Local Office Service Assessment

Central Iowa Flooding of August 2010

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
Des Moines, Iowa

Cover Photograph: Photo is courtesy of the *Des Moines Register*, Des Moines, Iowa. Photo is from 11 August 2010. It is an aerial photograph looking north showing Iowa State University and the city of Ames. Jack Trice Stadium, home to Iowa State University football team is in the foreground. Hilton Coliseum, home to Iowa State University basketball, gymnastics, volleyball and wrestling teams is near the top center. The Squaw Creek in Ames produced severe flooding of the Iowa State University campus. According to Iowa State University Vice President Warren Madden, estimated damage costs for the University alone were between $30 and $40 million.

Cover layout by Jeffrey Zogg, NWS Weather Forecast Office Des Moines, Iowa

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April 2012

National Weather Service
John L. Hayes
Assistant Administrator

Preface

During August of 2010, record flooding took place in portions of central Iowa with the most significant flooding occurring during a three-day period from 09-11 August. The setup for this high-impact hydrologic event began in the previous winter which was characterized by above normal precipitation and below normal temperatures resulting in anomalously high snow water equivalent values across the state of Iowa. The subsequent spring and summer saw much above normal precipitation. Statewide precipitation amounts for June and July made for the wettest June on record and the fifth wettest July on record in Iowa.

For three consecutive nights beginning on 09 August, thunderstorms with prolonged heavy rainfall affected central Iowa. Three-day precipitation totals ranged from 6 to more than 10 inches resulting in record flooding along the Walnut Creek, Fourmile Creek, Squaw Creek and South Skunk River basins. Extensive damage occurred in many communities including Ames, Clive, Colfax, Des Moines, Oskaloosa, Urbandale and West Des Moines. Other locations along these same streams were also impact by this flood event.

Due to the magnitude and impact of this event, an internal Service Assessment Team was formed at the National Weather Service Forecast Office in Des Moines, Iowa to evaluate the effectiveness of services provided by the National Weather Service during this event. The recommendations from this assessment, when implemented, will lead to improvements in the quality of National Weather Service products and procedures to enhance decision-making processes associated with flood events.

Note: The publication of this Service Assessment was delayed because of various reasons including other commitments and tasks for the Service Assessment team leader. During the period from the August 2010 event to the Service Assessment's publication, the NWS Forecast Office in Des Moines, Iowa has implemented many of the recommendations contained herein. Finally, although the publication of this Service Assessment has been delayed, it is believed that its facts, findings and recommendations should still be shared. Sharing this information will help meet the ultimate goal of this document, which is to further the NWS mission of protecting lives and property as well as enhancing the national economy.

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April 2012

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Service Assessment Team

The team consisted of the following individuals, listed in alphabetical order by last name:

Jacob Beitlich	General Forecaster, NWS Forecast Office Chanhassen, Minnesota (formerly Meteorologist Intern, NWS Forecast Office Des Moines, Iowa)
Jeffrey Johnson	Warning and Coordination Meteorologist, NWS Forecast Office Des Moines, Iowa
Kenneth Podrazik	General Forecaster, NWS Forecast Office Des Moines, Iowa
Bradley Small	Lead Forecaster, NWS Forecast Office Des Moines, Iowa
Jeffrey Zogg	Senior Service Hydrologist, NWS Forecast Office Des Moines, Iowa (Team Lead)

Table 1. NWS Forecast Office Des Moines, Iowa local office Service Assessment Team membership.

Acknowledgements

The Service Assessment Team would like to thank the many people who made this Service Assessment possible. Valuable contributions were made by many members of the NWS, the media and officials at various levels in the private and public sectors. The time and insights they provided to help enhance the delivery of future flood related services are greatly appreciated.

Executive Summary

This local office service assessment focuses on the record flooding that took place in central Iowa during the three-day period from 09-11 August 2010. It is specific only to the NWS Forecast Office Des Moines, Iowa area of responsibility which includes 51 central Iowa counties. See Figure 1 for a map showing the location of the NWS Weather Forecast Office Des Moines, Iowa CWA.

The previous winter was characterized by above normal precipitation and below normal temperatures resulting in anomalously high snow depths across the state. The SWE—which is the amount of liquid water stored in the snowpack—was nearly double the normal value. The combination of high SWE values and above normal soil moisture content set the stage for a high risk of flooding for the upcoming warm season.

The situation worsened as the late spring and early summer months were much wetter than normal with statewide precipitation amounts of 10.45 inches for June 2010 and 7.93 inches for July 2010. These precipitation amounts were 5.81 inches above normal (i.e., 225% of normal) for June and 3.68 inches above normal (i.e., 187% of normal) for July. This ranked as the wettest June and the fifth wettest July in the 138 years of weather recordkeeping in Iowa (State of Iowa 2010).

Several flooding events resulted from the successive and extremely wet months but those events are beyond the scope of this assessment. Given the antecedent conditions mentioned above, one can understand the potential for a major flooding event in conjunction with repeated heavy rainfall.

This major event manifested itself during the three-day period beginning 09 August 2010. Deep convection developed and moved across central Iowa for three consecutive nights. The widespread 72-hour storm total precipitation values ranged from 6 to more than 10 inches resulting in record flooding along the Walnut Creek, Fourmile Creek, Squaw Creek and South Skunk River basins. Thus this service assessment reflects the efforts of the entire NWS Forecast Office Des Moines, Iowa staff to provide exemplary flood warning and forecast services with the attendant positive and negative aspects. Many of the findings and recommendations herein reflect their desire to provide better and more effective service in future events.

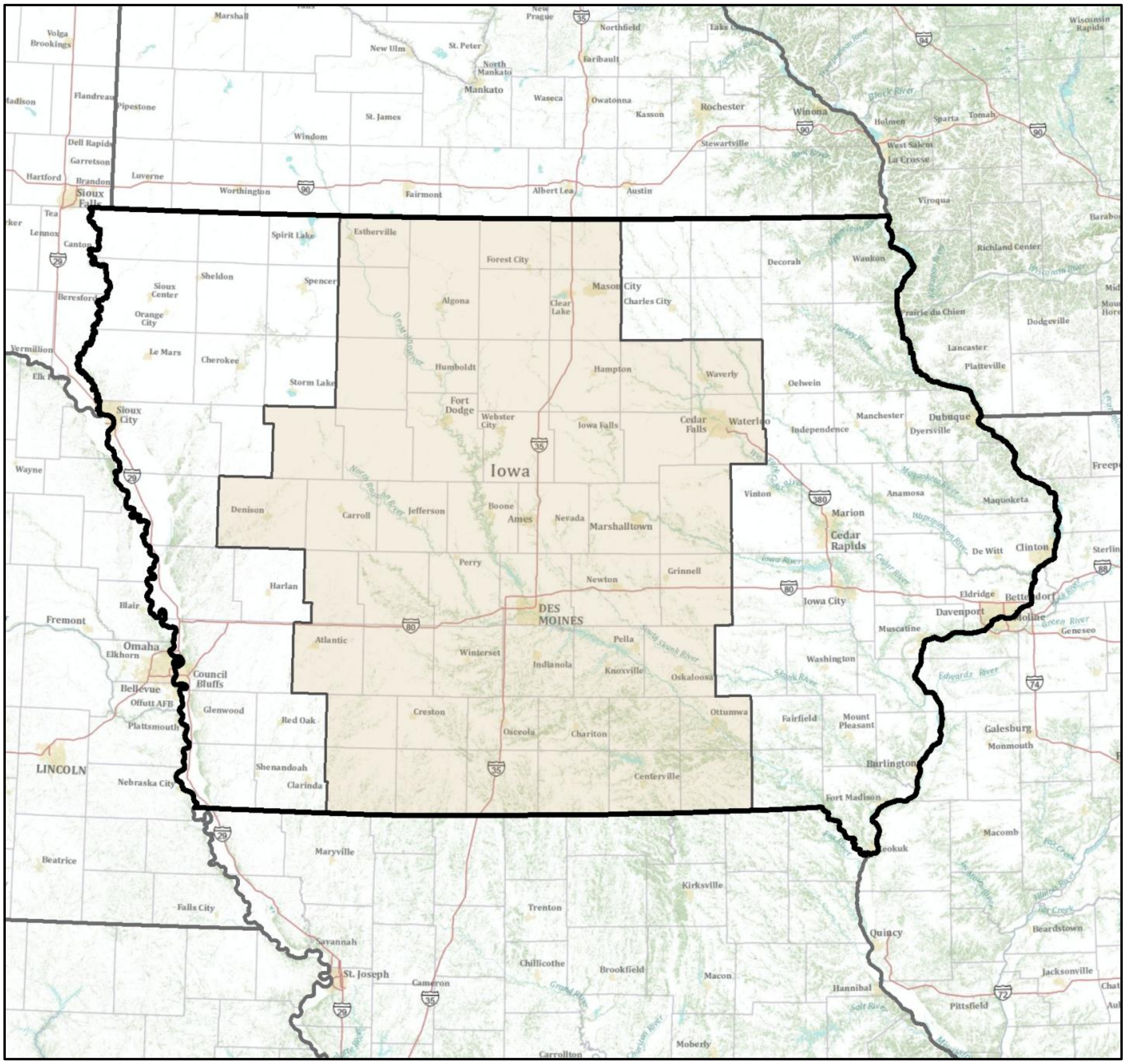


Figure 1. Map of Iowa showing the NWS Forecast Office Des Moines, Iowa CWA (shaded).

Service Assessment Report

A. INTRODUCTION

1. NWS Mission

The National Weather Service is a line office of the National Oceanic and Atmospheric Administration (NOAA). The NWS provides weather, water and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas for the protection of life and property and the enhancement of the national economy. NWS data and products form a national information database and infrastructure which can be used by other government agencies, the private sector and the global community.

These services are delivered through the efforts of staff stationed at 122 WFOs, 13 RFCs, 9 national centers of NCEP, 21 Center Weather Service Units, the Alaska Aviation Weather Unit, 13 Weather Service Offices, 2 Tsunami Warning Centers, 6 Regional Headquarters and a number of other units. Oversight, policy and support are provided by NWS Headquarters in Silver Spring, Maryland.

2. Purpose of Local Office Service Assessment

The primary purpose of this local office service assessment is to improve the ability of the NWS to protect life and property. This will be accomplished by presenting facts, findings, recommendations and best practices of NWS Weather Forecast Office (WFO) Des Moines, Iowa (DMX, hereafter referred to only as DMX) performance during the central Iowa flash flooding and river flooding of August 2010. It will also document the meteorology, hydrology and impacts of the event. The greatest impacts were in central Iowa including the Des Moines and Ames metropolitan areas as well as in the communities of Colfax and Oskaloosa.

This assessment will focus on flooding only. No other modes of severe weather will be considered. Specifically, it focuses on the flooding that occurred near its peak, which affected central Iowa from 09-24 August 2010. Of most interest was the record flooding on Walnut Creek and Fourmile Creek in the Des Moines area, record flooding on the South Skunk River and the near-record flooding on Squaw Creek in the Ames area. See Figure 2 for a map showing all stream basins that were addressed in this service assessment, Figure 37, Figure 38, Figure 39 and Figure 40 for orientation maps and Table 2 for a summary of peak stages, flows and AEPs for selected USGS gaging sites in the service assessment study area.

The focus areas of this service assessment are:

- Timeliness, quality, accuracy and usefulness of NWS warnings and forecasts from the perspective of high impact services and DSS

- Effectiveness of NWS internal and external collaboration and coordination
- Usefulness of the tools and data in the forecast process
- Effectiveness of hydrologic forecasting and warning procedures at DMX
- Identification and evaluation of opportunities to improve collaboration among other federal, state and local agencies
- The meteorological and hydrological nature of this event as well as the resulting impacts

3. Methodology

DMX formed the assessment team after the flooding ended in late August 2010 with the goal of evaluating DMX service and operations, plus identifying external responses to the event. The team also strove to accurately detail the NWS's role in the event and to improve future operations.

Team efforts consisted of the following:

- Review of the meteorological and hydrologic aspects of the event
- Interviews of selected DMX partners and users
- Evaluation of NWS operations and activities including short- and long-fused products as well as coordination and verification. Time scales ranged from flash flooding to main stem river flooding
- Evaluation of DMX DSS including feedback from its partners and users regarding its products and services
- Development of significant findings and recommendations to improve the effectiveness of DMX products and services

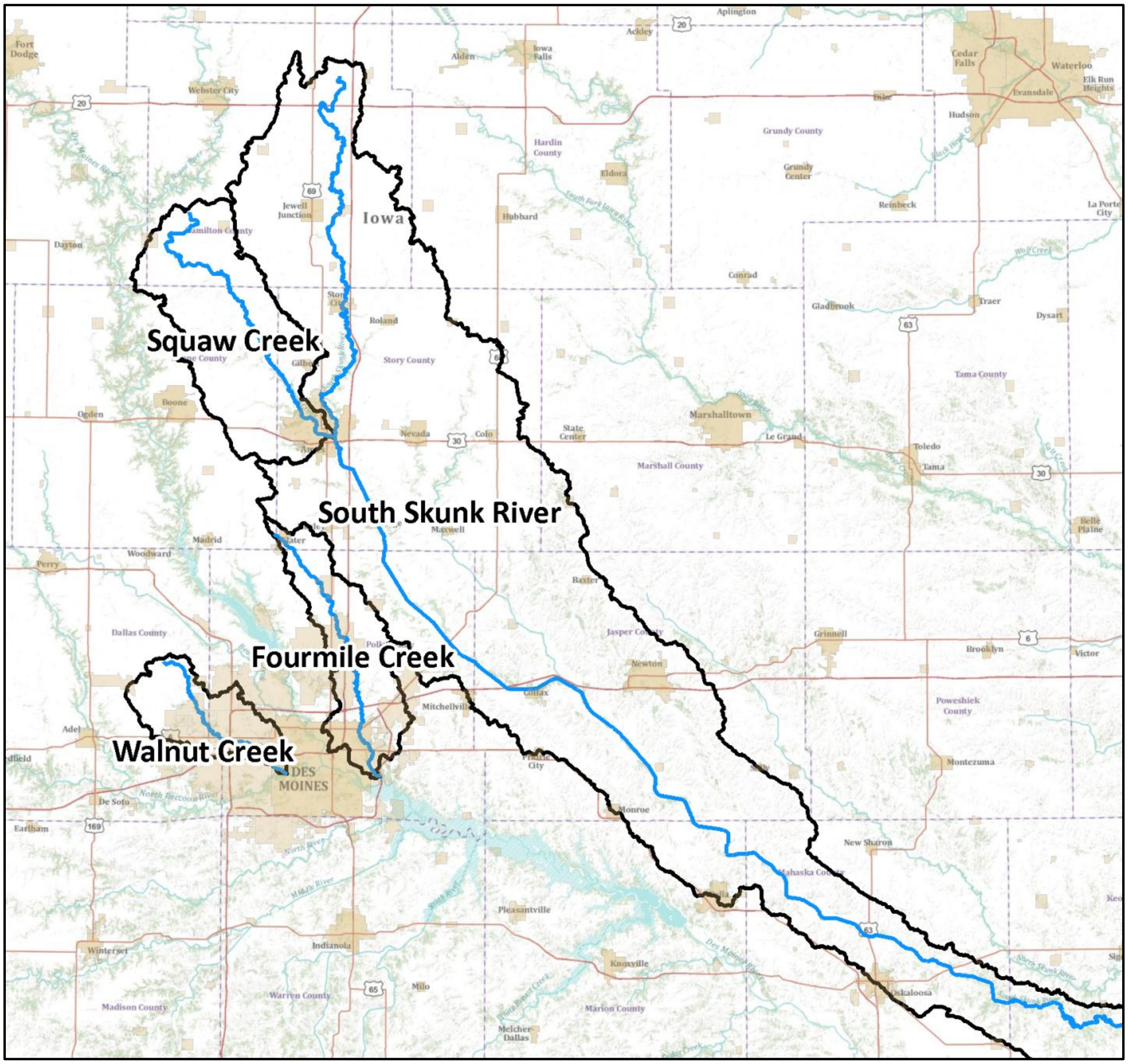


Figure 2. Map showing all stream basins that were addressed in this service assessment.

Station Name	**Site ID/ NWSLI**	**Crest Date**	**Peak Stage (ft)**	**Peak Flow (cfs)**	[a] **Peak Flow AEP**
S Skunk River near Ames Riverside Rd	AMEI4	11 August 2010	19.04	**14,800**	0.2 to 1%
S Skunk River near Ames Hwy 30	AESI4	11 August 2010	26.72	**36,200**	< 0.2%
S Skunk River at Colfax	CFXI4	14 August 2010	23.85	**24,000**	0.2 to 1%
S Skunk River near Oskaloosa	OOAI4	16 August 2010	26.40	25,200	1 to 2%
Squaw Creek at Ames Lincoln Way	AMWI4	11 August 2010	18.13	22,400	< 0.2%
Walnut Creek at Des Moines 63rd St	DOSI4	09 August 2010	18.59	11,700	[b] 2 to 4%
Fourmile Creek near Ankeny NE 86th Ave	ANKI4	11 August 2010	13.69	**4,730**	[c] 4 to 10%
Fourmile Creek at Des Moines Easton Blvd	DFMI4	11 August 2010	16.14	**9,620**	0.2 to 1%

Table 2. Peak stages, flows and AEPs for selected USGS gaging sites in the service assessment study area. Bolded flows indicate record high discharges. Source: USGS Iowa Water Science Center (David Eash), personal communication.

Notes:

[a] Unless otherwise noted, peak flow AEPs are computed using weighting of independent estimates (WIE) method. See Tables 3 and 4 in USGS publication OFR 2010-1190 for descriptions of the WIE method, flood-probability ranges and equivalent flood recurrence-intervals.

[b] Computed using Bulletin 17B stream gage probability analysis because regional regression equations are not applicable due to urbanization.

[c] Computed using regional regression equations because of short peak-flow record of seven years.

B. EVENT AND HYDROMETEOROLOGICAL SUMMARY

1. Antecedent Conditions

The winter of 2009-2010 was characterized by above normal precipitation across central Iowa, much of which fell as snow. Persistent cold temperatures helped maintain this snowpack through the winter months. By late winter, SWE values were nearly double the normal value across most of the state. In addition, soil moisture values were high as well due in part to above average precipitation during Fall 2009. The combination of these two parameters meant an elevated risk of flooding leading into the spring thaw and convective warm season.

Record rainfall occurred across Iowa during June 2010 with a statewide average of 10.45 inches. This total was 5.81 inches above normal (i.e., 225% of normal). It was also the highest June total in the 138-year history of Iowa recordkeeping. The July 2010 statewide average was 7.93 inches. This total was 3.68 inches above normal (i.e., 187% of normal). It was also the 5th wettest July on record.

Soil moisture values heading into August 2010 were in the 90th percentile over nearly all of Iowa and in the 95th percentile for central Iowa (Figure 3). Several flooding events resulted from these extremely wet couple of months but those events are beyond the scope of this assessment.

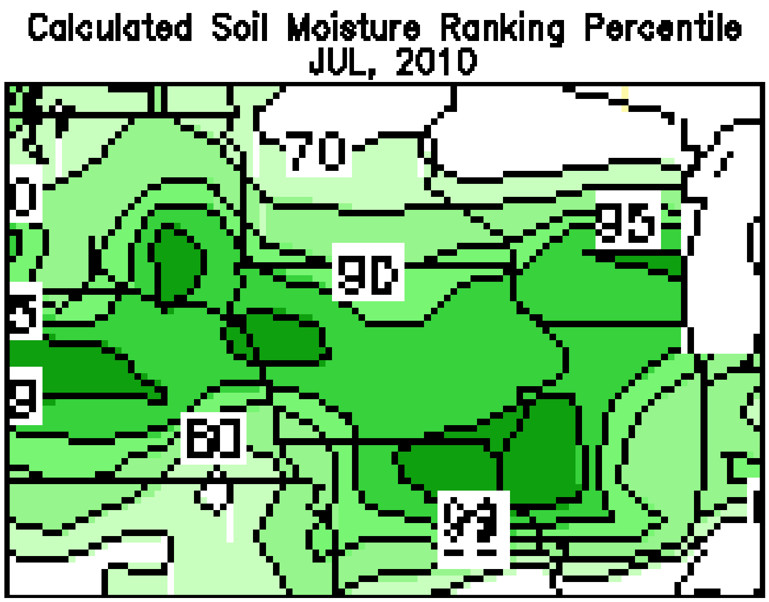


Figure 3. NCEP/CPC calculated soil moisture ranking percentile for July 2010. Green shading indicates above normal soil moisture.

2. Event Conditions

This major event manifested itself during the three-day period beginning 09 August 2010 and ended 11 August 2010. The synoptic configuration during this timeframe was conducive to flash flooding. It was similar to the conceptual models of Maddox et al. (1979) with weak upper level flow parallel to a surface boundary and strong moisture transport. The air mass which produced the heavy rainfall that led to flash flooding and eventual river flooding was tropical in nature with precipitable water levels near record levels (Figure 4). A stationary front remained across the region with weak steering flow aloft. Deep convection developed and moved across central Iowa for three consecutive nights. Fueled by moisture transport from a strong low level jet, these storms were not only efficient rain producers but also slow movers. A more detailed discussion of the synoptic and mesoscale features can be found in Appendices I, II and III.

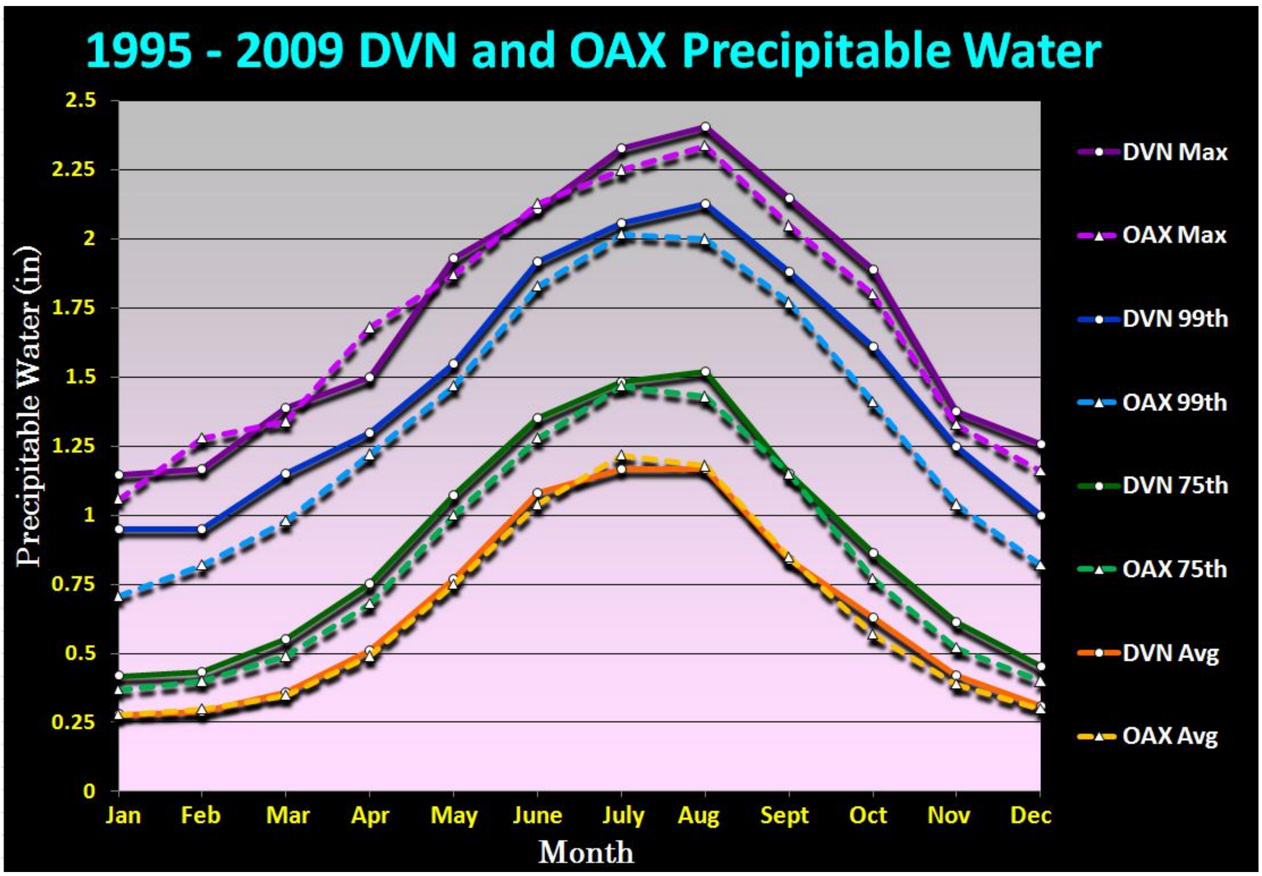


Figure 4. Fifteen-year precipitable water values integrated through the layer from the surface up to 300 mb according to RAOB soundings for both Davenport and Omaha. The circles/solid lines represent Davenport while the triangles/dashed lines represent Omaha. The purple shaded lines show the maximum amount observed, the blue shaded lines give the 99th percentile, green lines show the 75th percentile while the orange shaded lines represent the average precipitable water during a given month. The values observed over central Iowa during the 3-day stretch from 09-11 August 2010 were generally in the 2.0 to 2.3 range which are near the 99th percentile (box)

when interpolated between the two sites. See Sections G.3, G.4 and G.5 for more detail.

3. Impacts

The first of several MCSs developed on the night of 08-09 August 2010 over northeast Nebraska and moved across central Iowa during the early morning hours of 09 August 2010. Several FFWs were issued. Record flooding occurred along Walnut Creek causing considerable damage to the western side of the Des Moines metropolitan area. Another round of storms developed over central Iowa later that evening and slowly propagated southeast during the early morning hours of 10 August 2010. This caused major flash flooding near the town of Oskaloosa. During the night of 11 August 2010 already flooded areas received additional heavy rainfall. Areas hardest hit were the Fourmile and Squaw Creek basins. The widespread 72-hour storm totals ranged from 6 to more than 10 inches across central Iowa resulting in record flooding along the Fourmile, Squaw, South Skunk and Walnut Creek basins near the towns of Ames, Colfax and Oskaloosa (Figure 5). During that time frame, 25 multiple county FFWs were issued along with 52 river FLWs. Overall the estimated damage from both river and flash flooding was estimated in excess of $65 million.

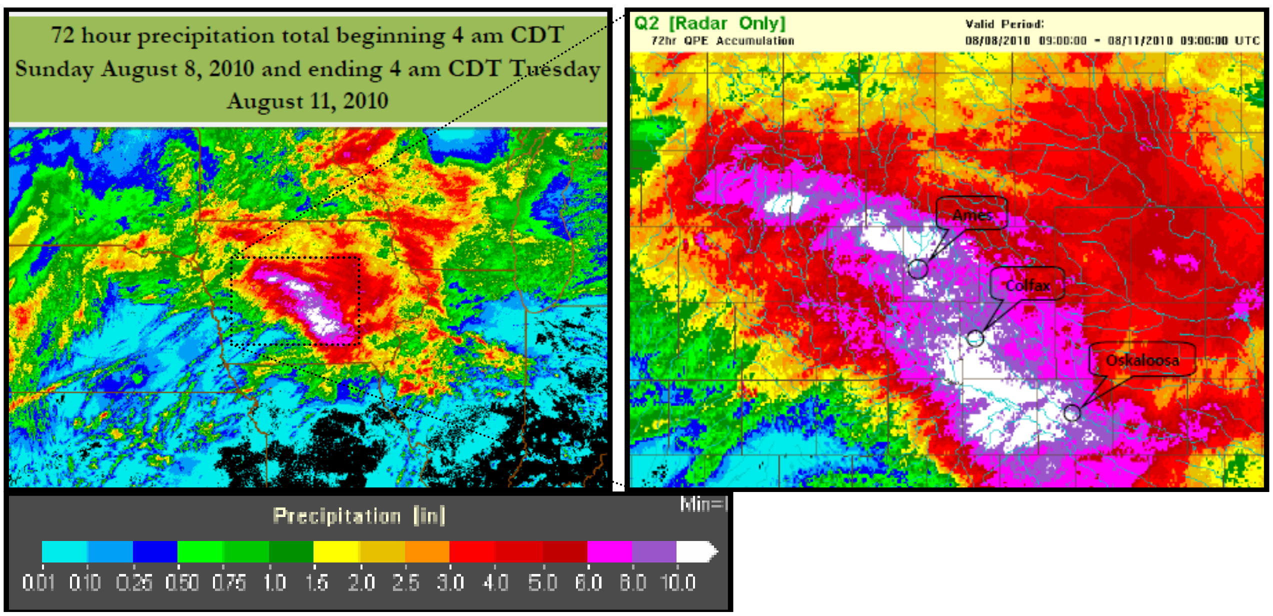


Figure 5. Q2 radar estimated total rainfall accumulation during the three-day period ending on 11 August 2010. The left most image shows a large scale view. The zoomed-in image on the right shows more detail. In the legend warmer colors show those areas of higher rainfall amounts with white indicating over 10 inches. The cities of Ames, Colfax and Oskaloosa are highlighted.

4. Flash Flood Warnings and Statements

a. Day 1

Heavy rainfall in the Walnut Creek and Fourmile Creek headwaters caused flash flooding and rapid stream rises. The first FFW was issued at 0250Z on 09 August 2010 for north central Iowa and at 0304Z on 09 August 2010 for central Iowa. Eleven total FFWs were issued between the hours of 0250Z and 0953Z on 09 August 2010. Six of these warnings were verified and the average lead time for all events was over two and a half hours. One event had negative lead time however. Wording within these warnings was not out of the ordinary and focused on the increased threat of nocturnal flooding while driving:

> "NATIONAL WEATHER SERVICE DOPPLER RADAR INDICATED SLOW MOVING THUNDERSTORMS WITH VERY HEAVY RAINFALL ACROSS THE WARNED AREA..."
>
> "DO NOT DRIVE YOUR VEHICLE INTO AREAS WHERE THE WATER COVERS THE ROADWAY. THE WATER DEPTH MAY BE TOO GREAT TO ALLOW YOUR CAR TO CROSS SAFELY. TURN AROUND DONT DROWN...."
>
> "BE ESPECIALLY CAUTIOUS AT NIGHT WHEN IT IS HARDER TO RECOGNIZE THE DANGERS OF FLOODING..."

Follow up statements included spotter and law enforcement reports with details of specific intersections. As the storms approached the Des Moines metropolitan area additional wording was inserted to highlight the threat of urban flooding:

> "FLASH FLOODING IS MOST LIKELY IN CITIES AND TOWNS IN THE WARNED AREA...BUT IS ALSO POSSIBLE IN RURAL AREAS TOO..."

b. Day 2

The rainfall during the early morning hours of 10 August 2010 was very concentrated. It caused localized but devastating flash flooding in a few small basins that had experienced heavy rain the previous night. This time the basins that received the most rainfall were Walnut Creek and Beaver Creek as well as several smaller fast response creeks. The first of five FFWs was issued at 0551Z for five counties in central Iowa including the Des Moines metropolitan area. These products stressed the higher potential for flooding in urban communities as opposed to rural areas:

> "FLASH FLOODING IS MOST LIKELY IN TOWNS AND CITIES...BUT IS ALSO POSSIBLE IN RURAL AREAS."

FFSs continued to give updated information as measured rainfall reports of 4 to 6 inches arrived through various sources. An NWSChat message from local media partner KCRG-TV at 0921Z 10 August 2010 reported evacuations ongoing in the Oskaloosa area. Several attempts were made to contact law enforcement from that county. Due to the extreme volume of calls, however, the information of stranded people relayed by the dispatch center at 0925Z was vague. A few reports were coming in of people trapped east of Oskaloosa. Less than an hour later the emergency manager returned a phone call confirming the reports of people trapped and asked for assistance with the rescues. The NWS issued a second FFS at 1006Z with the wording:

> "MAHASKA COUNTY EMERGENCY MANAGEMENT HAS ASKED FOR ANYONE WITH A FLAT BOTTOM BOAT TO REPORT TO THE OSKALOOSA FAMILY RESTAURANT IMMEDIATELY. THIS RESTAURANT IS LOCATED AT 1802 A AVENUE EAST IN OSKALOOSA...ON THE EAST SIDE OF TOWN."

This FFS was also put directly in the media chat to help get the word out. Just 24 minutes later at 1032Z the EM called to say that they had enough boats to assist in the rescues.

c. Day 3

From the evening of 10 August 2010 through the early morning of 11 August 2010, a third and final round of thunderstorms developed across central Iowa which led to the issuance of nine additional multi-county FFWs across the southern half of the DMX CWA and resulted in one fatality. Given the previous two days of heavy rain the wording in these FFWs was heightened and the term FLASH FLOOD EMERGENCY was used for portions of Polk County including portions of the Des Moines metropolitan area. Reports merited the emphatic wording since at 0530Z law enforcement personnel reported "impassible deep water over the road" at several locations along with "numerous stalled cars." Water was flowing over I-35 and the storms were forecast to dump an additional 1 to 2 inches of rain. At 0538Z a Flash Flood Emergency was issued:

> "AT 1234 AM CDT...A FLASH FLOOD EMERGENCY IS IN PROGRESS ACROSS THE METRO AREA. LOCAL LAW ENFORCEMENT OFFICIALS REPORTED DEEP WATER FLOWING ACROSS INTERSTATE 35 NEAR MILE MARKER 97 NORTH OF ANKENY...WITH CARS STALLED AND SPUN OUT ON THE INTERSTATE. THUNDERSTORMS WITH EXTREMELY HEAVY RAINFALL WILL CONTINUE ACROSS THE AREA AND PRODUCE ADDITIONAL RAINFALL AMOUNTS UP TO 2 INCHES. MAJOR FLASH FLOODING IS LIKELY OR GOING TO CONTINUE THROUGHOUT THE METRO AREA OF DES MOINES."

A few hours later three vehicles were swept off the road by flood waters in the Mud Creek basin. There were a total of 12 young adults in the cars and one person did not survive.

5. River Flood Warnings and Statements for Major and Record Flooding

a. <u>Day 1</u>

A total of 26 river FLWs were issued on 09 August 2010 for 14 river forecast points with multiple warnings issued at numerous river forecast points to upgrade the flood severity. Three of the initial warnings had negative lead time. One particular warning discussed in detail below is a good example of the obstacles encountered during this event. This warning was issued 09 August 2010 at 0551Z for site DOSI4 along Walnut Creek calling for moderate flooding. The stage data at 0538Z was already above flood stage and rising rapidly. The initial forecast crest was 15.4 feet during the morning of 09 August 2010. An FLS was issued at 0623Z on 09 August 2010 to raise the crest to 16-16.5 feet. The ingested data was old, however, so the FLS provided inaccurate information (bold):

```
...FLOOD WARNING REMAINS IN EFFECT UNTIL THIS MORNING...

THE FLOOD WARNING CONTINUES FOR
  THE WALNUT CREEK AT DES MOINES 63RD ST...OR FROM 1 1/3 MILES
  UPSTREAM OF NORTH WALNUT CREEK...TO THE RACCOON RIVER.
* UNTIL THIS MORNING.
* AT 11:15 PM SUNDAY THE STAGE WAS 4.5 FEET.
* FLOOD STAGE IS  13 FEET.
* NO FLOODING IS OCCURRING AND MODERATE FLOODING IS FORECAST.
* FORECAST...RISE ABOVE FLOOD STAGE AFTER MIDNIGHT...AND CONTINUE
  RISING TO BETWEEN 16 AND 16.5 FEET EARLY THIS MORNING. GO BELOW
  FLOOD STAGE LATE THIS MORNING.
```

Less than an hour later a new FLW was issued 0648Z to upgrade from moderate to major flood severity at DOSI4 and also to clarify the information (in bold). The statement still said that no flooding was occurring, however, when in fact the stage was already above moderate flood level.

```
...FORECAST FLOODING INCREASED FROM MODERATE TO MAJOR SEVERITY...

THE FLOOD WARNING CONTINUES FOR
  THE WALNUT CREEK AT DES MOINES 63RD ST...OR FROM 1 1/3 MILES
  UPSTREAM OF NORTH WALNUT CREEK...TO THE RACCOON RIVER.
* UNTIL THIS MORNING.
* AT 133 AM MONDAY THE STAGE WAS 16.0 FEET.
* FLOOD STAGE IS  13 FEET.
* NO FLOODING IS OCCURRING AND MAJOR FLOODING IS FORECAST.
* FORECAST...RISE TO 17.4 FEET EARLY THIS MORNING. GO BELOW FLOOD
  STAGE LATE THIS MORNING.
```

In summary, DOSI4 experienced record flooding with a crest of 18.59 feet. This warning had negative lead time and the two follow up statements were incorrect with the crest underestimated by several feet. It should be noted, however, that this example was a negative outlier when compared to the other river forecasts but is a good example of ways to improve future products for DSS. For more information please see Appendix I.

b. Day 2

A total of seven river FLWs were issued during the morning of 10 August 2010. Four of these warnings were for renewed flooding in the fast response basins which flooded the previous night and had since fallen below flood stage. The remaining three warnings were for upgrades in flood severity. The wording in the heading of the product reflected this repeated flooding to increase the clarity of the warning:

> "HEAVY RAINFALL TONIGHT THUS FAR IS LEADING TO RENEWED FLOODING ON THE FOURMILE CREEK ON THE EAST SIDE OF THE DES MOINES METRO AREA..."
>
> "HEAVY RAINFALL TONIGHT THUS FAR IS LEADING TO RENEWED FLOODING IN THE WALNUT CREEK BASIN ON THE WEST SIDE OF THE DES MOINES METRO AREA..."

c. Day 3

The final round of thunderstorms prompted 21 more river FLWs between 23Z on 10 August 2010 and 22Z on 11 August 2010. Eight of these warnings were new issuances while the remaining 13 were for upgrades in flood severity. Eight of the upgrades were for major flooding or greater while six of these (i.e., DFMI4, AMWI4, AMEI4, AESI4, CFXI4 and OOAI4) called for record flooding. Special wording in the heading of the warning text highlighted this life-threatening situation. At 1601Z on 11 August 2010 an FLS was issued at those sites expecting record flooding with Particularly Dangerous Situation (PDS) wording included in the text. Details on potential impacts and crest uncertainty were also given. The example below is for DFMI4 along Fourmile Creek with the Particularly Dangerous Situation (PDS) statement included.

```
...FORECAST FLOODING CHANGED FROM MODERATE TO RECORD SEVERITY FOR
FOURMILE CREEK IN THE DES MOINES METRO AREA...

INTENSE RAINFALL OF 3 TO 5 INCHES IN THE MIDDLE TO UPPER PORTIONS OF
THE FOURMILE CREEK BASIN IS EXPECTED TO RESULT IN RECORD FLOODING ALONG
FOURMILE CREEK...

...THIS IS A PARTICULARLY DANGEROUS SITUATION...

PEOPLE ALONG FOURMILE CREEK SHOULD PREPARE FOR FLOOD LEVELS NEVER SEEN
BEFORE ALONG THE CREEK. THERE IS MORE UNCERTAINTY THAN NORMAL IN THE
FORECAST CREST OF FOURMILE CREEK DUE TO THE EXPECTED UNPRECEDENTED
LEVELS. WE WILL CONTINUE MONITORING THIS SITUATION AND ISSUE UPDATES AS
NEEDED.

...IMPORTANT--RECORD FLOODING IS NOW FORECAST...
...FORECAST FLOODING INCREASED FROM MODERATE TO RECORD SEVERITY...

THE FLOOD WARNING CONTINUES FOR
  THE FOURMILE CREEK AT DES MOINES EASTON BLVD...OR FROM BELOW
  INTERSTATE 80...TO THE DES MOINES RIVER.
* MINOR FLOODING IS OCCURRING AND RECORD FLOODING IS FORECAST.
* FORECAST...RISE TO BETWEEN 16 AND 17 FEET BETWEEN 8 AND 10 AM THIS
  MORNING...THEN BEGIN FALLING.
* CREST HISTORY...THE PRESENT RECORD CREST IS 15.4 FEET IN 2008.
* IMPACT...FLOOD WATERS FROM FOURMILE CREEK MAY AFFECT I-80 BETWEEN
  MILE MARKERS 138 AND 141 AS EARLY AS 5 AM THIS MORNING.
```

For the flooding in the Ames area, forecasters at both DMX and NCRFC collaborated in real-time with Ames city officials to accurately determine the amount of runoff that was occurring and also to provide accurate crest forecasts. This collaboration also helped ensure that a consistent message was provided by both the NWS and the City of Ames. DMX shared Q2 QPE data with local city officials. The Q2 data indicated that locally intense rainfall fell in portions of the Squaw Creek basin above Ames. Neither the Ames ALERT network nor the DMX radar precipitation estimates fully captured the magnitude of this intense rainfall. In addition, Ames officials and NCRFC forecasters shared information in real-time concerning model forecasts for both Squaw Creek and the South Skunk River. This collaboration worked well and forecasts calling for record flooding were issued for AMWI4, AMEI4 and AESI4. Meanwhile major flooding also occurred from local runoff at Colfax and Oskaloosa. The record crests occurred several days later from the enormous volume of water that came from upstream. Situational awareness and collaboration with DMX partners were important as emergency managers relied on accurate forecasts for DSS.

One example involved I-80 in Jasper County in the Colfax area. Floodwaters from the South Skunk River threatened to close the road. DMX initiated DSS for Jasper County officials and provided periodic briefings. On one instance a met-intern received a phone call from the emergency manager requesting a briefing in five minutes. The met-intern proceeded to call the

NCRFC and discuss the possibility of the South Skunk river exceeding the current record forecast and therefore closing I-80. Both parties agreed that the forecast was accurate and I-80 was not at risk. A few minutes later the met-intern received a phone call from the Jasper County EM and relayed the information. Even though the recommended protocol was followed one critical step was skipped. The met-intern failed to notify the lead forecaster or the SSH of the request for the critical forecast. The SSH thought the forecast crest was underdone and indeed the South Skunk rose over a foot above the level given to the EM in the briefing. Once the SSH was made aware of the situation, he was forced to explain the circumstances to the Jasper County EM. This example proves the crucial importance of situational awareness between all personnel during high impact events.

C. FACTS, FINDINGS, RECOMMENDATIONS AND BEST PRACTICES

1. DMX Operations and Activities

a. Situational Awareness

Fact 1: Real-time Q2 data allowed DMX staff to better determine actual QPE values especially underneath the most intense rainfall.

Fact 2: The most useful Q2 data included Q2 QPE as well as Q2 Z-R fields.

Best Practice 1: DMX staff used real-time Q2 data to supplement QPE data from radar.

Finding 1: An FLW was issued for Walnut Creek at Des Moines 63rd St with zero lead time. The stage at issuance was 0.9 feet over flood stage and was rising rapidly. Des Moines ALERT data was unavailable and DCP data only provided 15 minute increments of data every hour. The creek rose over eight feet in an hour so higher temporal resolution data was critical.

Recommendation 1: Emphasize staff awareness of AWIPS stage and rate-of-change alarms. Create a pre-event hydro checklist to ensure ALERT data is current and available wherever ALERT systems exist.

b. Operational Practices

Fact 3: The DMX SSH was scheduled to work normal operational forecast shifts for each of the three nights during this event. This was due to the office shift planning schedule which was finalized several months in advance. For each night during this event the SSH was relieved of his normal operational forecast shift duties to focus solely on hydrologic activities. Additional staff was brought in to help with normal operational forecast shift duties.

Fact 4: NCRFC forecasts underrepresented Squaw Creek and South Skunk River stream levels late on 10 August 2010 even before additional heavy rains impacted those basins. DMX staff proactively issued FLWs before guidance arrived.

Best Practice 2: LARCs were manually interrogated the morning of 09 August 2010 to provide better temporal resolution with Des Moines ALERT data not being ingested into AWIPS.

Best Practice 3: DMX evaluation of the 09 August 2010 river forecast for the Squaw Creek at Ames Lincoln Way and coordination with NCRFC improved the forecast by 3.7 feet, accurately keeping it out of the major flood category.

Best Practice 4: Proactive coordination with the NCRFC resulted in contingency forecasts for Squaw Creek based on varied amounts of QPF.

Finding 2: In many instances DMX software formatters for ESFs, FLWs and FLSs did not capture the second, higher crest. They also incorrectly identified stage trends. These problems occurred primarily with the South Skunk River near Oskaloosa (OOAI4) and resulted in inconsistent and incorrect forecasts even within days of the ultimate crest. This was especially apparent in crest timing with dramatic run to run changes. See Figure 12 (on Page 42) for a timeline of the forecast crest and time below flood stage for OOAI4.

Recommendation 2: DMX staff should visually evaluate hydrographs when composing products to ensure that text wording accurately reflects expected conditions. Any formatter configuration issues beyond the control of DMX should be addressed at higher levels within the NWS.

Finding 3: DMX RiverPro software formatters produced incorrect information. In one instance they inserted "no flooding is occurring" wording while current stage was three feet over flood stage. In another instance, the formatters pulled in old river stage data.

Recommendation 3: DMX staff should ensure that the RiverPro software is using the latest data. RiverPro should also be configured to automatically ingest the latest data without manual, forced data refresh. This change would need to be implemented at a higher level than DMX. Staff should also proofread text products to ensure formatters are generating correct information. Formatter code should be checked for potential bugs and errors.

Finding 4: The second crest above flood stage was missed along the Walnut Creek at Des Moines 63rd Street (DOSI4) on 10 August 2010. The Site Specific unit hydrograph was incapable of generating this type of response.

Recommendation 4: DMX researched the hydrologic response at DOSI4 and coordinated those findings with the NCRFC. NCRFC staff agreed that a change is needed and developed a unit hydrograph more representative with two crests. A new unit hydrograph was loaded for DOSI4 in November 2010.

2. DMX Decision Support Services

Fact 5: Heavy rain wording was introduced into the HWO on the morning of 06 August 2010.

Fact 6: Heavy rain continued to be mentioned in the HWO into 08 August 2010 including the afternoon issuance (1541 CDT on 08 August 2010) with a Flash Flood Watch. There was no mention of flooding however.

Fact 7: A Flash Flood Watch was in effect for record Walnut Creek flood with around 12 hours lead time to the crest.

Fact 8: Hours later another HWO was issued (1712 CDT on 08 August 2010) which hit the forecast much harder. It specifically mentioned 1 to 2 inch QPF amounts on average and locally up to 5 inches. A Flash Flood Watch remained in effect but there was still no mention of flooding in the HWO.

Fact 9: An FLW was issued for Walnut Creek at Clive I-80/35 (CLVI4) and Des Moines 63rd Street (DOSI4) with 5 to 7 hours lead time to the crest. The crest errors were -0.06 and -3.19 feet respectively. The 63rd St error was reduced to around 1 foot at 6 hours lead time.

Fact 10: A record crest forecast for Fourmile Creek (DFMI4) was issued 6 hours before the crest time with little error.

Fact 11: Significant and incorrect timing changes were made by NCRFC for Oskaloosa (OOAI4). Cresting timing changed from 18Z 15 August 2010 to 00Z 18 August 2010 just over a day before actual crest. Forecast error increased further from 42 to 54 hours late in the morning before the crest.

Fact 12: DMX partners made extensive use of Weather Story, HWO, AHPS page and heat products. DMX partners used heat products as DSS tools in flood recovery activities.

Fact 13: The crest on Squaw Creek was 12 hours sooner than forecasted due to rainfall traveling down the basin.

Fact 14: DMX partners made use of the details in the office's call-to-action product statements.

Best Practice 5: An interim Flash Flood Watch update was issued to highlight the potential flood severity with the headline "Extreme Flash Flood Possible Overnight" (see Finding 7 for further enhancements).

Best Practice 6: A Flash Flood Emergency was declared for Polk County within an FFS. This declaration preceded record flooding along Fourmile Creek which inundated mobile homes and apartments. It also preceded a flash flood death which occurred along Mud Creek. In both cases the Flash Flood Emergency declaration provided several hours of lead time.

Best Practice 7: Particularly Dangerous Situation (PDS) wording was included in the FLW for Fourmile Creek. This warning preceded record flooding which inundated mobile homes and apartments.

Best Practice 8: DMX places river forecast and data points—including ALERT gages—on its AHPS Web pages. DMX partners complimented the office on its AHPS Web page configuration because they were easily able to find the information they needed.

Best Practice 9: The Mahaska County emergency manager requested flat boats for rescue operations. This request was included in an FFS issued 0506 CDT on 10 August 2010. DMX staff inserted this request into an FFS. The response was so good that the request for assistance was removed in a subsequent FFS 30 minutes later.

Finding 5: An FFW was issued with the wording "Minor Flooding of poor drainage areas." Record flooding resulted on Walnut Creek and potentially North Walnut Creek which inundated apartment buildings leading to rescues. In addition, flood waters washed out a train track which led to a train derailment.

Recommendation 5: Unless confidence is quite high, refrain from using wording that downplays Flash Flood potential in FFWs. Benefits likely do not outweigh the risks of minimizing the flood severity.

Finding 6: Specific rivers and creeks were rarely mentioned in FFW and FFS products.

Recommendation 6: Hydro warning staff should either manually enter highest impacted basins per data from FFMP or select the appropriate WarnGen bullet for automatic inclusion. Staff should also utilize the local DMX database of flood prone areas.

Finding 7: An interim Flash Flood Watch update was issued to highlight the potential flood severity with the headline "Extreme Flash Flood Possible Overnight."

Recommendation 7: DMX should examine including Particularly Dangerous Situation (PDS) wording in Flash Flood Watches or other similar consistent heightened awareness headlines or messages.

Finding 8: Although some impacts were conveyed to the media via NWSChat, impact statements were not included in DMX FLSs or FLWs due to a lack of confidence in their accuracy. This included locations that received record or near record flooding with substantial inundation of property including Colfax and the Des Moines and Ames metropolitan areas.

Recommendation 8: DMX should continue and expedite their efforts to update and confirm impact statements so that they can be included in future statements and warnings. Also consider the use of locally-developed flood inundation maps to help communicate this information.

Finding 9: At some locations such as Colfax the impact statements were incorrect.

Recommendation 9: NWS staff should continue working on these statements to improve their accuracy.

Finding 10: Feedback from partners and users indicates that the NWS Web site is difficult to navigate.

Recommendation 10: The DMX Services Team needs to elevate the priority of setting up online Web site tutorials. These would help DMX users find the information they are looking for in a timely manner. Even though the Web site is in the process of being redesigned they should still try to create the online tutorials.

Finding 11: Partners expressed uncertainty in the true meaning of "Flash Flood Emergency."

Recommendation 11: DMX needs to develop a local policy for addressing high-end flash flood events. Although the NWS Directives allow for the term "Flash Flood Emergency," such a term may not be the best one to use for DMX partners and users.

a. <u>Communication and Collaboration with Partners</u>

This flooding event required significant interaction between DMX and its partners. The primary partners for this event included various government agencies as well as the media. The primary government agency offices are listed below in alphabetical order. They included but were not limited to:

- Federal level
    - NCRFC
- State of Iowa level
    - Iowa DOT
    - Iowa DPS
    - Iowa HSEMD
- County level
    - Boone County EMA
    - Dallas County EMA
    - Jasper County EMA
    - Mahaska County EMA
    - Polk County EMA
    - Story County EMA

- Local community level
    - City of Ames
    - City of Clive
    - City of Des Moines
    - City of Johnston

Based on DMX interactions with partner agencies during this event, the following common themes emerged:

- Staff at DMX as well as its partners all exhibited dedication to their respective agency missions. All agency staffs were taxed with an extreme workload during this event.
- DMX partners complimented the DMX staff on their dedication, accessibility and knowledge during this event.
- The positive working relationships between DMX and its partners helped facilitate good interagency communication and understanding during this stressful event. These positive working relationships took several years' worth of effort to develop. They also require ongoing efforts to continue.

Fact 15: DMX partners provided several compliments expressing their appreciation for DMX's accessibility by phone 24/7 during the entire event.

Fact 16: DMX staff's positive attitude, patience and dedication to customer service were noted by its partners.

Best Practice 16: Years of networking and relationship building prior to the event between DMX and its partners led to more effective communication and coordination during this event. The communication was much better than during the Great Flood of 1993 in Iowa. An example of better communication is the MICRN system which was developed after the Great Flood of 1993.

3. Relationship Building between DMX and its Partners

DMX believes strongly in the value of having positive working relationships with its partners. It takes considerable effort and time to develop and nurture these relationships. As the August 2010 flood event showed, the effort put into these relationships can reap dividends during high-impact events.

Many of the staff at DMX are involved in relationship building with its partners. This is accomplished via various methods—both informal and formal. A good example of a formal method is the office's COVIP. The WCM leads the COVIP but involves many staff members.

COVIP is a very important program at DMX. It was developed to routinely visit all emergency managers, broadcast media partners, aviation partners and others in the DMX CWA. Each partner is visited by a staff member from DMX at least every three years.

Information about NWS partner's severe weather operations, warning dissemination, flash flood and hazardous weather impacts, NWS products and services used, coordination and collaboration issues and any other issue partners wish to discuss are covered at the COVIP meetings. Information collected has been documented and made available to the staff for use during severe weather and flash flood operations. High impact flash flood basins have been identified and cataloged for use in NWS flash flood products. Since COVIP began in 2004 over 200 visits have been conducted in the DMX CWA.

Although DMX makes relationship building with its partners a high priority, this event showed that some of the staff does not know about all of the office's partners. An example was when a representative from Iowa HSEMD called for a verbal briefing on the river forecast but the DMX staff member did not know about this organization. Likewise, there were a couple times when some of the DMX staff who answered the telephone did not know about the stage or forecast status of the most impacted river forecast points.

Finding 12: In some instances a few employees were not aware of the key partners and major river forecast points that were about to experience a flood of record.

Recommendation 12: Set up orientation materials for new employees to make them aware of all DMX partners not just those involved in hydrology. Also include the major river forecast points in the staff and shift briefings so that those working shift can confer with the lead forecaster or SSH before issuing products or briefings.

4. Communication Methods

In addition to traditional communication methods such as the telephone, DMX used additional communication methods to interact with its partners during this event. Besides the telephone the two most heavily used communication methods included:

- NWSChat
- MICRN

NWSChat is a National Weather Service operational system that utilizes private, secure group chat and instant messaging to communicate with the media and key government partners. 230 NWSChat entries were noted throughout the three events, 212 between local television and radio media and 18 between emergency management and dispatch offices including Story County Emergency Management and Westcom Dispatch (Cities of Clive, Urbandale and West Des Moines).

NWSChat proved to be an efficient method to quickly gather, relay and coordinate weather and hydrologic information between all participants. This included the NWS receiving flood and rainfall reports as well as road closure information. This was especially helpful with detailed information provided by Westcom pertaining to flooding and road closures along Walnut Creek near 63rd Street and Grand Ave in West Des Moines. The power of this medium was also noted during the Oskaloosa flash flood when a call for flat boats from the emergency manager was rescinded only 28 minutes later after the need had quickly been met.

NWSChat has gained wide acceptance and use by television media but interest has yet to increase among radio stations, emergency managers and dispatch offices. NWS staff needs to continue public relations work showing the benefits of NWSChat. The number of users is directly proportional to the success of the system in terms of efficiency and the extent of information sharing.

MICRN was developed after the Great Flood of 1993 as a way to help facilitate better communication between agencies in central Iowa. It is a network comprised of 45 mainly government agencies in seven central Iowa counties. MICRN activities include: National Weather Service watch, warning and advisory dissemination, briefings about ongoing and expected hazardous weather, coordination with partners and coordination between other MICRN partners. MICRN is extremely important in communicating important hazardous weather and non-weather emergency information between government agencies in central Iowa.

Best Practice 10: Frequent briefings to the MICRN network were made during the early morning hours of 09 August 2010 before the record Walnut Creek flood. They included coordination with officials from the Cities of Clive and West Des Moines.

Best Practice 11: Numerous updates and clarifications were provided to the media via NWSChat.

Best Practice 15: Extensive updates of DMX products were broadcast over the MICRN network. This communication tool was used to its fullest potential.

Finding 14: NWSChat was not used to its fullest potential. IADOT used NWSChat but emergency management did not.

Recommendation 14: Continue spreading the word about the usefulness of this instant communication tool.

5. The City of Ames

The City of Ames has staff in its WPCD who run a local HEC-HMS model on the Squaw Creek and South Skunk River at and above the City of Ames. Data from the City's ALERT system are among the major inputs into this model. The City of Ames WPCD staff have developed a database of past events on Ames area streams. Through this database and experience the City of Ames WPCD staff has local expertise on the behavior of Ames area streams.

During the Great Flood of 1993 as well as during subsequent floods communication between DMX and the City of Ames WPCD was inadequate. Often the NWS would release its own forecasts and the City of Ames WPCD would release its own forecasts too. Confusion would result especially when the forecasts did not agree with each other.

Prior to 2005, DMX and the City of Ames WPCD met and made an agreement that the two agencies would coordinate their forecasts when elevated stream levels were expected in the Ames area. Typically DMX has initiated this coordination as the NWS river forecasts incorporate both QPE and QPF whereas the City of Ames WPCD uses solely QPE. This arrangement has led to more consistent forecasts between DMX and the City of Ames WPCD for the Ames area.

Both DMX and the City of Ames WPCD took the coordination to a new level during the August 2010 flooding. Communication between the two agencies started before the Ames flood event and continued for its duration. The communication was frequent at times too. DMX also involved NCRFC in its coordination with the City of Ames WPCD, facilitating direct contact between the two offices. In addition, DMX shared Q2 QPE data with the City of Ames WPCD because the WPCD staff were not aware of that information.

Fact 17: DMX shared Q2 QPE data with the City of Ames WPCD during the event. The Q2 data helped City of Ames WPCD supplement data from the Ames ALERT system rain gage network in making forecasts for the Squaw Creek and Skunk River.

Best Practice 12: The Squaw Creek forecast was proactively coordinated with the City of Ames WPCD as early as 2116 CDT on 10 August 2010.

Best Practice 13: Contingency forecasts from NCRFC with varied amounts of QPF heightened awareness that Squaw Creek may experience major flooding.

Best Practice 14: Extensive coordination between DMX, the City of Ames WPCD and the NCRFC resulted in a crest error of only 0.6 feet with around nine hours lead time to actual crest during the high impact event that flooded Ames and Hilton Coliseum. (The projected crest time was 11 hours late however.)

6. Communicating Uncertainty

DMX highlighted the potential for flooding leading up to this event through various products including its outlook and watch products such as the HWO and FFA respectively. Its warning products for flooding and flash flooding such as the FLW and FFW indicated that flooding or flash flooding were imminent. Per NWS Directives, the probability levels of flood events occurring when mentioned in outlook, watch and warning products are listed in Table 3.

Product Type	Probability	Relevant NWS Directive
Outlook—for flooding or flash flooding (HWO)	[a] No threshold	NWSI 10-517 (Multi-Purpose Weather Products Specification), Section 4 (Hazardous Weather Outlook)
Watch—for flooding or flash flooding (FFA)	50 to 80%	NWSI 10-922 (WFO Hydrologic Products Specification), Section 3 (Areal Flood Watches)
Warning—for flooding or flash flooding (FLW and FFW)	Greater than 80%	NWSI 10-922, Section 7 (Flood Warning for Forecast Points) and Section 5 (Flash Flood Warnings)

Table 3. Probability levels of flood events occurring when mentioned in NWS outlook, watch and warning products.

Notes:

[a] Outlooks are used to convey information on possible flooding and other weather hazards for the seven-day forecast period.

Although NWS offices try to adhere to above prescribed thresholds as much as possible, exceptions do occur. Consider the following hypothetical example involving an FFA. Staff at a WFO issues an FFA for approaching storm systems a few days out. When the FFA is issued the probability of flooding occurring is on the low end of the 50 to 80% range. Then, information from later model runs indicate that the probability of flooding has fallen to below 50%, thus outside the probability range associated with the FFA. Although the probability has fallen below 50% the WFO staff decides to keep the FFA in effect because they believe the models are having difficulty handling the approaching storm system.

The above hypothetical example has happened at DMX. Similarly, there have been situations where the probability of flooding fluctuated between the upper and lower ends of the 50 to 80% probability range while the FFA was in effect.

After the August 2010 flooding DMX partners indicated a desire to know if the flood event probabilities changed from one FFA issuance to another. Partners cited the above examples. They said that although the implicit probability in the products is valuable there is also considerable value in knowing how the probability changes from one FFA issuance to another.

Finding 13: Partners want to know the degree of confidence or uncertainty in the forecast. They also want to know if the confidence or uncertainty changes over time especially for FFAs.

Recommendation 13: The Hydrology section of the AFD now addresses this issue. Outreach should be done to ensure that DMX partners and users know where to find this information.

7. Verification

This section will address the qualitative performance of DMX flood-related warnings and forecasts for this event. Much of the data in this section has been taken from the NWS Performance Management Web site (National Weather Service 2011).

Some of the below verification measures include Probability of Detection, False Alarm Rate and Critical Success Index. The explanations of each measure are below. For more information refer to SWPC 2011 or CAWCR 2011. The citations for those information sources are located in the References section of this document.

- **Probability of Detection (POD)**. A measure of categorical forecast performance equal to the total number of correct event forecasts (i.e., hits) divided by the total number of events observed. Simply stated, it is the percent of events that are forecast.
- **False Alarm Rate (FAR)**. A measure of categorical forecast performance equal to the number of false alarms divided by the total number of event forecasts.
- **Critical Success Index (CSI)**. Also called the Threat Score. The CSI is a measure of categorical forecast performance equal to the total number of correct event forecasts (i.e., hits) divided by the total number of storm forecasts plus the number of misses (i.e., hits + false alarms + misses). The CSI is not affected by the number of non-event forecasts that verify (i.e., correct rejections). However, the CSI is a biased score that is dependent upon the frequency of the event.

a. <u>FFW Verification</u>

A total of 25 FFWs were issued for this event. Table 4 shows the verification data regarding these warnings. Goals regarding U.S. Congress passage of the Government Performance Results Act of 1993 (GPRA) are listed where applicable. GPRA helps set quantitative measures of various Federal Government agencies including the NWS. GPRA is statutory; its performance measurement requirements are law (U.S. Office of Management and Budget 2011).

Criteria	Value	NWS GPRA Goal

# of FFWs	25	
# of verified FFWs	19	
# of unverified FFWs	6	
# of events	62	
# of warned events	46	
# of unwarned events	3	
POD	0.93	0.91
FAR	0.24	
CSI	0.72	
Average lead time	127.0 minutes	107.0 minutes

Table 4. FFW verification for DMX.

b. River Forecast Point FLW Verification

Table 5 shows the DMX FLW verification for this event. Note that the site CLVI4 is not included, as official verification data was not available for that location.

Site ID	**# of Warnings**	**Average Lead Time (hrs)**	**Average Absolute Time Error (hrs)**	**POD**	**FAR**	**CSI**
AESI4	1	0.08	0.35	1.00	0.00	1.00
AMEI4	1	0.00	0.00	0.50	0.00	0.50
AMWI4	2	1.16	1.14	1.00	0.00	1.00
CFXI4	1	1.48	5.95	1.00	0.00	1.00
DFMI4	3	0.67	1.31	0.75	0.00	0.75
DOSI4	3	0.00	0.00	0.50	0.00	0.50
OOAI4	1	10.43	23.57	1.00	0.00	1.00
TOTAL	12	[a] 1.36	[a] 3.01	0.71	0.00	0.71

Table 5. Point-based river FLW verification for DMX.

Notes:

[a] Values are weighted by number of warnings.

c. River FLW Timelines

The graphics below show the timeline regarding the initial river FLW and subsequent FLSs for each forecast point except for CLVI4. The top row of each chart shows the actual event timing for comparison. Refer to the legend near the upper right of each graphic for an explanation of all the symbols.

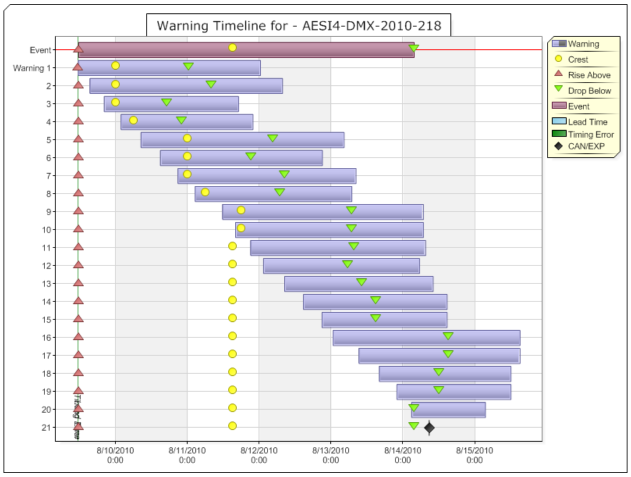


Figure 6. River FLW timeline for each FLW and subsequent updates for AESI4.

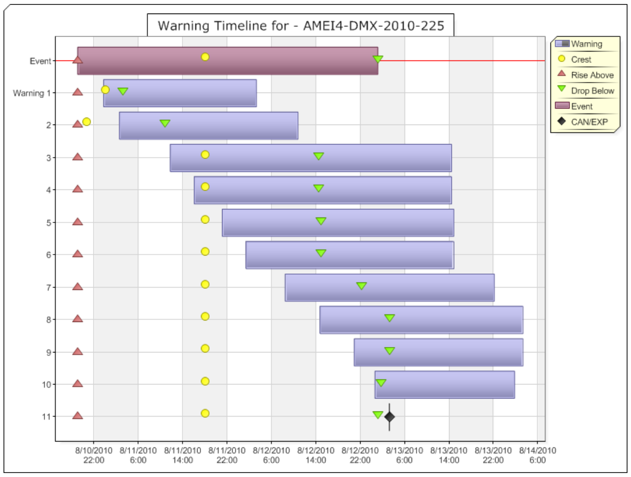


Figure 7. River FLW timeline for each FLW and subsequent updates for AMEI4.

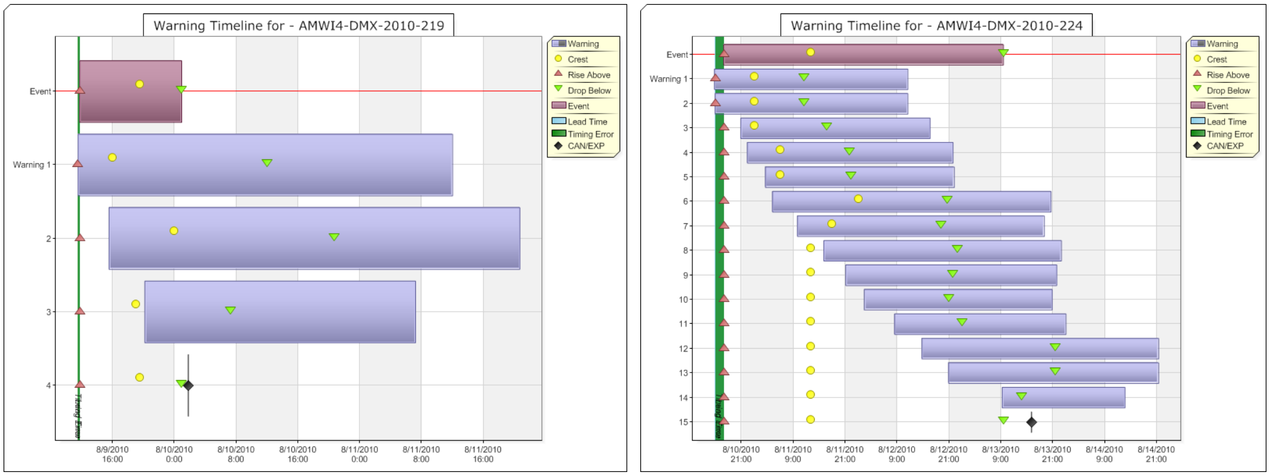


Figure 8. River FLW timeline for each FLW and subsequent updates for AMWI4.

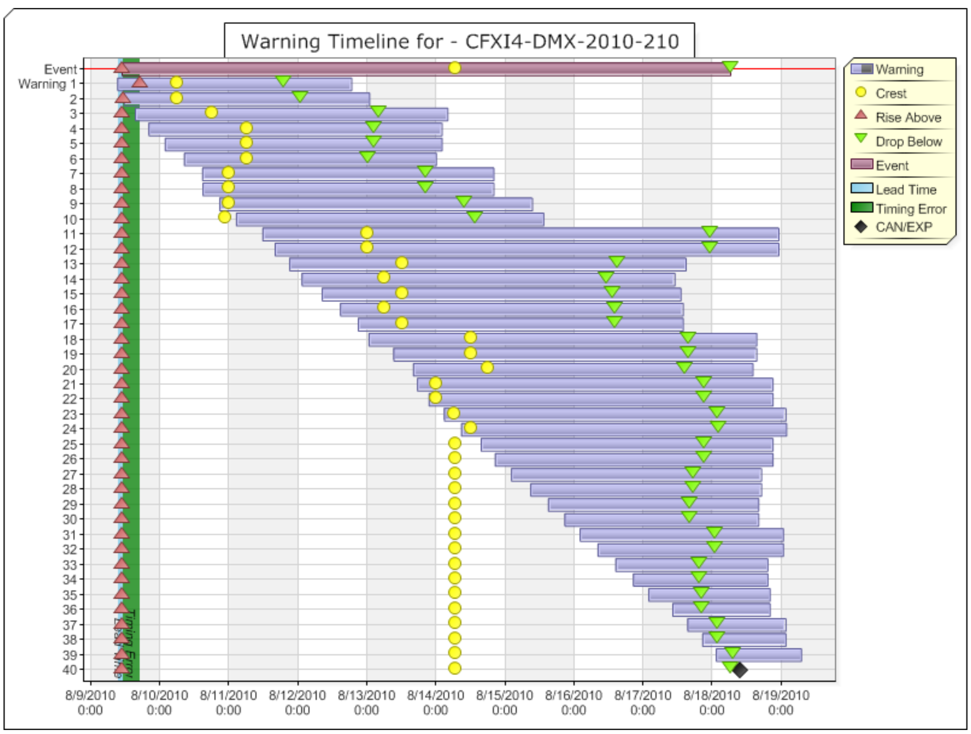


Figure 9. River FLW timeline for each FLW and subsequent updates for CFXI4.

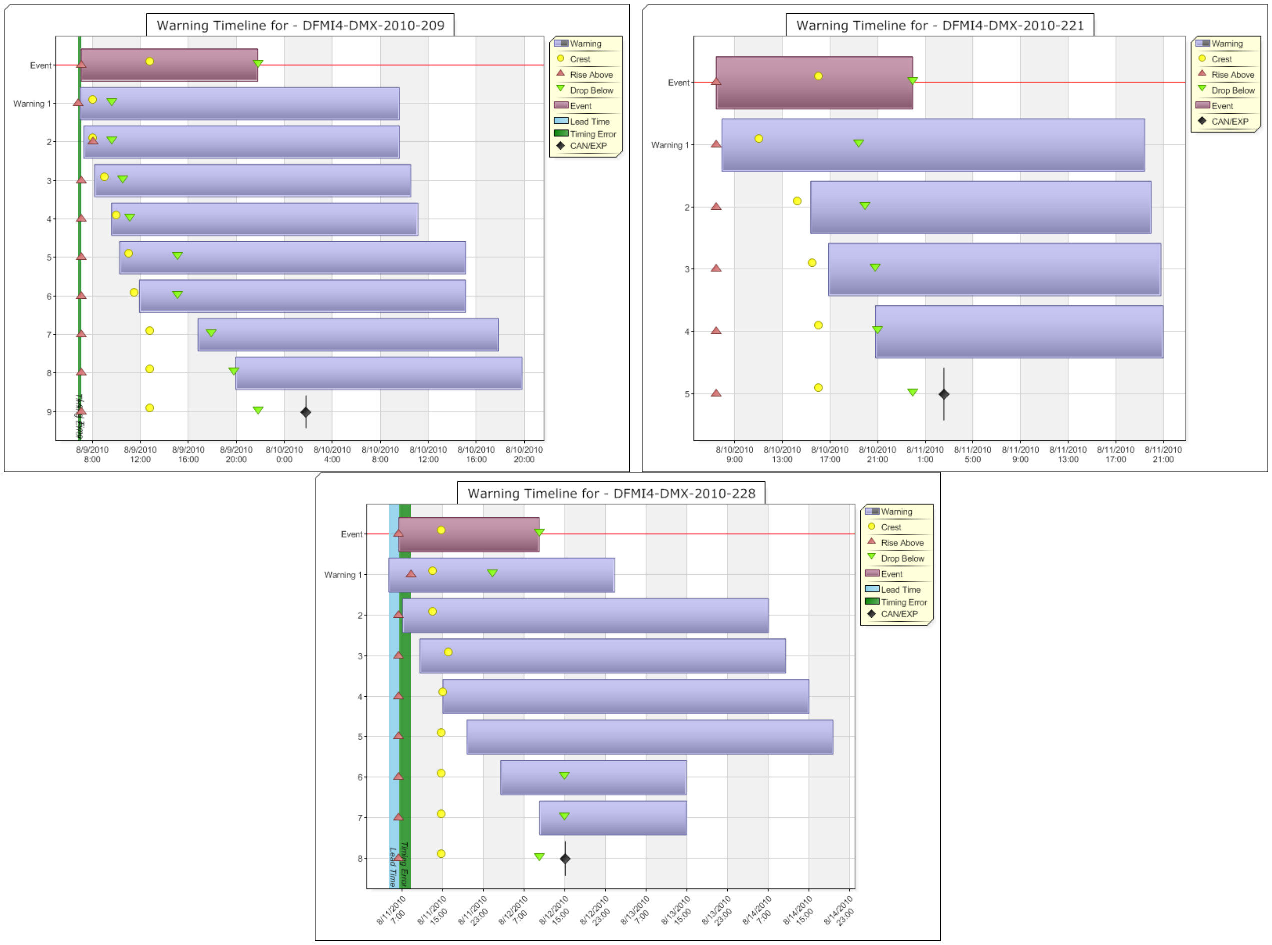
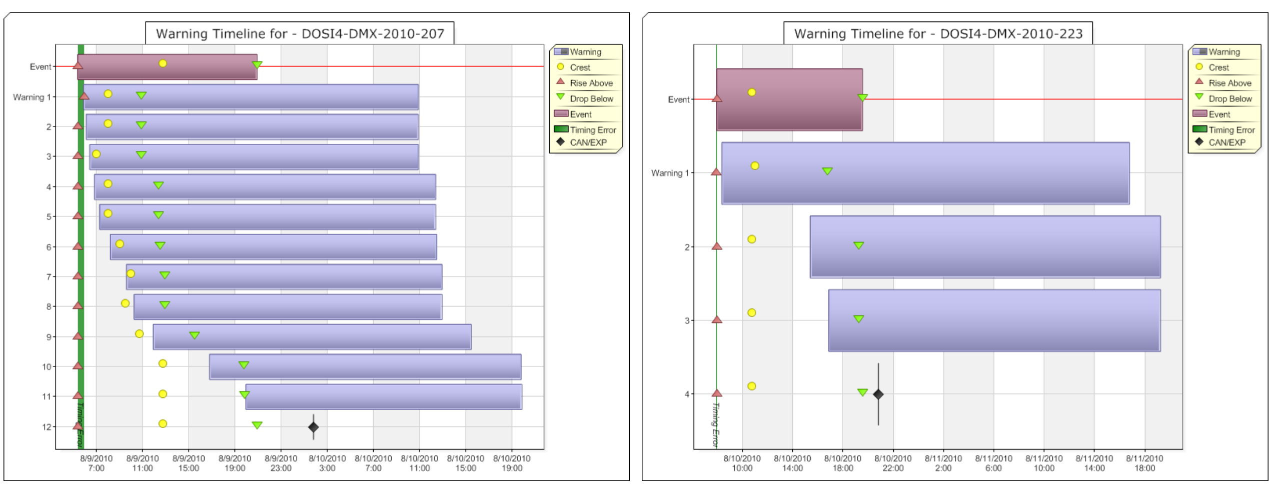


Figure 10. River FLW timeline for each FLW and subsequent updates for DFMI4.



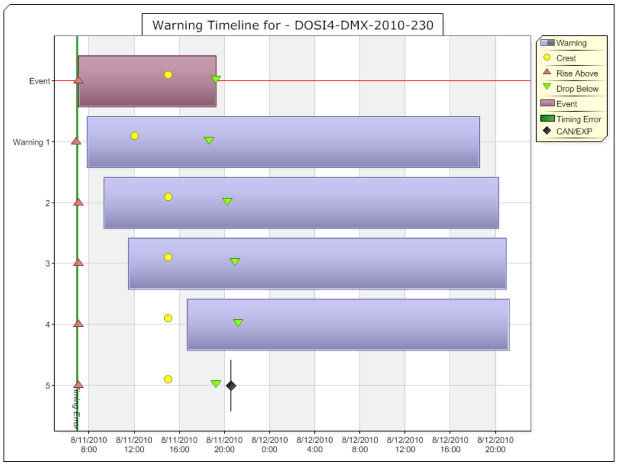


Figure 11. River FLW timeline for each FLW and subsequent updates for DOSI4.

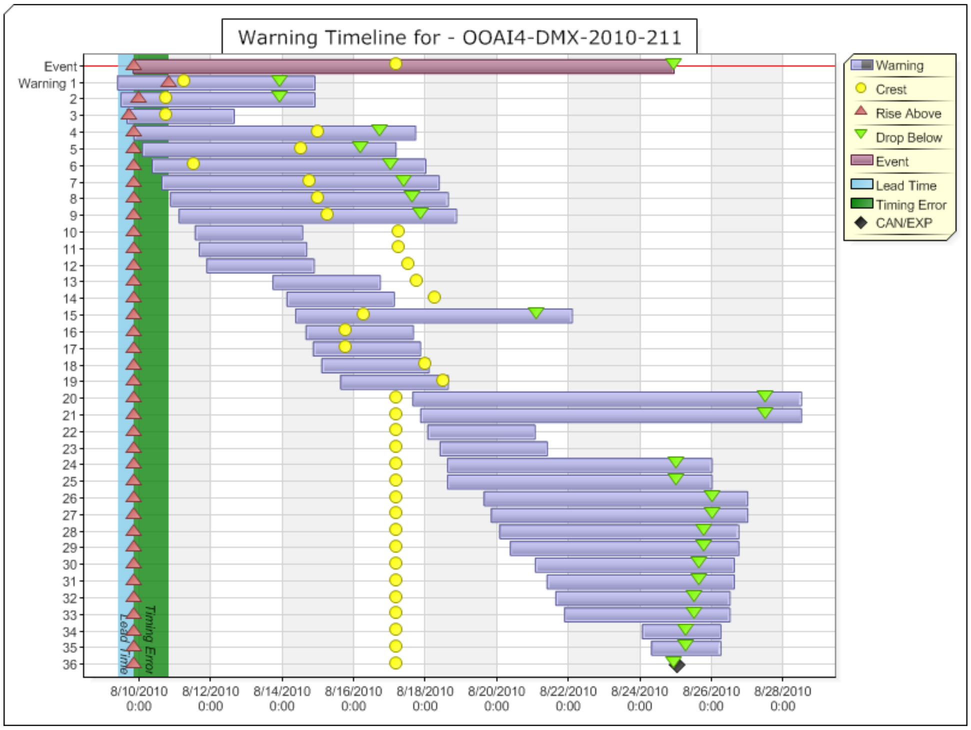


Figure 12. River FLW timeline for each FLW and subsequent updates for OOAI4.

d. <u>NCRFC River Forecast Guidance Verification</u>

The verification data in this section addresses river forecast guidance received by DMX from NCRFC. The river forecast guidance serves as the starting point in the river forecast process.

For significant changes—or for changes to river forecasts during high-end flood events such as this one—DMX coordinated nearly every change with NCRFC.

There are three graphs provided for each location. One graph measures Mean Absolute Error, one measures Mean Error and one measures Root Mean Squared Error. The explanations of each measure are below. For more information refer to SWPC 2011 or CAWCR 2011.

- **Mean Absolute Error (MAE)**. The average magnitude of the forecast errors for all river forecasts for the same forecast time in the verification time period. Mathematically,

$$MAE = \frac{1}{N}\sum_{i=1}^{N} | F_i - O_i |$$

Equation 1. Mean Absolute Error.

- **Mean Error**. Also called the (additive) bias. Mean Error does not measure the magnitude of the errors. It does not measure the correspondence between forecasts and observations (i.e., it is possible to get a perfect score for a bad forecast if there are compensating errors). Mathematically,

$$Mean\ Error = \frac{1}{N}\sum_{i=1}^{N} (F_i - O_i)$$

Equation 2. Mean Error.

- **Root Mean Square Error (RMSE)**. It measures the “average” error, weighted according to the square of the error. RMSE does not indicate the direction of the deviations. The RMSE puts greater influence on large errors than smaller errors, which may be a good things if large errors are especially undesirable, but may also encourage conservative forecasting. Mathematically,

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N} (F_i - O_i)^2}$$

Equation 3. Root Mean Squared Error.

Note that for each graph, there are three lines—one corresponding to forecasts above flood stage, a second one corresponding to forecasts below flood stage and a third one corresponding to combined above and below flood stage forecasts. The reader should focus primarily on the above flood stage forecasts for this event. Although the verification data is for the entire month of August, most of the data concerning forecasts above flood stage is from this particular flood event because this event was mainly when the streams were above flood stage. Note also that the scales of the y-axes vary from graph to graph and for location to location.

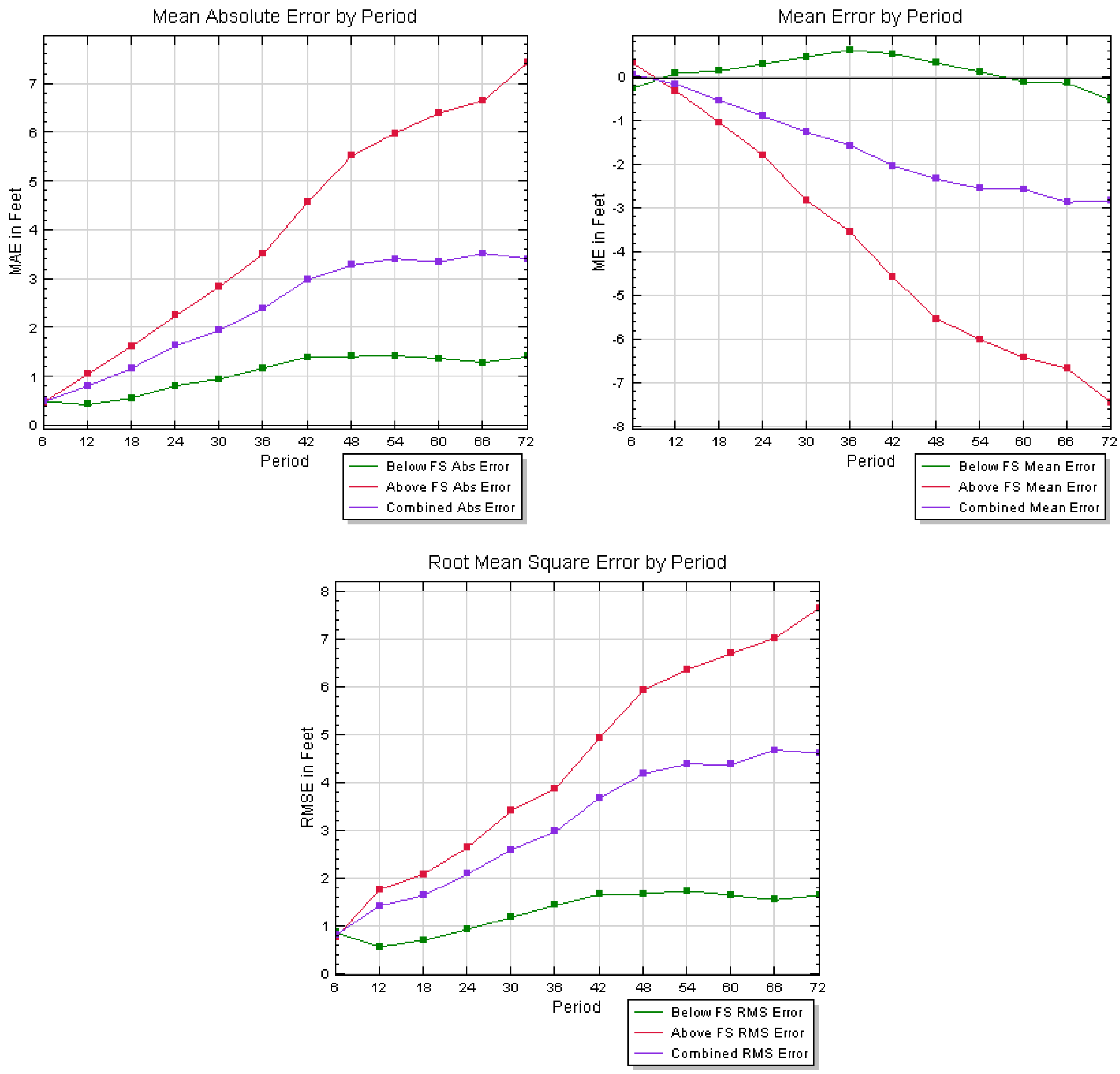


Figure 13. NCRFC river forecast guidance verification for AESI4.

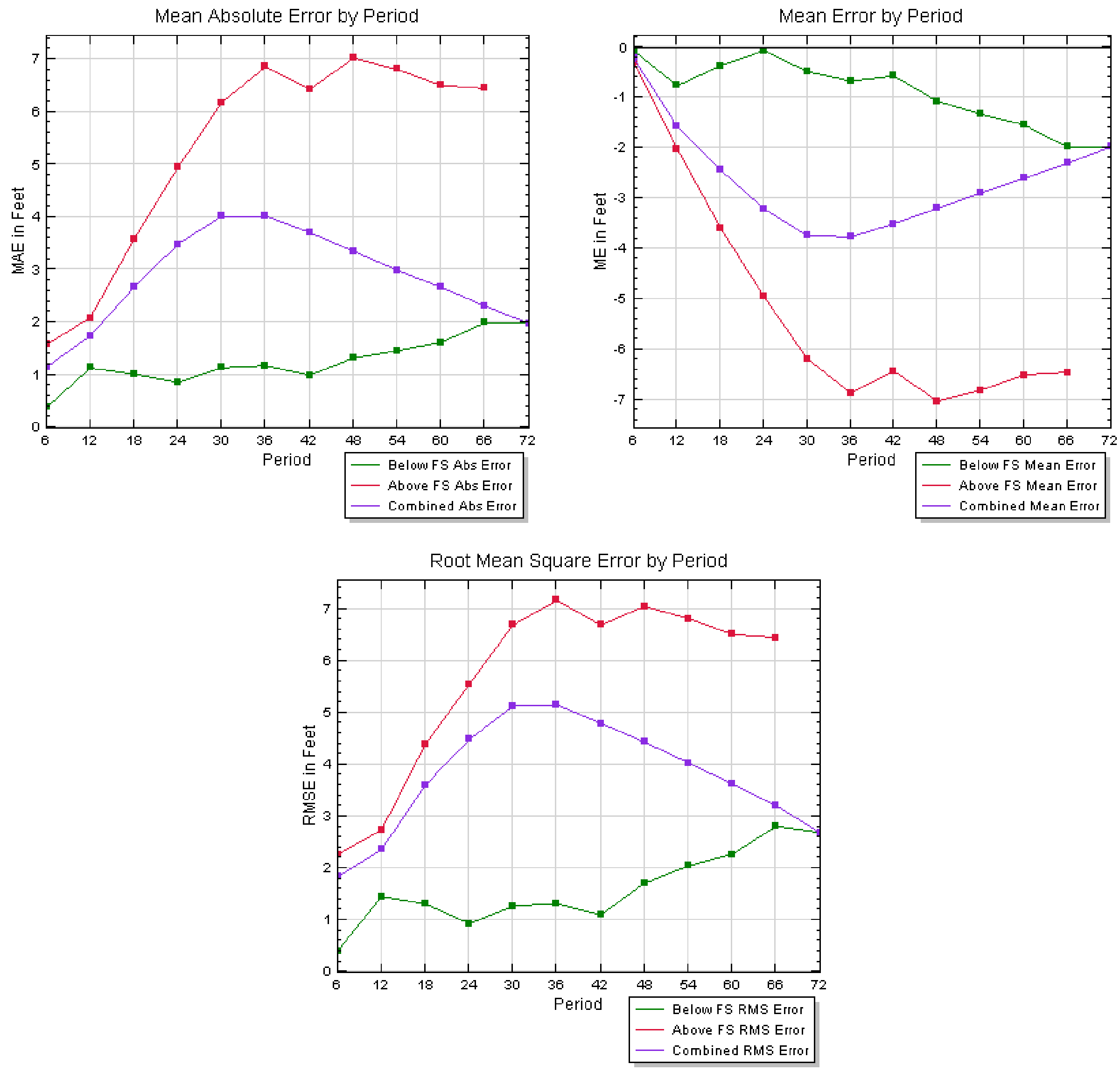


Figure 14. NCRFC river forecast guidance verification for AMEI4.

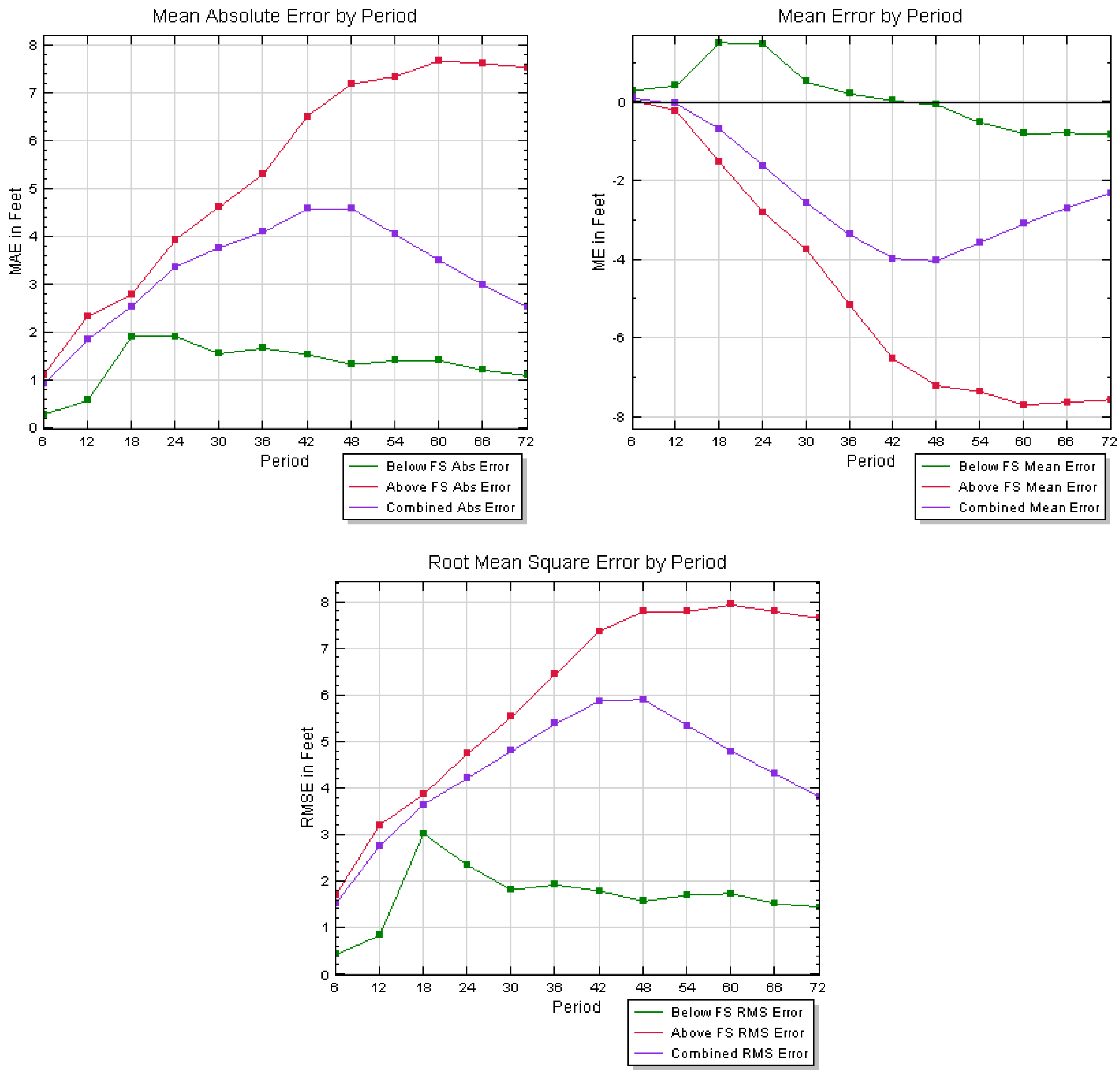


Figure 15. NCRFC river forecast guidance verification for AMWI4.

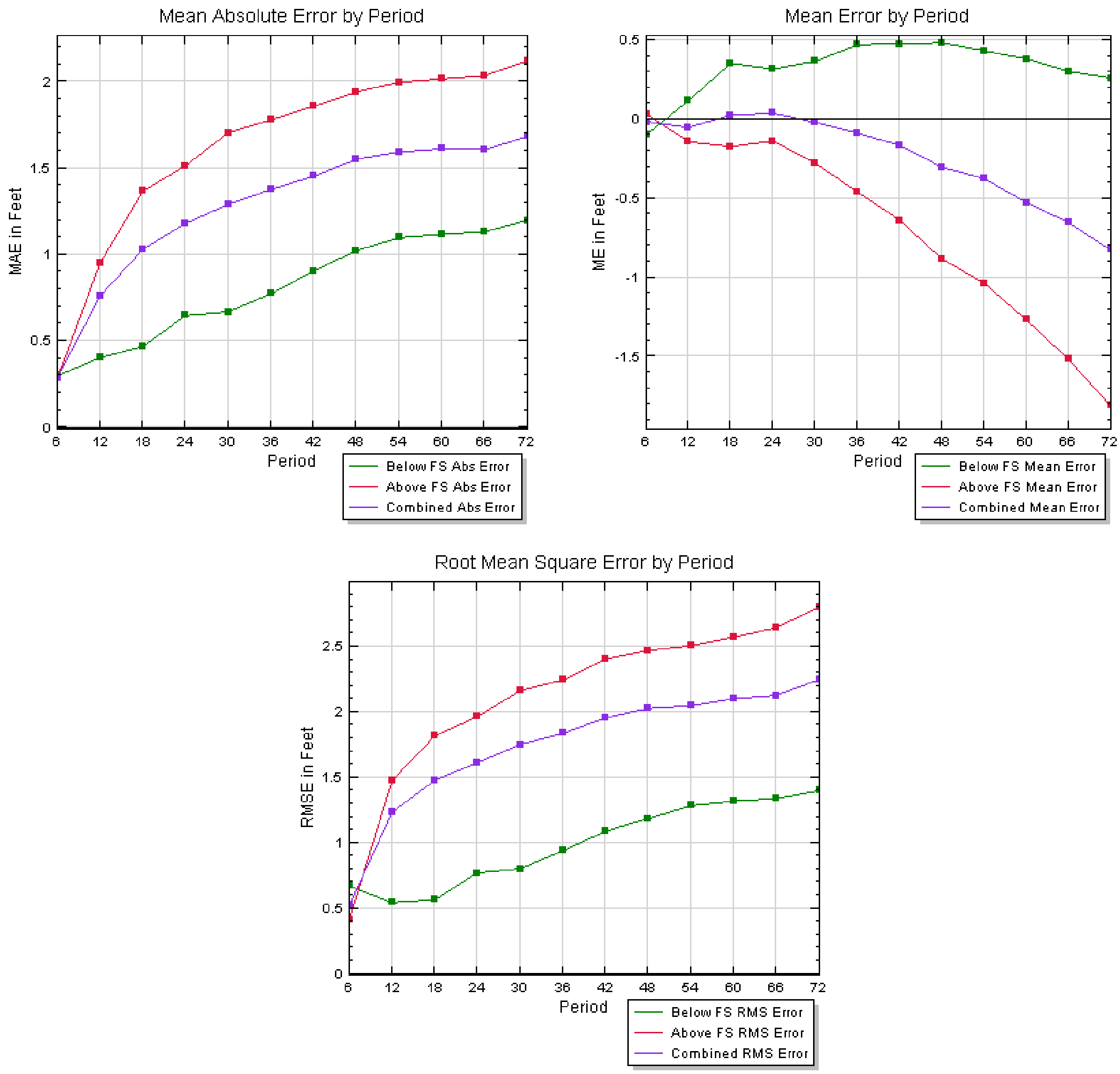


Figure 16. NCRFC river forecast guidance verification for CFXI4.

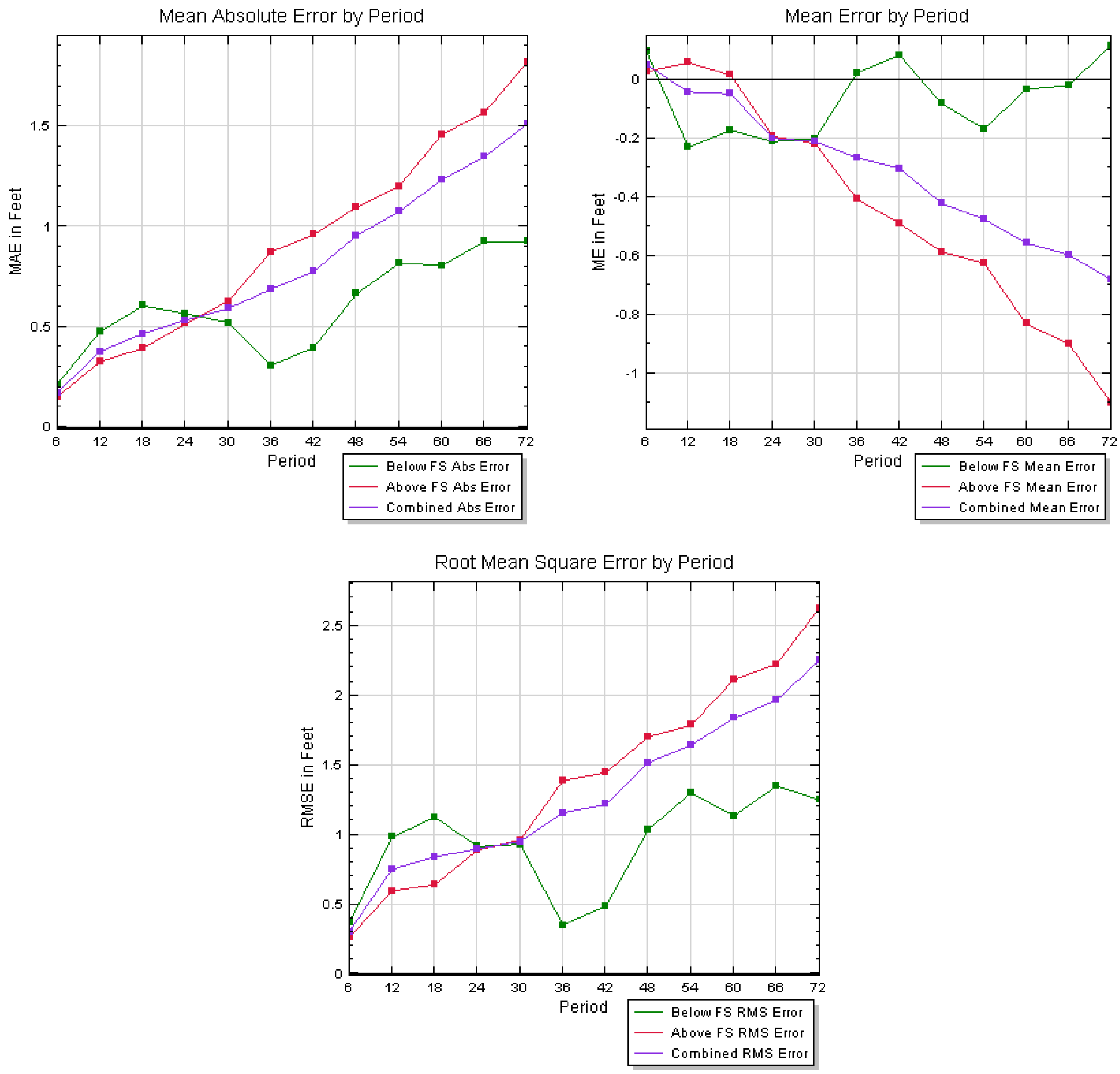


Figure 17. NCRFC river forecast guidance verification for OOAI4.

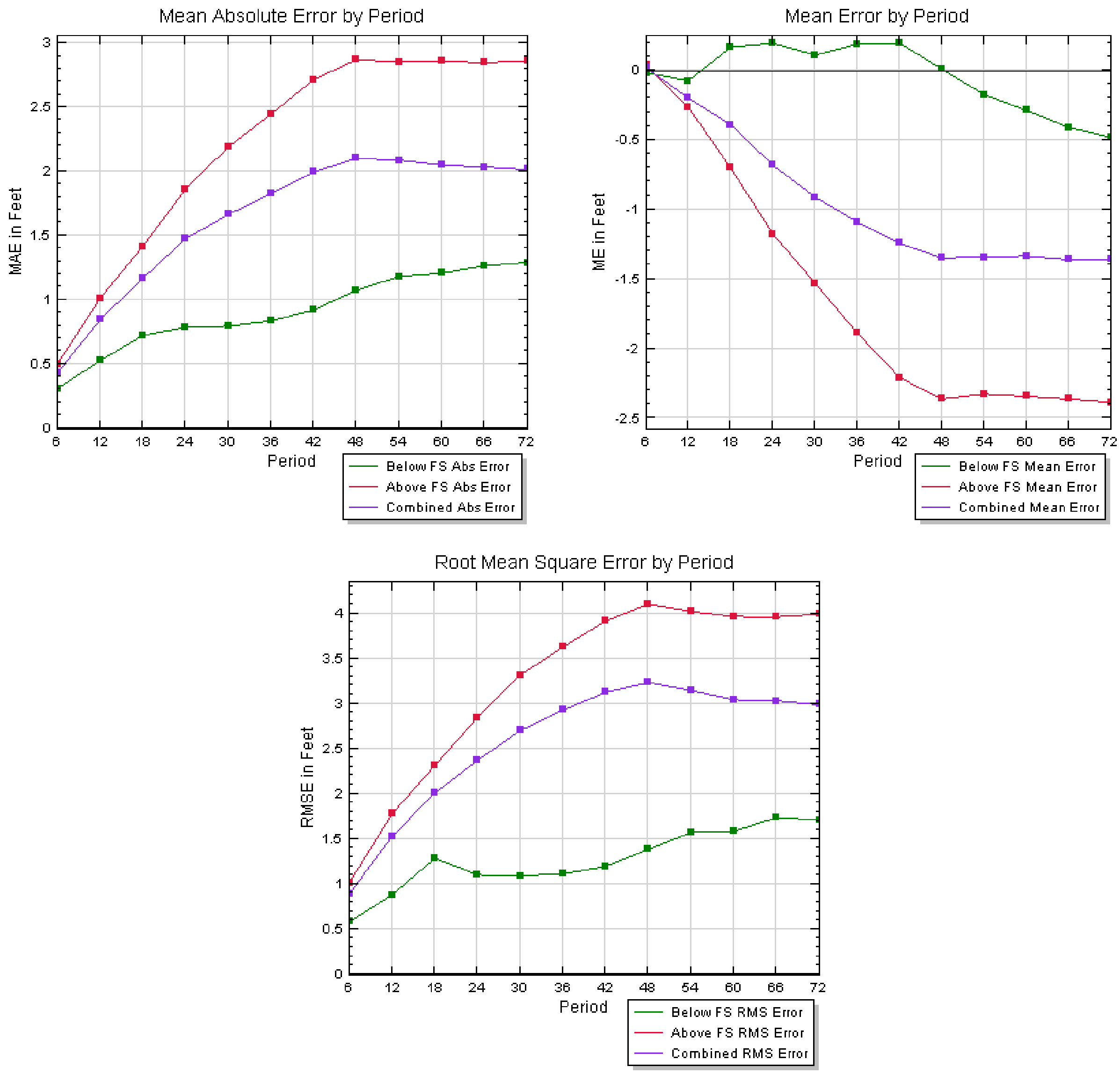


Figure 18. Aggregate NCRFC river forecast guidance verification for AESI4, AMEI4, AMWI4, CFXI4 and OOAI4.

D. SUMMARY OF FACTS

1. DMX Operations and Activities

a. Situational Awareness

Fact 1: Real-time Q2 data allowed DMX staff to better determine actual QPE values especially underneath the most intense rainfall.

Fact 2: The most useful Q2 data included Q2 QPE as well as Q2 Z-R fields.

b. Operational Practices

Fact 3: The DMX SSH was scheduled to work normal operational forecast shifts for each of the three nights during this event. This was due to the office shift planning schedule which was finalized several months in advance. For each night during this event the SSH was relieved of his normal operational forecast shift duties to focus solely on hydrologic activities. Additional staff was brought in to help with normal operational forecast shift duties.

Fact 4: NCRFC forecasts underrepresented Squaw Creek and South Skunk River stream levels late on 10 August 2010 even before additional heavy rains impacted those basins. DMX staff proactively issued FLWs before guidance arrived.

2. DMX Decision Support Services

a. Products

Fact 5: Heavy rain wording was introduced into the HWO on the morning of 06 August 2010.

Fact 6: Heavy rain continued to be mentioned in the HWO into 08 August 2010 including the afternoon issuance (1541 CDT on 08 August 2010) with a Flash Flood Watch. There was no mention of flooding however.

Fact 7: A Flash Flood Watch was in effect for record Walnut Creek flood with around 12 hours lead time to the crest.

Fact 8: Hours later another HWO was issued (1712 CDT on 08 August 2010) which hit the forecast much harder. It specifically mentioned 1 to 2 inch QPF amounts on average and locally up to 5 inches. A Flash Flood Watch remained in effect but there was still no mention of flooding in the HWO.

Fact 9: An FLW was issued for Walnut Creek at Clive I-80/35 (CLVI4) and Des Moines 63rd

Street (DOSI4) with 5 to 7 hours lead time to the crest. The crest errors were -0.06 and -3.19 feet respectively. The 63rd St error was reduced to around 1 foot at 6 hours lead time.

Fact 10: A record crest forecast for Fourmile Creek (DFMI4) was issued 6 hours before the crest time with little error.

Fact 11: Significant and incorrect timing changes were made by NCRFC for Oskaloosa (OOAI4). Cresting timing changed from 18Z 15 August 2010 to 00Z 18 August 2010 just over a day before actual crest. Forecast error increased further from 42 to 54 hours late in the morning before the crest.

Fact 12: DMX partners made extensive use of Weather Story, HWO, AHPS page and heat products. DMX partners used heat products as DSS tools in flood recovery activities.

Fact 13: The crest on Squaw Creek was 12 hours sooner than forecasted due to rainfall traveling down the basin.

Fact 14: DMX partners made use of the details in the office's call-to-action product statements.

b. <u>Communication and Collaboration with Partners</u>

Fact 15: DMX partners provided several compliments expressing their appreciation for DMX's accessibility by phone 24/7 during the entire event.

Fact 16: DMX staff's positive attitude, patience and dedication to customer service were noted by its partners.

Fact 17: DMX shared Q2 QPE data with the City of Ames WPCD during the event. The Q2 data helped City of Ames WPCD supplement data from the Ames ALERT system rain gage network in making forecasts for the Squaw Creek and Skunk River.

E. SUMMARY OF BEST PRACTICES

1. DMX Operations and Activities

a. Situational Awareness

Best Practice 1: DMX staff used real-time Q2 data to supplement QPE data from radar.

b. Operational Practices

Best Practice 2: LARCs were manually interrogated the morning of 09 August 2010 to provide better temporal resolution with Des Moines ALERT data not being ingested into AWIPS.

Best Practice 3: DMX evaluation of the 09 August 2010 river forecast for the Squaw Creek at Ames Lincoln Way and coordination with NCRFC improved the forecast by 3.7 feet, keeping it out of the major flood category.

Best Practice 4: Proactive coordination with the NCRFC resulted in contingency forecasts for Squaw Creek based on varied amounts of QPF.

2. DMX Decision Support Services

a. Products

Best Practice 5: An interim Flash Flood Watch update was issued to highlight the potential flood severity with the headline "Extreme Flash Flood Possible Overnight" (see Finding 7 for further enhancements).

Best Practice 6: A Flash Flood Emergency was declared for Polk County within an FFS. This declaration preceded record flooding along Fourmile Creek which inundated mobile homes and apartments. It also preceded a flash flood death which occurred along Mud Creek. In both cases the Flash Flood Emergency declaration provided several hours of lead time.

Best Practice 7: Particularly Dangerous Situation (PDS) wording was included in the FLW for Fourmile Creek. This warning preceded record flooding which inundated mobile homes and apartments.

Best Practice 8: DMX places river forecast and data points—including ALERT gages—on its AHPS Web pages. DMX partners complimented the office on its AHPS Web page configuration because they were easily able to find the information they needed.

Best Practice 9: The Mahaska County emergency manager requested flat boats for rescue operations. This request was included in an FFS issued 0506 CDT on 10 August 2010. DMX staff inserted this request into an FFS. The response was so good that the request for assistance was removed in a subsequent FFS 30 minutes later.

b. Communication and Collaboration with Partners

Best Practice 10: Frequent briefings to the MICRN network were made during the early morning hours of 09 August 2010 before the record Walnut Creek flood. They included coordination with officials from the Cities of Clive and West Des Moines.

Best Practice 11: Numerous updates and clarifications were provided to the media via NWSChat.

Best Practice 12: The Squaw Creek forecast was proactively coordinated with the City of Ames WPCD as early as 2116 CDT on 10 August 2010.

Best Practice 13: Contingency forecasts from NCRFC with varied amounts of QPF heightened awareness that Squaw Creek may experience major flooding.

Best Practice 14: Extensive coordination between DMX, the City of Ames WPCD and the NCRFC resulted in a crest error of only 0.6 feet with around nine hours lead time to actual crest during the high impact event that flooded Ames and Hilton Coliseum. (The projected crest time was 11 hours late however.)

Best Practice 15: Extensive updates of DMX products were broadcast over the MICRN network. This communication tool was used to its fullest potential.

Best Practice 16: Years of networking and relationship building prior to the event between DMX and its partners led to better communication and coordination during this event. The communication was much better than during the Great Flood of 1993 in Iowa. An example of better communication is the MICRN system which was developed after the Great Flood of 1993.

F. SUMMARY OF FINDINGS AND RECOMMENDATIONS

1. DMX Operations and Activities

a. Situational Awareness

Finding 1: An FLW was issued for Walnut Creek at Des Moines 63rd St with zero lead time. The stage at issuance was 0.9 feet over flood stage and was rising rapidly. Des Moines ALERT data was unavailable and DCP data only provided 15 minute increments of data every hour. The creek rose over eight feet in an hour so higher temporal resolution data was critical.

Recommendation 1: Emphasize staff awareness of AWIPS stage and rate-of-change alarms. Create a pre-event hydro checklist to ensure ALERT data is current and available wherever ALERT systems exist.

b. Operational Practices

Finding 2: In many instances, DMX software formatters for ESFs, FLWs and FLSs did not capture the second, higher crest. They also incorrectly identified stage trends. These problems occurred primarily with the South Skunk River near Oskaloosa (OOAI4) and resulted in inconsistent and incorrect forecasts even within days of the ultimate crest. This was especially apparent in crest timing with dramatic run to run changes.

Recommendation 2: DMX staff should visually evaluate hydrographs when composing products to ensure that text wording accurately reflects expected conditions. Any formatter configuration issues beyond the control of DMX should be addressed at higher levels within the NWS.

Finding 3: DMX RiverPro software formatters produced incorrect information. In one instance they inserted “no flooding is occurring” wording while current stage was three feet over flood stage. In another instance the formatters pulled in old river stage data.

Recommendation 3: DMX staff should ensure that the RiverPro software is using the latest data. RiverPro should also be configured to automatically ingest the latest data without manual, forced data refresh. This change would need to be implemented at a higher level than DMX. Staff should also proofread text products to ensure formatters are generating correct information. Formatter code should be checked for potential bugs and errors.

Finding 4: The second crest above flood stage was missed along the Walnut Creek at Des Moines 63rd Street (DOSI4) on 10 August 2010. The Site Specific unit hydrograph was incapable of generating this type of response.

Recommendation 4: DMX researched the hydrologic response at DOSI4 and coordinated those findings with the NCRFC. NCRFC staff agreed that a change is needed and developed a unit hydrograph more representative with two crests. A new unit hydrograph was loaded for DOSI4 in November 2010.

2. DMX Decision Support Services

a. Products

Finding 5: An FFW was issued with the wording "Minor Flooding of poor drainage areas." Record flooding resulted on Walnut Creek and potentially North Walnut Creek which inundated apartment buildings leading to rescues. In addition, flood waters washed out a train track which led to a train derailment.

Recommendation 5: Unless confidence is quite high, refrain from using wording that downplays Flash Flood potential in FFWs. Benefits likely do not outweigh the risks of minimizing the flood severity.

Finding 6: Specific rivers and creeks were rarely mentioned in FFW and FFS products.

Recommendation 6: Hydro warning staff should either manually enter highest impacted basins per data from FFMP or select the appropriate WarnGen bullet for automatic inclusion. Staff should also utilize the local DMX database of flood prone areas.

Finding 7: An interim Flash Flood Watch update was issued to highlight the potential flood severity with the headline "Extreme Flash Flood Possible Overnight."

Recommendation 7: DMX should examine including Particularly Dangerous Situation (PDS) wording in Flash Flood Watches or other similar consistent heightened awareness headlines or messages.

Finding 8: Although some impacts were conveyed to the media via NWSChat, impact statements were not included in DMX FLSs or FLWs due to a lack of confidence in their accuracy. This included locations that received record or near record flooding with substantial inundation of property including Colfax and the Des Moines and Ames metropolitan areas.

Recommendation 8: DMX should continue and expedite their efforts to update and confirm impact statements so that they can be included in future statements and warnings. Also consider the use of locally-developed flood inundation maps to help communicate this information.

Finding 9: At some locations such as Colfax the impact statements were incorrect.

Recommendation 9: NWS staff should continue working on these statements to improve their accuracy.

Finding 10: Feedback from partners and users indicates that the NWS Web site is difficult to navigate.

Recommendation 10: The DMX Services Team needs to elevate the priority of setting up online Web site tutorials. These would help DMX users find the information they are looking for in a timely manner. Even though the Web site is in the process of being redesigned they should still try to create the online tutorials.

Finding 11: Partners expressed uncertainty in the true meaning of "Flash Flood Emergency."

Recommendation 11: DMX needs to develop a local policy for addressing high-end flash flood events. Although the NWS Directives allow for the term "Flash Flood Emergency," such a term may not be the best one to use for DMX partners and users.

b. Communication and Collaboration with Partners

Finding 12: In some instances a few employees were not aware of the key partners and major river forecast points that were about to experience a flood of record.

Recommendation 12: Set up orientation materials for new employees to make them aware of all DMX' partners not just those involved in hydrology. Also include the major river forecast points in the staff and shift briefings so that those working shift can confer with the lead forecaster or SSH before issuing products or briefings.

Finding 13: Partners want to know the degree of confidence or uncertainty in the forecast. They also want to know if the confidence or uncertainty changes over time especially for FFAs.

Recommendation 13: The Hydrology section of the AFD now addresses this issue. Outreach should be done to ensure that DMX partners and users know where to find this information.

Finding 14: NWSChat was not used to its fullest potential. IADOT used NWSChat but emergency management did not.

Recommendation 14: Continue spreading the word about the usefulness of this instant communication tool.

G. APPENDICES

1. Acronyms

Acronym	**Definition**
12Planet	Internal NWS Chat Software
AEP	Annual Exceedance Probability
AFD	Area Forecast Discussion
AGL	Above Ground Level
AHPS	Advanced Hydrologic Prediction Service
ALERT	Automated Local Evaluation in Real-Time
AWIPS	Advanced Weather Interactive Processing System
cfs	Cubic Feet per Second
CAPE	Convective Available Potential Energy
CDT	Central Daylight Time
COVIP	County Visitation Program
CWA	County Warning Area
DMX	Weather Forecast Office (WFO) Des Moines, Iowa
DOT	Department of Transportation
DPS	Department of Public Safety
DSS	Decision Support Services
EAS	Emergency Alert System
EM	Emergency Management/Manager
EMA	Emergency Management Agency
ESF	Hydrologic Outlook
EOC	Emergency Operations Center
FEMA	Federal Emergency Management Agency
FFA	Flash Flood Watch
FFG	Flash Flood Guidance
FFMP	Flash Flood Monitoring and Prediction
FFS	Flash Flood Statement
FFW	Flash Flood Warning
FLS	River Flood Statement
FLW	Flood Warning
GFS	Global Forecast System
HPC	Hydrometeorological Prediction Center
HSEMD	Homeland Security and Emergency Management Division
HWO	Hazardous Weather Outlook
IR	Infrared
ITCZ	Inter-Tropical Convergence Zone
LARC	Limited Automatic Remote Collector
LSR	Local Storm Report
mb	Millibar
MCS	Mesoscale Convective System
MICRN	Metropolitan Incident Command Radio Network

MSL	Mean Sea Level
NAM	North American Model
NCEP	National Centers for Environmental Prediction
NCRFC	North Central River Forecast Center
NOAA	National Oceanic and Atmospheric Administration
NWR	NOAA Weather Radio All Hazards
NWS	National Weather Service
NWSChat	Internet-based chat software
NWSI	National Weather Service Instruction
QPE	Quantitative Precipitation Estimation
QPF	Quantitative Precipitation Forecast
RAOB	Rawinsonde Observation
RFC	River Forecast Center
SSH	Senior Service Hydrologist
SSHPS	Site Specific Hydrologic Prediction System
SWE	Snow Water Equivalent
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
USDA	United States Department of Agriculture
UTC	Universal Time Coordinated
WFO	Weather Forecast Office
WPCD	Water and Pollution Control Department

Table 6. Acronyms used in this service assessment report.

2. NWS Definitions

a. Fact, Finding, Recommendation and Best Practice

Fact: A verifiable statement describing something important learned from the assessment for which no action is necessary. Facts are not numbered but often lead to recommendations.

Finding: A statement describing something important learned from the assessment for which an action may be necessary. Findings are numbered in ascending order and are associated with a specific recommendation or action.

Recommendation: A specific course of action based on an associated finding that should improve NWS operations and services. Not all recommendations may be achievable but they are important to document. If the affected office(s) and the Office of Climate, Water and Weather Services determine a recommendation will improve NWS operations and/or services and it is achievable, then the recommendation will likely become an action. Recommendations should be clear, specific and measurable.

Best Practice: An activity or procedure producing outstanding results during a particular situation that could be used to improve effectiveness and/or efficiency throughout the organization in similar situations. No action is required.

b. Flood Severity Levels

The NWS specifies the following definitions of flood categories in NWS Manual 10-950 (Definitions and General Terminology):

Minor Flooding: Minimal or no property damage but possibly some public threat.

Moderate Flooding: Some inundation of structures and roads near stream. Some evacuations of people and/or transfer of property to higher elevations.

Major Flooding: Extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations.

Record Flooding: Flooding which equals or exceeds the highest stage or discharge observed at a given site during the record-keeping period. The highest stage on record is not necessarily above the other three categories. It may be within any of them or even less than the lowest.

c. Other Definitions

Annual Exceedance Probability (AEP) and Annual Recurrence Interval (ARI):

- **Annual Exceedance Probability (AEP)**: The chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 cfs has an AEP of 5%, it means that there is a 5% chance (i.e., a 1 in 20 chance) of a peak discharge of 500 cfs (or larger) occurring in any one year.
- **Annual Recurrence Interval (ARI)**: The long-term average number of years between the occurrence of a flood as big as (or larger than) the selected event. For example, floods with a discharge as great as (or greater than) the 20-year ARI design flood will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event. It is implicit in this definition that the periods between exceedances are generally random.
- **Note**: The AEP and ARI are reciprocals of each other. For example an AEP of 0.02 (i.e., 2%) has an ARI of 50 years. Also an AEP of 0.50 (i.e., 50%) has an ARI of 2 years.

Partners: Refers to organizations acting in an official capacity such as federal agencies (e.g., USACE, USGS), media, local community officials and local and state EM agencies.

Users: General public and private entities such as businesses.

National Weather Service offices are responsible for forecasts and warnings with respect to hydrological events as outlined below.

HPC: Provides forecasts, guidance and analysis products and services to support the 24/7 public forecasting activities of the NWS and other HPC customers. HPC develops and distributes daily QPFs to all CONUS NWS offices and posts them online for public use. QPFs are evaluated and used by the RFCs to prepare river stage forecasts.

RFC: There are 13 NWS RFCs across the United States which provide hydrologic forecasting. RFCs also provide a range of hydrometeorological data including river stage forecasts for over 4,400 locations. Each RFC provides these river forecasts to local WFOs within the RFC's service area. The NCRFC, located in Chanhassen, Minnesota is responsible for forecasts along the Mississippi River and its tributaries including the South Skunk River, Squaw Creek, Walnut Creek and Fourmile Creek. River forecasts from the NCRFC are provided to DMX for evaluation and public dissemination.

WFOs receive river forecasts and guidance from RFCs. After reviewing the river forecasts for accuracy WFO forecasters use this guidance to compose flood watches, warnings and advisories for public dissemination.

3. 08-09 August 2010 Weather Event Overview

The air mass which produced the heavy rainfall that led to flash flooding and eventual river flooding was tropical in nature. In Figure 19 the 250 mb map shows a long wave trough located over the Desert Southwest with a strong ridge over the Southern Plains. The subtropical jet emerged across Four Corners region and traveled through the ridge over the High Plains and across the Great Lakes (A). As seen in the 500 mb map several embedded short waves were ejected off the upper level low and triggered convection (B). At lower levels of the atmosphere both the 850 and 925 mb maps indicate a very moist environment. At 850 mb there is a stream of +18^{o}C dew points centered over western Iowa (C) and 925 mb there is an area of +20^{o}C dew points with a local maximum of +26^{o}C are observed over Iowa (D).

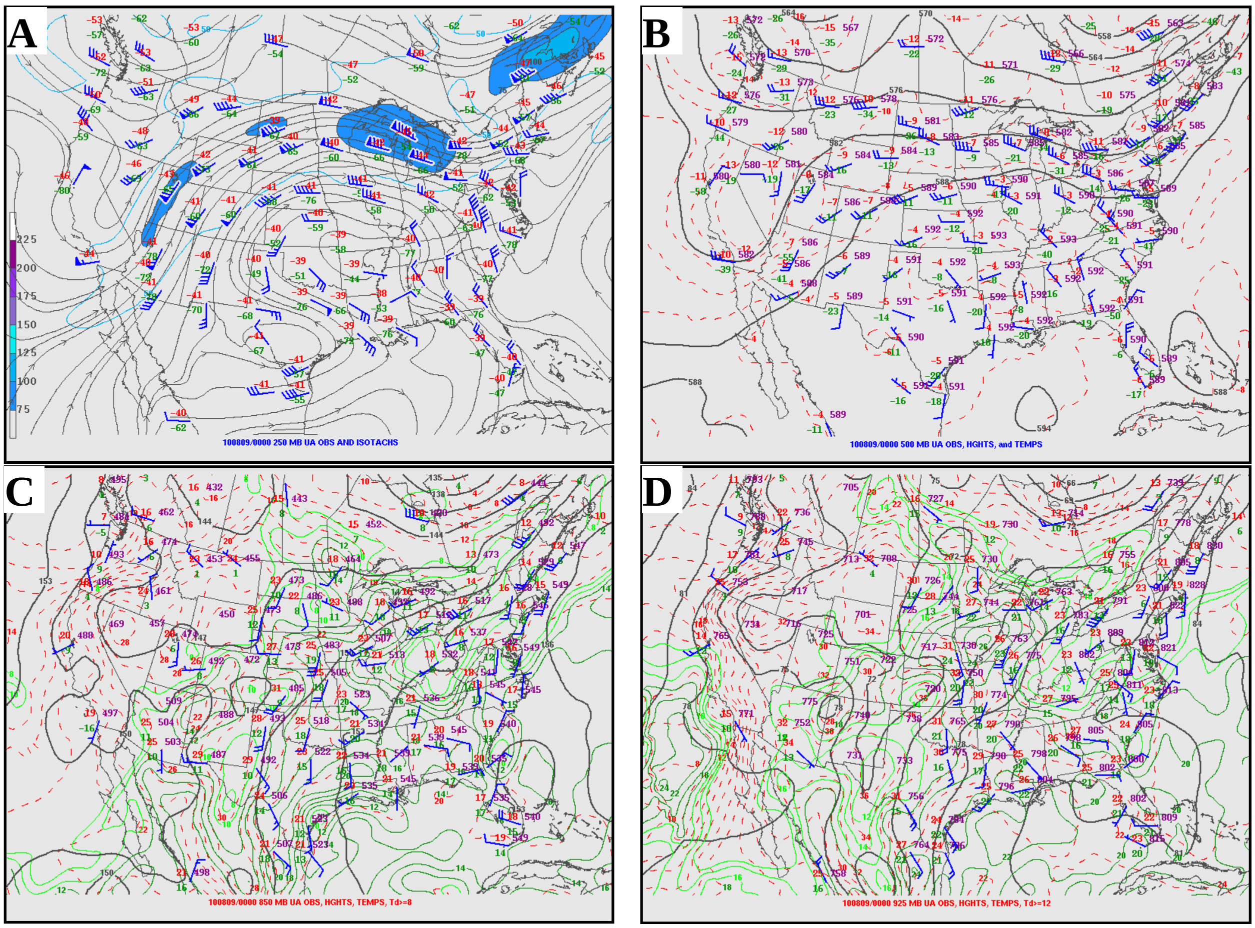


Figure 19. Four panel plot showing A) 250 mb, B) 500 mb, C) 850 mb and D) 925 mb upper air plots and analyses valid at 00Z on 09 August 2010. The synoptic set-up that preceded the record flooding in the Walnut Creek basin shows weak steering flow in the upper levels and abundant moisture in the lower levels. This configuration is similar to heavy rain conceptual model developed by Maddox et al. (1979).

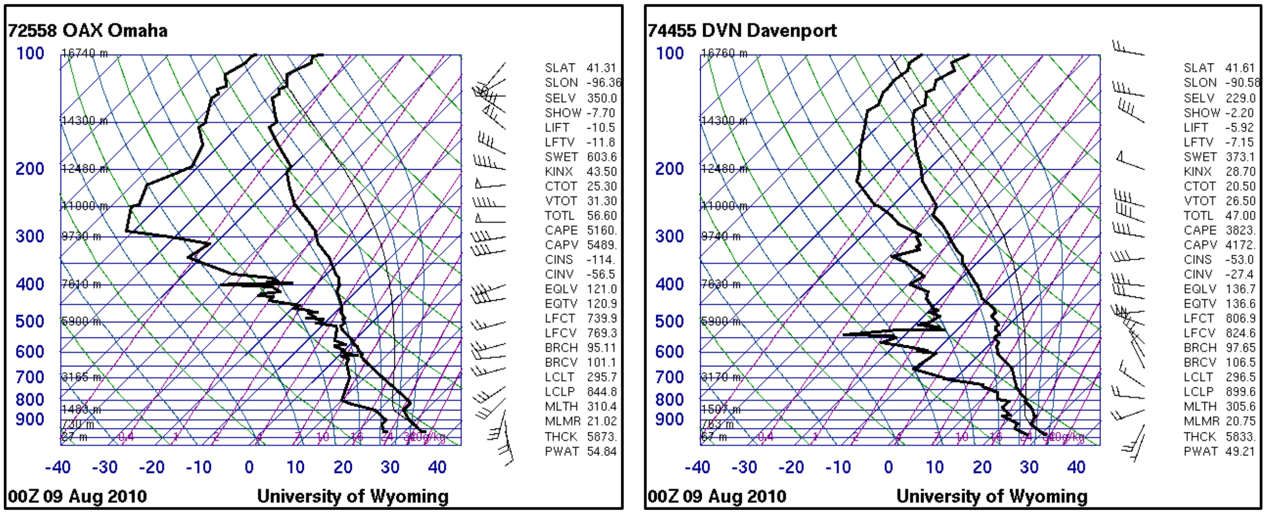


Figure 20. Atmospheric soundings from Omaha (left) and Davenport (right) at 00Z on 09 August 2010. Both soundings show large CAPE values as well as high precipitable water (PWAT) values. The winds across Davenport (DVN) are noticeably weak with values less than 30 knots in the lowest 500 mb.

Upper air soundings (Figure 20) from Omaha and Davenport on 00Z on 09 August 2010 identified a moist atmosphere with precipitable water values of 2.16 and 1.94 inches respectively. According to a database from the NWS Rapid City, South Dakota these values exceed in the 99th percentile for each location when compared to the 15-year average. Figure 21 shows a 00Z surface analysis with IR satellite overlaid indicating the developing MCS over northeast Nebraska which eventually moved across central Iowa early morning on 08 August 2010. As the MCS moved eastward with the mean flow it was sustained by the veering winds associated with the low level jet and developed south. The result was east/southeastward propagation. The first FFW was issued at 0250Z on 09 August 2010 for north central Iowa and at 0340Z on 09 August 2010 for central Iowa. Eleven total FFWs were issued between the hours of 0250Z and 0953Z on 09 August 2010. Radar screen captures show the original line of storms that moved through central Iowa as well as the new cells which developed on the southern side (Figure 22). The average lead time for all events was over two and a half hours.

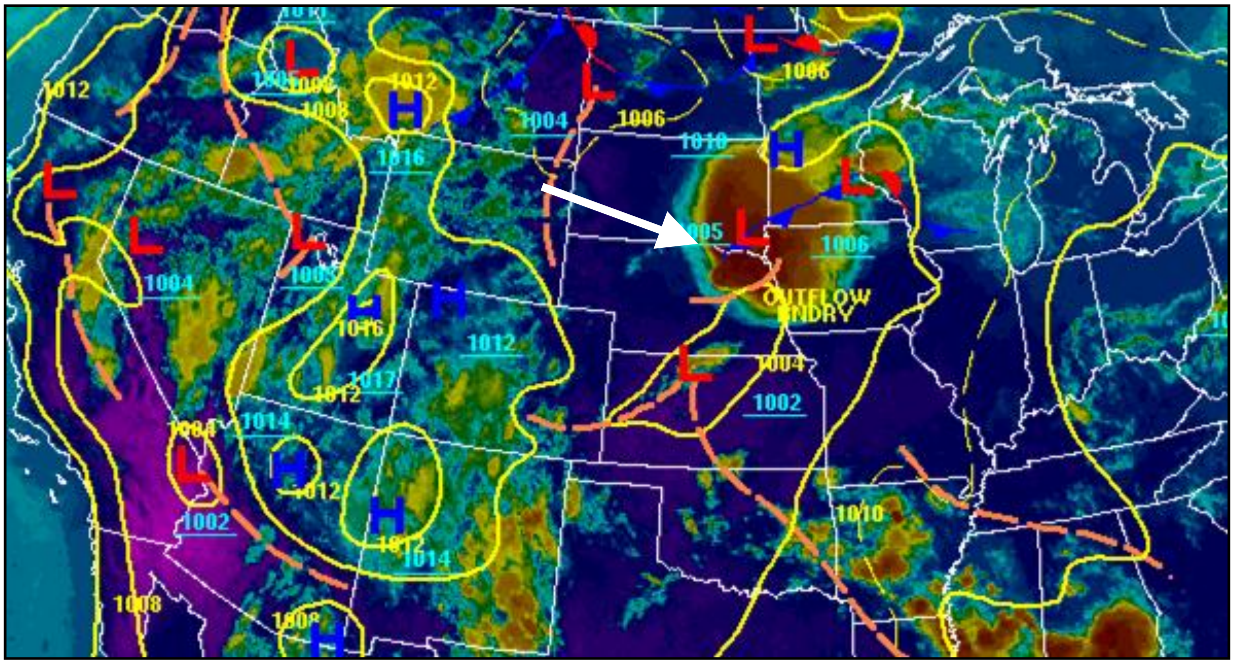


Figure 21. Surface analysis and IR image from 00Z on 09 August 2010 show a large MCS (white arrow) located over the Missouri River valley. This thunderstorm complex slowly propagated southeast across Iowa.

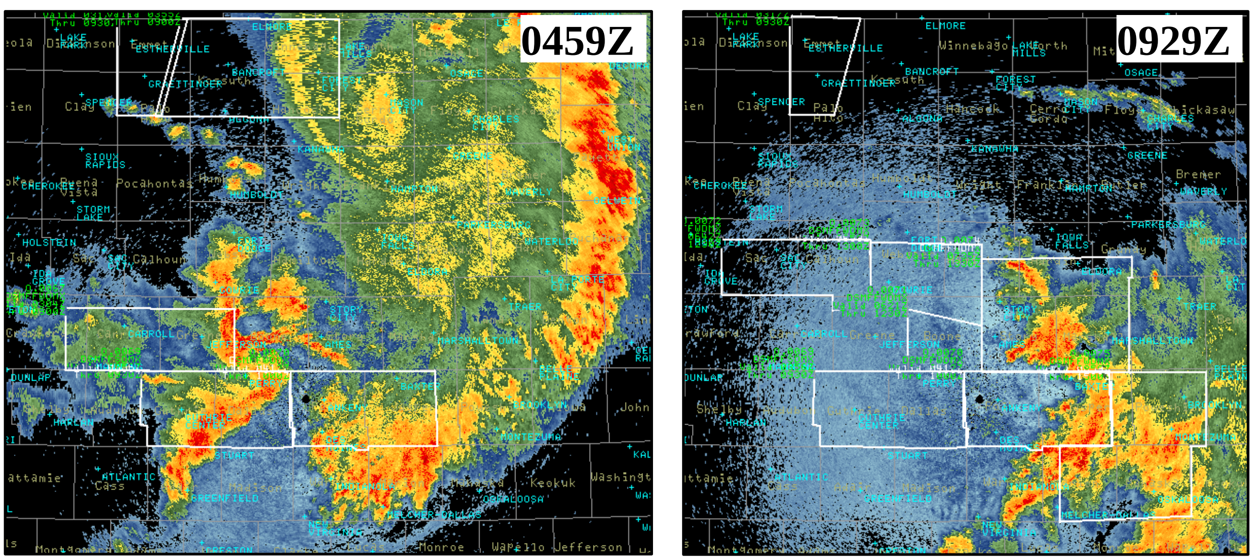


Figure 22. These two images show the FFWs (white polygons) across central Iowa during the early morning hours of 09 August 2010. The widespread rainfall resulted in 11 FFWs and primed central Iowa for the historic flooding that ensued over the next several days.

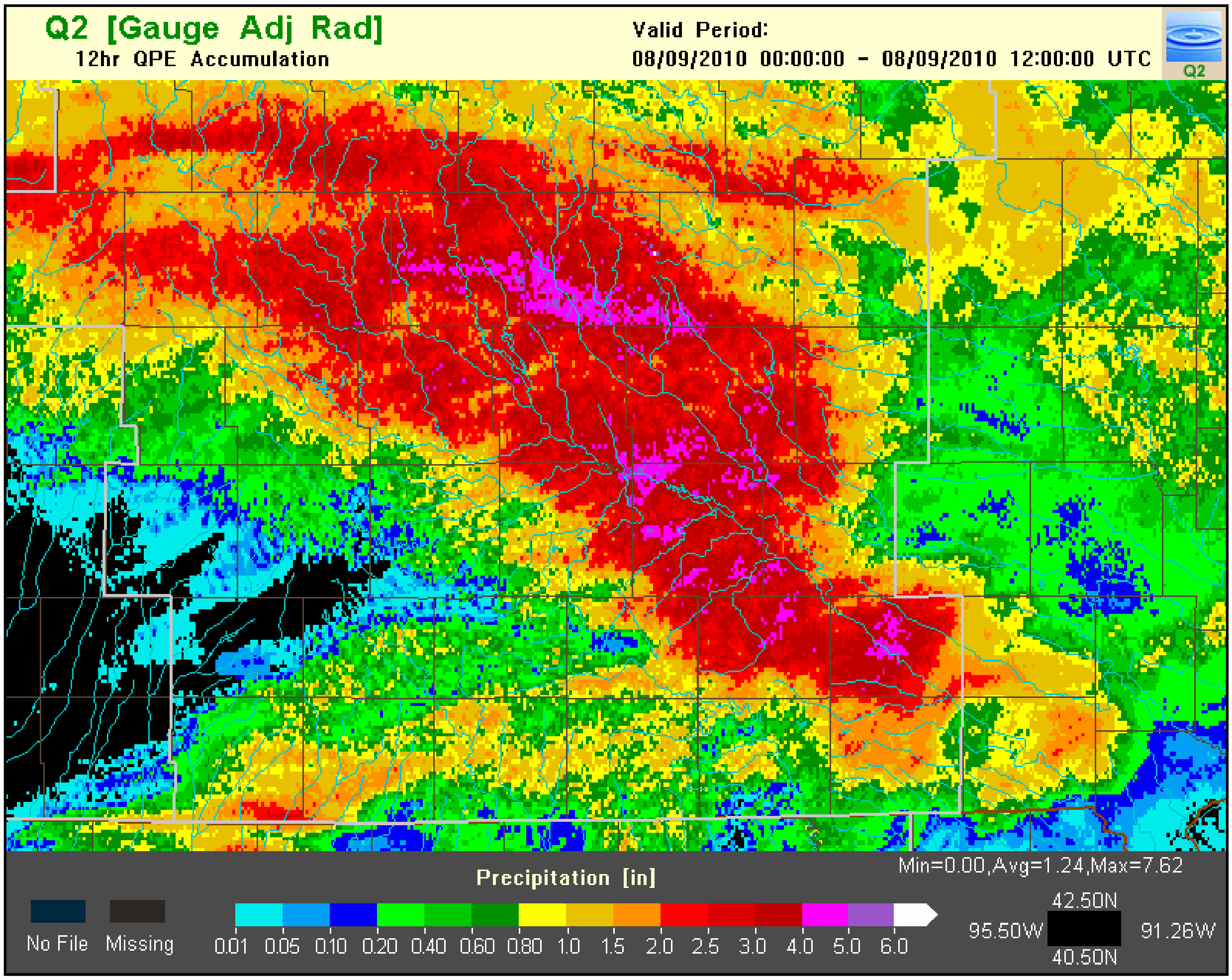


Figure 23. Q2 gage adjusted radar accumulations for the 12 hour period ending at 12Z on 09 August 2010. In reference to the legend at the bottom of the image, reds indicate rainfall totals of 2 or more inches while the magenta indicates at least 4 inches of rain.

Twelve hour rainfall totals at some locations in the Walnut Creek Basin were in excess of 4 inches (Figure 23). Basins hit particularly hard were Walnut Creek and Fourmile Creek. Heavy rainfall in these headwaters caused flash flooding and rapid stream rises. Both river flooding and flash flooding caused problems in the Des Moines metropolitan area. Record river flooding occurred on Walnut Creek at 63rd St in Des Moines causing significant damage to several homes and businesses (Figure 24). In addition, the rainfall that fell during the morning of 09 August 2010 primed the conditions for the major flooding that followed in the next 48 hours.

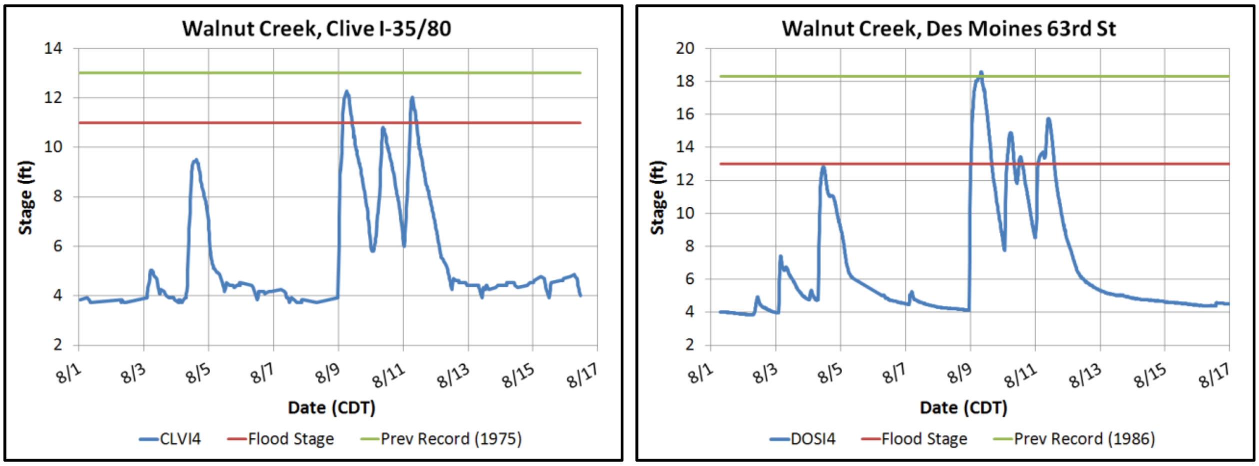


Figure 24. River gage data for Walnut Creek at site CLVI4 and further downstream at DOSI4 for the days leading to, during and after the mid-August 2010 flooding. Walnut Creek experienced its worst flooding on the morning of 09 August 2010. The blue line shows the observed gage readings, the red line is flood stage and the green line is record flooding. The right image shows the record crest of 18.59 feet observed at DOSI4.

4. 09-10 August 2010 Weather Event Overview

The first of several MCSs exited central Iowa by late morning on 09 August 2010. Clearing occurred during the afternoon hours allowing the instability to rebuild over the region. As shown Figure 25 which is valid at 00Z on 10 August 2010, the air mass as a whole changed very little from the night before. The upper level ridge had shifted slightly east but was still in place over Iowa with a jet streak across the United States-Canada border (A). The 500 mb map shows weak flow with the ridge axis directly over the state. Although the geopotential height contour intervals are too large to show the embedded short waves, the nonlinear orientation of the wind barbs are evidence of their existence (B). Again moving down to the lower levels of the atmosphere, the dew points at 850 mb have pooled with a +20^{o}C bulls eye across southern Iowa. The winds are southerly at about 10 to 20 knots and have not yet increased significantly (C). Closer to the surface at 925 mb there is a state wide region of +20^{o}C dew points with higher values in central Iowa. Southwesterly winds at 25 knots across northern Kansas and southeasterly winds over Iowa help pinpoint the warm front draped across the Iowa-Missouri border.

When comparing the 850 and 925 mb winds from 00Z on the 10th to 00Z on the 9th it is clear that at this time the low level jet was weaker than it was the previous day. After sunset the atmosphere decoupled and the southerly winds increased (not shown) which resulted in increased moisture transport and helps to explain why convective initiation did not take place until after 03Z. When the low level jet finally did develop, southerly winds were oriented perpendicular to the isentropes in the lower levels along the warm front. This configuration of a local jet in warm air advection favored convergence and in turn convergence at lower levels led to upward vertical motion and thus convection.

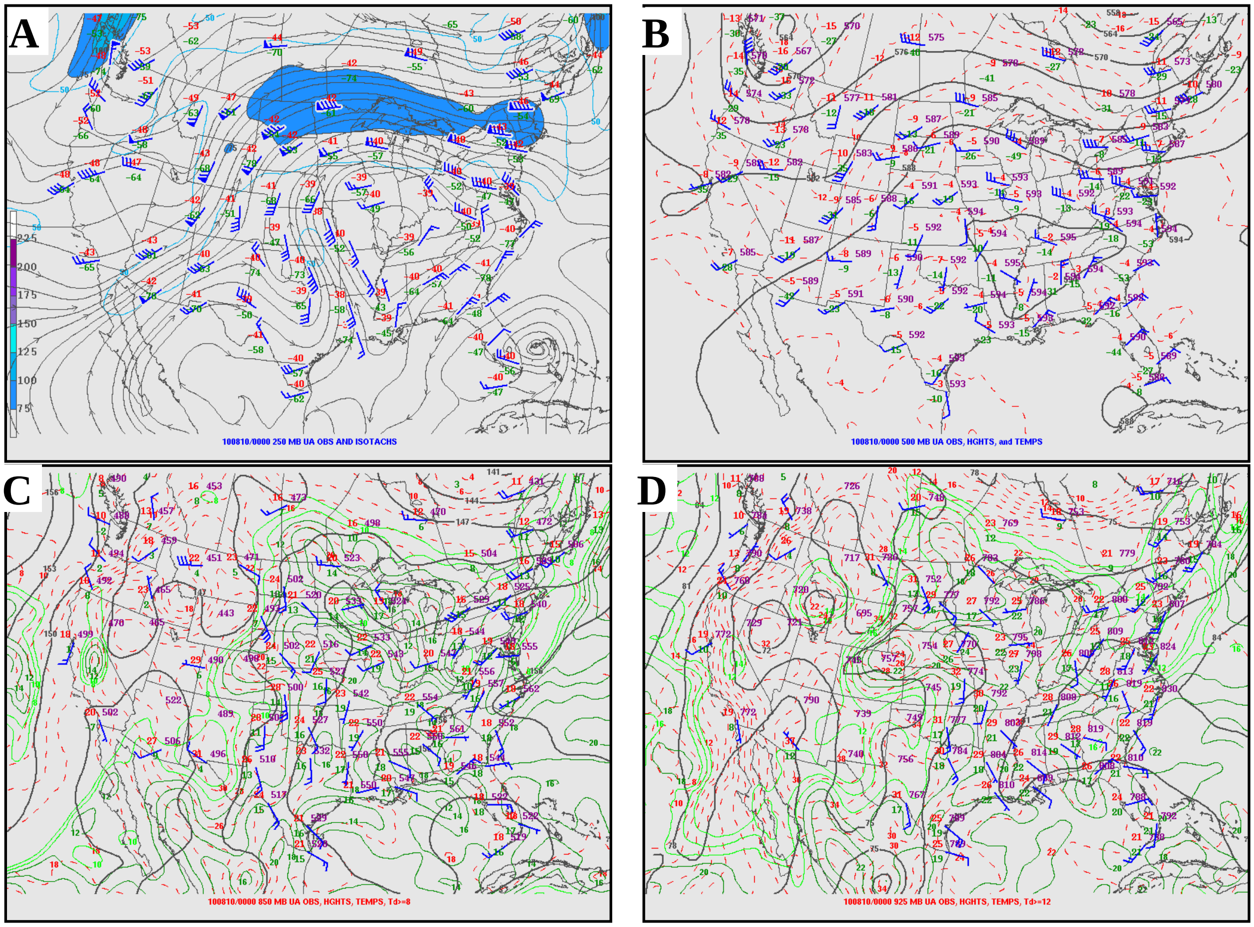


Figure 25. Four panel plot showing A) 250 mb, B) 500 mb, C) 850 mb and D) 925 mb upper air plots and analyses valid at 00Z on 10 August 2010. The synoptic set-up that preceded the flash flooding at Oskaloosa changed little over the past 24 hrs.

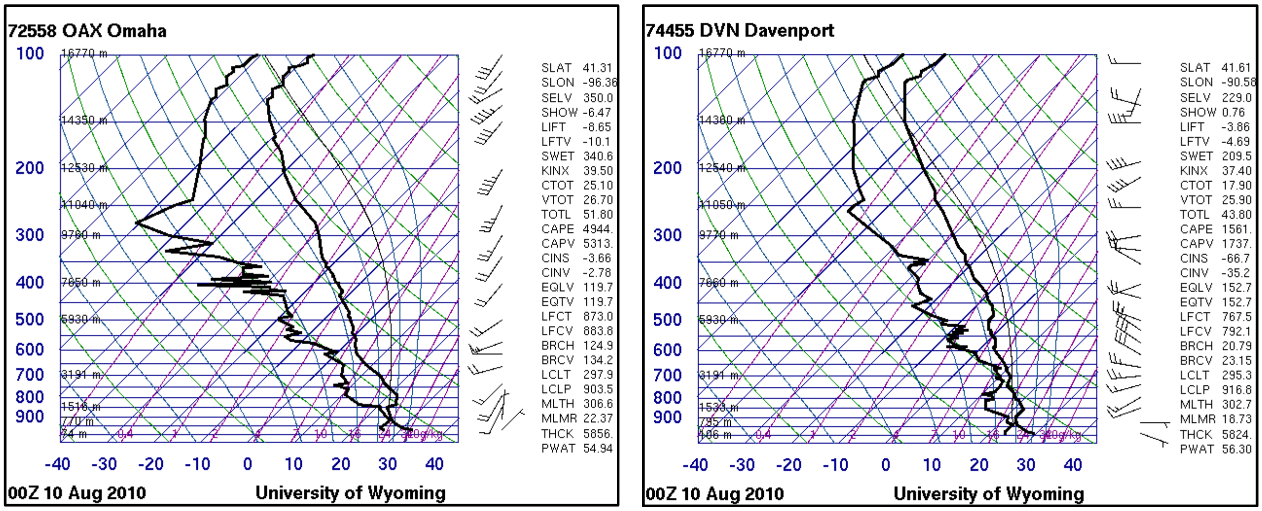


Figure 26. Atmospheric soundings from Omaha (OAX) and Davenport (DVN) on 10 August 2010.

Soundings from both Omaha and Davenport show the tropical air mass was still in place across the Corn Belt. Amazingly every wind barb plotted from the DVN sounding shows winds throughout the column were less than 50 knots. Precipitable water values of 2.16 inches at OAX and 2.22 inches at DVN remained near record levels so any thunderstorms that formed had plenty of moisture to work with. The combination of low LCLs and the freezing layer near 550 mb meant a deep warm cloud depth and allowed the storms to be efficient rainfall producers through collision and coalescence (Figure 26). A surface frontal boundary that had stalled across the state was pushed south from the previous night's MCS. The boundary slowly progressed north throughout the day and was located just south of Iowa by 00Z on 10 August 2010. It continued to progress north during the evening hours and became the focal point for another round of nocturnal convection (Figure 27).

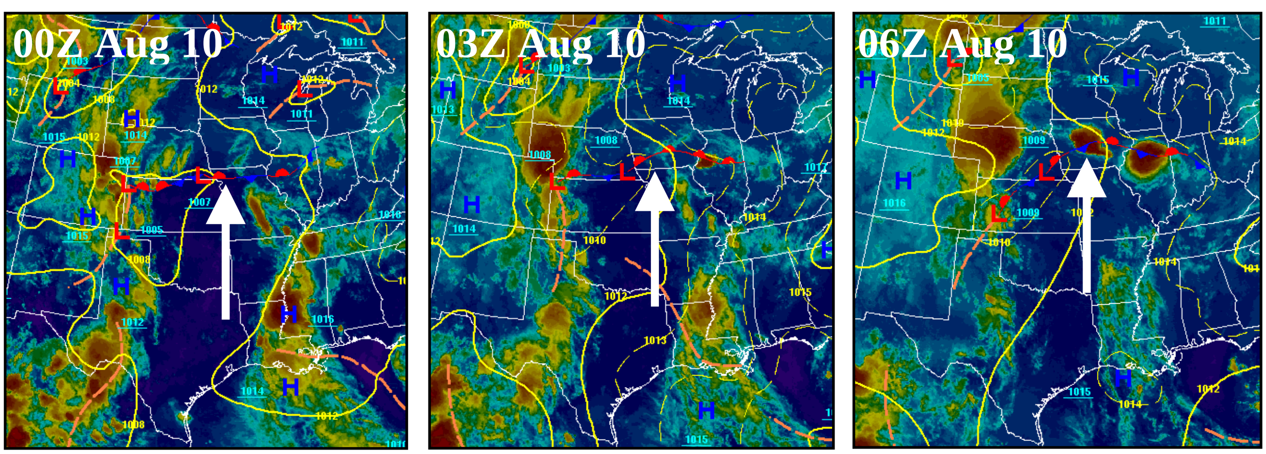


Figure 27. Surface analysis from 00, 03 and 06Z on 10 August 2010 along with IR imagery

shows thunderstorms that developed over central Iowa along the hybrid warm/stationary front. The white arrows identify the stationary front leftover from the previous morning's convection. The time progression shows this front lifting north as a warm front throughout the evening of 10 August 2010.

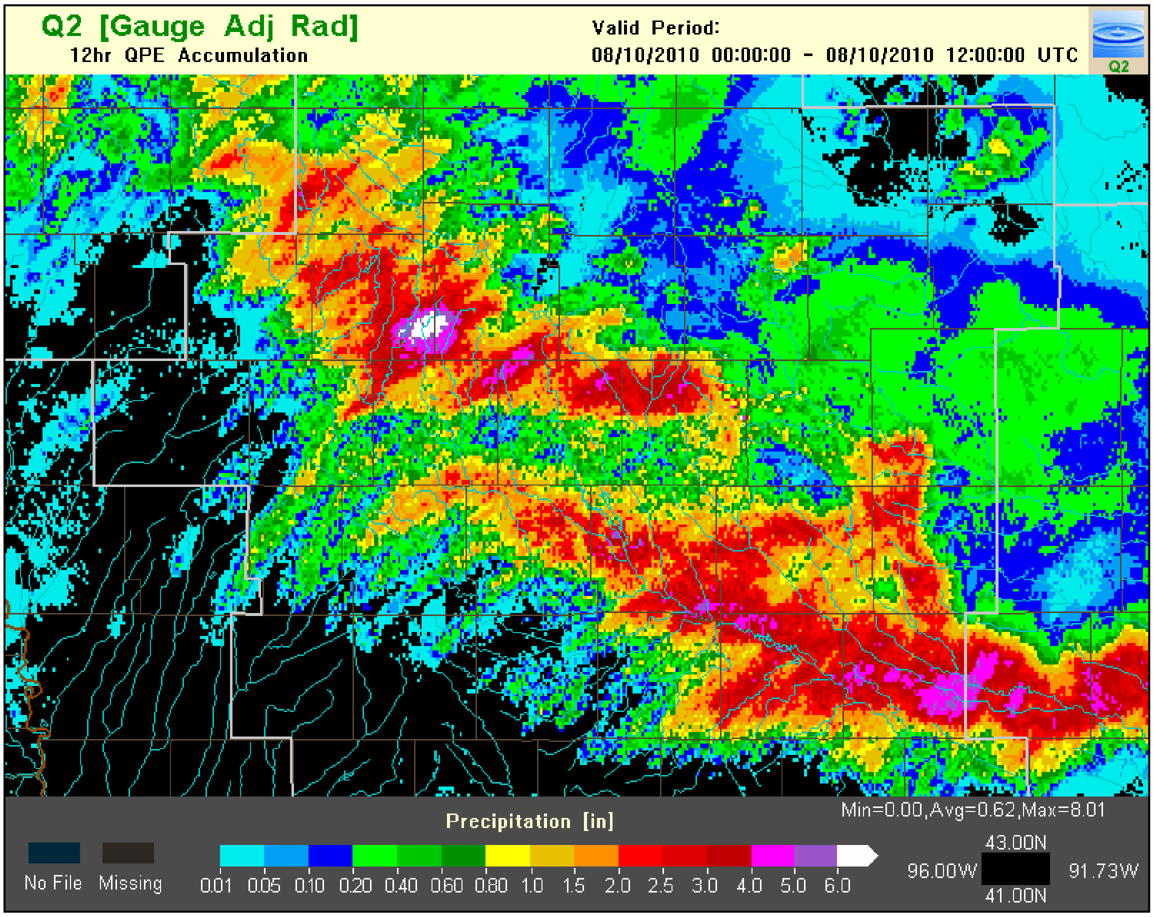


Figure 28. Q2 gage adjusted radar accumulations for the 12 hour period ending at 12Z on 10 August 2010. The 2 inch reports (red) are not as widespread as they were the previous night but the localized amounts were higher (purple and white).

The rainfall during the early morning hours of 10 August 2010 was very concentrated. It caused localized but devastating flash flooding in a few small basins that had experienced heavy rain the previous night (Figure 28). This time the basins that received the most rainfall were Walnut Creek and Beaver Creek as well as several smaller fast response creeks. Flash flooding was particularly severe near the Oskaloosa area where citizens volunteered their flat bottom boats to assist with evacuations. Record river flooding occurred at WBCI4 along Walnut Creek (Figure 29). This location was closer to the head waters of the basin and the crest dampened slightly as it went downstream before it reached the Des Moines metropolitan area.

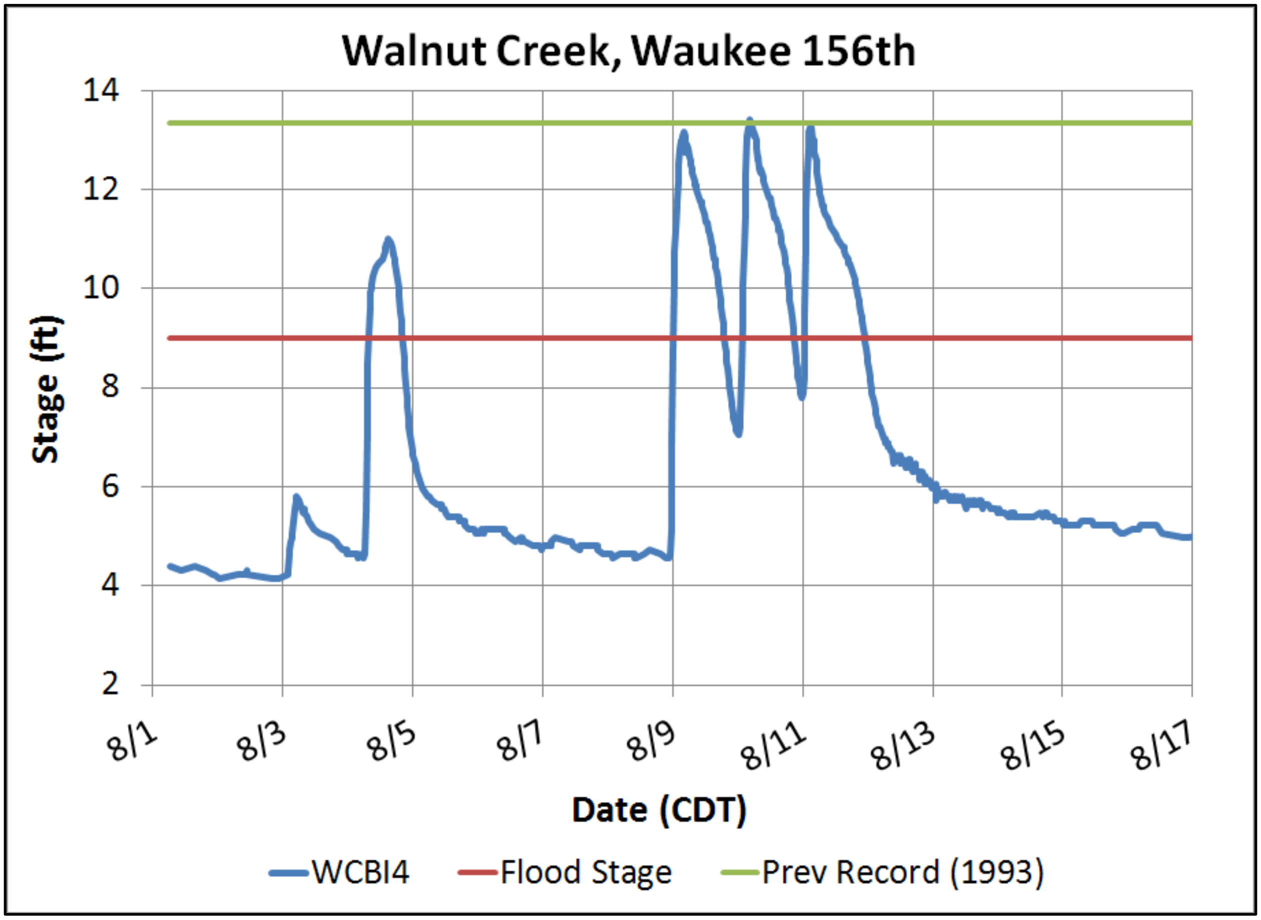


Figure 29. Stage at WCBI4 along Walnut Creek which is a river data point in the headwaters of that basin. Three flooding events occurred on consecutive nights from 09-11 August 2010. The record river stage of 13.41 feet was recorded at 0924Z on 10 August 2010.

5. 10-11 August 2010 Weather Event Overview

The third and final round of thunderstorms came on the evening of 11 August 2010. The four panel synoptic maps are again similar to the previous two days (Figure 30). First notice the weak southwesterly flow and upper level trough across the Missouri River Valley at 250 mb with a local minimum in wind speed across western Iowa (20 knots). Meanwhile, downstream over the Great Lakes region is an upper level ridge with a local wind maximum across central Wisconsin (45 knots). The ageostrophic divergence associated with velocity changes resulting from both the flow curvature and speed was one of the forcing mechanisms favorable for convection (A). Another forcing mechanism was the 500 mb positive vorticity advection ahead of the shortwave (B). This upper level support is reflected at the lower levels in the geopotential height field by the NW to SE oriented trough across central Iowa. The wind barbs at both these levels also indicate that moisture continues to be advected from the Gulf.

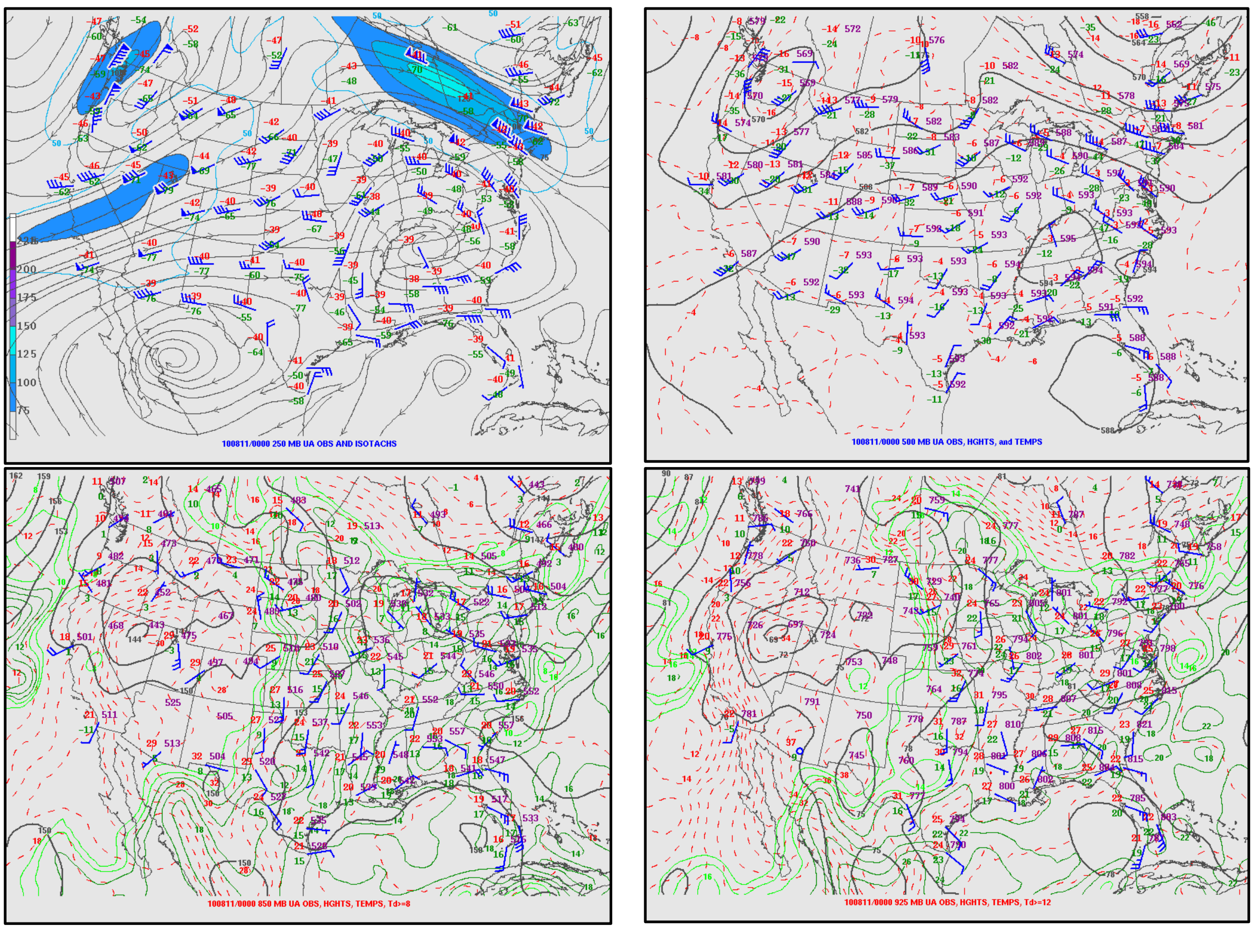


Figure 30. Four panel plot showing A) 250 mb, B) 500 mb, C) 850 mb and D) 925 mb upper air plots and analyses valid at 00Z on 11 August 2010. The synoptic set-up has several ingredients in place that were favorable for final round of heavy rainfall.

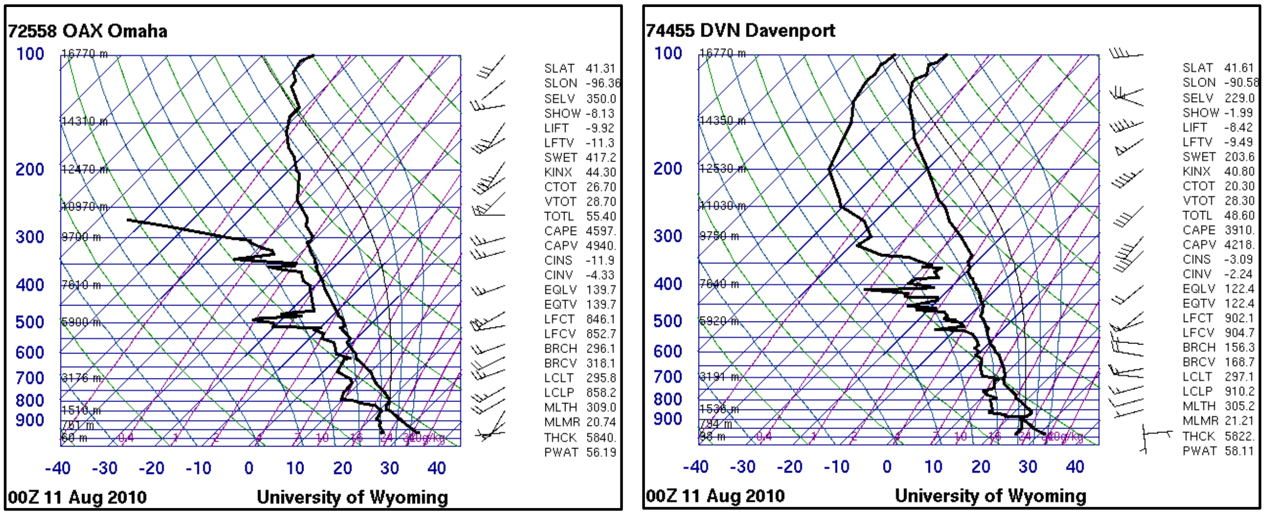


Figure 31. Atmospheric soundings from Omaha (OAX) and Davenport (DVN) on 11 August 2010.

As was the case from the previous two days, 00Z atmospheric soundings from Omaha and Davenport show an unusually tropical air mass across Iowa, arguably more so than the prior two days (Figure 31). Precipitable water at these two sites was 2.21 inches at OAX and 2.29 inches at DVN. The vertical wind profile in the lowest 500 mb was 25 knots or less. Cloud bases were around 900 mb and the equilibrium level was above 150 mb. In summary, these soundings were more characteristic of the environment in the ITCZ than the Midwest.

The 00Z surface analysis shows the same frontal boundary draped across central Iowa with the small cloud shield of the developing MCS across northern Iowa (Figure 32). Fed by the low level jet overrunning the warm front, this storm complex propagated very slowly south southeastward along the surface boundary. This movement is somewhat discernible by two radar screen captures with FFWs overlaid (Figure 33). At 0015Z a multicell complex was ongoing across north central Iowa. The outflow boundary pushed off the southeast and became the focus for future convection. A little more than four hours later the entire complex had expanded in size and the developing cells were clearly on the southern edge of the reflectivity gradient. The storms were efficient rain producers, the entire complex was slow moving and it tracked directly down the river basins that were still swollen from the previous two nights' rainfall. The final round of storms resulted in widespread 2 to 4 inch totals across central Iowa with a few basins experiencing more than 5 inches (Figure 34). Most of this rain fell in the 6-hour window from 00 to 06Z.

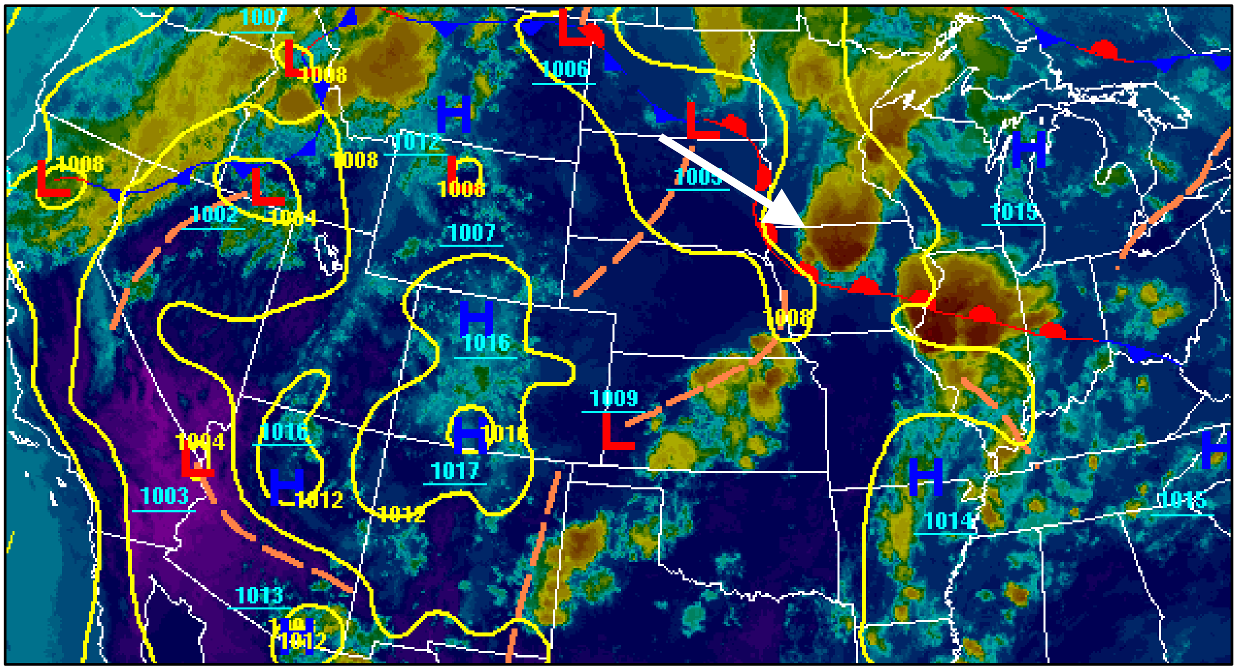


Figure 32. Surface analysis from 00Z along with IR imagery on 11 August 2010 shows the warm front persisting over Iowa. The thunderstorm complex indicated by the white arrow developed along this boundary causing historic flooding in Central Iowa.

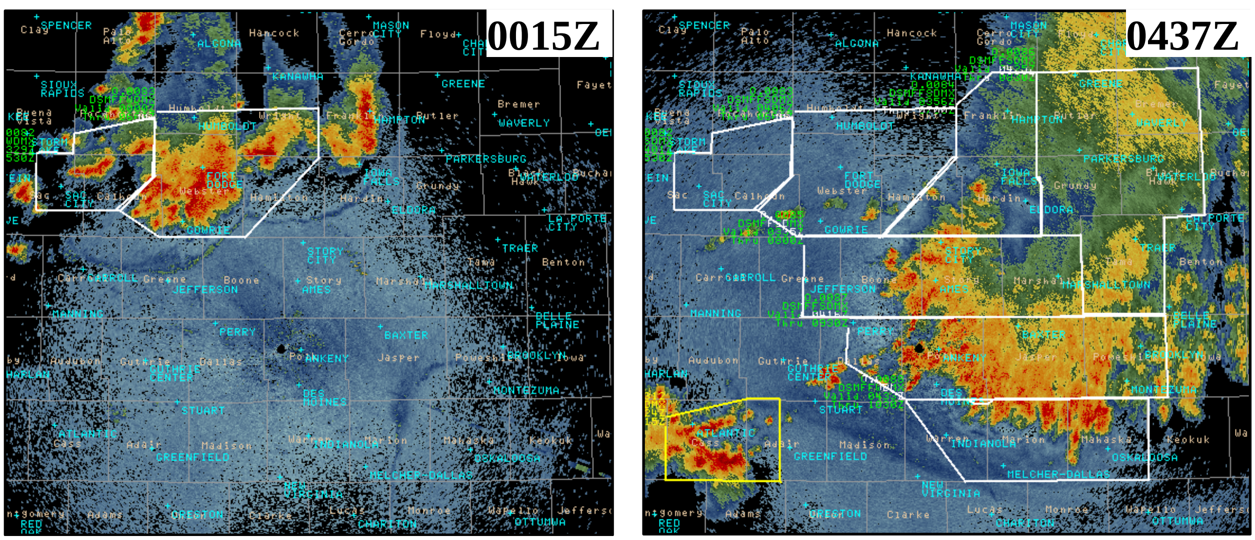


Figure 33. Radar reflectivity from early 11 August 2010 with the white polygons indicating the areas under FFWs.

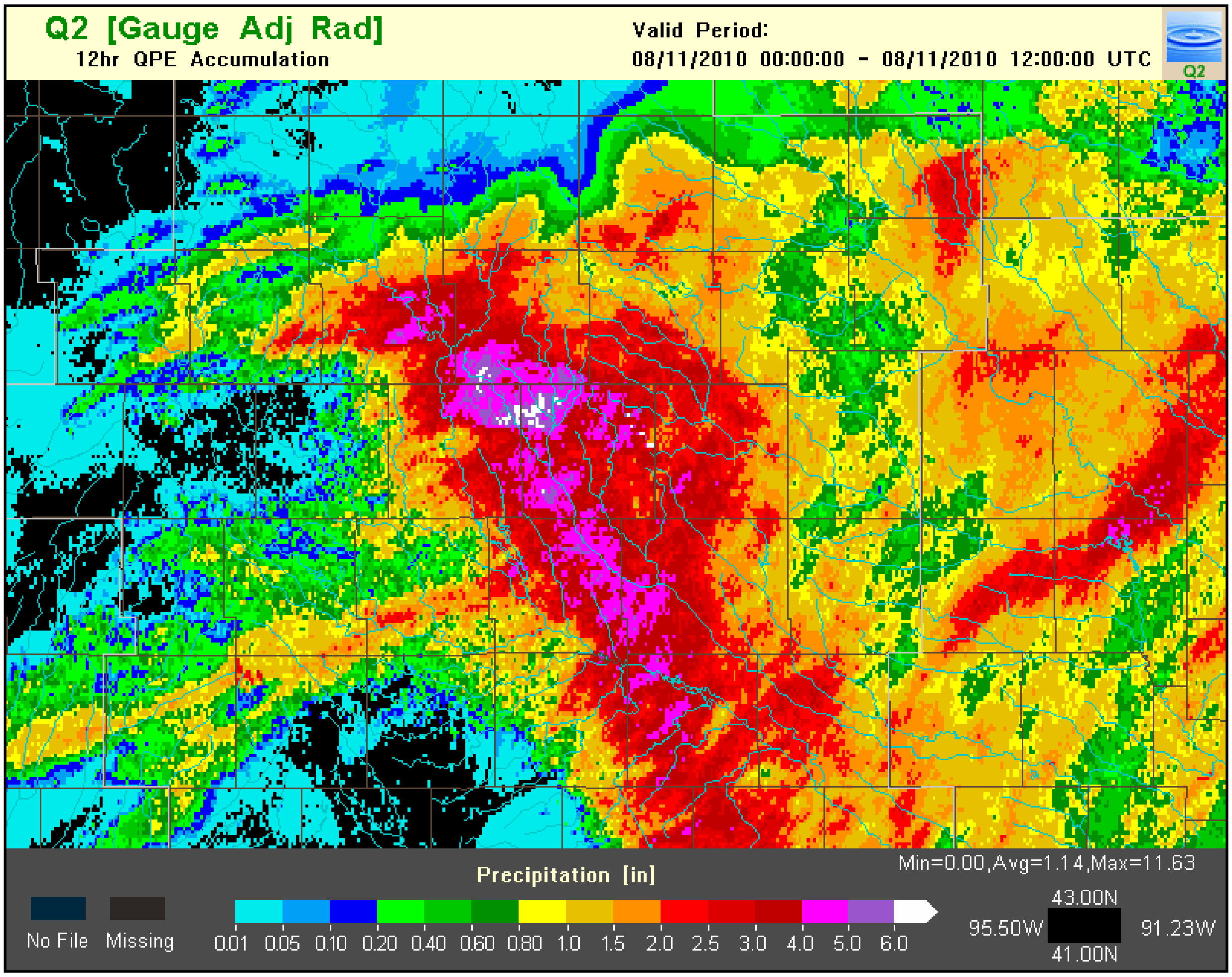


Figure 34. Twelve hour rainfall totals beginning on 00Z on 11 August 2010. Widespread rainfall totals of more than 4 inches fell in the Squaw Creek and Fourmile Creek basins.

Nine total multi-county FFWs were issued as a result of the heavy rain on 11 August 2010. Given the prior two days' rainfall totals as well as numerous real-time storm reports a Flash Flood Emergency was issued in an FFS to convey the unprecedented flooding which was occurring at the time. Since the ground was nearly saturated at the start of the rainfall, the infiltration rate was so small that nearly all rainfall resulted in runoff. This caused abrupt rises along area creeks and small rivers. Record flooding occurred in the Fourmile Creek River Basin that includes the highly populated areas of east Ankeny and east Des Moines (Figure 35). One fatality occurred when three vehicles carrying 12 young adults were swept away by one of Fourmile Creek's small tributaries.

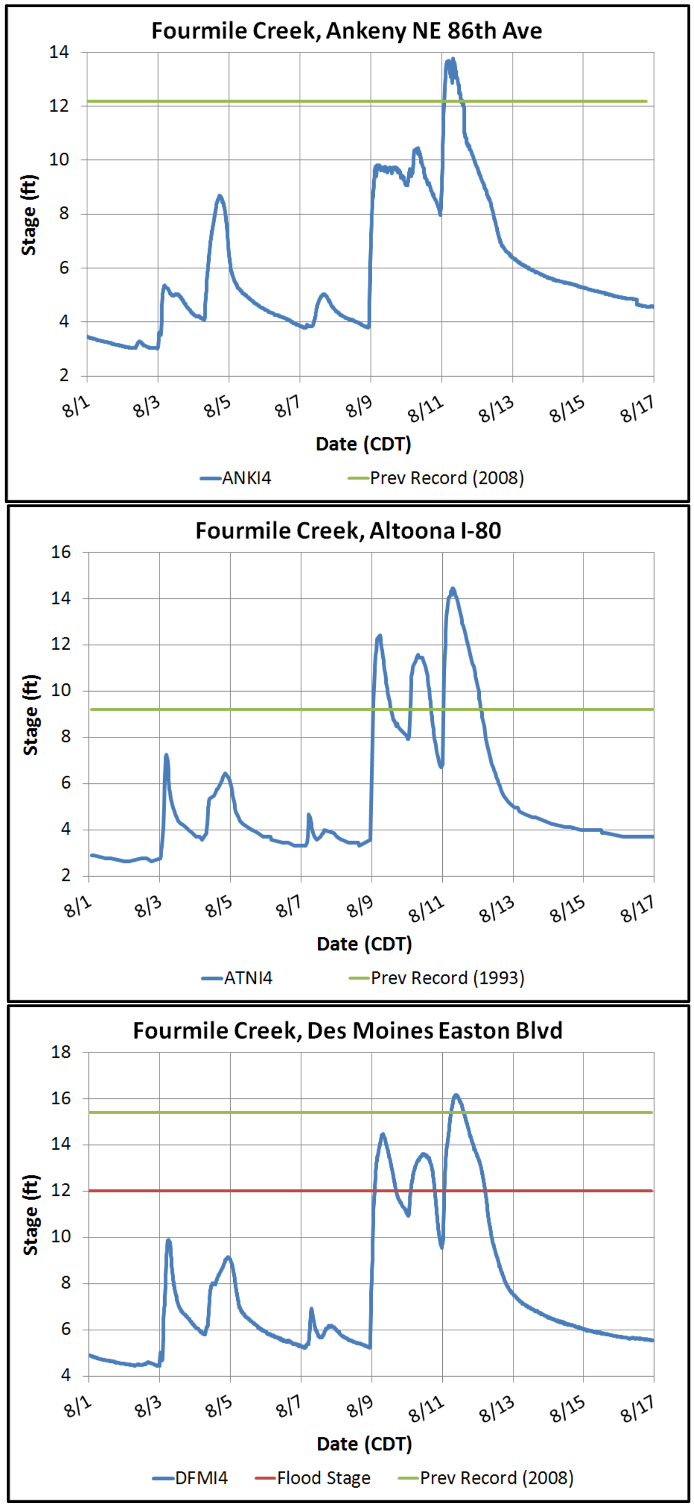


Figure 35. Hydrographs at each gaging site along the Fourmile Creek where record flooding was observed during the early morning hours of 11 August 2010.

Historical flooding also occurred at several locations along Squaw Creek and the South Skunk River (Figure 39 and Figure 40). Initially, local runoff caused major to record flooding in Ames, Colfax and Oskaloosa (Figure 36). The city of Ames was affected when basin-wide 4 to 6 inch rainfall totals fell across the headwaters of the South Skunk River and Squaw Creek . Thirty people had to be rescued when flood waters surrounded the local Wal-Mart. Several buildings on the Iowa State campus had significant flood damage totaling between $30 and $40 million. Although the river gages along Squaw Creek at site AMWI4 did not support record flooding, several officials from Iowa State University stated that the flood impacts on 11 August 2010 were worse than the "record crest" of 1993. This could be a reflection of changes in the rating curve or the drainage plain.

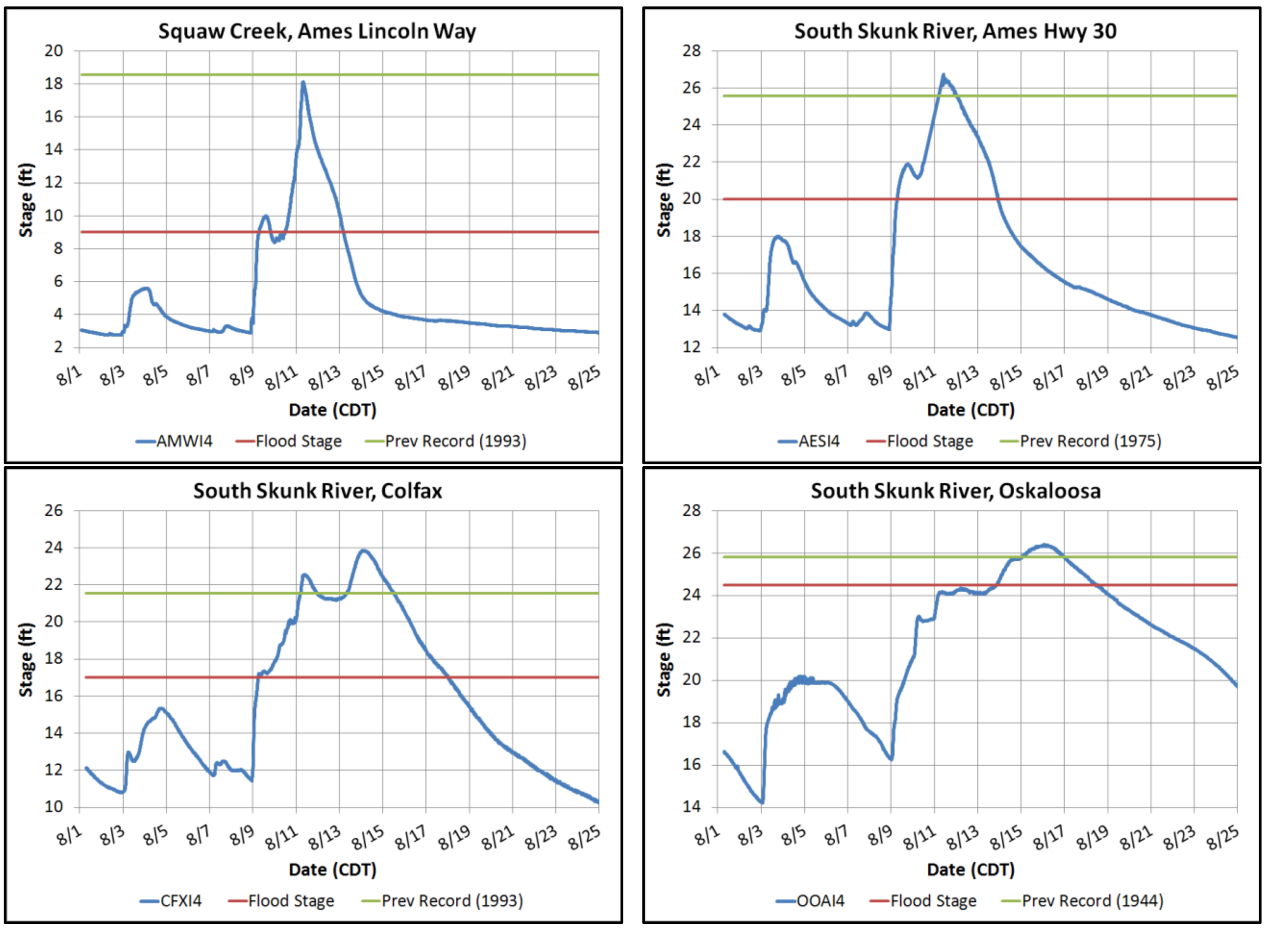


Figure 36. The hydrographs for AMWI4 (top left), AESI4 (top right), CFXI4 (bottom left) OOAI4 (bottom right). The blue line indicates the observed gage height, the horizontal red line depicts flood stage and the green line shows the record crest prior to the mid-August 2010 event. Record flooding occurred along the South Skunk River at AESI4, CFXI4 and OOAI4.

6. Individual stream basin maps

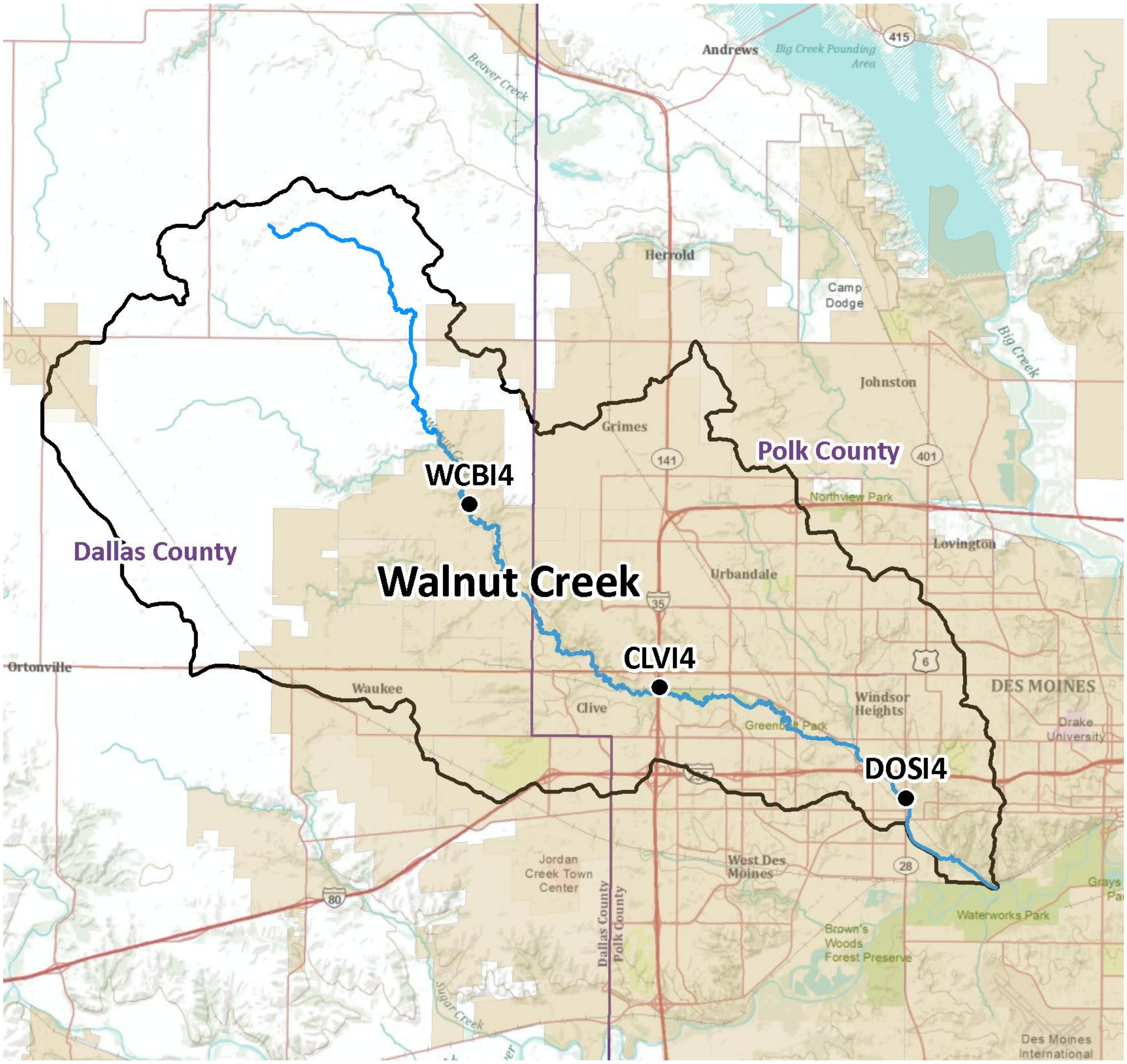


Figure 37. Map of the Walnut Creek basin.

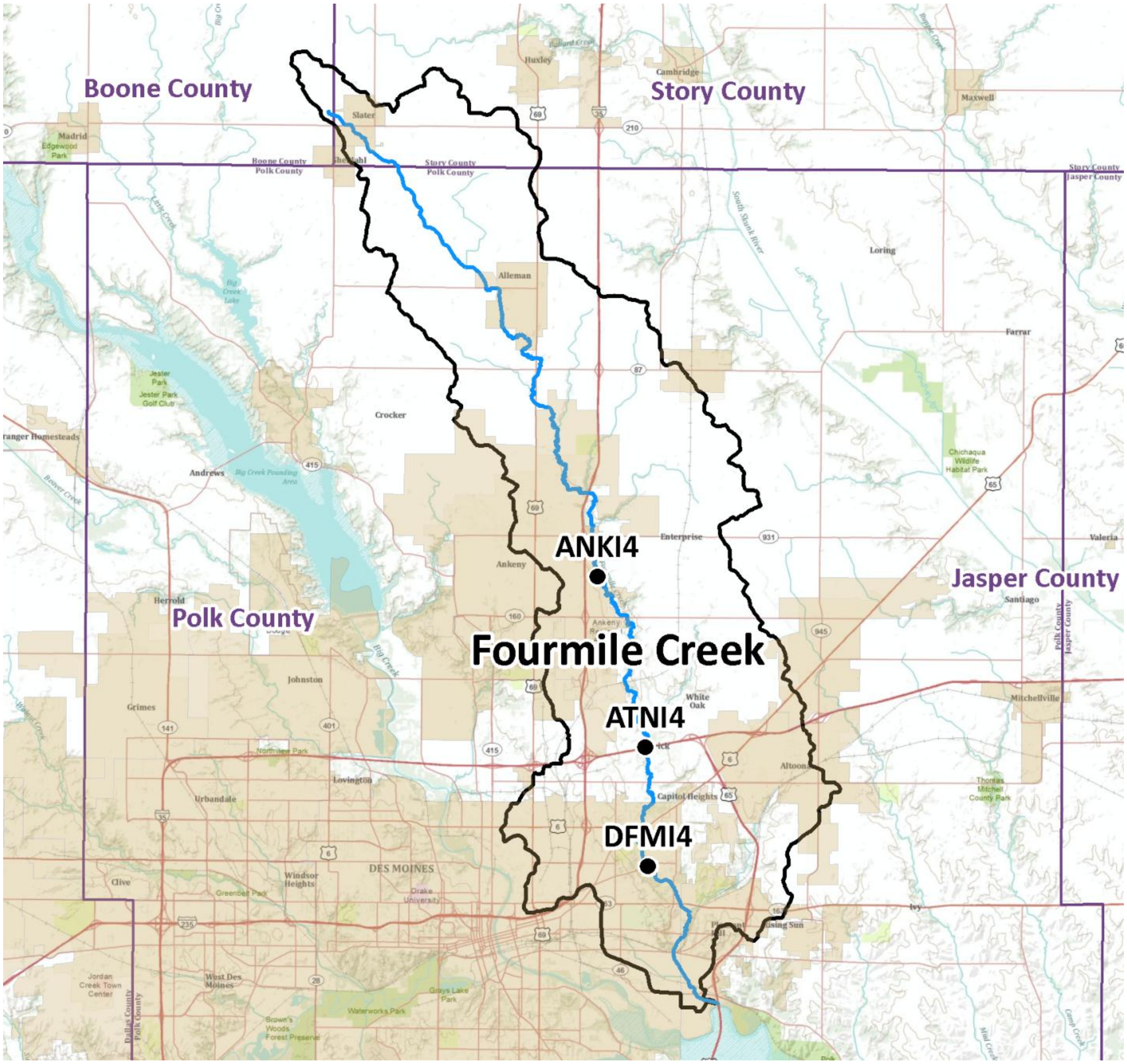


Figure 38. Map of the Fourmile Creek basin.

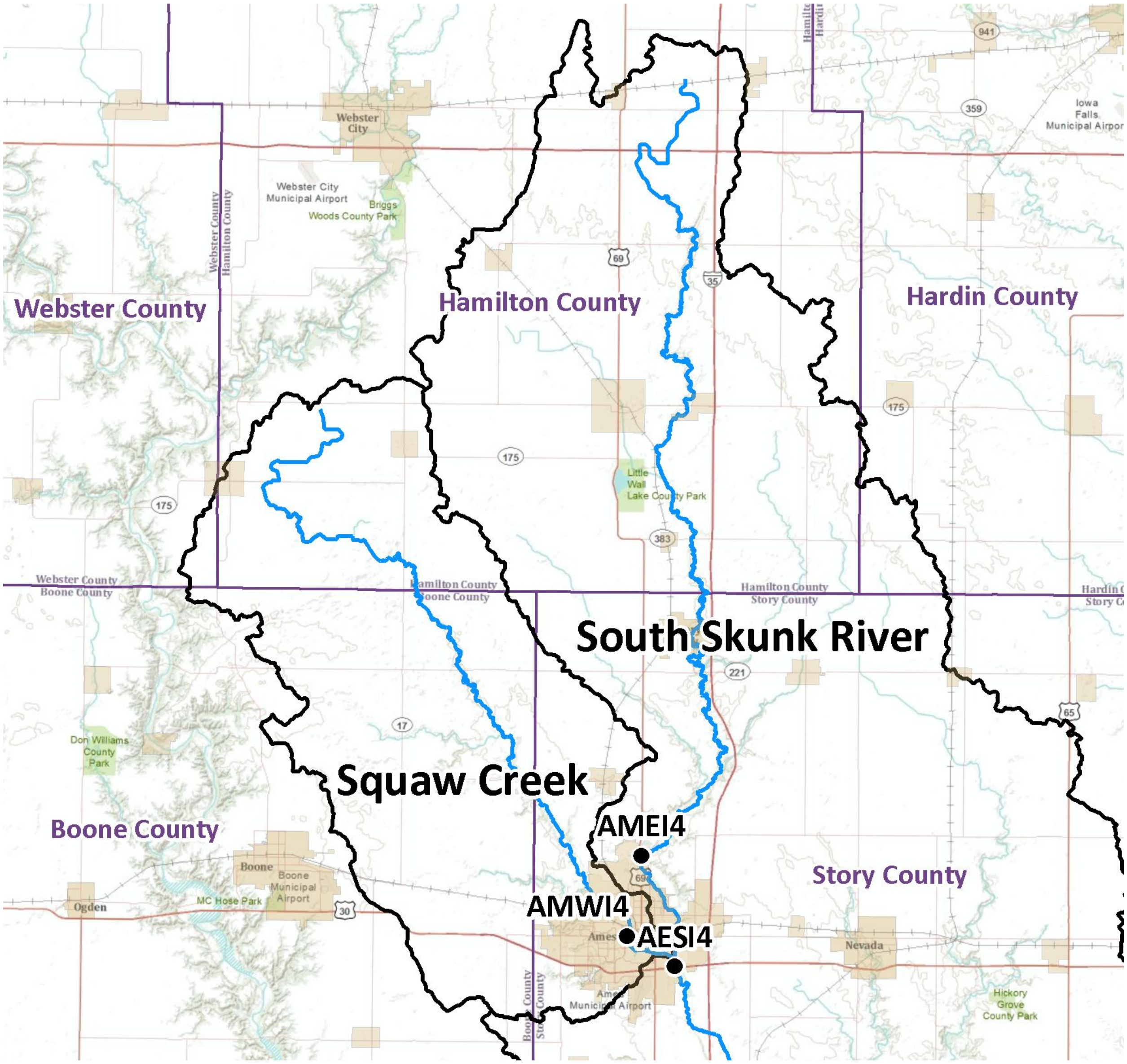


Figure 39. Map of the Squaw Creek and South Skunk River basins. AESI4 is downstream of the confluence of the two streams.

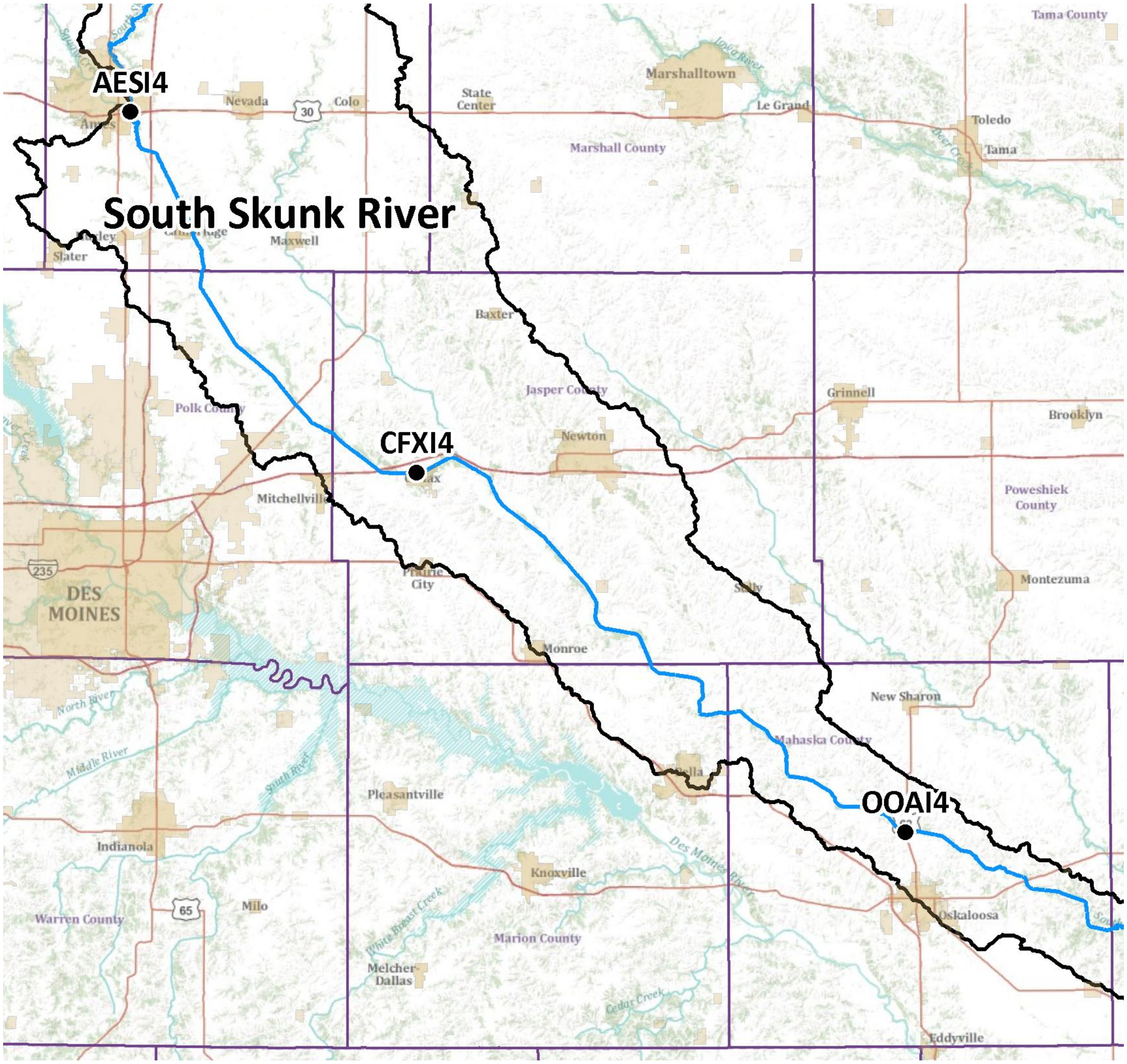


Figure 40. Map of the South Skunk River basin from the Ames to Oskaloosa areas. Record flooding was observed at all three locations following the heavy rainfall of 11 August 2010.

7. References

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