloaded, and antiquated, prone to lengthy delays in delivering critical weather information to local emergency managers.

(b) Not all local emergency managers subscribe to NIDS and/or NWWS. This is particularly true of the less affluent counties.

(c) Not all emergency managers are on or have 24-hour access to the National Warning System (NAWAS).

(d) NOAA Weather Radio (NWR) has dead spots, even within the normally effective 40 mile radius.

(e) River Authorities are often queried about the latest river forecasts during periods when river conditions are critical and rapidly changing, but they do not always have access to NWS river forecasts.

Recommendation 4.8 — All options by which needful agencies may have access to NWS products and warnings should be reviewed with them, including a full disclosure of the various products available, and proper product identification. In addition, NWS should continue to be aggressive in encouraging and working with the State's Department of Public Safety to upgrade its current method, TLETS, and getting critical weather information to all local emergency management officials.

Finding 4.9 — While the staff of NWSO Houston/Galveston functioned at an optimum level during this heavy rain event, it seemed to be stretched by lack of fully trained WSR-88D forecasters on-station. During this episode, there were only two fully trained WSR-88D forecasters available on staff (fully trained is defined as OSF trained and all on-station training for UCP, PUP, etc. completed; partly trained is defined as OSF trained and not all on-station training completed). Much of the WSR-88D workload fell upon the five fully trained non-forecaster staff, the MIC, SOO, WCM, Service Hydrologist, and Marine Focal Point. Over the extended period of time of this flood event, the available WSR-88D trained staff was pushed to the limit. (Presently, 11/94, NWSO Houston/Galveston has two forecasters attending the OSF training course.)

Recommendation 4.9 — Maintaining a staff of fully trained forecasters at WSR-88D field offices should be of the highest priority. High staff turnover rates make this difficult.

Sufficient slots at OSF WSR-88D training classes must be available to ensure that forecast staffs at soon-to-be-commissioned and commissioned WSR-88D offices are fully trained in a timely manner.

CONCLUDING DISCUSSION — General response by emergency managers, media, other agencies, and the public to the warnings and forecasts issued by NWSO Houston/Galveston has been positive. This is not trivial considering the stressful situations which the heavy rains and record flooding imposed on southeast Texas, including the major metropolitan area of Houston, the nation's fourth largest city. Especially noteworthy is the service provided considering the relatively small experienced staff, and problems they were encountering with the WSR-88D. See Section 7. Upon realizing the Houston media was making extensive use of WSR-88D products, it is highly commendable that NWSO Houston/Galveston issued a statement advising the media of the underestimations of rainfall, urging them to use the WSR-88D precipitation products with caution. Overall, a commendable dedication to duty was clearly demonstrated by all the NWSO staff.

SECTION 5

HARRIS COUNTY FLOOD CONTROL DISTRICT (HCFCD)
HOUSTON, TEXAS

DISCUSSION — The Harris County Flood Control District (HCFCD) is responsible for the planning, design, and construction of an infrastructure for flood management for the streams and bayous in Harris County, most of this in the highly urbanized Houston area. It is estimated the HCFCD spends $20 million per year maintaining 3000 miles of bayous, creeks, and ditches.

HCFCD owns and operates about 70 automated stream and precipitation gages comprising an ALERT network intended to provide them with near real-time conditions over the drainages for which they are responsible for providing "management", in order to minimize flood damage and maintain transportation, communications, etc. throughout the Houston (Harris County) metropolitan area. They rely heavily on historical data in conjunction with the current conditions as described by their ALERT network data to internally predict water surface rises on their various watercourses. However, HCFCD does not wish to make forecasts for the general public, despite a great interest by that public in "what is going to happen" next.

The HCFCD Director expressed to the Survey Team his concerns about the media gathering at his office during major flood events. HCFCD is not equipped nor well prepared to respond to weather-related media inquiries, and does not see this as a condition of its charter. Unfortunately, from the HCFCD's standpoint, the centralized location of its headquarters in metropolitan Houston is more convenient than NWSO Houston/Galveston for the Houston media. Under the circumstances, the Director believes the Houston City/Harris County EOC is the more appropriate gathering place for the media, and he believes NWS involvement in the media's interface there should be greater than it is. He also mentioned the extreme importance of 12-24 hour watch/warning notifications for significant rainfall and flooding to the HCFCD for their use in planning and preparing their own operations, and he feels the watch/warning process is vital to the public's safety preparations and precautions as well.

The HCFCD headquarters, located at 9900 Northwest Freeway in metropolitan Houston, were visited by the Survey Team on Friday, October 28 in the company of NWSO Houston/Galveston's MIC, WCM, and Service Hydrologist.

FINDINGS AND RECOMMENDATIONS

Finding 5.1 — Although rainfall was significant across Harris County, many of the drainages managed by HCFCD escaped the very heaviest rainfall and most severe flooding, which occurred in other drainages surrounding Harris County. A rainstorm of the magnitude experienced north of Harris County, if it were to occur over Harris County, with its tremendous metropolitan development, would likely have been calamitous.

Recommendation 5.1 — Flooding in Harris County will be a continuing threat, and this October event shows the potential for true calamity. Perhaps an annual flood workshop for the Houston area similar to the Houston Hurricane Workshop should be conducted, or flood preparedness should become a major topic of the Hurricane Workshop. A greater number of damaging floods than hurricanes will adversely affect Harris County and surroundings through the years, and it should be emphasized these are not always associated with hurricanes or even tropical storms, and may occur at any time of the year.

Finding 5.2 — HCFCD would like to develop flash flood tables for its various drainages for its own internal use, but feels it needs assistance to do so.

Recommendation 5.2 — NWSO Houston/Galveston and WGRFC should approach HCFCD with an offer to assist in the development of applicable tables. This may also be a viable CIAMS/Partners Project among the NWSO, WGRFC, HCFCD, and CIAMS. In this latter case NWS involvement is still important since expertise in developing flash flood tables is almost unique to the agency.

Finding 5.3 — Data from the HCFCD ALERT Network is available to NWSO Houston/Galveston via dial-up. HCFCD also has the capability to receive SJRA ALERT data, which should also then be available to NWS.

Recommendation 5.3 — It is important that NWSO Houston/Galveston successfully bring up full base-station capability at the office in order to have up-to-date receipt of all the ALERT data available from HCFCD. In addition, back-up dial in from WGRFC should be established into HCFCD.

Finding 5.4 — The HCFCD expressed a desire to see more timely forecasts and warnings for the San Jacinto River basins. Difficulties in providing these were discussed.

Recommendation 5.4 — The HAS functions at WGRFC, especially including QPF assimilation, should be implemented as soon as possible at WGRFC. Forecasts for the San Jacinto River Basin should benefit appreciably from the inclusion of short term QPF.

CLOSING DISCUSSION — The HCFCD had no specific complaints about NWS performance during this flood event. They are well aware of agency constraints, and expressed their own difficulties in maintaining their own significant data network. Flood warning is not the HCFCD's job, and they are sincerely interested in seeing the NWS assume greater responsibility in Harris County in this regard. They do provide information on existing conditions of rivers, streams, and bayous, but will not develop any forecasts for external release.

SECTION 6

SAN JACINTO RIVER AUTHORITY (SJRA)
CONROE, TEXAS

DISCUSSION — The San Jacinto River Authority (SJRA) is one of about ten major river authorities in Texas. The SJRA receives no appropriations and does not levy or collect taxes. The SJRA's income is primarily derived from the sale and distribution of water and the treatment of wastewater. The mission of the SJRA is to develop, conserve, and protect the water resources of the San Jacinto River watershed. The SJRA's Headquarters and Lake Conroe Division Office are located at the Lake Conroe damsite on the headwaters of the West Fork of the San Jacinto River.

The San Jacinto River watershed covers approximately 4,000 square miles, of which about 440 square miles are above Lake Conroe. At normal pool elevation, Lake Conroe has a surface area of nearly 21,000 acres and a storage capacity of 430,300 acre-feet. The lake's large volume provides for attenuation of flood inflows. However, flood control benefits are incidental as dam operations strive to maintain a "constant" conservation pool elevation. During the height of the October flooding above Lake Conroe the pool reached an all-time record elevation of 205.58 feet NGVD. Conservation pool elevation is 201.00 feet NGVD. During the flood a maximum inflow to the lake has been estimated at greater than 150,000 cfs, and SJRA operated the dam's gates to finally permit a record maximum release of about 34,000 cfs.

SJRA's second reservoir, Lake Houston, is located considerably downstream of Lake Conroe, on the San Jacinto River mainstem. The drainage area above Lake Houston is 2,828 square miles. This reservoir furnishes water for irrigation, municipal, and industrial use in the Houston Metropolitan area. During flooding SJRA exercises no effective control of Lake Houston, where flows over a 2/3-mile-long spillway are free-flowing.

The SJRA has an automated network of precipitation and streamflow monitoring stations, and their base station for radio receipt of the gaged data is located at their headquarters office at Lake Conroe. Included in the network are six tipping-bucket raingages positioned in the drainage area above Lake Conroe, and about five streamgages downstream of the dam on various branches or forks of the San Jacinto River. NWSO Houston/Galveston has dial-in capability to the SJRA ALERT data, and in addition SJRA enters daily data on Lake Conroe's status to the Automated Touch Tone Data Collection computer at NWSFO Austin/San Antonio.

The Survey Team visited the SJRA headquarters office at the Lake Conroe damsite on Friday, October 28, in company with NWSO Houston/Galveston's MIC and Service Hydrologist.

FINDINGS AND RECOMMENDATIONS

Finding 6.1 — The SJRA's Lake Conroe data telephoned in to NWSFO Austin/San Antonio each morning normally includes an average discharge over a 24-hour period, as well as a pool elevation and precipitation.

Recommendation 6.1 — For serious flooding situations, instantaneous discharges, as well as rainfall reports at synoptic times would be advantageous for timely, accurate forecasts for the San Jacinto River drainages downstream of Lake Conroe. NWSO Houston/Galveston and WGRFC should work together with SJRA to implement an appropriate reporting strategy.

Finding 6.2 — SJRA personnel at Lake Conroe were not surprised when rain began at and above Lake Conroe, but they in no way anticipated the 20-inch-plus deluge that occurred there. In essence they worked the critical early-Monday morning (October 17) dam operations in a minimum staffing configuration. SJRA personnel routinely monitor, and appreciate, NOAA Weather Radio, but they are not on NWWS.

Recommendation 6.2 — Lack of a Flash Flood Watch for an area including Montgomery County may have led SJRA to believe, until too late, that the early rains were routine. Hopefully, NWS forecasters in the future can be more aggressive in determining defined areas at risk for heavy rainfall in southeast Texas.

Finding 6.3 — SJRA utilizes a computer program which is designed to forecast inflows to Lake Conroe based upon observed rainfalls above the dam.

Recommendation 6.3 — WGRFC may wish to compare SJRA model performance with its own, with an eye towards optimizing each agency's prediction capability.

CLOSING DISCUSSION — The SJRA was not critical of NWS services provided during this flood episode. They emphasized that even with adequate lead times of accurate weather forecasts they would not operate Lake Conroe in any appreciably different fashion than was done. The major advantage to them of more timely watches and warnings would be in planning operations staffing.

SECTION 7

WSR-88D PERFORMANCE

DISCUSSION — The commissioned NWSO Houston/Galveston's WSR-88D functioned throughout this heavy rain event and was able to archive a complete set of Level II data. The tapes will be duplicated at NCDC with copies distributed to Operations Support Facility (OSF) and the Cooperative Institute for Applied Meteorological Studies (CIAMS) at Texas A&M University for further study. There were, however, some problems that arose with the radar program which are mentioned below. It should be noted that the staff of NWSO Houston/Galveston worked their WSR-88D to its fullest capacity and that noted problems with it were primarily the result of new technology being tested during an extreme event.

FINDINGS AND RECOMMENDATIONS

Finding 7.1 — Since undergoing their VME MicroFive Retrofit, NWSO Houston/Galveston has experienced a Principal User Processor (PUP) hangup problem when dialing into adjacent radars. At times, the Radar Product Generator (RPG) is up and running, but the PUP no longer receives products. The OSF Hotline suggests "FESTUS,CLEAR" and "PUPDOWN" and "PUPUP" to fix or reboot the RPG. These somewhat cryptic and labor intensive procedures are operationally unacceptable. A similar problem has been noted at NWSFO Jackson. Such problems make it difficult to access adjacent WSR-88Ds and will result in reduced accessibility by forecasters of adjacent WSR-88Ds. The OSF is aware of the problem and is working on a fix.

Finding 7.2 — Since their retrofit, another problem at NWSO Houston/Galveston is a less stable RPG which simply halts for unknown reasons. A few crashes resulted in a totally down Unit Control Position (UCP) which required going to the Radar Data Acquisition (RDA) and flipping circuit breakers to restart. This is really disruptive during a severe weather event. Checking "ST,S" after recovery yields no clue as to the problem. OSF hotline staff has been notified of this problem.

Finding 7.3 — NWSO Houston/Galveston has found that Archive IV data may be easily lost since the retrofit software was installed. There is no way that the PUP operator can actually determine if Archive IV is recording except by going back to the archive device and looking at it. The status message is not satisfactory. When the status message is displayed, it may show "AUTO ARCHIVE ACTIVE" when in fact it is not.

Recommendation 7.3 — A request-for-change needs to be submitted to modify the message available to the PUP operator to verify the status of the Archive IV.

Finding 7.4 — While radar estimates of areal coverage for rainfall were accurate during this event, rainfall estimates by the NWSO Houston/Galveston WSR-88D rainfall algorithm were deficient in some areas. This underestimation was noted early in the event by the NWSO forecasters who sent out a message to NWS and NIDS users to use rainfall estimates with

caution. Gaged rainfalls indicated a fairly large area of 5-day totals of 20 inches or more, with maximums approaching 30 inches. See Appendix F. NWSO Houston/Galveston WSR-88D estimates for the same period did not exceed 15 inches. See Appendix R. The Applications Branch of OSF is evaluating this rainfall event and will rerun the event from the Archive Level II tapes to more clearly understand causes of this underestimation. While some answers are not presently available, the following are problems with known causes:

A. A discontinuity ring is easily seen on the rainfall products caused by a tilt test error on the hydro scan - the cut off between the first and second scan was 50 miles instead of 50 kilometers. This error affected the rainfall estimates in the 30 to 50 mile range. This error, first noted by NWSO Houston/Galveston forecasters during this event, was one introduced by Unisys affecting all retrofitted sites, and had previously gone undetected. A correction notification has been sent to all retrofitted sites as a result.

B. The standard Z-R relationship of the WSR-88D was not representative of the warm subtropical air mass causing this heavy rain event. In fact, it is felt by the NWSO staff that more than one Z-R relationship would have been needed to adequately interpret different parts of this event. The Z-R relationship is an adaptable parameter controlled by OSF. Forecasters need to understand this limitation of the radar program and use other available information such as raingage networks to make subjective adjustments to algorithm rainfall estimates.

C. The WSR-88D rainfall algorithm has a 53 dBz adaptable parameter cutoff such that any reflectivities above that level are considered not to be rain but hail. In a warm air mass, higher reflectivities above 53 dBz might allow the rainfall estimates to increase. This value is controlled by OSF but can be adjusted upon request and justification.

Recommendation 7.4C – Adjustments to the 53 dBz threshold certainly appear to be needed for various climatic regimes. Additionally, national guidelines based on studies soon need to be developed by OSF before adjustments to the 53 dBz threshold are implemented. This would ensure consistency across the WSR-88D network.

D. The NWSO Houston/Galveston WSR-88D has a filter that was installed to eliminate interference from a cable TV transmission.

Recommendation 7.4D – An evaluation to determine if the filter was/is working as designed and if it had any effect on WSR-88D algorithms, including rainfall estimations, needs to be accomplished.

E. There was some concern from field offices relating to consistency of adjacent WSR-88D radar outputs.

Recommendation 7.4E — Standards for absolute calibration of WSR-88D radars need to be established. In other words, will adjacent radars see and record similar features while observing the same event? This applies to base reflectivity and values derived from algorithms.

F. Clutter filter procedures by local offices could affect rainfall estimates. All indications show that the NWSO Houston/Galveston staff correctly used clutter suppression and that such procedures were not a factor in affecting rainfall estimates.

G. During this heavy rain event, it is felt that much of the rainfall originated at low levels of the atmosphere below the 1.5 degree minimum tilt level of the algorithm. Perhaps a 0.5 degree tilt out to a certain range would have picked up additional rainfall.

Finding 7.5 — While such heavy rainfall events may seem rare, they indeed are not unusual. If forecasters are to be prepared to forecast such events in the future, they must learn from the past.

Recommendation 7.5 — With Computer Based Learning technology and Archive Level II data available, the development of a heavy rain case study module could form the basis of future forecasting of such events. Resources such as COMET and CIAMS should develop a case study module for WFO/RFC forecasters using the abundant data available from this event. In addition, the capability of all WSR-88Ds to record Level II data, and an archive of such data for research purposes at NCDC, should be ensured.

CONCLUDING DISCUSSION

As previously mentioned, some of these early findings and observations do not have answers at this time but will or could be explored by OSF and research organizations such as CIAMS. Because Archive Level II data are available, such inquires have already begun.

SECTION 8

SURVEY TEAM WRAP-UP

Finding 8.1 — The Survey Team has made a determined effort to submit this report quickly before the event recedes into the dim past. We believe we've succeeded. The finished draft was handed to the Regional Director only six weeks following the event's occurrence. Many survey reports are submitted later, often excessively later, and become impotent instruments incapable of effecting change. This should not be this report's fate!

The Survey Team has been careful to mostly raise issues over which the field offices in conjunction with regional-level offices have jurisdiction. This means changes as prescribed in many cases can commence now. While the time required to bring to full fruition some of the recommendations may be lengthy, important needed changes can at least begin almost immediately.

Recommendation 8.1 — The report should reach the field no later than the beginning of 1995. Coordination among the involved field offices of NWS, external agencies, and appropriate regional offices should result in status reports to the Regional Director, SRH, on actions taken with a first report due April 1, 1995, and a second by July 1, 1995. These actions should either bring to closure the applicable recommendations or begin the office(s) and agencies on the road to desired and satisfactory closure.

Finding 8.2 — This report presents a considerable amount of data, product lists, etc. These, coupled with first-hand observations by the Survey Team, culminate in our view that NWSO Houston/Galveston functioned at an optimum level, considering the scope of the event, the state of the staff, and the stress introduced by many problems including technical ones.

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APPENDIX A

NWS OFFICE STAFFINGS — OCTOBER 1994

WGRFC FORT WORTH

1 Hydrologist-in-Charge
1 Development and Operations Hydrologist
4 Senior Hydrologists
1 Senior Hydrometeorologist (HAS)
2 Hydrometeorlogists (HAS)
3 Hydrologists
1 Hydrologist Intern
1 Hydrometeorological Technician

NWSFO AUSTIN/SAN ANTONIO

1 Meteorologist-in-Charge
1 Deputy Meteorologist-in-Charge
1 Warning/Coordination Meteorologist
1 Science and Operations Officer
5 Lead Forecasters
6 Forecasters
1 Data Acquisition Program Manager
5 Hydrometeorological Technicians
1 Electronic System Analyst
1 Senior Electronic Technician
2 Electronic Technicians
1 Area Electronic Supervisor
1 Sector Facilities Technician
1 Cooperative Program Manager/Trainer
1 Service Hydrologist
1 Secretary

NWSO HOUSTON/GALVESTON

1 Meteorologist-in-Charge
1 Warning/Coordination Meteorologist
1 Science and Operations Officer
4 Forecasters
1 Marine Focal Point/Forecaster
1 Data Acquisition Program Manager
4 Hydrometeorological Technicians
1 Electronic Systems Analysis
1 Electronic Technician (ASOS)
1 Port Meteorological Officer
1 Service Hydrologist
1 Secretary

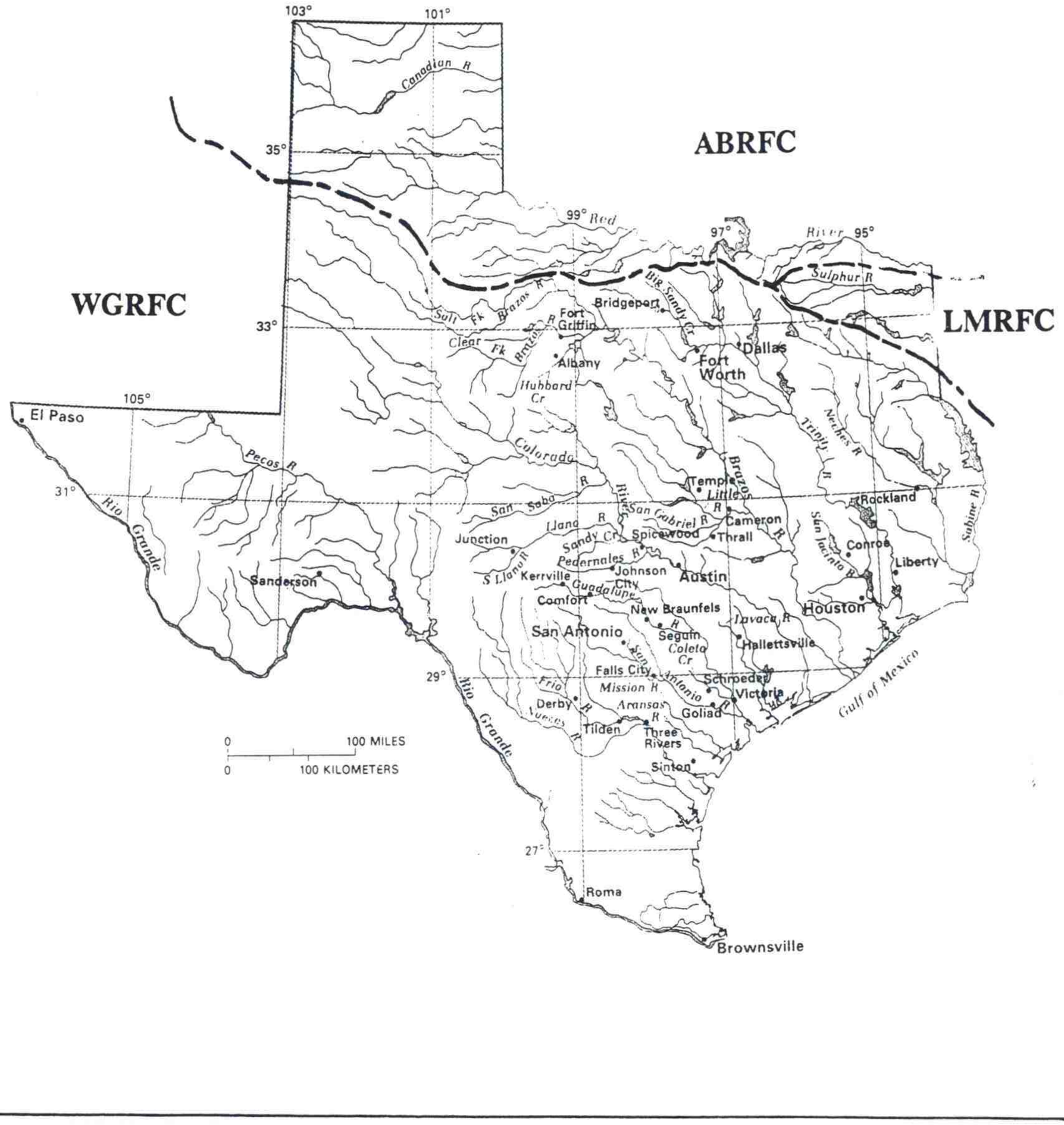
APPENDIX B

HOURS OF OPERATION OF WGRFC — OCTOBER 15-24, 1994

DATE		HOURS
Sat	10/15	0700 - 1500
Sun	10/16	0700 - 1500
Mon	10/17	0715 - 2200
Tue	10/18	0630 - 2200
Wed	10/19	0600 - MIDNIGHT
Thu	10/20	MIDNIGHT - MIDNIGHT
Fri	10/21	MIDNIGHT - MIDNIGHT
Sat	10/22	MIDNIGHT - MIDNIGHT
Sun	10/23	MIDNIGHT - MIDNIGHT
Mon	10/24	MIDNIGHT - 2200

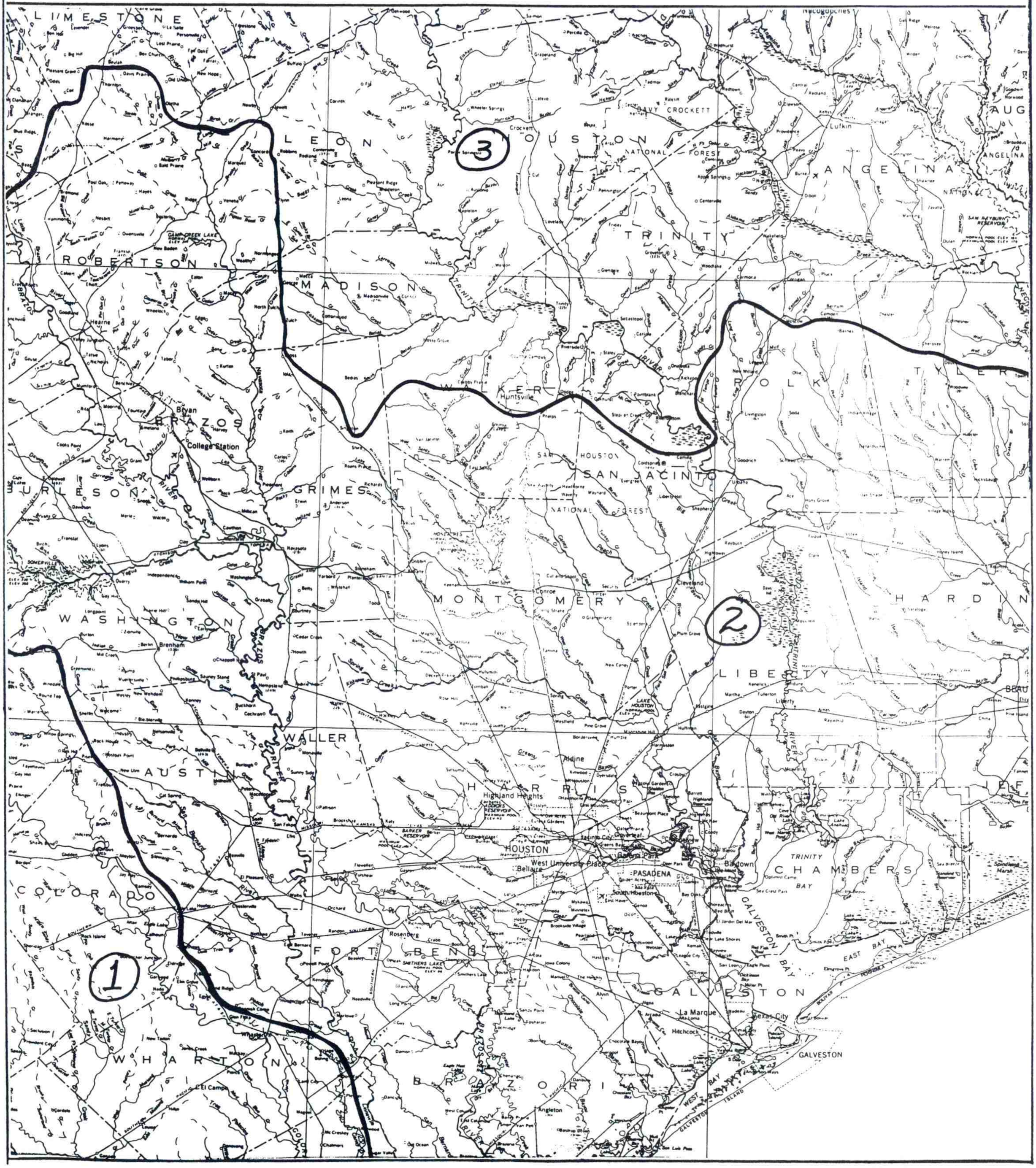
APPENDIX C

WGRFC FORECAST AREA IN TEXAS

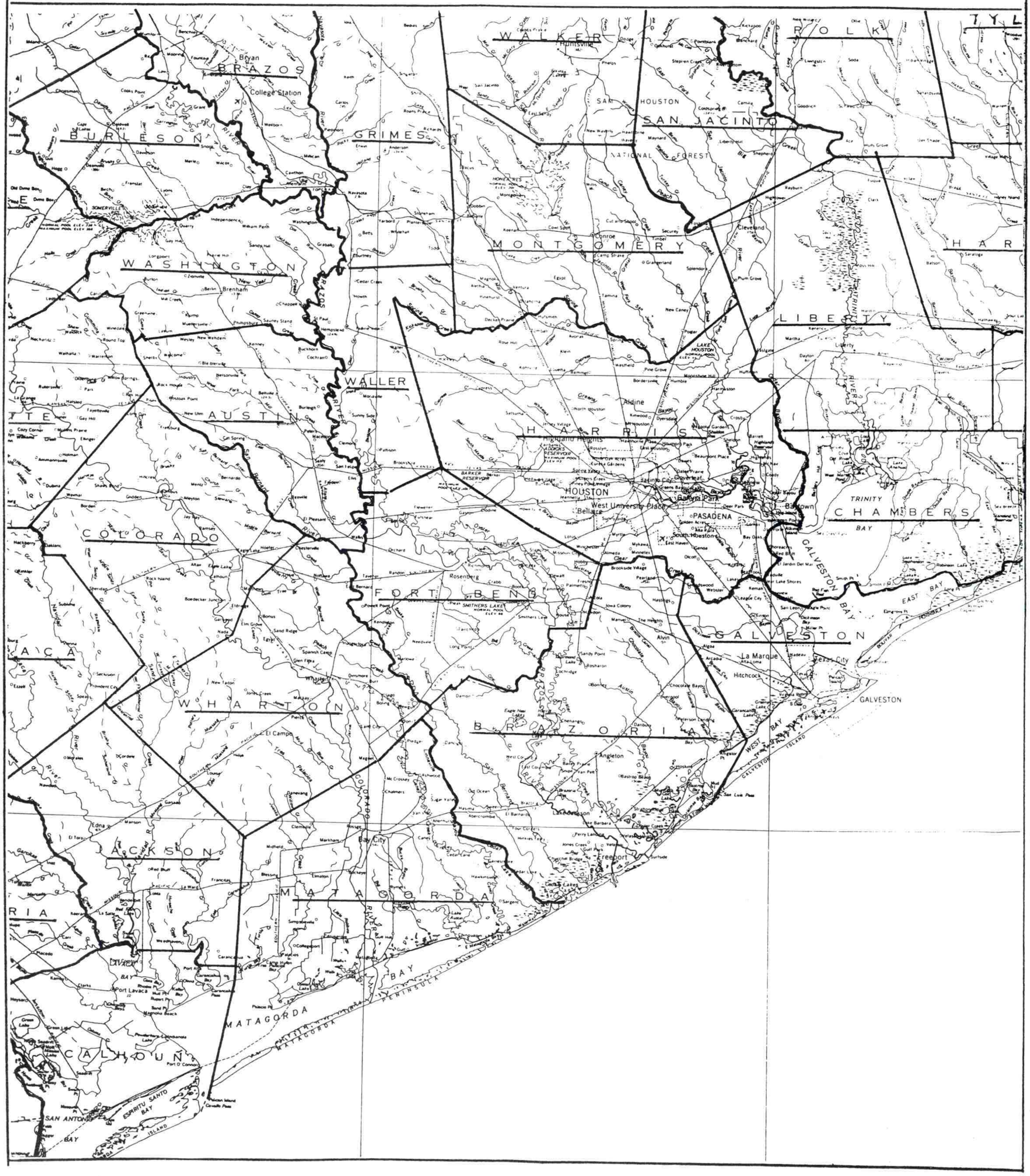


HYDROLOGIC SERVICE AREAS (HSA)

1. **NWSFO AUSTIN/SAN ANTONIO HSA**
2. **NWSO HOUSTON/GALVESTON HSA**
3. **NWSFO DALLAS/FT. WORTH HSA**



TEXAS COUNTIES AFFECTED



DRAINAGES OF SOUTHEAST TEXAS

1. LAVACA NAVIDAD
2. COLORADO
3. SAN BERNARD
4. BRAZOS
5. SAN JACINTO
6. TRINITY
7. NECHES
8. SABINE
9. COASTAL BAYOUS

APPENDIX D

TEXAS COUNTIES IMPACTED

INDIVIDUAL ASSISTANCE

According to the Texas Department of Public Safety's Division of Emergency Management, the following Texas Counties were approved Disaster Declarations for Individual Assistance.

Angelina	Hardin	Orange
Austin	Harris	Polk
Bastrop	Houston	San Augustine
Brazoria	Jackson	San Jacinto
Brazos	Jasper	Shelby
Burleson	Jefferson	Trinity
Chambers	Lavaca	Tyler
Colorado	Lee	Victoria
DeWitt	Liberty	Waller
Fayette	Madison	Walker
Fort Bend	Matagorda	Washington
Galveston	Montgomery	Wharton
Grimes	Nacogdoches	

Red Cross damage summaries coupled with individual telephone registrations of damage indicate between 15,000 and 19,000 residences suffered damage during these October floods.

PUBLIC FACILITIES AND INFRASTRUCTURE

In addition, Approved Public Assistance Declarations for Public Facilities and Infrastructures applied to the following counties.

Burleson	Lavaca	San Jacinto
Fayette	Liberty	Trinity
Grimes	Matagorda	Tyler
Harris	Montgomery	Walker
Jackson	Polk	Waller
Jasper	San Augustine	Wharton

DAMS

An accounting of dams by county, either damaged or failed, is provided below.

COUNTY	DAMAGED	FAILED
Burleson		1
Grimes	1	
Harris	1	
Liberty/Polk		1
Montgomery	7	
Tyler	3	
Polk	1	
Washington	1	

No information specific to dam size, degree of damage, etc. is available.

WATER/WASTEWATER FACILITIES

Damage to water and wastewater facilities was reported in the following counties.

Bastrop	Jackson	Polk
Brazos	Jasper	San Jacinto
Chambers	Jefferson	Trinity
Fayette	Liberty	Tyler
Fort Bend	Matagorda	Walker
Hardin	Montgomery	Waller
Harris	Orange	Washington

APPENDIX E

FLOOD OF OCTOBER 1994
DEATHS

COUNTY	TIME	NAME	AGE
1.Grimes	945 PM Sun	Chandrell Calhoun	5
		Anthony McIntosh	8

Car in which they were riding was swept off the road on FM 1774 about 1 mile south of Anderson at Anderson Creek.

2. Grimes	930 PM Sun	Harold Benkoski	67

Car he was driving was swept off the road on FM 1774 about 1 mile south of Anderson at Anderson Creek.

3. Montgomery	Sunday night	Candelario Cantu	43
		Angelica Cantu	36

Car was swept into Weirs creek near Conroe. They escaped from their car but the swift current carried them into the creek.

4. Harris	930 AM Mon	Clarence Wright	46

Stepped of bridge into rain swollen ditch in Baytown.

5. Polk	Mon AM 0500	L.C. Walker	78+

Pickup stalled out in high water near the town of Corrigan in northeast Polk County on FM 352. He was found in pickup truck.

6. San Jacinto	Mon AM	Robert Street	73

Rancher went out to try to rescue his cows during the predawn hours drowned in process.

7. Montgomery	Mon	George Matlock	42

Van got stranded in high water on Loop 336 near Stewart Creek in Conroe and man had heart attack and died.

8. Harris	Mon PM	Joe Lackey	14

Young man was playing in drainage ditch in La Porte near the high school when he was sucked under water.

9. Polk	430 PM Mon	Wille Dean Jackson	45

Wille was on a horse trying to rescue a lady from the flood when the horse tripped and he fell into the flood waters and was swept away. This occurred near FM 2969 below Lake Livingston.

10. Harris	Late Mon	Julie Ann Langton	32

Apparently fell into Rummel Creek in west Houston near 10700 of the Katy Freeway while walking her dog.

11. Chambers	645 AM Tue	Peter James Langlinais	2 months

Car hit high water and overturned into Cedar Bayou. Father lost grip on baby and he was swept away.(FM 565 and hwy 146)

12. Montgomery	Wed	James Cruse	68

Body found under the River Bridge at the River Plantation subdivision. Exact time of death unknown.

13. Montgomery	Wed	Wessie Ann Joe	63

She refused to leave her home and her body was found wednesday night in the Lost Lakes subdivision.

14. Montgomery	?	?	63

Body found tuesday Oct.25 near Magnolia Bend.

15. Fort Bend	Thursday	Gerald Baker	5

Boy was playing in a flooded creek and was taken under by strong currents near the town of Fulshear.

APPENDIX F

PROVISIONAL NWS COOPERATIVE OBSERVER DAILY RAINFALL - INCHES
OCTOBER 1994

STATION	COUNTY	SUN 10/16	MON 10/17	TUE 10/18	WED 10/19	4-DAY TOTAL	OBSERVATION INTERVAL
Anahuac	Chambers	0.11	2.30	4.83	3.07	10.31	8A - 8A
Angleton	Brazoria	0.15	0.84	2.26	2.10	5.35	8A - 8A
Bay City Water Works	Matagorda	0.15	1.63	2.21	0.02	4.01	8A - 8A
Baytown Lab	Harris	4.23	3.64	15.74	2.01	25.62	8A - 8A
Brenham	Washington	0.10	10.38	3.64	0.89	15.01	7A - 7A
Bryan	Madison	0.38	6.52	1.18	0.45	8.53	7A - 7A
Caldwell	Burleson	0	9.03	0.35	0.50	9.88	8A - 8A
Cleveland	Liberty	1.45	13.17	7.03	1.35	23.00	7:30A - 7:30A
Clodine	Fort Bend	1.05	5.33	1.89	0	8.27	8A - 8A
Cold Spring 5SSW	San Jacinto	0.88	9.13	2.55	1.17	13.73	7A - 7A
Columbus	Colorado	0.05	3.10	2.40	0.55	6.10	7:30A - 7:30A
Conroe	Montgomery	1.30	14.35	7.32	0.45	23.42	8A - 8A
Corrigan	Polk	1.67	14.69	8.27	1.12	25.75	6A - 6A
Crockett	Houston	0.16	2.90	2.53	0.27	5.86	7A - 7A
Crockett 12W	Leon	0.65	1.55	1.12	0.02	3.34	7A - 7A
Cypress	Harris	0.55	0.96	4.80	1.77	8.08	8A - 8A
Dacus	Montgomery	0.44	13.60	2.86	1.16	18.06	8A - 8A
Danevang	Wharton	0.45	0.16	3.38	6.05	10.04	7A - 7A
El Campo (KULP)	Wharton	0.22	0.12	13.29	0.08	13.71	5A - 5A
Freeport 2NW	Brazoria	0.10	0.40	0.30	0.10	0.90	6A - 6A
Groveton	Trinity	1.90	12.10	2.0	0.83	16.83	7A - 7A
Houston-Barker	Harris	0.73	0.38	4.58	2.28	7.97	7A - 7A
Houston-Heights	Harris	2.80	0.56	5.65	1.32	10.33	8A - 8A
Houston-Independence Hts	Harris	2.87	1.0	3.10	1.21	8.18	8A - 8A
Houston-Spring Branch	Harris	1.06	4.58	1.82	T	7.46	7A - 7A
Houston-Westbury	Harris	0	5.28	8.43	1.83	15.54	7A - 7A
Huntsville	Walker	0.32	10.21	1.64	1.23	13.40	9A - 9A
Liberty	Liberty	3.70	5.50	18.50	2.80	30.50	6A - 6A
Livingston	Polk	1.52	10.47	2.02	0.81	14.82	6A - 6A
Madisonville	Madison	0.97	5.26	0.90	0.73	7.86	8A - 8A
Matagorda 2	Matagorda	0.12	0.07	0.19	0	0.38	5P - 5P
Midway	Madison	0.46	3.51	1.49	0	5.46	7A - 7A
Montgomery	Montgomery	0.34	17.50	1.70	1.05	20.59	7A - 7A
New Caney 2E	Montgomery	2.23	6.65	9.28	0	18.16	6A - 6A
New Gulf	Wharton	3.46	2.25	3.46	4.13	13.30	8A - 8A
Pierce 1E	Wharton	0.50	0.28	6.00	7.95	14.73	8A - 8A
Port of Houston	Harris	1.98	1.12	15.70	1.93	20.73	6A - 6A
Richards	Grimes	0.30	11.98	2.15	2.25	16.68	7A - 7A
San Jacinto	Harris	3.40	3.50	14.00	0.78	21.68	7A - 7A
Sealy	Austin	3.00	5.50	2.15	0	10.65	
Sugar Land	Fort Bend	2.12	0.32	7.10	2.32	11.86	8A - 8A
Tomball	Harris	0.78	6.00	6.38	1.35	14.51	
Washington	Washington	0.10	15.46	3.25	1.20	20.01	8A - 8A
West Columbia	Brazoria	1.48	0.22	0.85	0.02	2.57	8A - 8A
Wharton	Wharton	0.22	0.29	11.58	0.50	12.59	8A - 8A

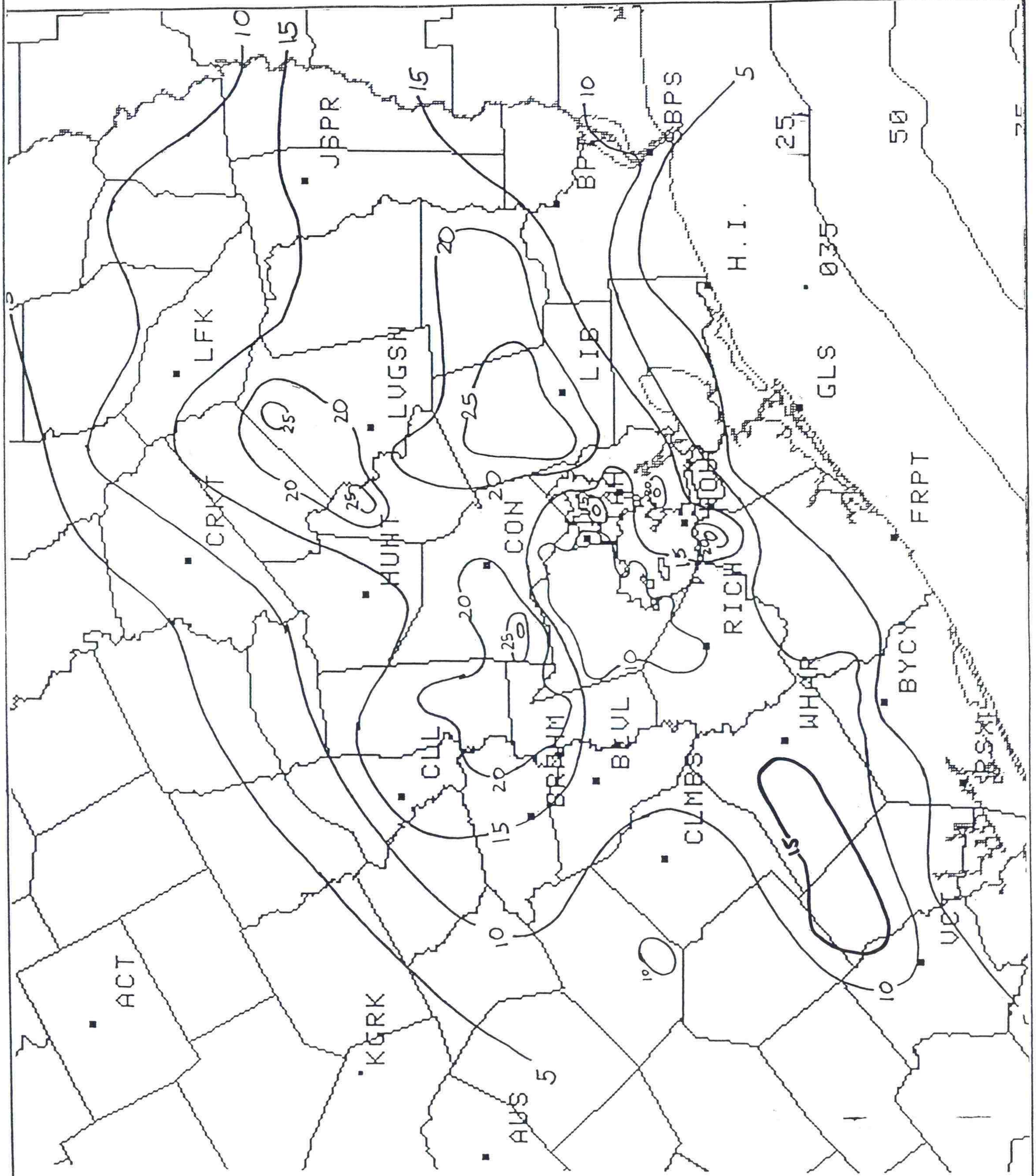
PROVISIONAL SUPPLEMENTAL DAILY RAINFALL - INCHES
OCTOBER 1994

STATION	COUNTY	SAT 10/15	SUN 10/16	MON 10/17	TUE 10/18	WED 10/19	5-DAY TOTAL
Addicks	Harris	1.64	0.64	3.49	5.10		10.69
Alameda Mall	Harris						18.90
Alief	Harris	2.25	0.33		6.65	0.25	9.48
Alto	Cherokee		3.60	3.80	0.80		8.20
Anderson	Grimes						21.00
Apple Springs	Trinity						17.75
Astrodome (NR)	Harris			7.25	6.55		13.80
Batson	Hardin						23.65
Bellville	Austin		6.95	3.08			10.03
Beaumont	Jefferson		4.60	3.40	2.20		10.20
Brenham 8NW	Washington	0.25	4.56	8.06	1.17		14.04
Buna	Jasper						19.35
Buna 2.5E	Jasper	1.00	1.20	10.00	3.20		15.40
Burkeville	Newton						11.80
Burton	Washington		9.43	1.78	0.58		11.79
Camilla	San Jacinto						20.00
Cat Spring	Austin						13.00
Chappel Hill	Washington	0.06	9.06	8.73	0.83		18.68
Clear Lake	Harris	2.70	0	2.30	7.20	0.30	12.50
College Station 7N	Brazos	0.18	0.16	5.15	1.05	0.55	7.09
Conroe 13SSE	Montgomery						14.62
Corrigan 2NE	Polk						25.99
Cottonwood (NR)	Brazos			7.20			7.20
Crockett 22SSW	Houston			13.50			13.50
Crockett 15S	Houston		1.50	6.50	5.50		13.50
Crockett 13N	Houston			3.50	1.00	2.00	6.50
Damon	Brazoria	1.61	0.38	2.37	4.00	0.08	8.29
Deer Park	Harris	9.00	5.00	4.00	4.00	1.00	23.00
Dickinson 1S	Galveston						4.43
Dime Box 1S	Lee						7.80
Dow Chemical	Brazoria	0.40	0.10	0.40	0.30	0.10	0.90
Easterly	Robertson		2.35	0.47	0.26		3.08
East Ganado	Jackson						12.20
El Campo	Wharton	0.53	0.22	0.12	13.29	0.08	14.24
Flamingo Lake	Montgomery						15.91
Friday	Houston	0.25	6.50	5.25	0.30		12.30
Galilee (Hwy 30)	Walker						9.96
Giddings	Lee						9.32
Grangerland	Montgomery		0.87	13.23	4.42	0.23	18.75
Groves	Jefferson	4.20		7.17	1.48		12.85
Hammerly (Westbelt)	Harris	0.30	1.92	1.70	8.20	1.50	13.62
Hobby Airport	Harris	2.47	0.47	7.86	7.23		18.03
Hobby Airport 4.5NE	Harris		3.96	0.69	11.97	2.43	19.29

STATION	COUNTY	SAT 10/15	SUN 10/16	MON 10/17	TUE 10/18	WED 10/19	5-DAY TOTAL
Hooks Airport	Harris	0.72	1.22	5.36	3.35	0.52	11.17
Hull	Liberty						27.80
Huntsville NE	Walker		0.30	11.10	1.20	1.00	13.60
I-45 at San Jacinto River	Montgomery						15.55
Jacinto City	Harris	3.75	0.28	10.78	3.15		17.96
Jasper	Jasper						19.25
Kennard	Houston			10.50			
Kennard 5SE	Houston		8.00	5.90	0.70		14.60
Kirbyville	Jasper						19.25
Kountze	Hardin						21.35
Lake Conroe	Montgomery						21.76
Lake Texana (Spillway)	Jackson						6.77
Lake Texana (blo splwy)	Jackson						9.69
La Port	Harris	0.03	0.05	1.50	10.89	3.39	15.86
League City	Galveston						8.90
Loma at Hwy 30	Walker						9.37
Lufkin	Angelina						11.55
Memorial at Hwy 6	Harris						11.25
Meyerland	Harris	3.41	0.51	9.41	2.24	0.01	15.58
Milano	Milam		3.76	0.23	0.67		4.66
Morales	Jackson						17.60
Neches	Anderson						5.00
New Waverly	Walker						15.50
North Ganado	Jackson						19.60
Onalaska	Polk		2.20	16.00	2.35	2.00	22.55
Pasadena	Harris						22.00
Peach Ck at Hwy 105	Montgomery						18.62
Pearland	Brazoria						17.17
Pearland East	Brazoria						15.20
Pearland Hwy 518	Brazoria						15.75
Pearland Country Club Dr	Brazoria			11.60	11.10		22.70
Pearland EOC	Brazoria			10.90	10.50		21.40
Pearland Veterans Dr	Brazoria			11.00	10.20		21.20
Pearland Hwy 288	Brazoria			13.30	14.90		27.90
Pierce Rch	Wharton		0.50	0.28	6.00	7.29	14.73
Plantersville	Grimes						19.25
Pleasure Island	Jefferson	1.75	0.54	4.21	1.05	0.15	7.70
Point Blank	San Jacinto						27.00
Port Arthur	Jefferson						10.43
Possum Walk Jct	Walker						13.98
Port Arthur 8NE	Jefferson		3.50	5.50			9.00
Provident City	Lavaca						11.90
Ratcliff	Houston			9.00			
Roans Prairie	Grimes						18.00
Rock Island	Lavaca						7.09
San Augustine	San Augustine	7.20	1.15	0.25	0.01		8.61
San Leon	Galveston						5.40
Schulenberg	Fayette						10.10
Sharpstown	Harris						13.91

STATION	COUNTY	SAT 10/15	SUN 10/16	MON 10/17	TUE 10/18	WED 10/19	5-DAY TOTAL
Silsbee	Hardin						16.75
Stoneham	Grimes						21.00
Sublime	Lavaca						6.69
SW Sugarland	Fort Bend		1.85	0.40	0.40	3.90	11.65
Tennington	Houston						14.20
Tex A&M Cluster Gages							
Central	Harris	0.14	14.53	3.51	0.98		19.16
SE76	Harris	0.47	9.94	5.68	0.45		16.54
SE61	Waller	0.23	14.30	4.28	1.02		19.83
SE64	Waller	0.25	14.70	3.69	0.57		19.21
SE62W103	Waller	0.27	14.94	3.96	1.33		20.50
SE62W303	Waller	0.24	13.21	3.79	1.26		18.50
Thompsons	Fort Bend	1.80	0.20	0.65	6.60		9.25
Village Cr St Pk	Hardin		1.15	3.94	11.00	1.75	17.84
Washington St Pk	Washington	0.10	9.30	6.30			15.70
West Beaumont	Jefferson			10.00	2.50		12.50
Weldon	Houston		5.90	0.80	0.70		7.40
West Groves	Jefferson	5.90		6.25	1.90		14.05
West Houston	Harris						10.89
Winnie 8E	Chambers		0.50	2.25	0.50		3.25
Wolf Crk Pk	San Jacinto		1.60	11.50	2.59	0.90	16.59
Woodville	Tyler	5.00	2.36	6.33	2.77		16.46
Zavalla	Angelina	3.00	6.50	1.10	0.10		10.70

RAINFALL TOTAL (INCHES) MAP FROM GAGED RAINFALL
OCTOBER 15-19, 1994



APPENDIX G

NWS DAILY RAINFALL OBSERVATIONS AVAILABLE TO WGRFC FOR DATES SHOWN — (LIST ONLY INCLUDES 4-DAY TOTALS GREATER THAN 4.00 INCHES)

ID	City	10/16	10/17	10/18	10/19	Total	
ALVT2	Alvin				4.85	4.85	p
ATOT2	Alto 8SW	0.21	5.46	1.42	0.23	7.32	
BATT2	Baytown			14.32	2.01	16.33	p
BDDT2	Broaddus	1.58	5.48	1.70	0.18	8.94	
BEAT2	Beaumont City		3.00	4.75		7.75	p
BNNT2	Bronson 2N	0.83	4.92	2.05	0.16	7.96	
BPT	Port Arthur WSO	2.23	0.96	4.46	0.48	8.13	
BRTT2	Bastrop	0.07	4.88	0.29	0.89	6.13	
BRYT2	Bryan 17NE	0.38	6.52	1.18	0.45	8.53	
BSSL1	Bossier City,LA 9SE		5.20	0.02	0.01	5.23	
BSUT2	Breslau		4.90			4.90	p
BTTL1	Belmont, LA	0.15	5.51	0.87		6.53	p
BUNT2	Buna 7S			17.35		17.35	p
BVKT2	Bevil Oaks	0.83	5.60	9.49	3.35	19.27	
BWRT2	Bon Weir 2ENE	1.52	1.93	4.45	1.14	9.04	
CDST2	Coldspring 5SSW	0.88	9.13	2.55	1.17	13.73	
CENT2	Center	1.65	8.10	0.15	0.05	9.95	
CHNT2	China	1.03	7.15	8.25		16.43	p
CHRT2	Chireno	1.65	9.42		0.09	11.16	p
CLL	College Station	0.18	13.89	0.55	1.01	15.63	
CNET2	Center 7SSE	1.65	6.19	0.24	0.12	8.20	
CODT2	Cordele 4E	0.43	0.63	9.49		10.55	p
COGT2	Corrigan 2ENE		14.69	8.27	1.12	24.08	p
CSET2	College Station 1SE		11.11		1.54	12.65	p
CTGT2	Carthage	0.51	5.63		0.08	6.22	p
CYPT2	Cypress	0.55	0.96	4.80	1.77	8.08	
DOWT2	Freeport Dow Chem	4.00	1.00	4.00	3.00	12.00	
DVGT2	Danevang 2SE	0.45	0.16		6.05	6.66	p
DWYT2	Deweyville #2	1.99	0.06	4.08	2.55	8.68	
EDNT2	Edna	0.47	0.24	7.10	10.48	18.29	
EFD	Ellingston AFB	1.74	1.21	7.28	3.56	13.79	
EMPT2	El Campo 22NW	0.20	1.02	7.20		8.42	p
ERCT2	Eagle Lake 3NW		3.54	2.2	4.01	9.75	p
FROT2	Sabinal 16SSE				5	5.00	p
GART2	Garrison	0.95	10.61			11.56	p
GBLT2	Hou-Green Bayou	3.27	1.50	8.86	0.91	14.54	
GIDT2	Giddings 3ESE		9.32			9.32	p
GLIT2	Goliad 1SE			2.10	6.93	9.03	p
GNDT2	Ganado 4NE	0.35	1.30	4.53		6.18	p
HBAT2	Houston Barker	0.73	0.38	4.58	2.28	7.97	
HDGL1	Hodges Garden, LA	1.51	4.00			5.51	p
HHET2	Houston Heights	2.80	0.56	5.65	1.32	10.33	
HPHT2	Hemphill	1.25	6.00	1.24		8.49	p
HSBT2	Houston Sp Branch	1.93	1.06	4.58	1.82	9.39	
HSIT2	Houston Simms Bayou	4.02	0.59	10.00	2.76	17.37	
HSJT2	Lake Houston	3.40	3.50	14.00	0.74	21.64	
HTHT2	Halletsville 2N		5.75	0.75		6.50	p
HUNT2	Huntsville	0.90	10.80		0.90	12.60	p
HWET2	Houston Westbury		5.28			5.28	p
HXTT2	Huxley	1.38	5.71	0.47	0.04	7.60	
IAH	Houston Intcntl Apt	2.01	1.41	4.78	1.17	9.37	
JAST2	Jasper 3SW		5.24	2.76		8.00	p
JSPT2	Sam Rayburn Res	1.71	4.83	2.78	0.42	9.74	
KHEL1	Keatchie, LA 3WSW	1.06	4.33			5.39	p

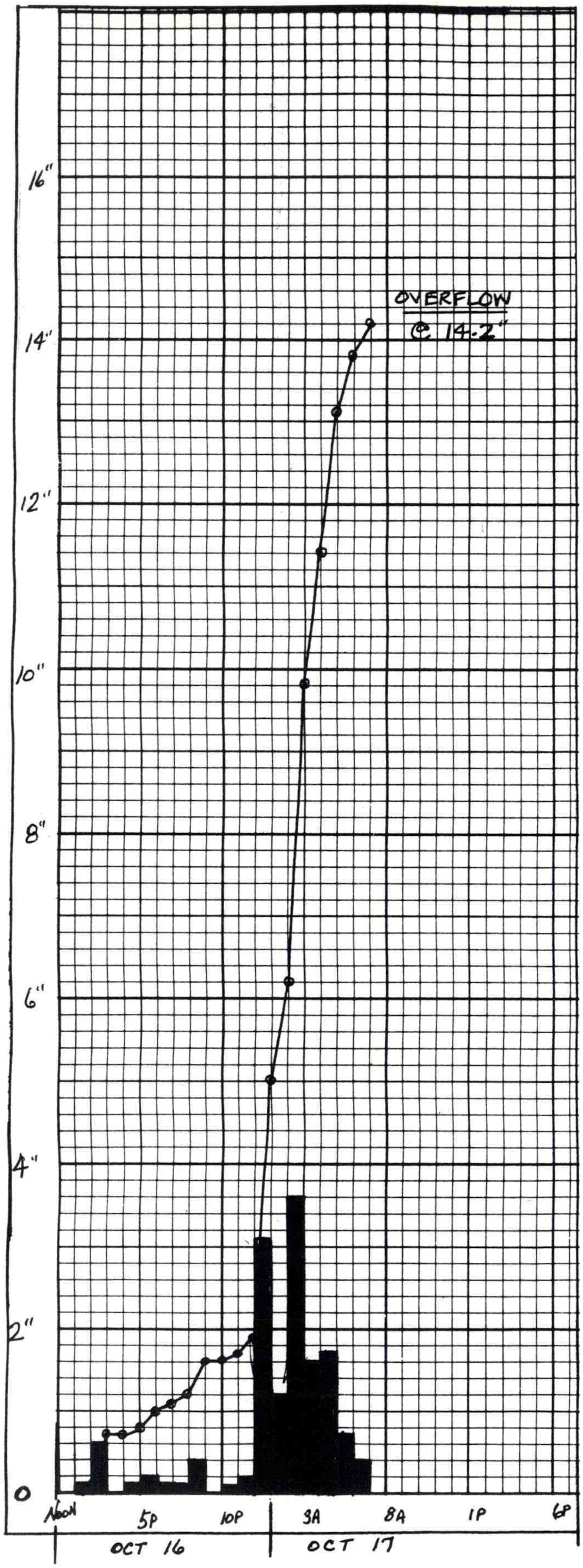
KTZT2	Kountze 3SE	0.97	5.26	0.90	2.35	9.48	
KVLL1	Keithville, LA	1.20	4.26	0.10	0.06	5.62	
LEXT2	Lexington		10.13			10.13	p
LFK	Lufkin FSS	1.34	9.69	1.03	0.26	12.32	
LGRT2	Lagrange	0.02	9.11	2.45	0.50	12.08	
LPWT2	La Pryor 17WSW				5.7	5.70	p
LRYT2	Liberty	3.60	4.40			8.00	p
LSVL1	Leesville, LA 5ENE		4.73	2.59	0.40	7.72	p
LUMT2	Lumberton		4.64	11.00		15.64	p
LVDT2	Lake Livingston Dam	1.79	8.51	2.93	1.03	14.26	
LVST2	Livingston 2NNE	1.52	10.47	2.02		14.01	p
MANL1	Mansfield, LA 3WSW	2.02	5.35	0.20		7.57	p
MLDT2	Muldoon		5.13			5.13	p
MLTT2	Moulton		4.00			4.00	p
MNWL1	Many, LA 9SW		6.10	1.36		7.46	p
MNYL1	Many, LA		4.30	1.31		5.61	p
MRAT2	Morales		0.63	8.50		9.13	p
MYYL1	Many, LA 15SW	1.85	4.13	2.01	0.16	8.15	
NCAT2	New Caney 2E		6.65			6.65	p
NCNT2	New Caney		6.94			6.94	p
NGUT2	Newgulf				4.13	4.13	p
ONAT2	Onalaska		16.00			16.00	p
ORET2	Orange 9N	3.11	0.10	5.50	1.70	10.41	
PDYT2	Priddy 3N			4.16		4.16	p
PPHL1	Pleasant Hill, LA 6NW	1.46	5.43	0.55	0.04	7.48	
PTHT2	Port Arthur City	4.60	4.07	4.75	1.87	15.29	
RIST2	Rising Star			4.00	0.11	4.11	p
RMOT2	Richmond		1.72	4.37	3.58	9.67	p
RNGT2	Runge	0.10	0.39	5.03	0.19	5.71	
SBGT2	Schulenburg 2WNW	0.04	6.81	1.65		8.50	p
SCHT2	Schulenburg		6.52	1.78	2.10	10.40	p
SHLT2	Sheldon	1.73	1.57	5.31	1.18	9.79	
SKDT2	Provident City		1.10	5.55		6.65	p
SNET2	San Augustine 11 ENE	1.26	4.72		0.08	6.06	p
SOMT2	Somerville Dam	0.03	15.25	4.87	0.61	20.76	
TCKT2	Throckmorton	0.20	5.04	0.02		5.26	p
TMAT2	Thomaston 2SW			7.98		7.98	p
TMST2	Thomaston		1.47	8.73		10.20	p
TOHL1	Natchitoches, LA		4.35	0.88	0.07	5.30	p
TOMT2	Tomball	0.78	6.00	6.38	1.35	14.51	
TRTT2	Trinity		12.75			12.75	p
VCT	Victoria WSO	0.14	0.34	3.69	4.46	8.63	
WALT2	Waller 3 SSW		14.00	6.00		20.00	p
WAST2	Washington St Park		15.46			15.46	p
WFDT2	Westfield Cypress Ck	1.18	2.13	5.47	1.10	9.88	
WHAT2	Wharton	0.28	0.11	5.45	6.66	12.50	
WHOT2	Wharton 2S			4.71	6.45	11.16	p
WWAT2	Woodway				5.58	5.58	p
WWDT2	Wildwood	2.60	6.35	3.88	1.86	14.69	
YKMT2	Yoakum			4.87	2.11	6.98	p
YPDT2	Pineland 8ESE	1.81	5.12	3.46	0.35	10.74	
ZWOL1	Zwolle, LA		5.20	1.10		6.30	p

p = partial 4-day total

PROVISIONAL NWS COOPERATIVE OBSERVER HOURLY RAINFALL
OCTOBER 16-18, 1994

		ADDICKS TX		THOMPSONS 3W3W TX		CONROE TX		WASHINGTON ST. PARK TX		EAGLE LAKE RES TX	
		PCP 1-HR	PCP ACCUM	PCP 1-HR	PCP ACCUM	PCP 1-HR	PCP ACCUM	PCP 1-HR	PCP ACCUM	PCP 1-HR	PCP ACCUM
OCT 16	NOON	0	0	0	0	0	0	0	0	0	0
	1PM	0	0	0	0	0.1	0.1	0	0	0	0
	2PM	0	0	0	0	0.6	0.7	0.2	0.2	0.2	0.2
	3PM	0	0	0	0	0	0.7	0.7	0.9	0	0.2
	4PM	0	0	0	0	0.1	0.8	0.4	1.3	0	0.2
	5PM	0	0	0	0	0.2	1.0	0.4	1.7	0	0.2
	6PM	0.25	0.25	0.10	0.10	0.1	1.1	0.2	1.9	0	0.2
	7PM	0	0.25	0	0.10	0.1	1.2	0	1.9	0.1	0.3
	8PM	0	0.25	0	0.10	0.4	1.6	0.5	2.4	0.2	0.5
	9PM	0	0.25	0	0.10	0	1.6	2.9	5.3	0.8	1.3
	10PM	0	0.25	0	0.10	0.1	1.7	3.2	8.5	2.1	3.4
	11PM	0	0.25	0	0.10	0.2	1.9	0.5	9.0	0.3	3.7
	MIDN	0	0.25	0	0.10	3.1	5.0	0.2	9.2	0	3.7
OCT 17	1AM	0	0.25	0	0.10	1.2	6.2	1.2	10.4	0	3.7
	2AM	0	0.25	0	0.10	3.6	9.8	2.2	12.6	0	3.7
	3AM	0	0.25	0	0.10	1.6	11.4	1.3	13.9	0	3.7
	4AM	0	0.25	0	0.10	1.7	13.1	0.5	14.4	0	3.7
	5AM	0	0.25	0	0.10	0.7	13.8	0.1	14.5	0	3.7
	6AM	0	0.25	0	0.10	0.4	14.2	0.1	14.6	0	3.7
	7AM	0	0.25	0	0.10	OVERFLOWED		0.5	15.1	0	3.7
	8AM	0	0.25	0	0.10			0.2	15.3	0	3.7
	9AM	0.05	0.30	0.10	0.20			0.1	15.4	0	3.7
	10AM	0.05	0.35	0.10	0.20			0.1	15.5	0	3.7
	11AM	0.70	1.05	0.10	0.20			0	15.5	0	3.7
	NOON	0.15	1.20	0.20	0.40			0	15.5	0	3.7
	1PM	0.05	1.25	0	0.40			0	15.5	0	3.7
	2PM	0.35	1.6	0	0.40			0	15.5	0	3.7
	3PM	0.50	2.10	0.05	0.45			0	15.5	0	3.7
	4PM	0.20	2.30	0.05	0.50			0	15.5	0.1	3.8
	5PM	0.05	2.35	0	0.50			0	15.5	0.4	4.2
	6PM	0.05	2.40	0.10	0.60			0	15.5	0.3	4.5
	7PM	0.10	2.50	0	0.60			0	15.5	0	4.5
	8PM	0.45	2.95	0.15	0.75			0	15.5	0	4.5
	9PM	0.05	3.00	0	0.75			0	15.5	0	4.5
	10PM	0	3.0	0	0.75			0	15.5	0	4.5
	11PM	0.20	3.2	0	0.75			0	15.5	0.2	4.7
	MIDN	055	3.75	0	0.75			0	15.5	0	4.7

		ADDICKS TX		THOMPSONS 3W3W TX		CONROE TX		WASHINGTON ST. PARK TX		EAGLE LAKE RES TX	
		PCP 1-HR	PCP ACCUM	PCP 1-HR	PCP ACCUM	PCP 1-HR	PCP ACCUM	PCP 1-HR	PCP ACCUM	PCP 1-HR	PCP ACCUM
OCT 18	1AM	0	3.75	0	0.75			0	15.5	0.1	4.8
	2AM	0.15	3.90	0	0.75			0	15.5	0.1	4.9
	3AM	1.20	5.10	1.25	2.00			0	15.5	0	4.9
	4AM	0.85	5.95	1.30	3.30			0	15.5	0	4.9
	5AM	0.10	6.05	0.10	3.40			0	15.5	0.1	5.0
	6AM	0.20	6.25	0.10	3.50			0	15.5	0.3	5.3
	7AM	0	6.25	0.05	3.55			0	15.5	0.3	5.6
	8AM	0	6.25	0.10	3.65			0	15.5	0.2	5.8
	9AM	0	6.25	0.05	3.70			0	15.5	0.8	6.6
	10AM	0.30	6.55	0.60	4.30			0	15.5	2.2	8.8
	11AM	0.20	6.75	0.60	4.90			0	15.5	0.4	9.2
	NOON	0.40	7.15	1.40	6.30			0	15.5	0.2	9.4
	1PM	0.10	7.25	0.65	6.95			0	15.5	0.1	9.5
	2PM	0.15	7.40	0.40	7.35			0	15.5	0.1	9.6
	3PM	0.20	7.60	0.25	7.60			0	15.5	0.1	9.7
	4PM	0.10	7.70	0.05	7.65			0	15.5	0	9.7
	5PM	0.10	7.80	0.05	7.70			0	15.5	0.1	9.8
	6PM	0.10	7.90	0.10	7.80			0	15.5	0.2	10.0
	7PM	0.25	8.15	0.20	8.00			0	15.5	0.1	10.1
	8PM	0.10	8.25	0.10	8.10			0	15.5	0.1	10.2
	9PM	0.15	8.40	0.05	8.15			0	15.5	0	10.2
	10PM	0	8.40	0	8.15			0	15.5	0	10.2
	11PM	0	8.40	0	8.15			0	15.5	0	10.2
	MIDN	0	8.40	0	8.15			0	15.5	0	10.2



HOURLY AND CUMULATIVE RAINFALL
CONROE, TEXAS

Recording Raingage Overflowed

Conroe Observer Reported
October 16-19

Sun	October 16	8A-8A	1.30"
Mon	October 17	8A-8A	14.35"
Tue	October 18	8A-8A	7.32"
Wed	October 19	8A-8A	0.45"
	Total		23.42"

APPENDIX I

*PROVISIONAL U.S.G.S. DISCHARGE/STAGES — OCTOBER 1994

NECHES RIVER BASIN	DATE	STAGE-FT	DISCHARGE-CFS
Attoyac Bayou - Chireno	10/18	23.4	21,500
Ayish Bayou - San Augustine	10/18	15.0	7,220
Neches R - Rockland	10/20	33.3	42,500
Neches R - Diboll	10/18	17.8	38,500
Village Cr - Kountze	10/18	25.5	43,000
Pine Island Bayou - Sour Lake	10/20	37.5	48,800
TRINITY RIVER BASIN			
Kickapoo Cr - Onalaska	10/17	41.9	84,600
Long King Cr - Livingston	10/17	30.5	45,000
Trinity R - Goodrich	10/18	48.9	124,000
Menard Cr - Rye	10/18	30.5	12,000
Trinity R - Romayor	10/19	42.7	122,000
Trinity R - Liberty	10/21	31.0	135,000
SAN JACINTO RIVER BASIN			
Cedar Bayou - Crosby	10/19	28.3	7,800
W Fk San Jacinto - Conroe	10/18	32.3	115,000
Spring Cr - Spring	10/18	44.1	78,800
E Fk San Jacinto - Cleveland	10/18	24.6	63,000
Caney Cr - Splendora	10/17	26.4	36,000
E Fk San Jacinto - New Caney	10/18	33.0	74,100
Lake Houston	10/19	52.8	
San Jacinto R - Sheldon	10/19	27.1	360,000
Sims Bayou - Houston	10/18	29.9	7,750
Greens Bayou - Ley Rd	10/18	36.1	21,800
BRAZOS RIVER BASIN			
Brazos R - Hempstead	10/17	51.6	109,000
Brazos R - Richmond	10/21	50.7	86,800
Brazos R - Rosharon	10/22	51.8	82,500

COLORADO RIVER BASIN	DATE	STAGE-FT	DISCHARGE-CFS
Colorado R - Columbus	10/18	37.5	56,100
Colorado R - Wharton	10/20	40.9	50,000
Colorado R - Bay City	10/20	39.3	74,500
LAVACA — NAVIDAD RIVER BASIN			
Lavaca R - Edna	10/19	35.5	135,000
W. Mustang Cr - Ganado	10/19	28.4	30,000
Sandy Cr - Louise	10/19	28.5	23,000

*NOTE — This provisional data (11/94) is subject to revision by the U.S.G.S. Official data publications by the U.S.G.S. which will be forthcoming should be consulted for verification before using any of the data included here.

APPENDIX J

*PROVISIONAL USGS RECORD DISCHARGES AND/OR STAGES FOR OCTOBER 1994

RIVER	OCTOBER 1994		PREVIOUS RECORD			R
	FT	CFS	FT	CFS	DATE	1994 to 100 yr
SAN JACINTO RIVER						
WF nr Conroe	32.3	115,000	30.9	110,000	11/1940	1.3
EF nr Cleveland	24.6	63,000	24.1	59,000	11/1940	1.0
EF nr New Caney	33.0	74,100	29.6	--		1.0
Lake Houston	52.8	--	49.6	--	5/1989	--
Sheldon	27.1	360,000	20.1	--	6/1973	1.6
Spring Cr at Spring	44.1	78,800	33.6	42,700	11/1940	1.7
TRINITY RIVER						
Romayor	42.7	122,000	45.8	111,000	5/1942	1.0
Liberty	31.0	135,000	30.0	106,000	5/1990	1.1
LA VACA RIVER						
Edna	35.5	135,000	33.8	83,400	5/1936	2.1
NECHES RIVER						
Pine Island Bayou nr Sour Lake	37.5	48,800	34.3	25,000	4/1979	2.0

*This provisional data (11/94) is subject to revision before final publications are released.

R = Ratio of 10/1994 Streamflow to 100-year Flood

APPENDIX K

CHRONOLOGICAL LIST OF PRODUCTS FROM WGRFC

TIME	DATE	DISSEMINATION
1145 CDT	Mon 10/17	AFOS - FTW RVF TX4 (NWSO HOU)
1200 CDT	Mon 10/17	AFOS - FTW RVF TX2 (WSFO SAT)
1230 CDT	Mon 10/17	AFOS - FTW RVF TX4 (NWSO HOU)
1430 CDT	Mon 10/17	Tel - NWSO HOU
1530 CDT	Mon 10/17	Tel - Lower Neches Valley Auth
1600 CDT	Mon 10/17	AFOS - FTW RVF TX2 (WSFO SAT)
1630 CDT	Mon 10/17	Tel - NWSO HOU
2030 CDT	Mon 10/17	Tel - NWSO HOU
2105 CDT	Mon 10/17	Tel - NWSO HOU
0700 CDT	Tue 10/18	Tel - NWSO HOU
0845 CDT	Tue 10/18	Tel - Sabine Riv. Auth
0930 CDT	Tue 10/18	Tel - NWSO HOU, Trinity Riv. Auth
1014 CDT	Tue 10/18	AFOS - FTW RVF LSA (NWSO HOU)
1045 CDT	Tue 10/18	AFOS - FTW RVF LBR (NWSO HOU)
1115 CDT	Tue 10/18	AFOS - FTW RVF TX2 (WSFO SAT)
1205 CDT	Tue 10/18	AFOS - FTW RVF TX4 (NWSO HOU)
1230 CDT	Tue 10/18	AFOS - FTW RVF TX4 (NWSO HOU)
1845 CDT	Tue 10/18	Tel - WSFO SAT
1915 CDT	Tue 10/18	Tel - WSFO SAT

TIME	DATE	DISSEMINATION
1930 CDT	Tue 10/18	Tel - NWSO HOU
2000 CDT	Tue 10/18	Tel - WSFO SAT, Lower Colorado Riv. Auth
2010 CDT	Tue 10/18	Tel - WSFO SAT, Lower Colorado Riv. Auth
0800 CDT	Wed 10/19	Tel - Lower Colorado Riv. Auth
1030 CDT	Wed 10/19	AFOS - FTW RVF LNE (NWSO HOU)
1100 CDT	Wed 10/19	AFOS - FTW RVF LTR (NWSO HOU)
1100 CDT	Wed 10/19	AFOS - FTW RVF LCO (WSFO SAT)
1100 CDT	Wed 10/19	AFOS - FTW RVF LSA (NWSO HOU)
1120 CDT	Wed 10/19	AFOS - FTW RVF LBR (NWSO HOU)
1145 CDT	Wed 10/19	AFOS - FTW RVF TX2 (WSFO SAT)
1200 CDT	WED 10/19	AFO - FTW RVF LCO (WSFO SAT)
1530 CDT	WED 10/19	Tel - NWSO HOU
0900 CDT	THU 10/20	Tel - NWSO HOU
0920 CDT	THU 10/20	AFOS - FTW RVF LTR (NWSO HOU)
0945 CDT	THU 10/20	AFOS - FTW RVF LSA (NWSO HOU)
1030 CDT	THU 10/20	AFOS - FTW RVF LNE (NWSO HOU)
1030 CDT	THU 10/20	AFOS - FTW RVF TX2 (WSFO SAT)
1130 CDT	THU 10/20	AFOS - FTW RVF SAT (NWSO HOU)
1150 CDT	THU 10/20	AFOS - FTW RVF LBR (NWSO HOU)
0230 CDT	FRI 10/21	Tel - TX EOC
0630 CDT	FRI 10/21	Tel - NWSO HOU, TX EOC

TIME	DATE	DISSEMINATION
1015 CDT	FRI 10/21	AFOS - FTW RVF TX2 (WSFO SAT)
1150 CDT	FRI 10/21	AFOS - FTW RVF TX4 (NWSO HOU)
1155 CDT	FRI 10/21	Tel - Orange Co. EMC
1500 CDT	FRI 10/21	Tel - NWSO HOU
1600 CDT	FRI 10/21	Tel - NWSO HOU
1010 CDT	SAT 10/22	Tel - WSO BPT
1059 CDT	SAT 10/22	AFOS - FTW RVF TX2 (WSFO SAT)
1120 CDT	SAT 10/22	AFOS - FTW RVF TX4 (NWSO HOU)
0930 CDT	SUN 10/23	AFOS - FTW RVF TX2 (WSFO SAT)
1055 CDT	SUN 10/23	AFOS - FTW RVF LBR (NWSO HOU)
1120 CDT	SUN 10/23	AFOS - FTW RVF TX4 (NWSO HOU)
1100 CDT	MON 10/24	AFOS - FTW RVF LBR (NWSO HOU)
1115 CDT	MON 10/24	AFOS - FTW RVF TX4 (NWSO HOU)

FORECASTS BY RIVERS, FROM WGRFC

SAN JACINTO RIVER FORECASTS FROM WGRFC

Time		Date		Dissemination
1230	CDT	Mon	10/17	AFOS - FTW RVF TX4 (NWSO HOU)
1430	CDT	Mon	10/17	Tel - NWSO HOU
2030	CDT	Mon	10/17	Tel - NWSO HOU
0700	CDT	Tue	10/18	Tel - NWSO HOU
1205	CDT	Tue	10/18	AFOS - FTW RVF TX4 (NWSO HOU)
1930	CDT	Tue	10/18	Tel - NWSO HOU
1115	CDT	Wed	10/19	AFOS - FTW RVF SAJ (NWSO HOU)
1130	CDT	Thu	10/20	AFOS - FTW RVF SAJ (NWSO HOU)
1150	CDT	Fri	10/21	AFOS - FTW RVF TX4 (NWSO HOU)
1120	CDT	Sat	10/22	AFOS - FTW RVF TX4 (NWSO HOU)
1120	CDT	Sun	10/23	AFOS - FTW RVF TX4 (NWSO HOU)
1115	CDT	Mon	10/24	AFOS - FTW RVF TX4 (NWSO HOU)

TRINITY RIVER FORECASTS FROM WGRFC

Time		Date		Dissemination
1145	CDT	Mon	10/17	AFOS - FTW RVF TX4 (NWSO HOU)
0930	CDT	Tue	10/18	Tel - NWSO HOU
1230	CDT	Tue	10/18	AFOS - FTW RVF TX4 (NWSO HOU)
1100	CDT	Wed	10/19	AFOS - FTW RVF LTR (NWSO HOU)
0900	CDT	Thu	10/20	Tel - NWSO HOU
0920	CDT	Thu	10/20	AFOS - FTW RVF LTR (NWSO HOU)
0230	CDT	Fri	10/21	Tel - TX EOC
0630	CDT	Fri	10/21	Tel - NWSO HOU, TX EOC
1150	CDT	Fri	10/21	AFOS - FTW RVF TX4 (NWSO HOU)
1120	CDT	Sat	10/22	AFOS - FTW RVF TX4 (NWSO HOU)
1120	CDT	Sun	10/23	AFOS - FTW RVF TX4 (NWSO HOU)
1115	CDT	Mon	10/24	AFOS - FTW RVF TX4 (NWSO HOU)

BRAZOS RIVER FORECASTS FROM WGRFC

Time		Date		Dissemination
1145	CDT	Mon	10/17	AFOS - FTW RVF TX4 (NWSO HOU)
1630	CDT	Mon	10/17	Tel - NWSO HOU
2105	CDT	Mon	10/17	Tel - NWSO HOU
1045	CDT	Tue	10/18	AFOS - FTW RVF LBR (NWSO HOU)
1230	CDT	Tue	10/18	AFOS - FTW RVF TX4 (NWSO HOU)
1120	CDT	Wed	10/19	AFOS - FTW RVF LBR (NWSO HOU)
1150	CDT	Thu	10/20	AFOS - FTW RVF LBR (NWSO HOU)
1150	CDT	Fri	10/21	AFOS - FTW RVF TX4 (NWSO HOU)
1120	CDT	Sat	10/22	AFOS - FTW RVF TX4 (NWSO HOU)
1055	CDT	Sun	10/23	AFO - FTW RVF LBR (NWSO HOU)
1100	CDT	Mon	10/24	AFOS - FTW RVF LBR (NWSO HOU)

NECHES RIVER FORECASTS FROM WGRFC

Time		Date		Dissemination
1230	CDT	Mon	10/17	AFOS - FTW RVF TX4 (NWSO HOU)
1530	CDT	Mon	10/17	Tel - Lower Neches Valley Auth.
2030	CDT	Mon	10/17	Tel - NWSO HOU
1230	CDT	Tue	10/18	AFOS - FTW RVF TX4 (NWSO HOU)
1030	CDT	Wed	10/19	AFOS - FTW RVF LNE (NWSO HOU)
1530	CDT	Wed	10/19	Tel - NWSO HOU
1030	CDT	Thu	10/20	AFOS - FTW RVF LNE (NWSO HOU)
1150	CDT	Fri	10/21	AFOS - FTW RVF TX4 (NWSO HOU)
1155	CDT	Fri	10/21	Tel - Orange Co. EMC
1600	CDT	Fri	10/21	Tel - NWSO HOU
1120	CDT	Sat	10/22	AFOS - FTW RVF TX4 (NWSO HOU)
1120	CDT	Sun	10/23	AFOS - FTW RVF TX4 (NWSO HOU)
1115	CDT	Mon	10/24	AFOS - FTW RVF TX4 (NWSO HOU)

SAN BERNARD RIVER FORECASTS FROM WGRFC

Time		Date		Dissemination
1030	CDT	Thu	10/20	AFOS - FTW RVF LNE (NWSO HOU)
1150	CDT	Fri	10/21	AFOS - FTW RVF TX4 (NWSO HOU)
1500	CDT	Fri	10/21	Tel - NWSO HOU
1120	CDT	Sat	10/22	AFOS - FTW RVF TX4 (NWSO HOU)
1120	CDT	Sun	10/23	AFOS - FTW RVF TX4 (NWSO HOU)
1115	CDT	Mon	10/24	AFOS - FTW RVF TX4 (NWSO HOU)

SABINE RIVER FORECASTS FROM WGRFC

Time		Date		Dissemination
1230	CDT	Mon	10/17	AFOS - FTW RVF TX4 (NWSO HOU)
0845	CDT	Tue	10/18	Tel - Sabine Riv. Auth.
1014	CDT	Tue	10/18	AFOS - FTW RVF LSA (NWSO HOU)
1230	CDT	Tue	10/18	AFOS - FTW RVF TX4 (NWSO HOU)
1100	CDT	Wed	10/19	AFOS - FTW RVF LSA (NWSO HOU)
0945	CDT	Thu	10/20	AFOS - FTW RVF LSA (NWSO HOU)
1150	CDT	Fri	10/21	AFOS - FTW RVF TX4 (NWSO HOU)
1010	CDT	Sat	10/22	Tel - WSO BPT
1120	CDT	Sat	10/22	AFOS - FTW RVF TX4 (NWSO HOU)
1120	CDT	Sun	10/23	AFOS - FTW RVF TX4 (NWSO HOU)
1115	CDT	Mon	10/24	AFOS - FTW RVF TX4 (NWSO HOU)

COLORADO RIVER FORECASTS FROM WGRFC

Time		Date		Dissemination
1200	CDT	Mon	10/17	AFOS - FTW RVF TX2 (WSFO SAT)
1600	CDT	Mon	10/17	AFOS - FTW RVF TX2 (WSFO SAT)
1115	CDT	Tue	10/18	AFOS - FTW RVF TX2 (WSFO SAT)
2000	CDT	Tue	10/18	Tel - WSFO SAT, Lower Colorado Riv. Auth.
2010	CDT	Tue	10/18	Tel - WSFO SAT, Lower Colorado Riv. Auth.
0800	CDT	Wed	10/19	Tel - WSFO SAT, Lower Colorado Riv. Auth.
1100	CDT	Wed	10/19	AFOS - FTW RVF LCO (WSFO SAT)
1030	CDT	Thu	10/20	AFOS - FTW RVF TX2 (WSFO SAT)
1015	CDT	Fri	10/21	AFOS - FTW RVF TX2 (WSFO SAT)
1059	CDT	Sat	10/22	AFOS - FTW RVF TX2 (WSFO SAT)
0930	CDT	Sun	10/23	AFOS - FTW RVF TX2 (WSFO SAT)

GUADALUPE RIVER FORECASTS FROM WGRFC

Time		Date		Dissemination
1115	CDT	Tue	10/18	AFOS - FTW RVF TX2 (WSFO SAT)
1845	CDT	Tue	10/18	Tel - WSFO SAT
1915	CDT	Tue	10/18	Tel - WSFO SAT
1145	CDT	Wed	10/19	AFOS - FTW RVF TX2 (WSFO SAT)
1030	CDT	Thu	10/20	AFOS - FTW RVF TX2 (WSFO SAT)
1015	CDT	Fri	10/21	AFOS - FTW RVF TX2 (WSFO SAT)
1059	CDT	Sat	10/22	AFOS - FTW RVF TX2 (WSFO SAT)
0930	CDT	Sun	10/23	AFOS - FTW RVF TX2 (WSFO SAT)
1115	CDT	Mon	10/24	AFOS - FTW RVF TX2 (WSFO SAT)

LAVACA-NAVIDAD RIVER FORECASTS FROM WGRFC

Time		Date		Dissemination
1200	CDT	Mon	10/17	AFOS - FTW RVF TX2 (WSFO SAT)
1600	CDT	Mon	10/17	AFOS - FTW RVF TX2 (WSFO SAT)
1115	CDT	Tue	10/18	AFOS - FTW RVF TX2 (WSFO SAT)
1200	CDT	Wed	10/19	AFOS - FTW RVF LCO (WSFO SAT)
1030	CDT	Thu	10/20	AFOS - FTW RVF TX2 (WSFO SAT)
1015	CDT	Fri	10/21	AFOS - FTW RVF TX2 (WSFO SAT)
1059	CDT	Sat	10/22	AFOS - FTW RVF TX2 (WSFO SAT)

APPENDIX L

EXTERNAL POINTS OF CONTACT – WGRFC

Texas State Emergency Operations Center, Austin, TX	
Don Couch, others	512-465-2208
Sabine River Authority	
Jim Washburn, others	409-565-2273
U.S. Coast Guard, Freeport, TX	
Chief Marcotte, OIC	409-233-7551
Ramsey State Correctional Facility, Unit #1	
Joe Klinkowsky, Doug Cadenhead	713-595-3491 ext. 1318
Dow Chemical, Brazos River and Oyster Creek operations	
Danny Smith	409-849-5101
Brazos River Authority	
E. G. Whiteswift, PIO	817-776-1443
Hardin County, TX	
Bob Burgers	409-385-5501
Lower Neches Valley Authority	
Tom Hebert	409-892-4011
U.S. Coast Guard, Beaumont, TX	
Lt J.G. Pat Clark	no phone number available
North Star Steel, Beaumont, TX	
Ecky Hall	409-769-1001
Orange County Emergency Management	
Chuck Frazier	409-882-7895
Beaumont, TX Department of Public Safety	
Gary LaCox	409-898-0770 ext. 54
Jasper Newton Electric Company	
Danny Wade	409-423-2241
Hazmat, Houston	
Jim Ally	713-422-0172
Conoco Rig, Near Silsbee	
Bob Strickler	409-899-5136
Lower Colorado River Authority, Austin, TX	
Randy Rieman	512-473-4053

SAN JACINTO RIVER FORECASTS FROM WGRFC

DATE Forecasts Made	MON - 17TH			TUE - 18TH			WED - 19TH	OBS.CREST/DAY
TIME CDT Forecasts Made	1230	1430	2030	0700	1230	1930	1115	
WF nr Conroe	26 M	27.5 M	30.5 T	Crg	Crg		Crd	32.3 T
WF nr Porter	30-31 T				33-34 T		Crg	40.1 T
WF nr Humble	25-26 W		30 W	30 W	32 W		32 W	35.9 R
EF nr Cleveland	21-22 W				24 W		Crg	25.9 M
EF nr New Caney	25-26 W				30 W		30 W	33.0 T
Lk Houston	48 W			49.5 T	49.5 W	52.5 W	Crg	52.8 W
Sheldon	16-17 R			19.5 T	20-21 W	22 W	24 W	27.1 W
Spring Creek nr Spring	25-26 T		30 T		32 W		Crd	40.7 T
Cypress Creek nr Westfield	31-32 T				34 W		Crg	26.9 W
Caney Creek nr Splendora	22-23 M				Crd			26.4 M
Luce Bayou nr Huffman	26-27 T				27 W		Crg	35.1 M
Peach Creek nr Splendora	18-19 M				Crd			

M = Monday T=Tuesday W=Wednesday R=Thursday

Crg=Cresting Crd=Crested

All crest forecasts and observations in feet

Note: All observed crest stages as shown are provisional as of 11/94.

APPENDIX N

FLOOD/FLASH FLOOD/RIVER PRODUCTS FROM NWSFO AUSTIN/SAN ANTONIO
SUN 10/16 - FRI 10/21

TIME			DATE		PRODUCT
152	PM	CDT	SUN	10/16	FFS
412	AM	CDT	MON	10/17	FFA
646	AM	CDT	MON	10/17	FFS
804	AM	CDT	MON	10/17	FLW
955	AM	CDT	MON	10/17	FFS
1210	PM	CDT	MON	10/17	FLW
1235	PM	CDT	MON	10/17	FFS
217	PM	CDT	MON	10/17	FFS
335	PM	CDT	MON	10/17	FFA
514	PM	CDT	MON	10/17	FLW
630	PM	CDT	MON	10/17	FFS
1110	PM	CDT	MON	10/17	FFS
1223	AM	CDT	TUE	10/18	FFW
140	AM	CDT	TUE	10/18	FFS
250	AM	CDT	TUE	10/18	FFS
435	AM	CDT	TUE	10/18	FFA
635	AM	CDT	TUE	10/18	FLW
635	AM	CDT	TUE	10/18	FFS
755	AM	CDT	TUE	10/18	FFS
815	AM	CDT	TUE	10/18	FLW
910	AM	CDT	TUE	10/18	FLW
934	AM	CDT	TUE	10/18	FFS
1015	AM	CDT	TUE	10/18	FLW
1155	AM	CDT	TUE	10/18	FLW
120	PM	CDT	TUE	10/18	FLW
150	PM	CDT	TUE	10/18	FFS
326	PM	CDT	TUE	10/18	FFW
330	PM	CDT	TUE	10/18	FFA
340	PM	CDT	TUE	10/18	FLW
555	PM	CDT	TUE	10/18	FFS
655	PM	CDT	TUE	10/18	FLW
830	PM	CDT	TUE	10/18	FLW
945	PM	CDT	TUE	10/18	FLW
1159	PM	CDT	TUE	10/18	FLW

TIME			DATE		PRODUCT
228	AM	CDT	WED	10/19	FFW
310	AM	CDT	WED	10/19	FFS
330	AM	CDT	WED	10/19	FFA
455	AM	CDT	WED	10/19	FFS
645	AM	CDT	WED	10/19	FFS
713	AM	CDT	WED	10/19	FFW
715	AM	CDT	WED	10/19	FLW
858	AM	CDT	WED	10/19	FFW
1220	PM	CDT	WED	10/19	RVS
1240	PM	CDT	WED	10/19	FLW
345	PM	CDT	WED	10/19	FFA
828	PM	CDT	WED	10/19	FFS
1100	AM	CDT	FRI	10/21	RVS

FFA FLASH FLOOD WATCH
FFS FLASH FLOOD STATEMENT
FFW FLASH FLOOD WARNING
FLW FLOOD WARNING
RVS RIVER STATEMENT

APPENDIX O

FLOOD/FLASH FLOOD/RIVER PRODUCTS FROM NWSO HOUSTON/GALVESTON
SUN 10/16 - SUN 10/23

TIME			DATE		PRODUCT
728	PM	CDT	SUN	10/16	FFW
756	PM	CDT	SUN	10/16	FFW
803	PM	CDT	SUN	10/16	FFW
946	PM	CDT	SUN	10/16	FFW
1001	PM	CDT	SUN	10/16	FFW
1022	PM	CDT	SUN	10/16	SPS
1118	PM	CDT	SUN	10/16	SPS
1135	PM	CDT	SUN	10/16	FLW
101	AM	CDT	MON	10/17	FFW
125	AM	CDT	MON	10/17	FLW
145	AM	CDT	MON	10/17	FFW
220	AM	CDT	MON	10/17	RVS
412	AM	CDT	MON	10/17	FFW
449	AM	CDT	MON	10/17	FFS
516	AM	CDT	MON	10/17	FFS
625	AM	CDT	MON	10/17	FFS
755	AM	CDT	MON	10/17	FFS
830	AM	CDT	MON	10/17	RVS
855	AM	CDT	MON	10/17	FFS
941	AM	CDT	MON	10/17	FFS
945	AM	CDT	MON	10/17	FLW
1040	AM	CDT	MON	10/17	FLW
1104	AM	CDT	MON	10/17	FFW
1115	AM	CDT	MON	10/17	FLW
1120	AM	CDT	MON	10/17	FFS
1230	PM	CDT	MON	10/17	RVS
1240	PM	CDT	MON	10/17	FFS
1245	PM	CDT	MON	10/17	FLW
145	PM	CDT	MON	10/17	FLW
202	PM	CDT	MON	10/17	FFS
310	PM	CDT	MON	10/17	FFS
348	PM	CDT	MON	10/17	FFW
505	PM	CDT	MON	10/17	FLW
603	PM	CDT	MON	10/17	FFS
623	PM	CDT	MON	10/17	FFW
803	PM	CDT	MON	10/17	FFS
830	PM	CDT	MON	10/17	FLW

TIME			DATE		PRODUCT
910	PM	CDT	MON	10/17	FLS
918	PM	CDT	MON	10/17	FLS
1003	PM	CDT	MON	10/17	FFS
1117	PM	CDT	MON	10/17	FFW
1203	AM	CDT	TUE	10/18	FFS
315	AM	CDT	TUE	10/18	FFS
446	AM	CDT	TUE	10/18	FFW
528	AM	CDT	TUE	10/18	FFW
550	AM	CDT	TUE	10/18	FFS
640	AM	CDT	TUE	10/18	FFS
640	AM	CDT	TUE	10/18	FLS
730	AM	CDT	TUE	10/18	FLS
810	AM	CDT	TUE	10/18	FFS
900	AM	CDT	TUE	10/18	FLS
952	AM	CDT	TUE	10/18	FFW
1030	AM	CDT	TUE	10/18	FLS
1046	AM	CDT	TUE	10/18	FFS
1145	AM	CDT	TUE	10/18	FFS
1213	PM	CDT	TUE	10/18	FFW
1240	PM	CDT	TUR	10/18	FLS
112	PM	CDT	TUE	10/18	FFW
120	PM	CDT	TUE	10/18	FFW
150	PM	CDT	TUE	10/18	FLS
539	PM	CDT	TUE	10/18	FFS
640	PM	CDT	TUE	10/18	FFW
655	PM	CDT	TUE	10/18	FFW
655	PM	CDT	TUE	10/18	FLS
935	PM	CDT	TUE	10/18	FLS
945	PM	CDT	TUE	10/18	FFS
1105	PM	CDT	TUE	10/18	FFS
440	AM	CDT	WED	10/19	FFS
600	AM	CDT	WED	10/19	FFS
1000	AM	CDT	WED	10/19	FFS
1145	AM	CDT	WED	10/19	RVS
1200	PM	CDT	WED	10/19	FLS
100	PM	CDT	WED	10/19	FLS
220	PM	CDT	WED	10/19	FLW
345	PM	CDT	WED	10/19	FLS

TIME			DATE		PRODUCT
410	PM	CDT	WED	10/19	FLS
544	PM	CDT	WED	10/19	FFS
913	PM	CDT	WED	10/19	FFS
834	AM	CDT	THU	10/20	FLS
943	AM	CDT	THU	10/20	FLS
1115	AM	CDT	THU	10/20	FLS
1245	PM	CDT	THU	10/20	FLS
135	PM	CDT	THU	10/20	FLS
205	PM	CDT	THU	10/20	RVS
1115	AM	CDT	FRI	10/21	FLS
1215	PM	CDT	FRI	10/21	FLS
1245	PM	CDT	FRI	10/21	FLS
110	PM	CDT	FRI	10/21	FLS
135	PM	CDT	FRI	10/21	RVS
325	PM	CDT	FRI	10/21	FLS
905	PM	CDT	FRI	10/21	FLS
1135	AM	CDT	SAT	10/22	FLS
1145	AM	CDT	SAT	10/22	FLS
1200	PM	CDT	SAT	10/22	FLS
1230	PM	CDT	SAT	10/22	RVS
1045	AM	CDT	SUN	10/23	FLS
1050	AM	CDT	SUN	10/23	FLS
1133	AM	CDT	SUN	10/23	FLS
1200	PM	CDT	SUN	10/23	RVS

FFS FLASH FLOOD STATEMENT
FFW FLASH FLOOD WARNING
FLS FLOOD STATEMENT
FLW FLOOD WARNING
RVS RIVER STATEMENT
SPS SPECIAL WEATHER STATEMENT

SUMMARY OF FLASH FLOOD AND FLOOD PRODUCTS FROM
NWSFO AUSTIN/SAN ANTONIO AND NWSO HOUSTON/GALVESTON
SU 10/16 — SU 10/23

PRODUCT	OFFICE NWSFO AUSTIN/SAN ANTONIO									OFFICE NWSO HOUSTON/GALVESTON								
	Su	Mo	Tu	We	Th	Fr	Sa	Su	Sum	Su	Mo	Tu	We	Th	Fr	Sa	Su	Sum
FFA	0	2	2	2	0	0	0	0	6	0	0	0	0	0	0	0	0	0
FFW	0	0	2	3	0	0	0	0	5	5	7	8	0	0	0	0	0	20
FFS	1	6	7	4	0	0	0	0	18	0	13	10	5	0	0	0	0	28
FLW	0	3	11	2	0	0	0	0	16	1	8	0	1	0	0	0	0	10
FLS	0	0	0	0	0	0	0	0	0	0	2	8	4	5	6	3	3	31
RVS	0	0	0	0	1	0	0	0	1	0	2	0	1	1	1	1	1	7
TOTALS	1	11	22	12	0	1	0	0	47	6	32	26	11	6	7	4	4	96

FFA Flash Flood Watch
FFW Flash Flood Warning
FFS Flash Flood Statement

FLW Flood Warning
FLS Flood Statement

RVS River Statement

APPENDIX P

ZCZC NFDQPFERD ALL
TTAA00 KNFD DDHHMM

SPECIAL EXCESSIVE RAINFALL POTENTIAL OUTLOOK
HYDRO-METEOROLOGICAL PREDICTION CENTER, NCEP, NWS, WASHINGTON, DC
600 PM EDT SUN OCT 16 1994

VALID OCT 16/2200 UTC THRU OCT 17/1200 UTC
REF AFOS GRAPHIC 94E

RNFL LIKELY TO EXCEED FFG VALUES TO THE RT OF A LN CRP NIR 20ESAT AUS TYR TXK ELD MLU AEX LCH 30SWLCH.

SERIOUS HVY RNFL SITUATION DVLPG OVR ERN TX AND PSBLY PTNS OF WRN LA AND SRN AR. INCREDIBLE MSTR IS IN PLACE OVR ERN TX..WITH SFC DWPTS IN THE UPR 70S..H85 DWPTS ABV 15C AND PWS ABV 2". THIS MSTR MORE LIKE WE'D SEE IN MID SUMMER THAN MID OCT! AND LOOKS AS IF A STG MSTR CONNECTION WL RMN IN PLACE FOR SOME TIME..WITH GRIDDED DATA FM THE MDLS SHOWING 30KTS OF SO OF LOW LVL INFLO CONTG INTO TX WELL INTO MON AND SATL WTR VAPOR PIX SHOWING A CONTD MSTR CONNECTION WAY DOWN INTO THE TROPICS. THIS WTR VAPOR PIX DOESN'T SHOW ANY WELL DEFINED S/WVS LIFTING TWDS TX..WHICH MAKES A FCST OF CONTG CNVCTN A LTL IFFY. BUT..AT THE SAME TIME..IF THERE WAS A WELL DEFINED S/WV..WE'D PROBABLY AT LEAST TEMPORARILY BREAK THE TROPICAL CONNECTION AND TEMPORARILY END THE CNVCTN. SO..BIGGEST QUESTION AT THIS TIME IS HOW LONG CNVCTN CAN BE SUSTAINED WITHOUT SEEING ANYTHING WELL DEFINED IN SATL IMAGERY. SINCE MSTR INFLO RMNS (WHICH SHLD CONT TO DESTABILIZE AMS) AND LOW LVL BNDRYS/MSTR CNVNGC ARE PRESENT (IF ONLY FM EXISTING CNVCTN)..HAVE TO BELIEVE MORE CNVCTN WL DVLP AND CONT WELL INTO LT SUN NGT..AT LEAST. GIVEN THE MSTR AVBLTY..IT'S ALMOST A GIVEN THAT SOME LOCATIONS WL RECEIVE IN EXCESS OF 5" OF RAIN BY MON MRNG..ESP OVR ERN TX. SRN AR AND WRN LA NOT AS THREATENED..BUT LIKELIHOOD OF SOME 3-5" RAINS THERE BY MON MRNG WL PROBABLY CAUSE SOME FLOODING PROBS THERE ALSO.

TERRY/FORECAST OPERATIONS BRANCH
NNNN

ZCZC NFDQPFERD ALL
TTAA00 KNFD DDHHMM

EXCESSIVE RAINFALL POTENTIAL OUTLOOK
HYDRO-METEOROLOGICAL PREDICTION CENTER, NCEP, NWS, WASHINGTON, DC
230 AM EDT MON OCT 17 1994

VALID OCT 17/1200 UTC THRU OCT 18/1200 UTC
REF AFOS GRAPHIC 94E

RAINFALL IS EXPECTED TO EXCEED FLASHFLOOD GUIDANCE VALUES TO THE RIGHT OF A LINE FROM CRP VCT CLL TXK ELD MLU AEX LCH.

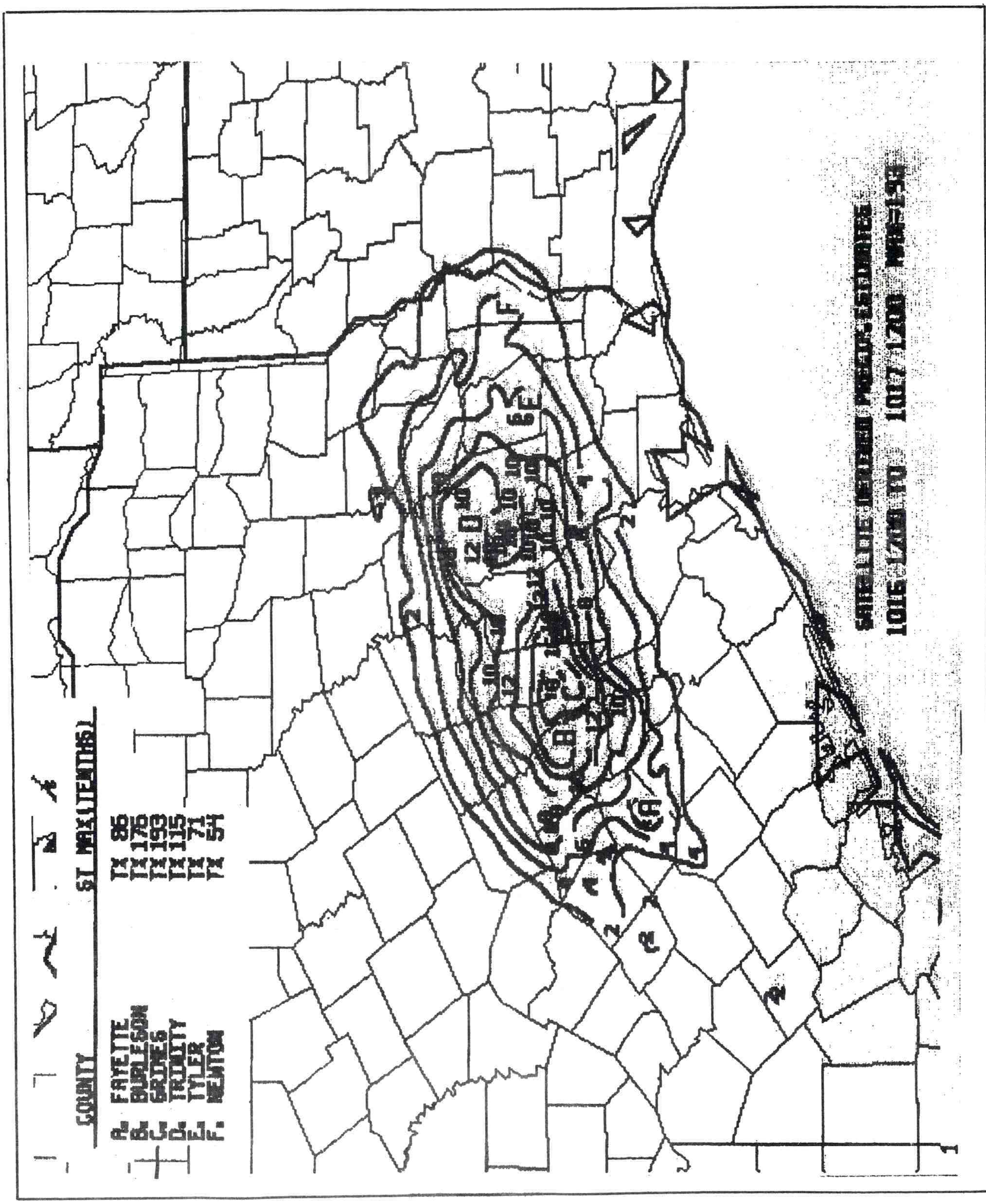
HEAVY RAINFALL CONTINUES OVER EASTERN TEXAS AND PORTIONS OF WESTERN LOUISIANA AND SOUTHERN ARKANSAS. STRONG MOISTURE FETCH HAS CARRIED INCREASED MOISTURE FAR NORTH..WITH PWS IN THE 2-2.5" RANGE ALONG THE TEXAS/LOUISIANA COAST. THESE VALUES ARE OVER 200 PERCENT OF NORMAL. NIGHTTIME SURFACE DEWPOINTS STILL REACH THE LOWER 70S AS FAR NORTH AS OKLAHOMA..850H DEWPOINTS IN OKLAHOMA ARE IN THE MID-TEENS..INCREASING TOWARD THE GULF. MODEL PREDICTIONS AND SATELLITE IMAGERY INDICATE THIS MOISTURE CONDUIT WILL CONTINUE THRU MONDAY. SATELLITE IMAGERY SHOWS CONVECTION CONTINUING TO DEVELOP ON THE SOUTHWEST AND WEST SIDES OF THE CURRENT PRIMARY CONVECTIVE AREA, AIDED BY INSTABILITY AND THE DYNAMICS AND MOISTURE OF THE SUBTROPICAL JET. THESE CONDITIONS ARE EXPECTED TO PERSIST. ISOLATED 3 HOUR RAINFALL AMOUNTS OF TWO TO FOUR INCHES CAN BE EXPECTED IN THREAT AREA. ISOLATED TOTAL 24 HOUR AMOUNTS OF NEAR 5" WILL BE POSSIBLE.

DYE/FORECAST OPERATIONS BRANCH
NNNN

APPENDIX Q

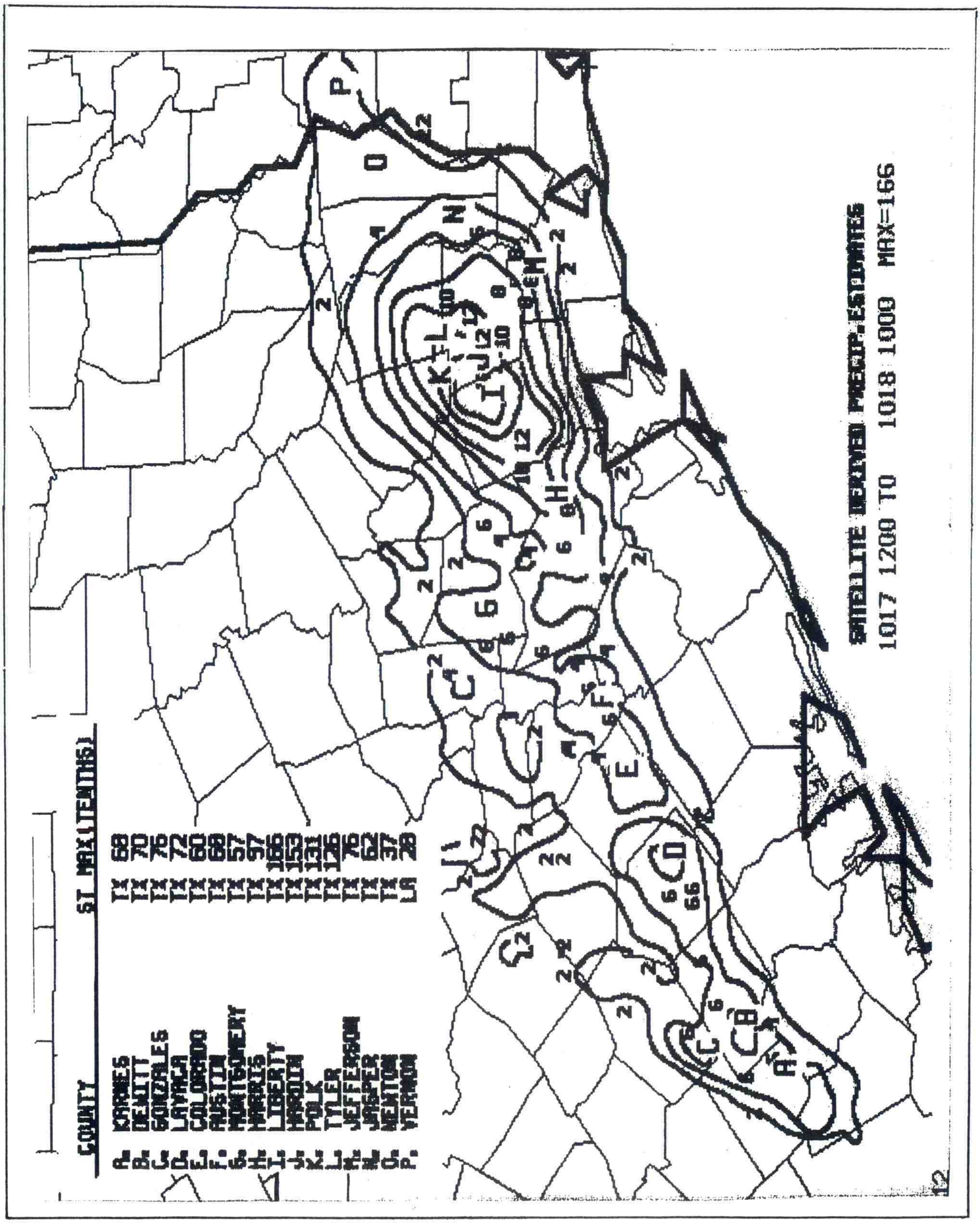
SATELLITE DERIVED PRECIPITATION ESTIMATES

OCTOBER 16-17, 1994



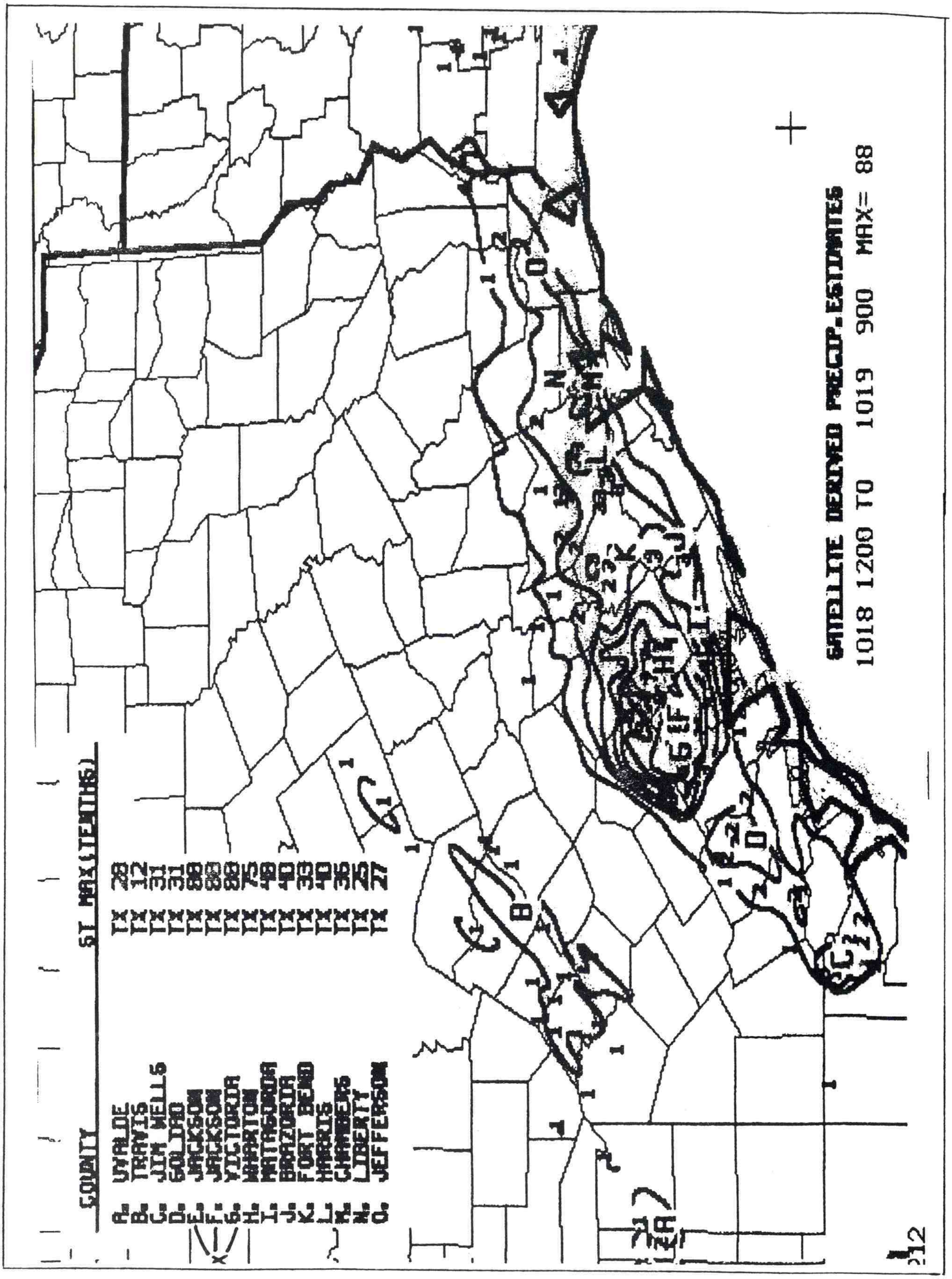
SATELLITE DERIVED PRECIPITATION ESTIMATES

OCTOBER 17-18, 1994



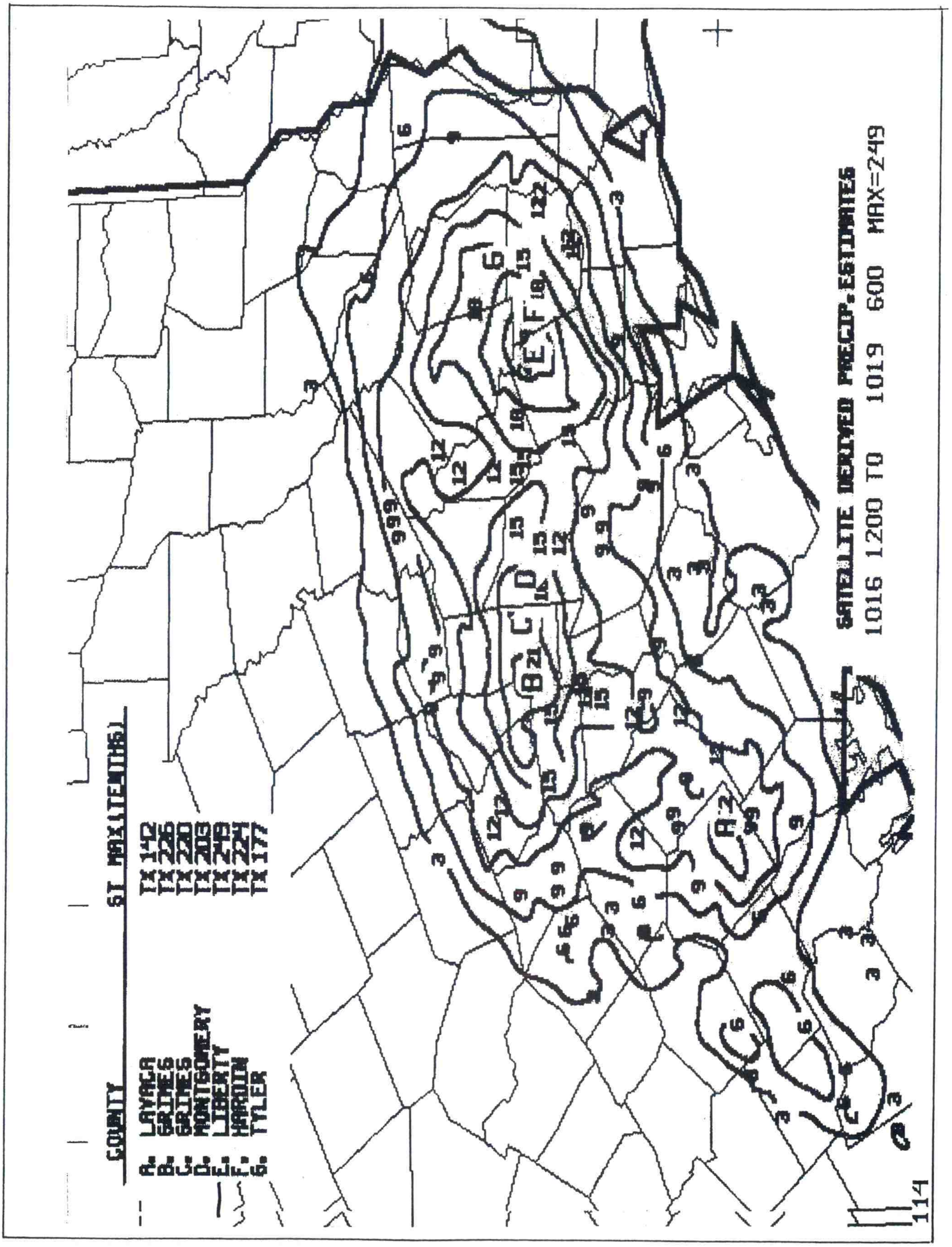
SATELLITE DERIVED PRECIPITATION ESTIMATES

OCTOBER 18-19, 1994



SATELLITE DERIVED PRECIPITATION ESTIMATES

OCTOBER 16-19, 1994



APPENDIX R

HOUSTON WSR-88D STORM PRECIPITATION ESTIMATES
OCTOBER 15-19, 1994