Increasing River Flooding Situational Awareness: A GIS Extent Mapping Approach

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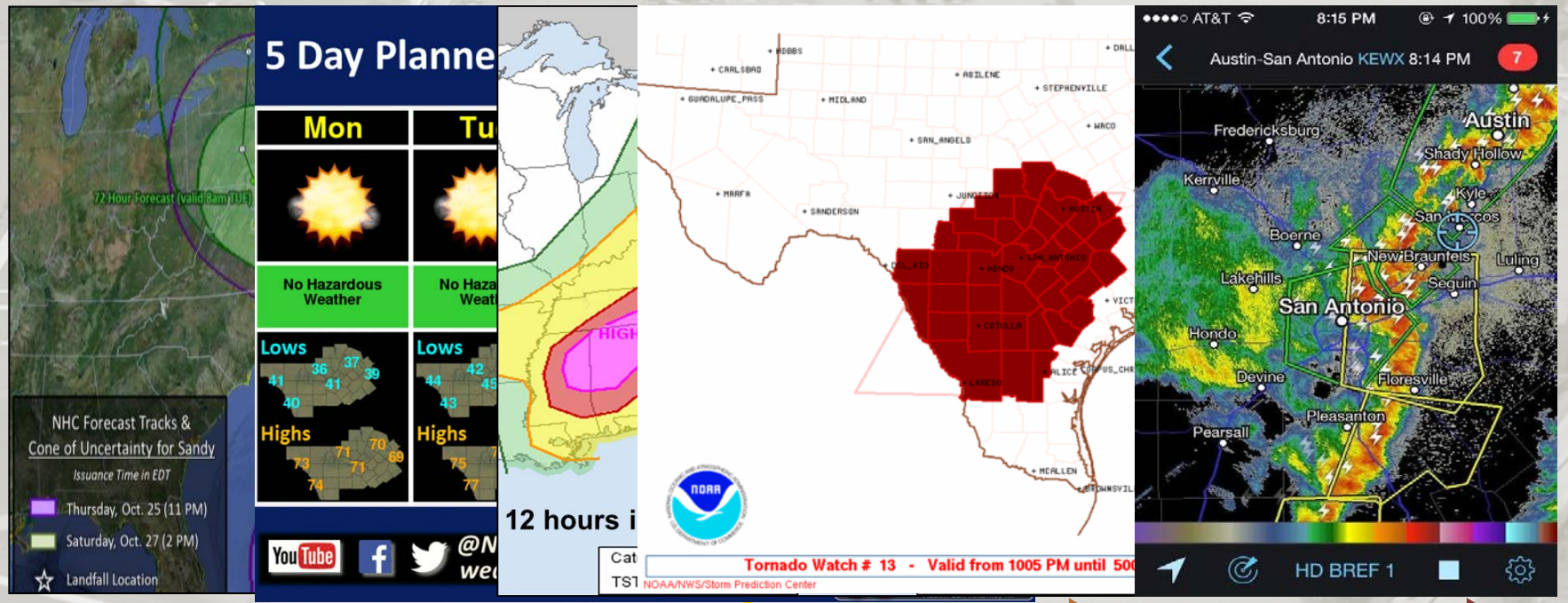
NWS San Antonio/Austin

SCAUG
04/16/15

NWS Mission & Partnerships

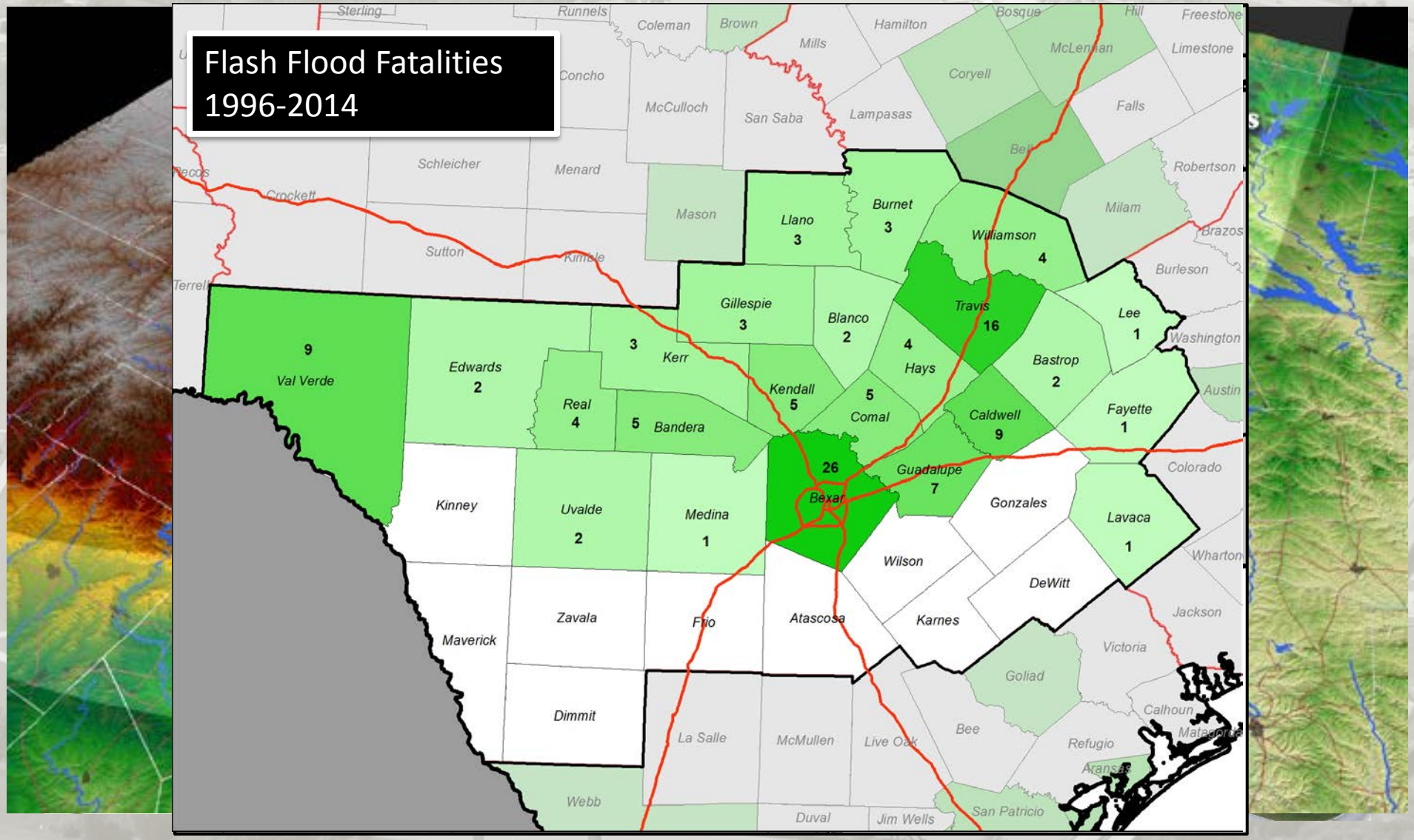
- Provide forecasts and warnings for protection of life and property.



Outlooks → Forecasts → Watches/Advisories → Warnings

Time	1-2 Weeks	1-7 days	6-36 hours	Hours - Minutes

Flash Flooding in San Antonio & Austin



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FLOOD STATEMENT
NATIONAL WEATHER SERVICE DENVER CO
1057 AM MDT TUE SEP 17 2013

...THE FLOOD WARNING CONTINUES FOR THE FOLLOWING RIVERS IN
COLORADO...

  SOUTH PLATTE RIVER NEAR JULESBURG AFFECTING SEDGWICK COUNTY.
  SOUTH PLATTE RIVER NEAR BALZAC AFFECTING LOGAN...MORGAN AND
  WASHINGTON COUNTIES.
  SOUTH PLATTE RIVER NEAR KERSEY AFFECTING WELD COUNTY
  CACHE LA POUDRE RIVER NEAR GREELEY AFFECTING WELD COUNTY.

.THE TOWN OF CROOK...WHICH IS HALFWAY BETWEEN STERLING AND JULESBURG
AND JUST NORTH OF INTERSTATE 76...WAS ORDERED TO EVACUATE EARLY THIS
MORNING BECAUSE OF THE POSSIBILITY OF FLOODING. THIS IS DUE TO THE
HISTORIC HIGH FLOWS ON THE SOUTH PLATTE RIVER WHICH IS FLOODING
DITCHES BY CROOK. THE RIVER NEAR CROOK IN LOGAN COUNTY WAS STILL
RISING AT 1015 AM MDT. SEDGWICK COUNTY OFFICIALS REPORTED HIGH FLOOD
WATERS HAVE PASSED THE LOGAN-SEDGWICK COUNTY LINE. THE SOUTH PLATTE
RIVER LEVELS ARE BANKFULL AT SEDGWICK FARTHER DOWNSTREAM IN SEDGWICK
COUNTY. IN WELD COUNTY A NUMBER OF ROADS REMAIN CLOSED ALONG THE
CACHE LA POUDRE RIVER IN AND NEAR GREELEY. NUMEROUS ROADS ARE
CLOSED DUE TO FLOODING...LAND AND ANY BUILDINGS HAVE BEEN INUNDATED
WITH FLOOD WATERS ALONG THE SOUTH PLATTE RIVER FROM LA SALLE
EASTWARD THROUGH WELD...MORGAN AND LOGAN COUNTIES IN NORTHEAST
COLORADO.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

DO NOT DRIVE INTO AREAS WHERE THE WATER COVERS THE ROADWAY AS THE
WATER DEPTH MAY BE TOO GREAT TO ALLOW YOUR CAR TO CROSS SAFELY. TURN
AROUND...DO NOT DROWN.

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/B3NC2.3.ER.130915T1004Z.130915T1215Z.000000T0000Z.NR/
1057 AM MDT TUE SEP 17 2013

THE FLOOD WARNING CONTINUES FOR
  THE SOUTH PLATTE RIVER NEAR BALZAC.
* UNTIL FURTHER NOTICE...OR UNTIL THE STREAM FALLS BELOW FLOOD STAGE.
* AT 6:30 AM TUESDAY THE STAGE WAS 11.2 FEET.
* FLOOD STAGE IS 10.0 FEET.
* MODERATE FLOODING IS OCCURRING AND MODERATE FLOODING IS FORECAST.
* FORECAST...THE RIVER WILL CONTINUE TO FALL TO A STAGE OF 11.1 FEET
  BY WEDNESDAY MORNING.
* IMPACT...AT 11.0 FEET...WATER FLOWS OVER U.S. HIGHWAY 6 NEAR ATWOOD.
* FLOOD HISTORY...THE FLOOD CREST NEAR 13.7 FEET ON SEPTEMBER 15 2013
  IS HIGHER THAN THE RECORD CREST OF 13.3 FEET ON JUN 10 1965.

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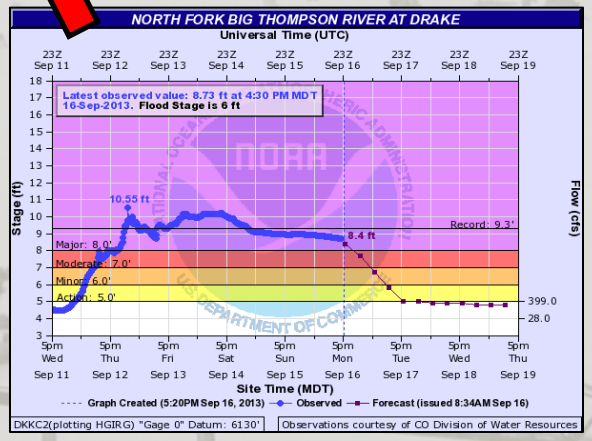
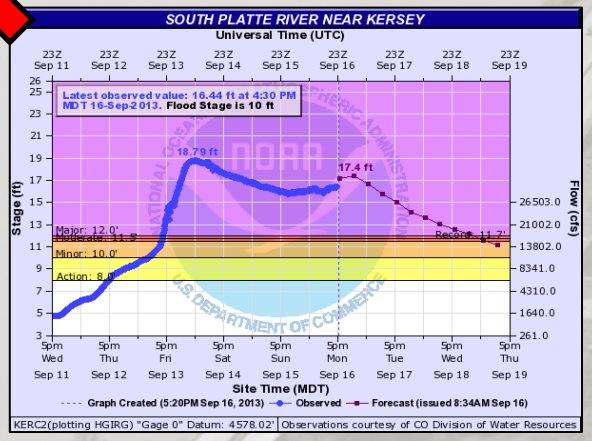
2) Tables to Graphics



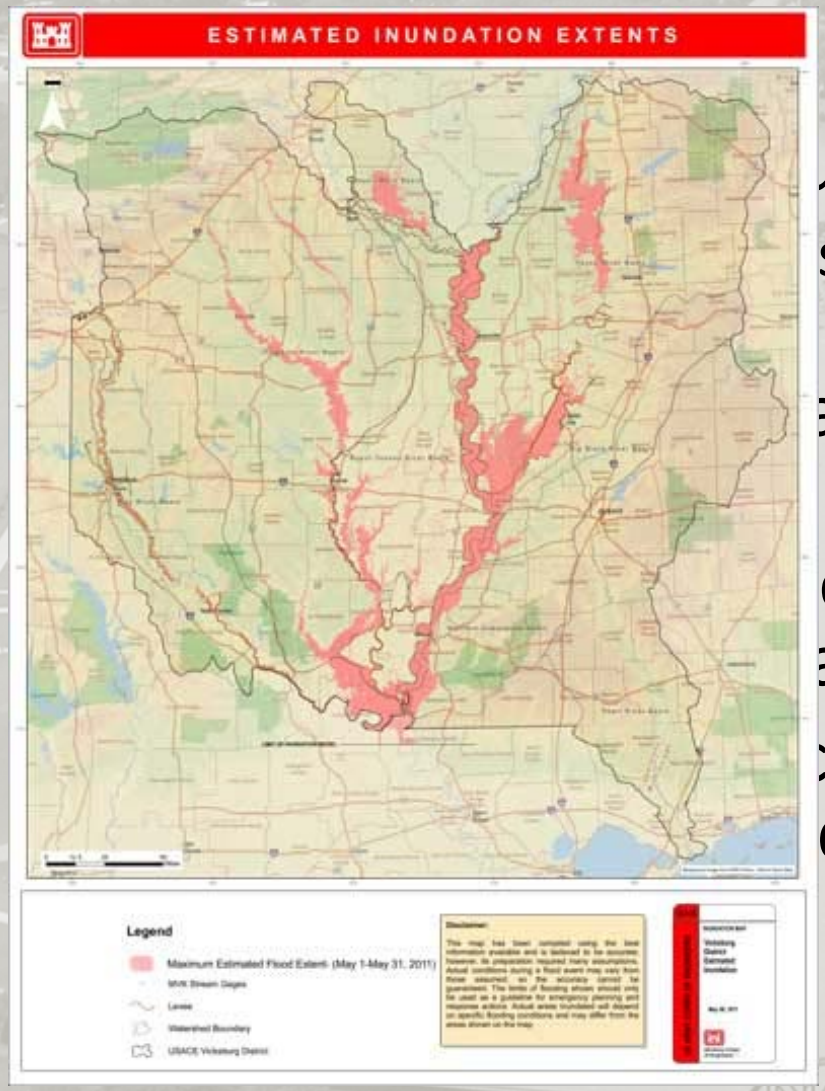


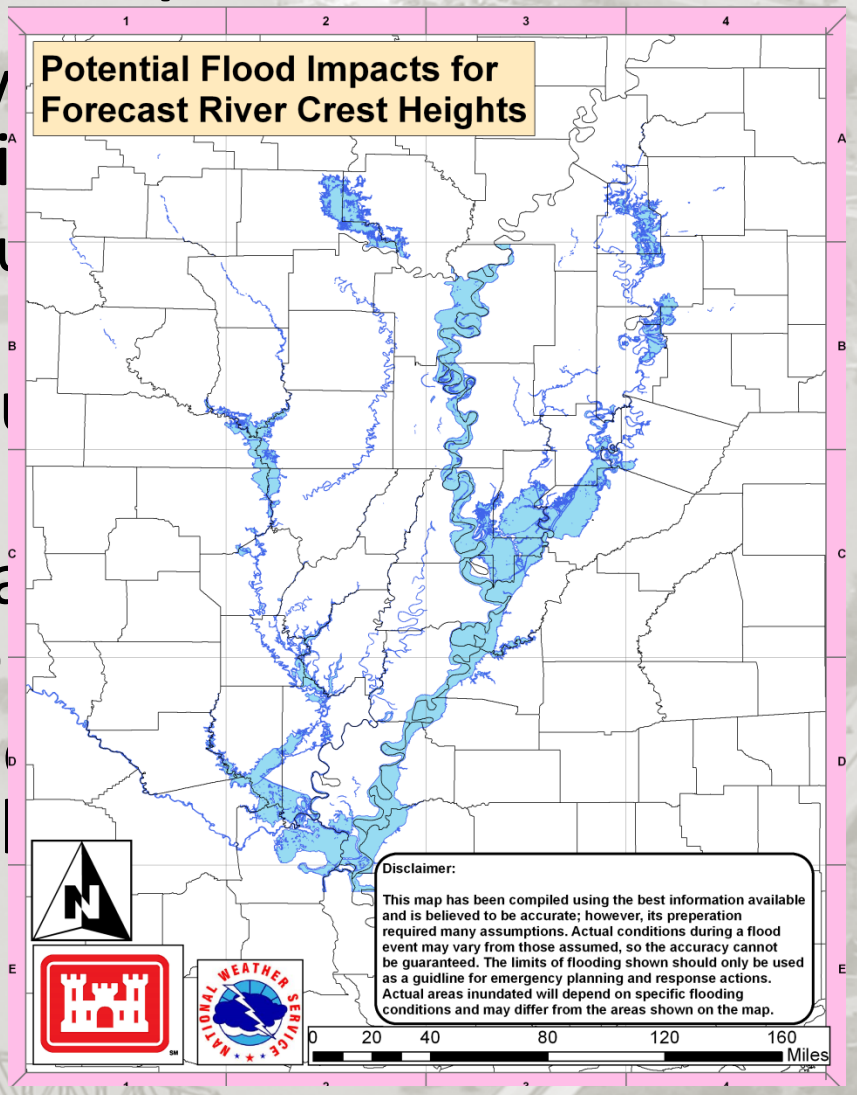
Evolution of River Flooding Awareness Continued

3) Extent and Inundation Mapping

4) Push Maps to EMs, Media, Web, Facebook, Twitter

NWS/US Army Corps of Engineers Partnership





River Flooding Extent Project Goals

- **Goal 1:** To efficiently produce acceptably accurate flood extents for **minor**, **moderate**, **major** & **record** flood stages at and along river gauge sites (for a site specific distance) to aid both internal and external coordination and communication of the NWS with Federal, State, County and City officials, along with the general public.
- **Goal 2:** To develop an intuitive internal (hopefully external) dynamic web map and information viewer displaying the flood stages.
- **Answer the questions of:**
  - **What does moderate flood stage mean to me?**
  - **What floods when the river reaches X feet?**
  - **What areas of my city/county need to be monitored or possibly evacuated based on the river forecast?**
  - **How much infrastructure is at risk if major flooding occurs?**

Project Methodology/Workflow

Phase 1 – Unedited Comparison

Table

Red_Gauges_Project

FID	Shape *	Id	Name	Elev_Minor	Elev_Mod	Elev_Major	Elev_Rec
0	Point	1	Upstream	76.65	80.65	84.65	89.88
1	Point	2	Bridge 1	76.42	80.42	84.42	89.65
2	Point	3	Gauge Bridge	76.3	80.3	84.3	89.53
3	Point	4	Dowstream	75.26	79.26	83.26	88.49

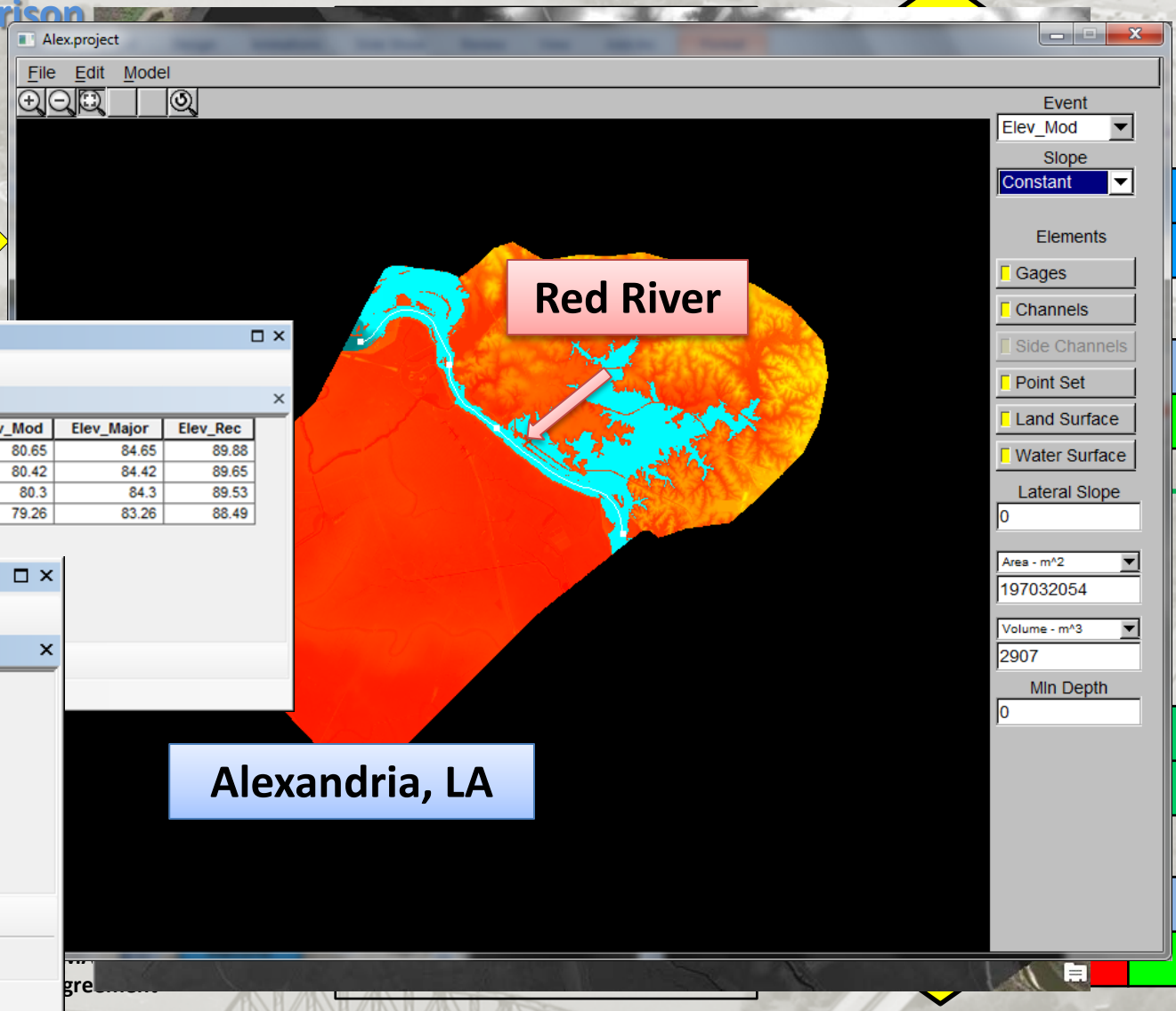
Table

Red_Streams

FID	Shape *	Id	FROM_	TO
0	Polyline	1	4	3
1	Polyline	2	3	2
2	Polyline	3	2	1

(0 out of 3 Selected)

Red_Streams



Sites Modeled and Statistics

- Six river sites tested at various elevation data resolutions:

River Site	LiDAR/DEM Resolution
Leaf River at Hattiesburg, MS	~ 9 Feet (3 Meter) LiDAR
Susquehanna River at Binghamton, NY	~ 6 Feet (2 Meter) LiDAR
Red River at Alexandria, LA	20 Feet (6 Meter) LiDAR
Susquehanna River at Harrisburg, PA	30 Feet (10 meter) DEM
Kentucky River at Frankfort, KY	5 Feet (1.5 Meter) LiDAR
Onion Creek at Austin, TX	30 Feet (10 Meter) DEM

- Spatial Statistical tests performed:
  - Cohen's Kappa Coefficient[2,4]
  - Overall pixel classification accuracy[6]
  - Computed for: ***Minor***, ***Moderate***, ***Major***, and ***Record*** stages

Cohen's Kappa Coefficient

- Assess inter-model reliability between two or more spatially observed/coded qualitative or categorical variables[2].

$$\kappa = \frac{Pr(a) - Pr(e)}{1 - \Pr(e)}$$

$Pr(a)$ = Relative Observed Agreement

20 + 15 = 35 35/50 = 0.7

$Pr(e)$ = Probability of Random Agreement

[(30/50) * (25/50)] + ([20/50) * (25/50)] = 0.5

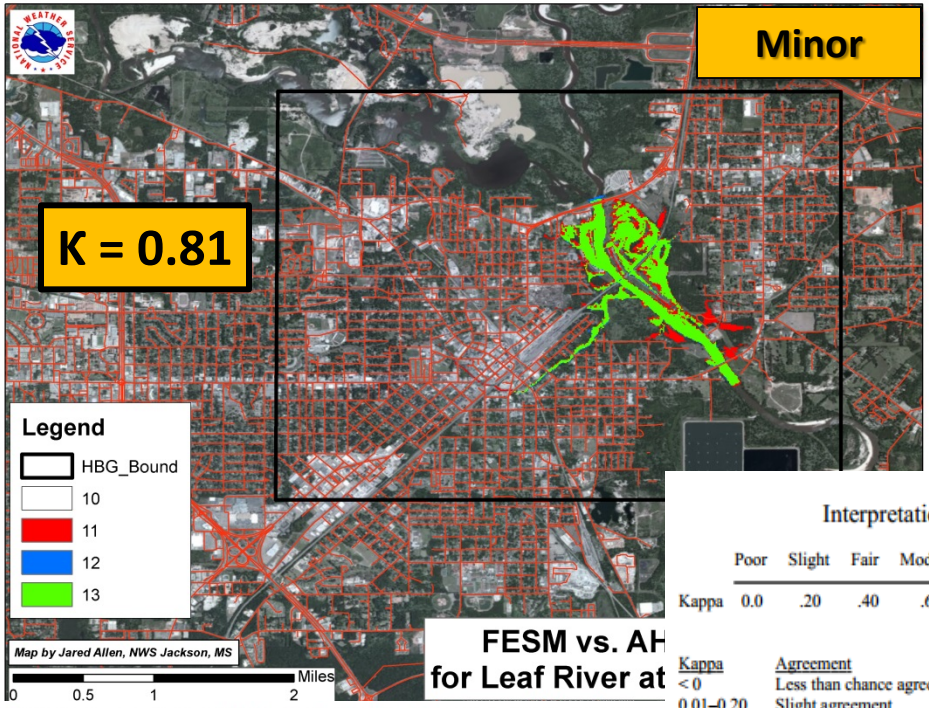
$$\kappa = \frac{0.7 - 0.5}{1 - 0.5} = 0.40$$

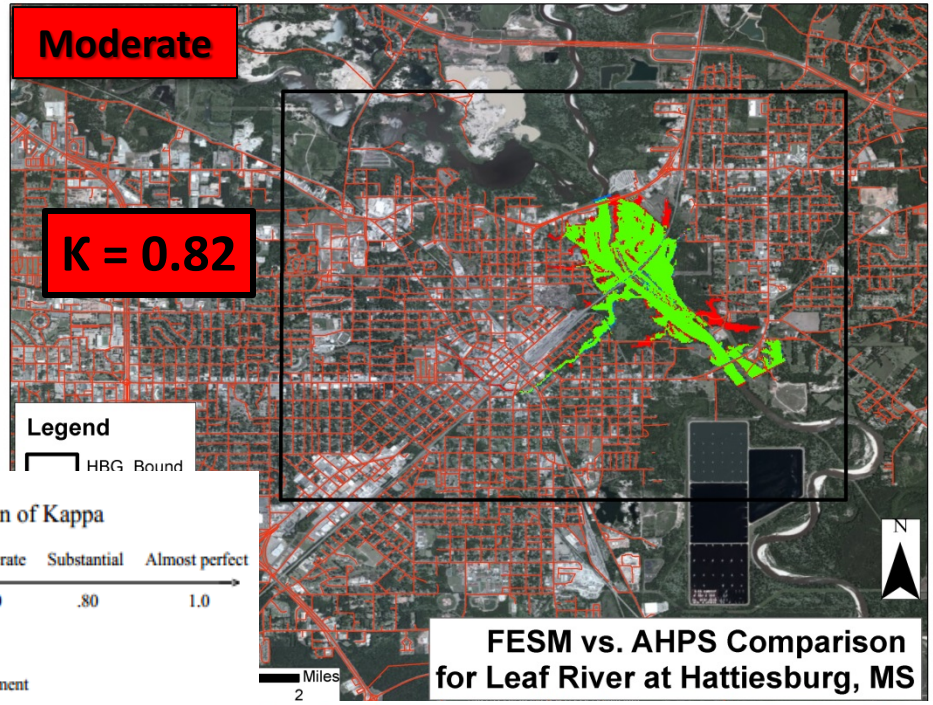
B

Interpretation of Kappa

	Poor	Slight	Fair	Moderate	Substantial	Almost perfect
Kappa	0.0	.20	.40	.60	.80	1.0

Kappa	Agreement
< 0	Less than chance agreement
0.01–0.20	Slight agreement
0.21– 0.40	Fair agreement
0.41–0.60	Moderate agreement
0.61–0.80	Substantial agreement
0.81–0.99	Almost perfect agreement





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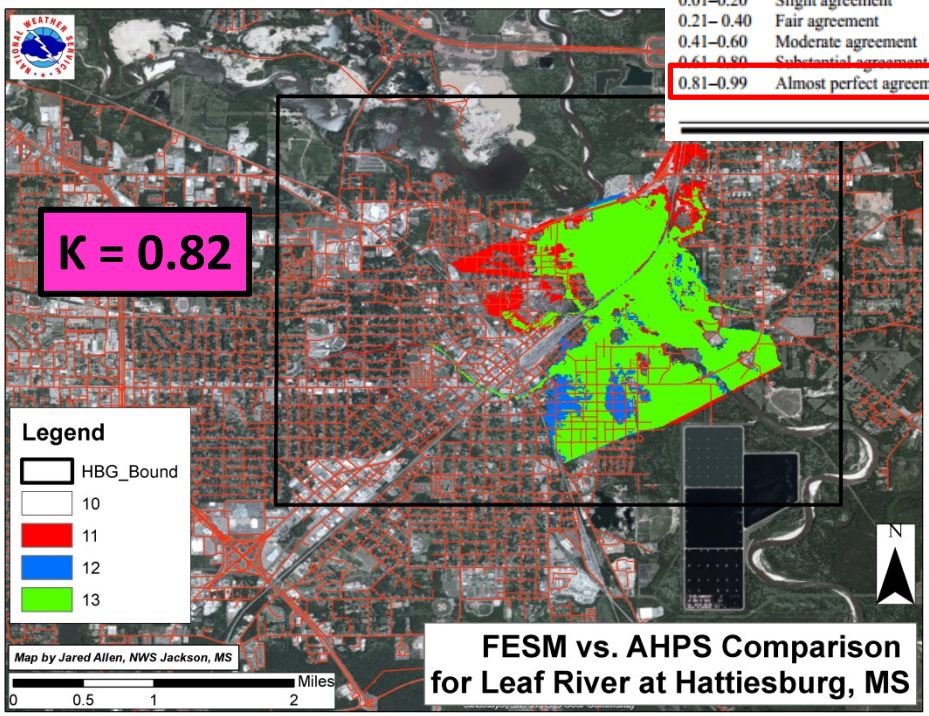
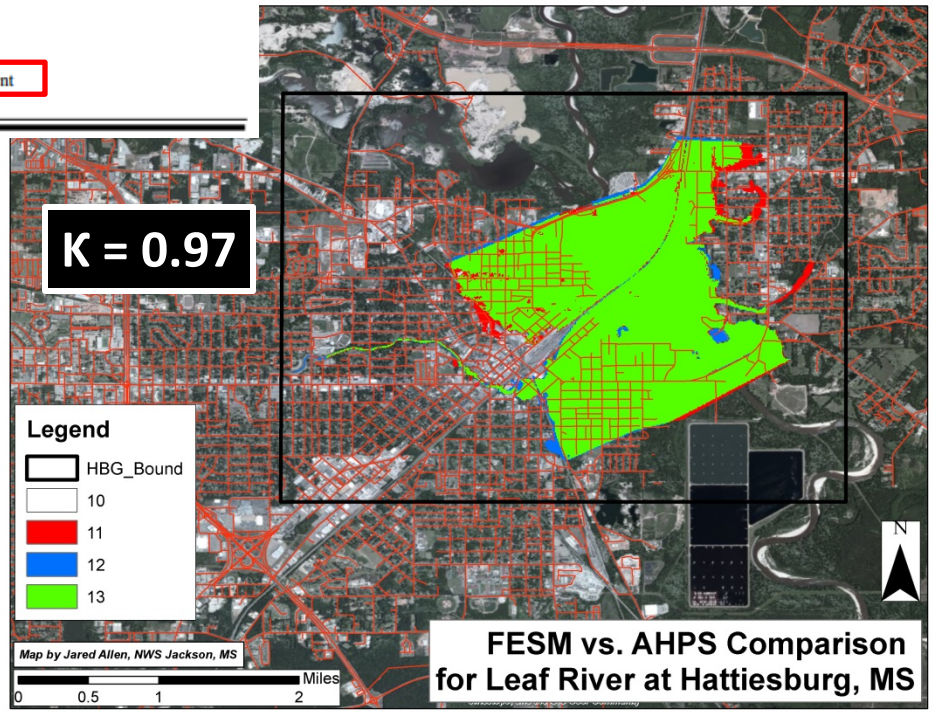




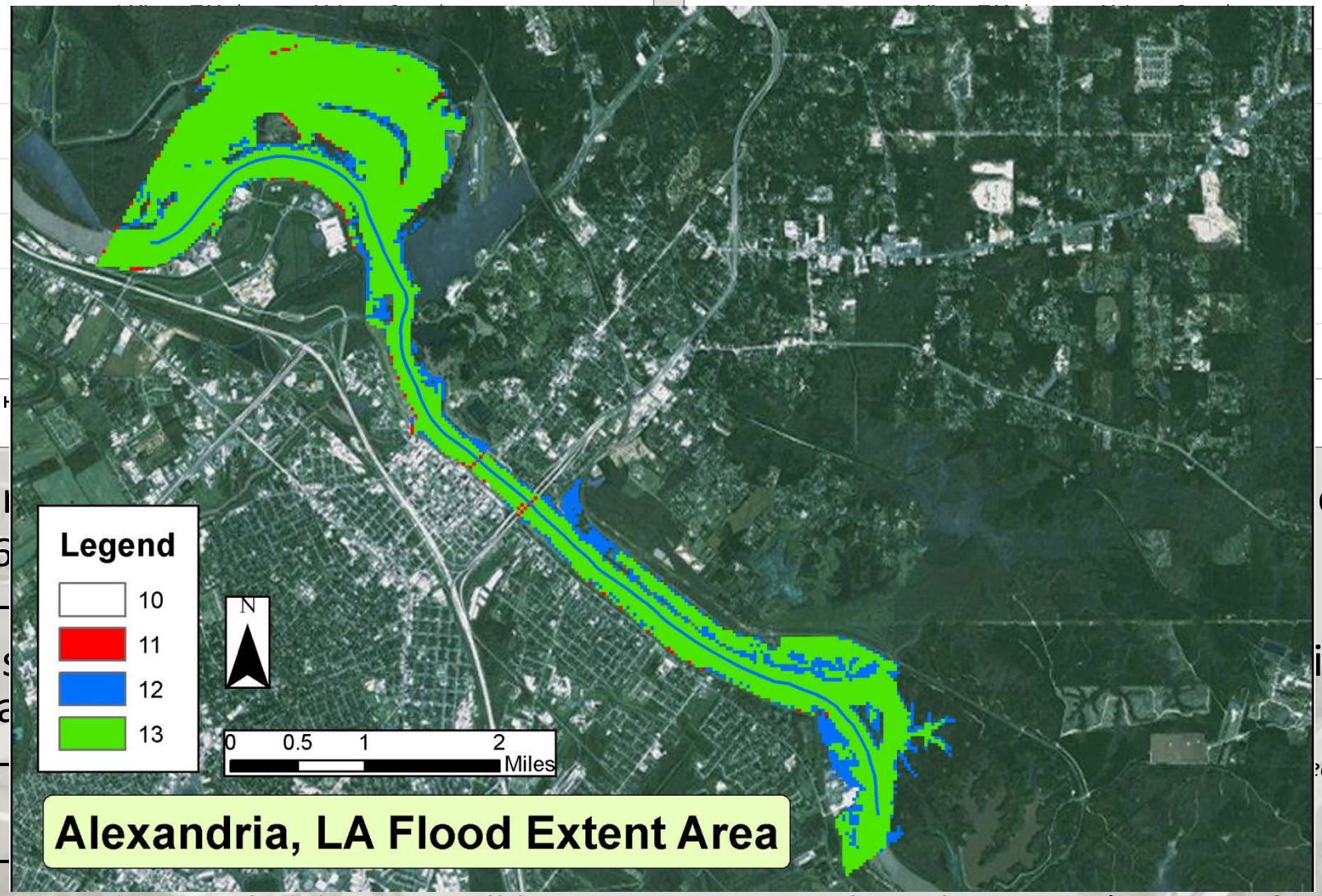
Results

Fig. 1

Unedited Flood Extents

Fig. 2

Edited Flood Extents



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  - 6…
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- U… …ig. 2)
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  - –… …*ement)*
  - –…
  - – Moderate Flood Stage still lowest on average but above 0.8 (near perfect)

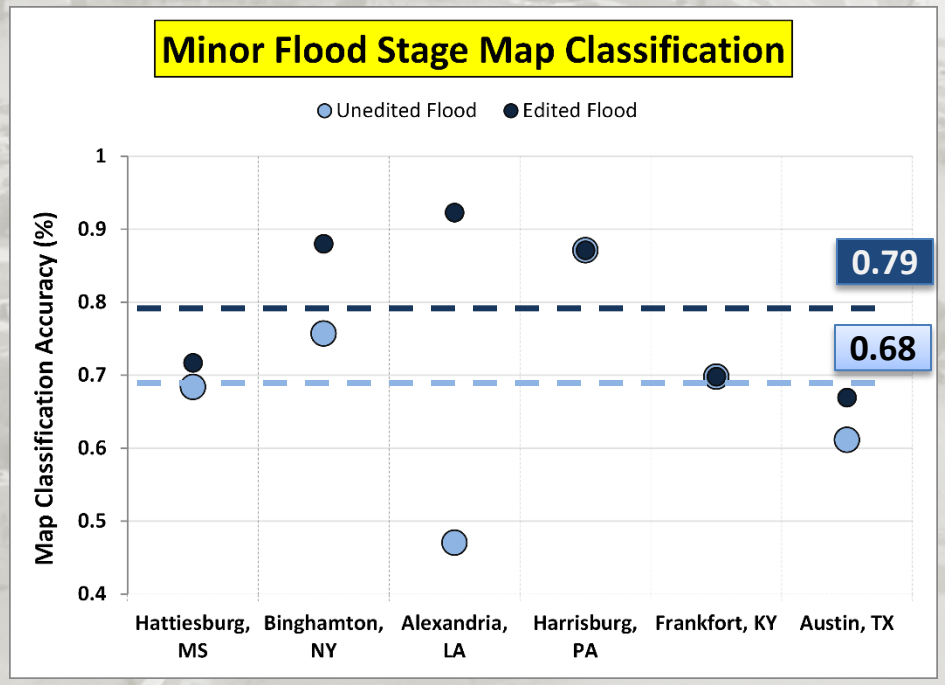
Flood Pixel **C**lassification **A**ccuracy

- FCA = $$\frac{Pixels\ of\ Flood_{Correct}}{(Pixels\ of\ Flood_{Correct} + Pixels\ of\ Flood_{Omission} + Pixels\ of\ Flood_{Commission})}$$

$$FCA = \frac{\sum 13PixelCount}{(\sum 13PixelCount + \sum 12PixelCount + \sum 11PixelCount)}$$

A series of flood classification accuracy graphs comparing unedited FESM Extents and edited FESM Extents against the accepted AHPS Extents were generated for:

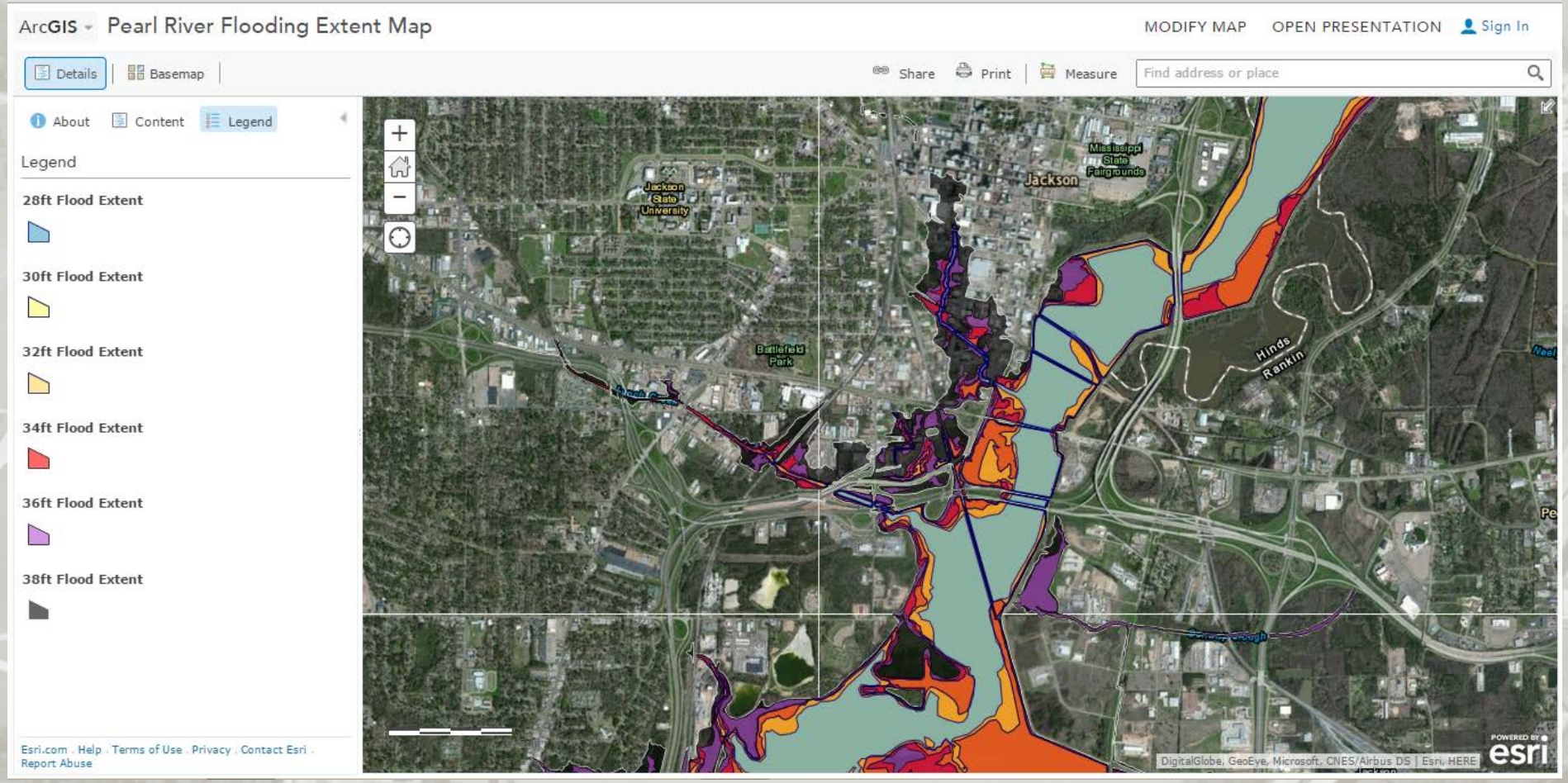
- ***Minor*** - ***Moderate*** - ***Major*** - ***Record***


Minor Flood Stage Map Classification
Unedited Flood
Edited Flood
Map Classification Accuracy (%)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.79
0.68
Hattiesburg, MS
Binghamton, NY
Alexandria, LA
Harrisburg, PA
Frankfort, KY
Austin, TX

Conclusions

- FESM/ArcGIS Methodology deemed spatially accurate
  - Effort vs. Cost Analysis
    - ***70-95% accurate***
    - ***Completed in a week or less & fraction of cost***
- Mapping Accuracy & Kappa can be successfully increased through quality control measures:
  - Set to match current Impact Statements – E19s
  - FEMA DFIRM Data
  - RFC Agreement
  - Emergency Manager & Local Water Authority Agreement
- Future Work
  - Test more sites with current methodology
    - Quantify QC improvements thru Classification and Kappa values
  - Develop internal AGOL website for critical partner access.

ArcGIS Online Integration



National Weather Service Weather Forecast Office

Jackson, MS

weather.gov

Home | Site Map | News | Organization | Search for: | NWS | All NOAA | Go

Tallahala Creek @ Laurel, MS Flood Extent Map

The flood extent areas depicted in the map below were compiled using experimental modeling techniques and historical floods of record documentation and accounts, in coordination with emergency management officials, the USGS, and the U.S. Army Corps of Engineers. The flood extent areas are approximate and are estimates. They are for *informational purposes only* and do not use for life-critical decisions. Always listen and heed local county and city officials if evacuation orders occur in your area or neighborhood.

Legend

Minor Flood Stage Extent

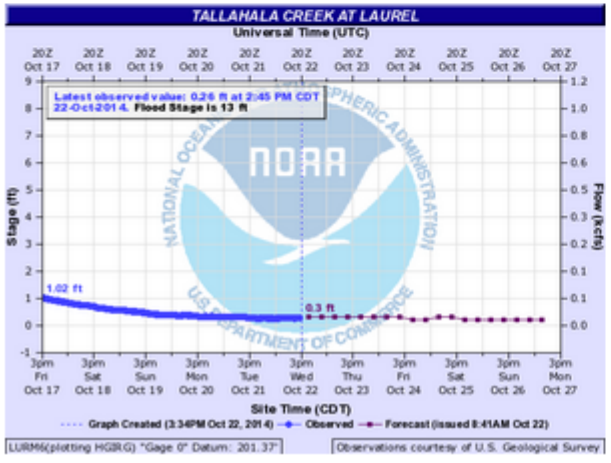
13' Gauge Height or 214.37' above MSL

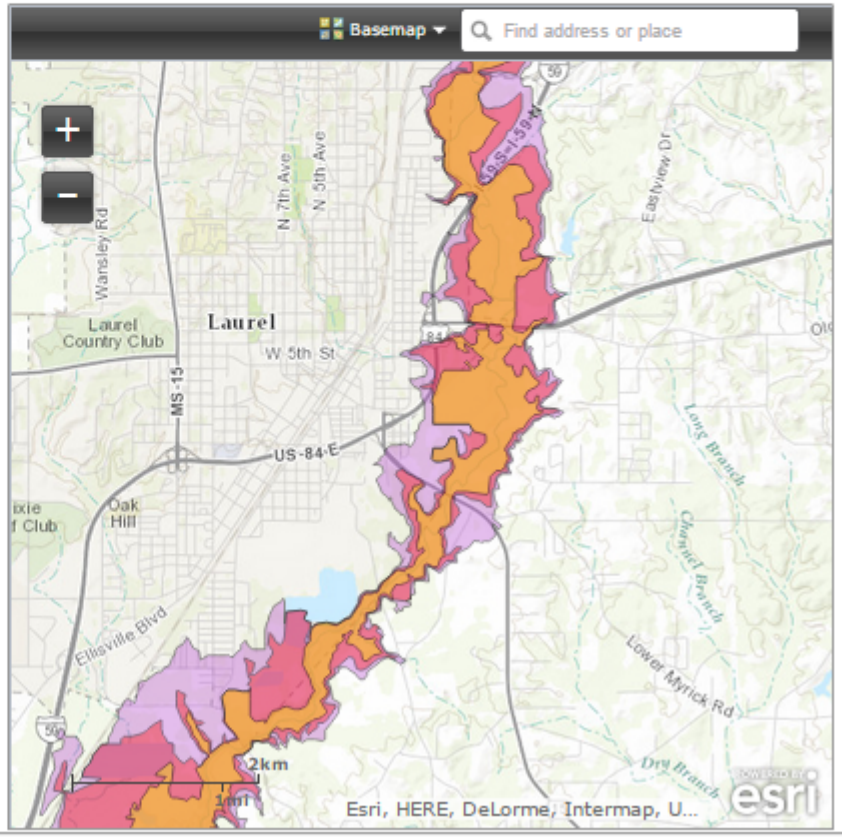
Moderate Flood Stage Extent

16.5' Gauge Height or 217.87' above MSL

Major Flood Stage Extent

19' Gauge Height or 220.37' above MSL





Critical for:

- Key Decision Timelines
- People and Resource Allocation
- EOC Awareness & Service [1,7]

Thank You!

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- Cited Sources:

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7. Wilson, M. D., & Atkinson, P. M. (2005). The use of elevation data in flood inundation modelling: a comparison of ERS interferometric SAR and combined contour and differential GPS data. International Journal of River Basin Management, 3(1), 3-20.
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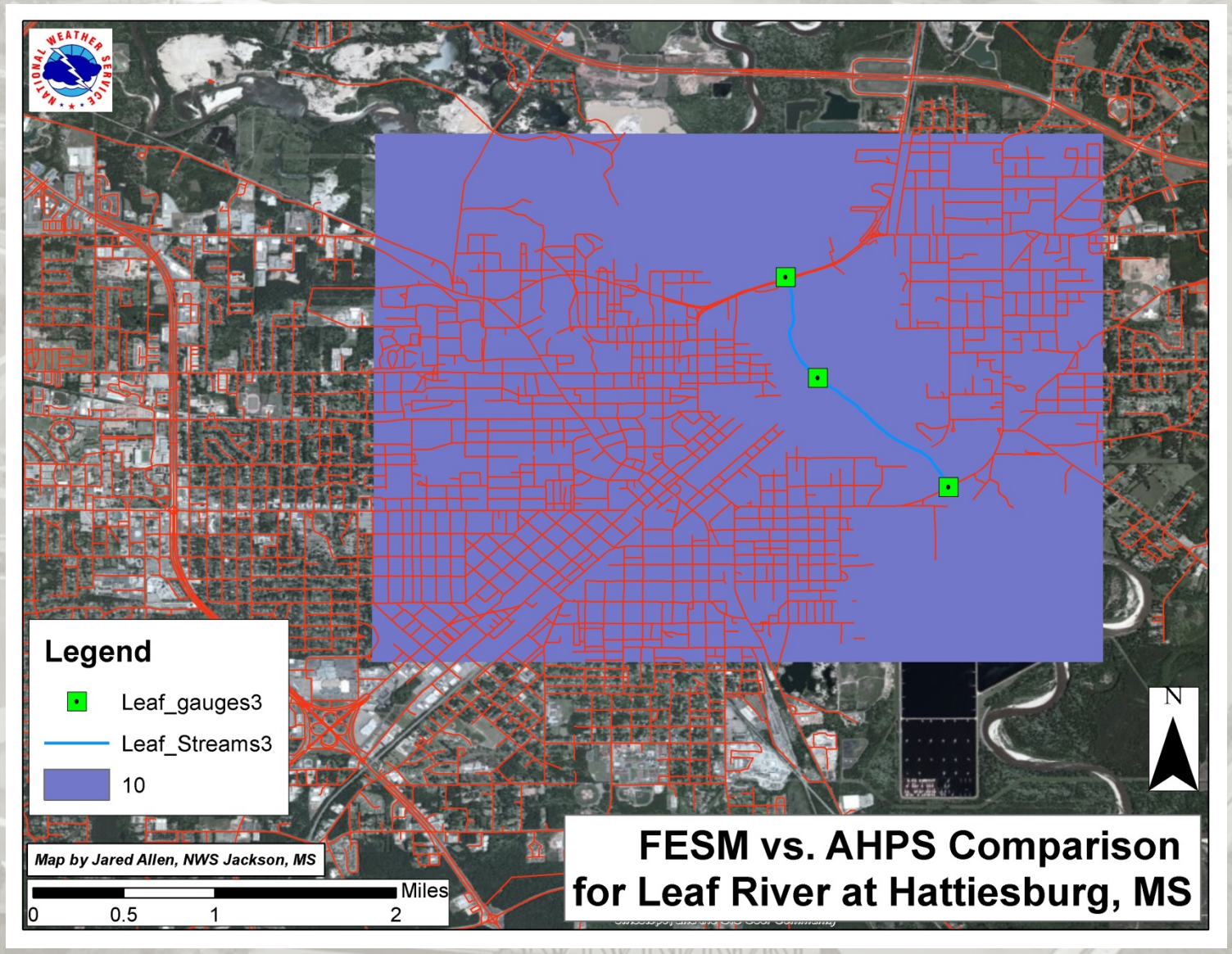
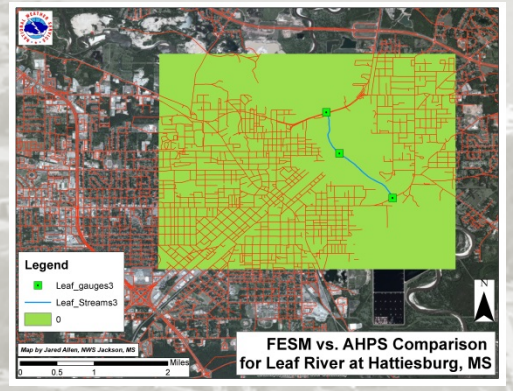
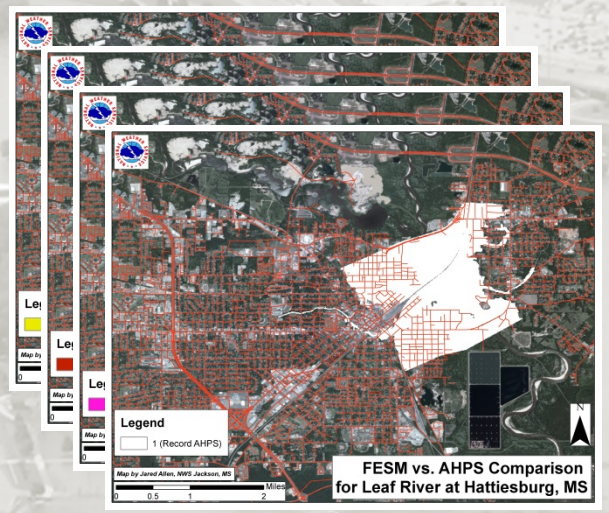
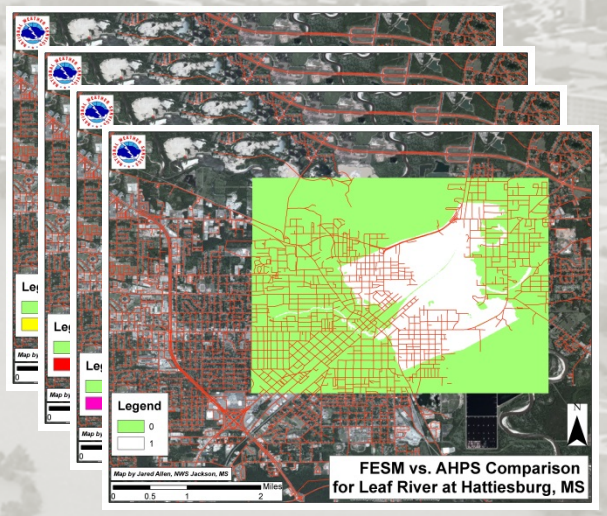
To Find Cohen's Kappa:



AHPS







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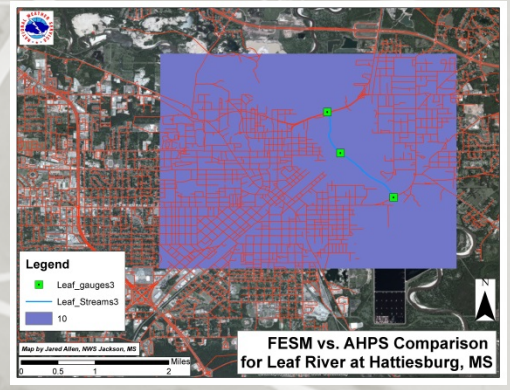
Grid = 1

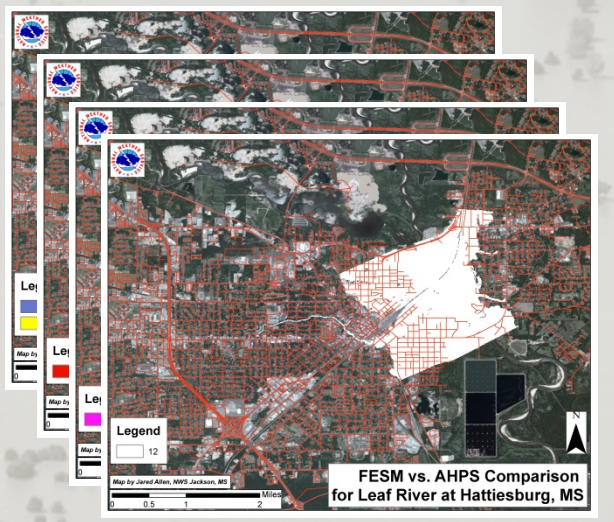
Grid = 0 & 1

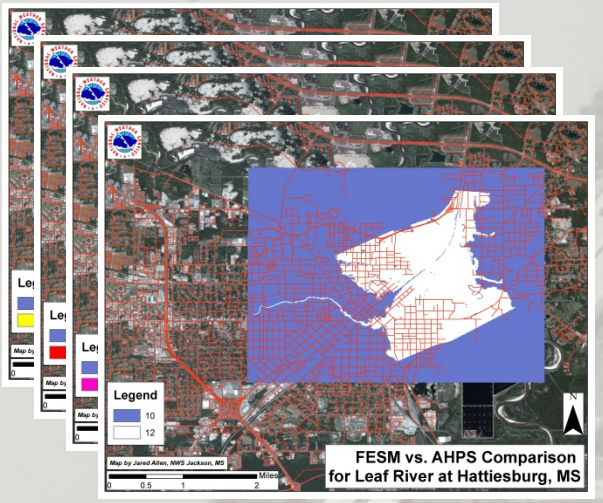
Reclassify Raster

Mosaic to New Raster

FESM



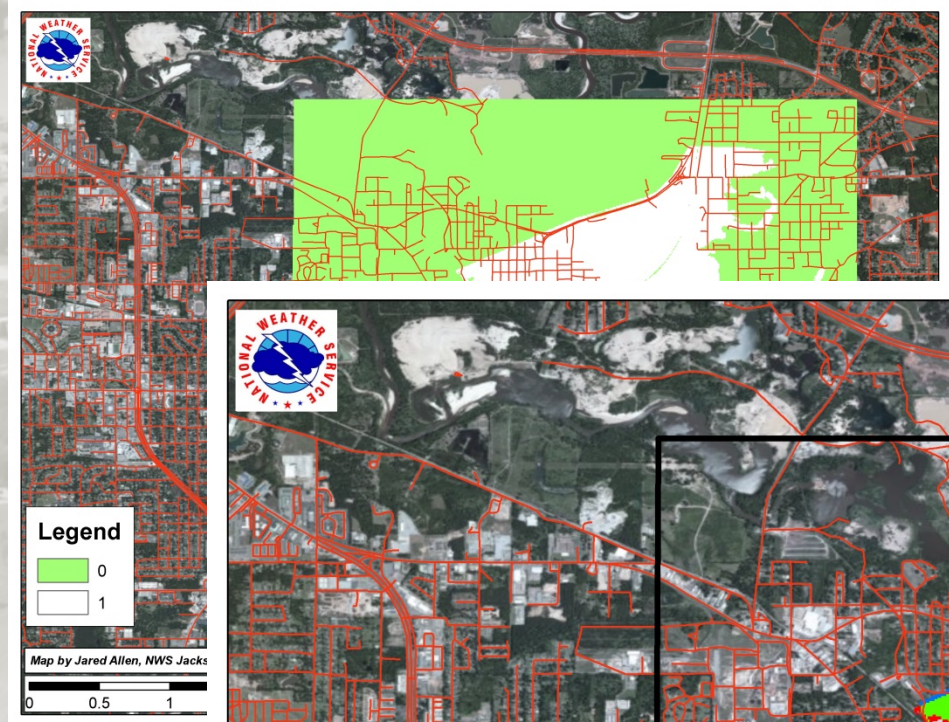


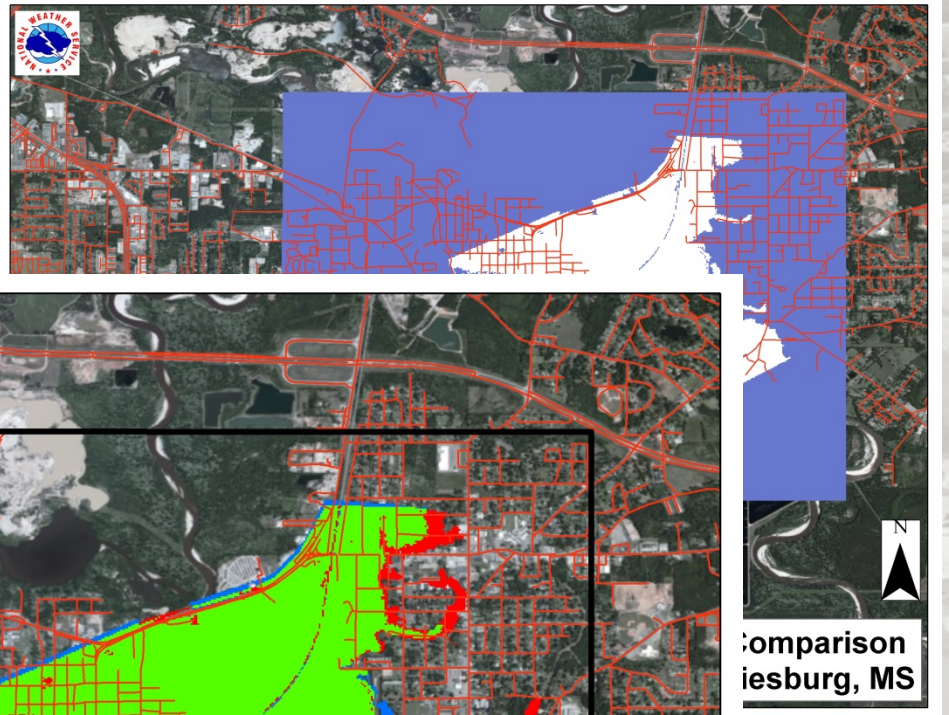


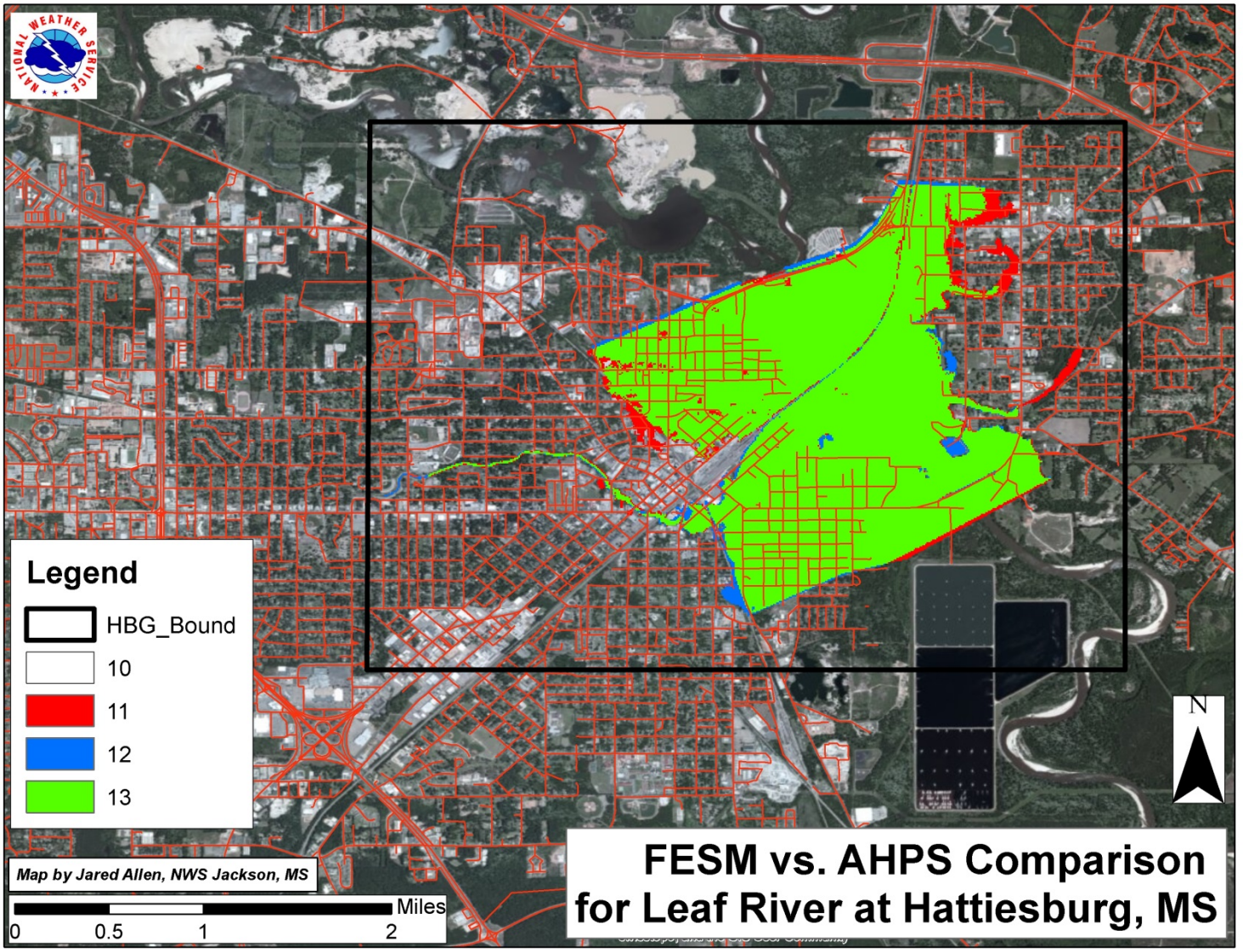
Grid = 10

Grid = 12

Grid = 10 & 12







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10 – Both
11 – Floo
12 – No F
13 – Both

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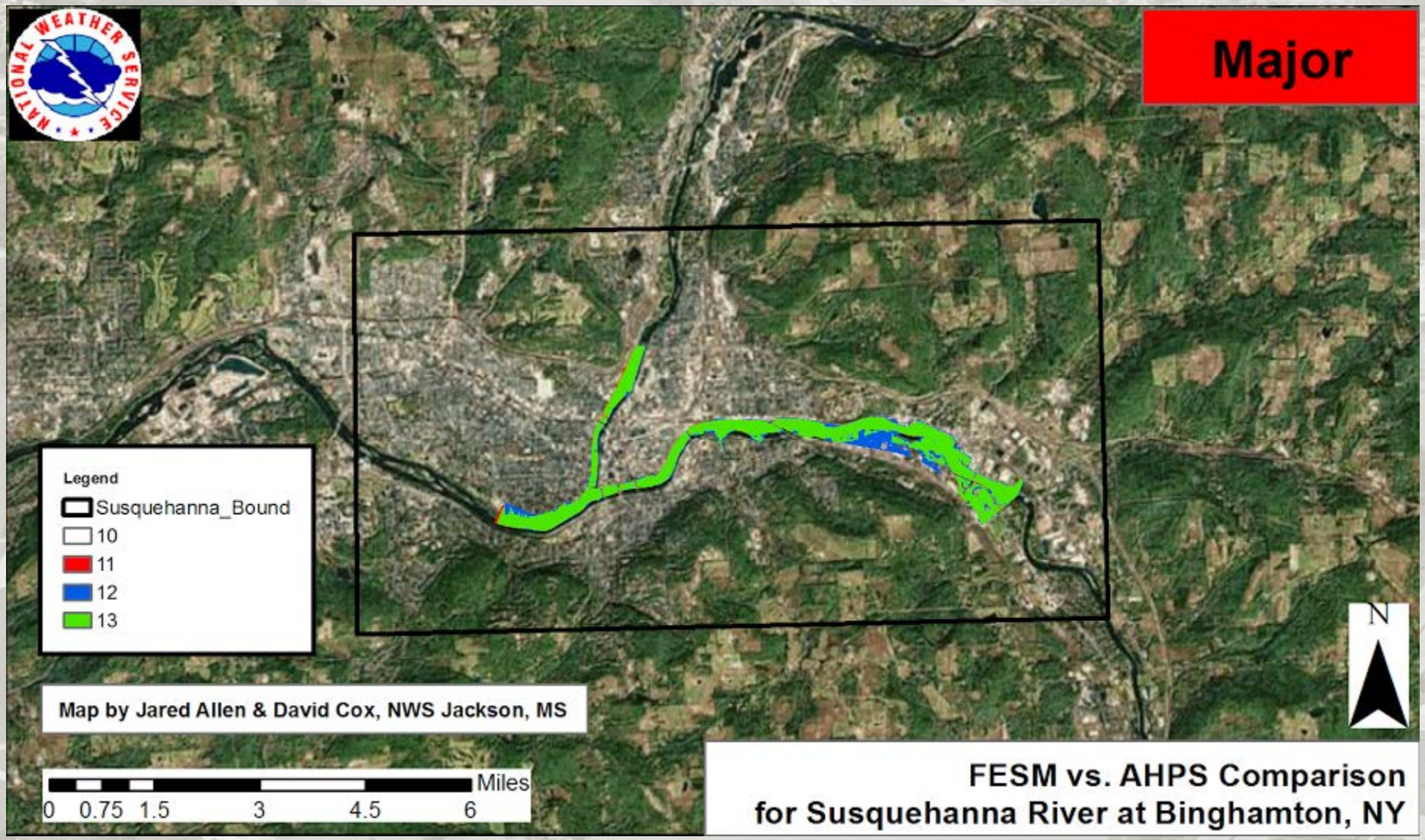
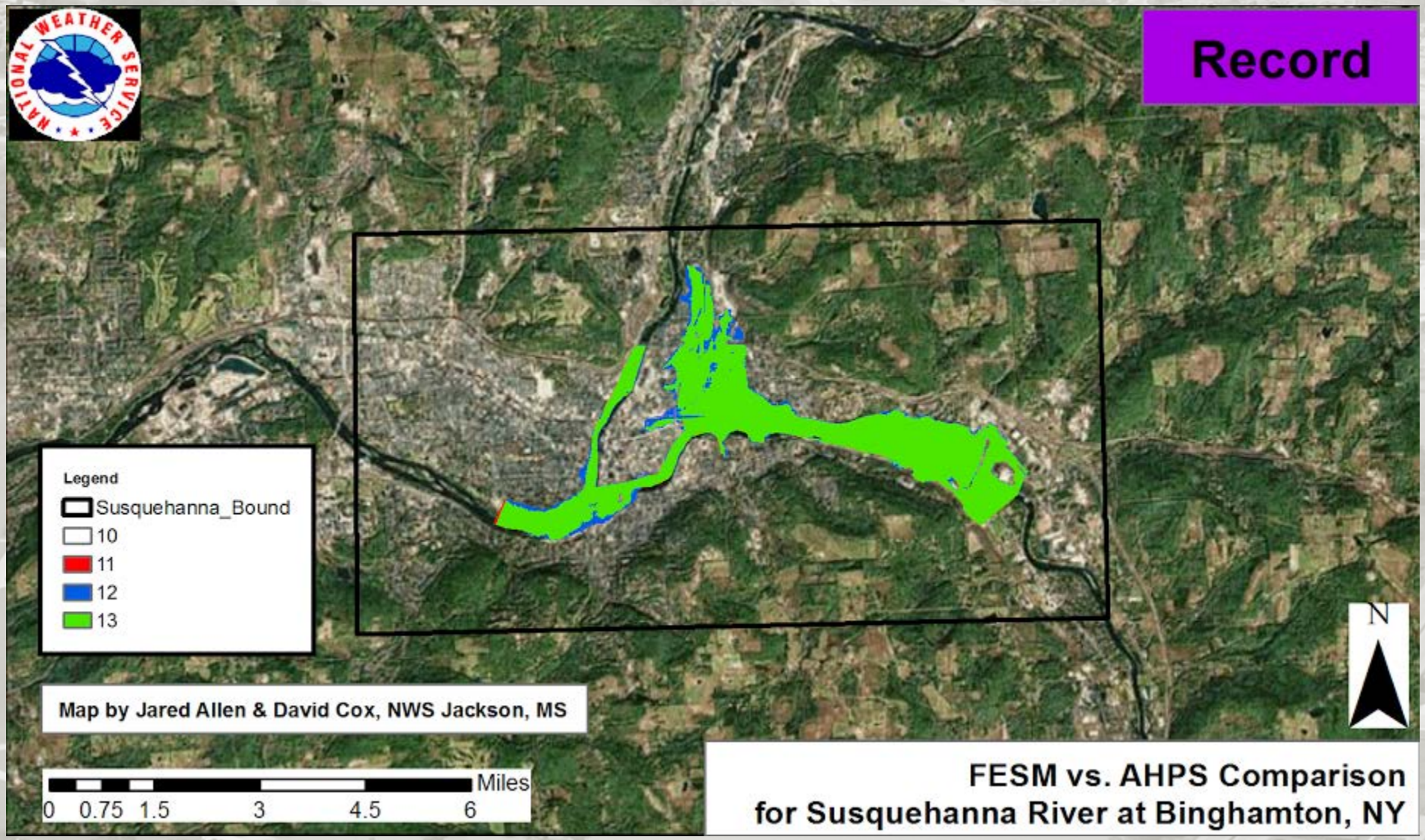

Major
Legend
Susquehanna_Bound
10
11
12
13
N
Map by Jared Allen & David Cox, NWS Jackson, MS
Miles
0 0.75 1.5 3 4.5 6
FESM vs. AHPS Comparison
for Susquehanna River at Binghamton, NY


Record
Legend
Susquehanna_Bound
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Map by Jared Allen & David Cox, NWS Jackson, MS
Miles
0 0.75 1.5 3 4.5 6
FESM vs. AHPS Comparison
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