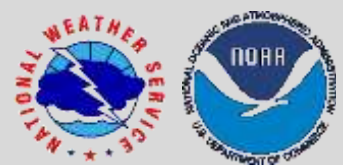


Be Flood SAF(ER)

Situational Awareness for
Emergency Response

A River Flooding
Extent Map Viewer

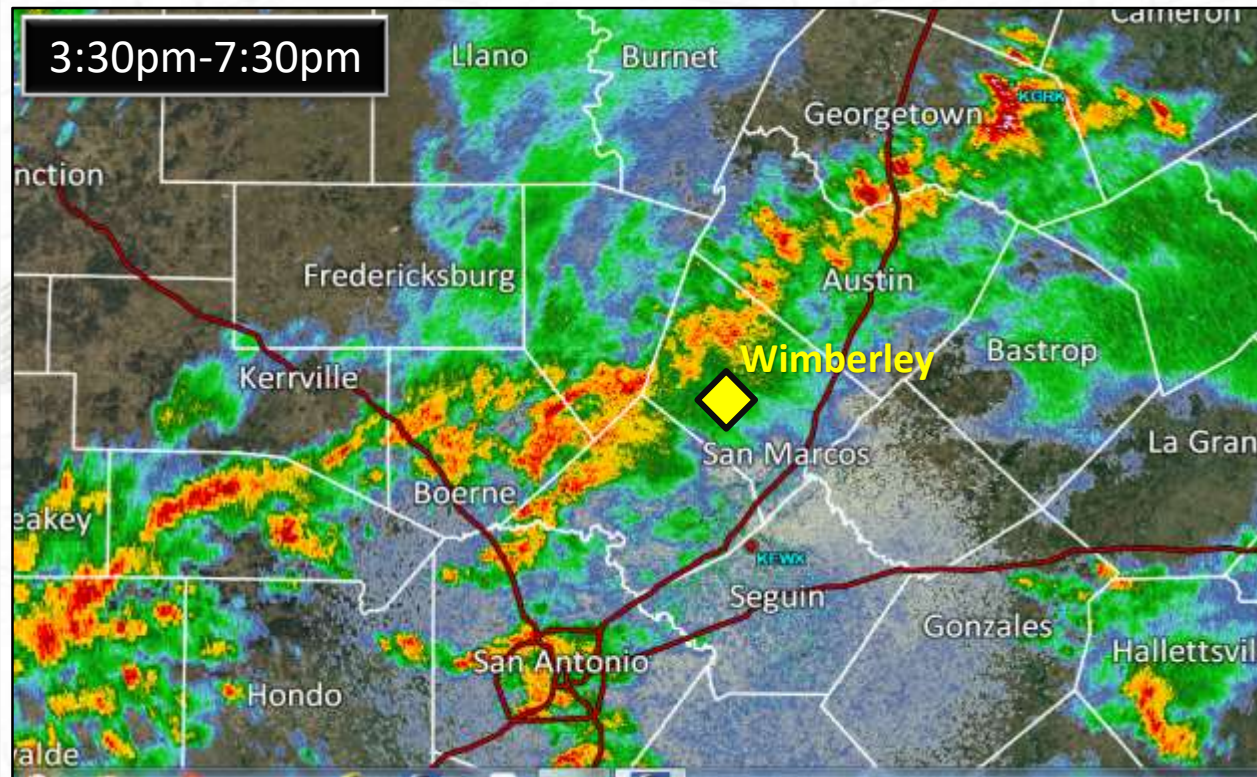


Jared Allen
NOAA/NWS
Austin/San Antonio, TX

Association of State Floodplain
Managers Conference

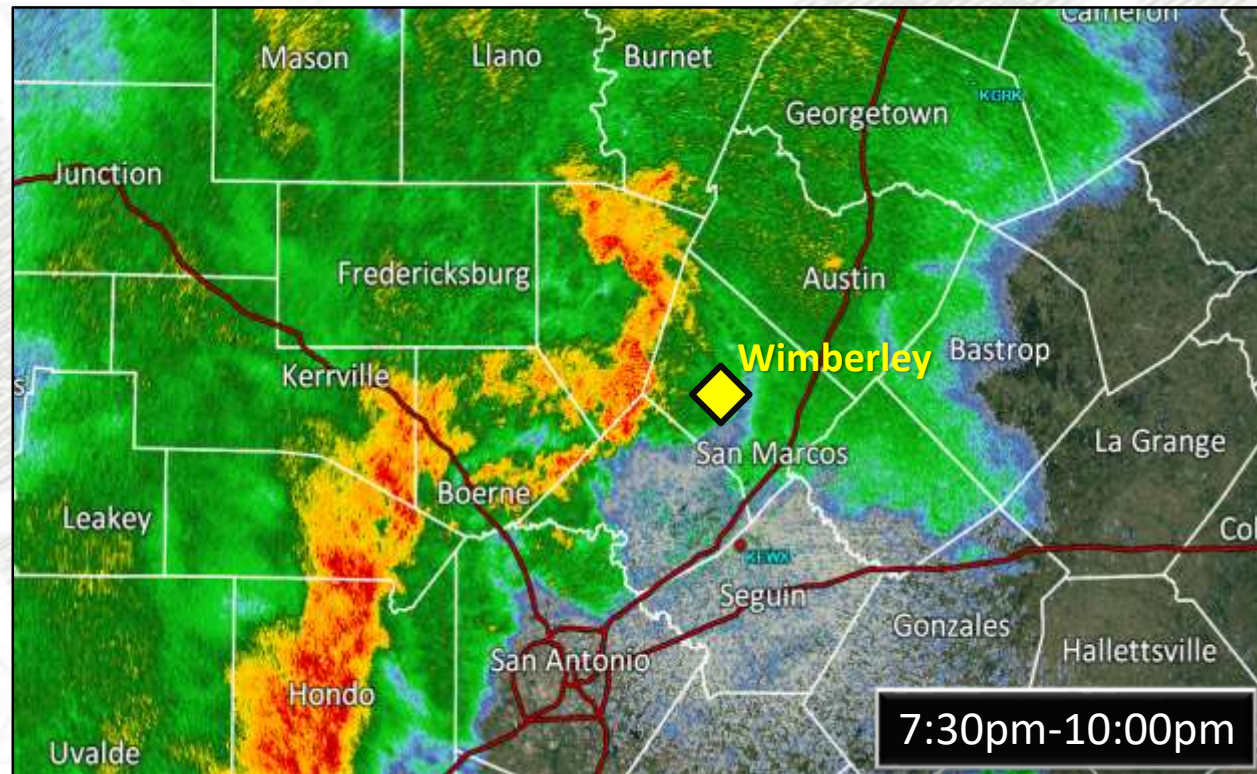
May 4th, 2017

23 May 2015 Radar Reflectivity Review



- Persistent training of convective storms for nearly 7 hours over Hill Country
- Resulted in widespread flash flooding and river flooding

- Quasi-stationary and regenerating convective thunderstorms
- 1-2" per hour rates on average



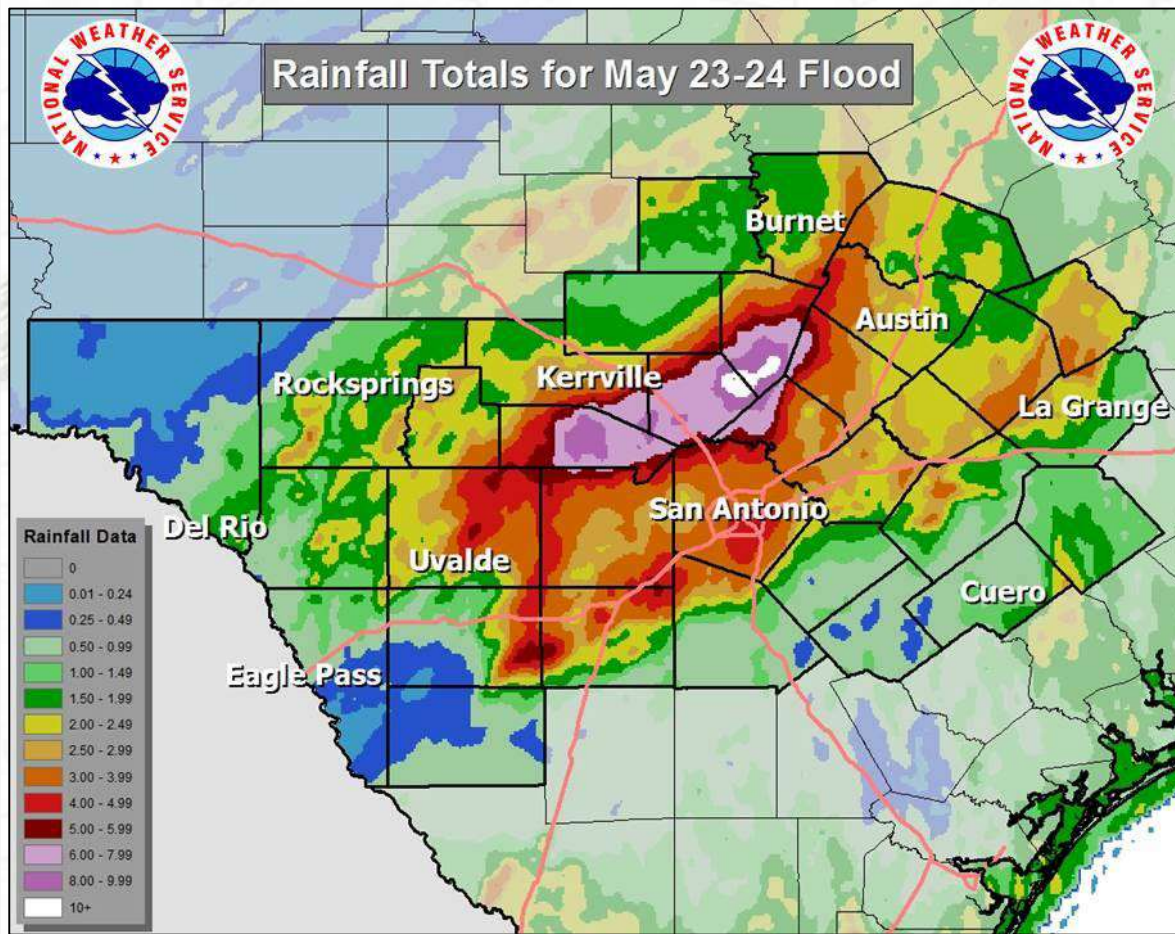
Modeled Run-off Flow (cms/km²)

FLASH Unit StreamFlow (cms/km²)
12Z May 23 – 11Z May 24, 2015

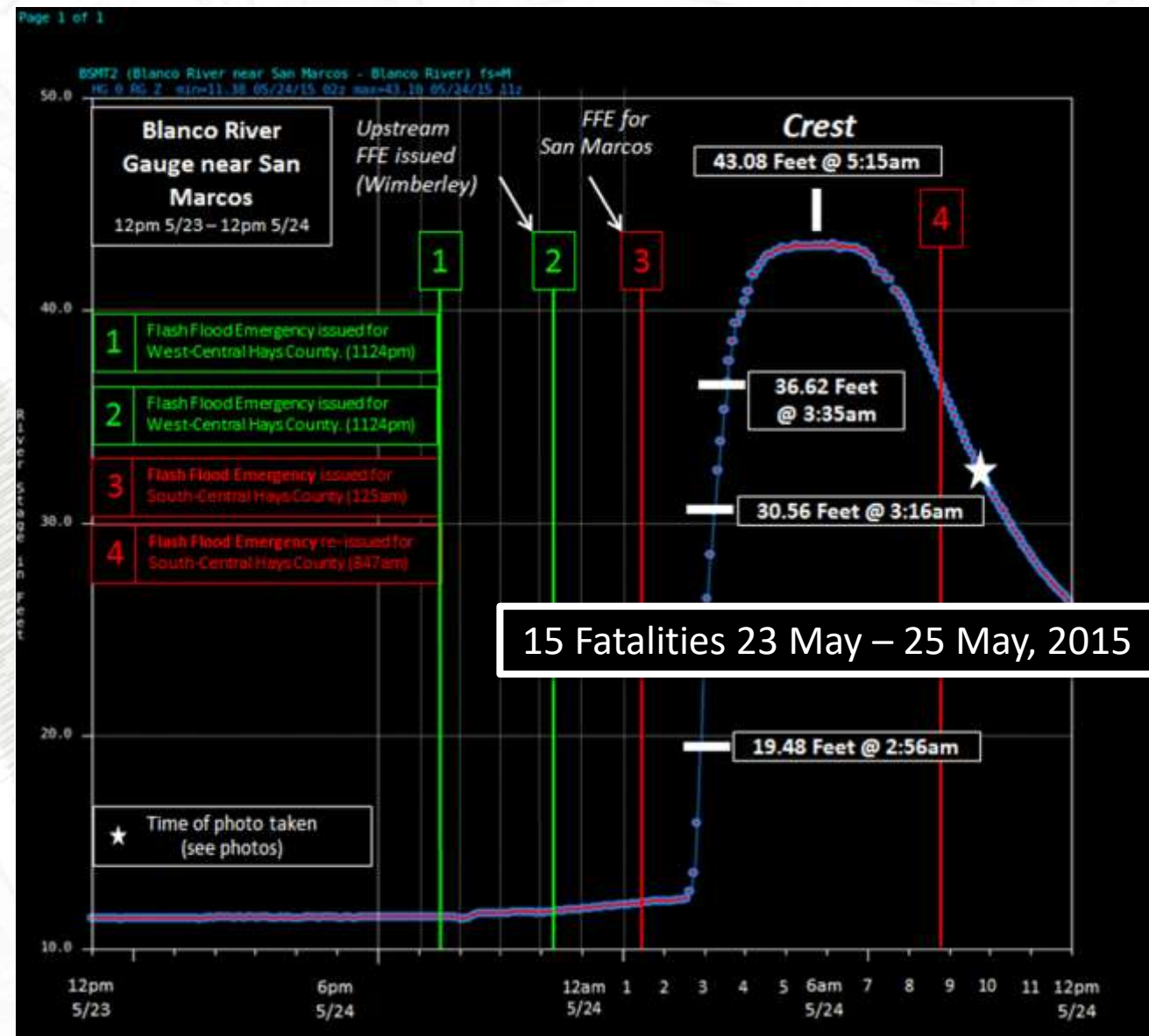
San Antonio



Rainfall Totals & Resultant River Flooding



- Maximum near 13 inches in Kendall and Blanco Counties
- Widespread 6"+ (purple area)



River & Creek Flash Flooding Reality

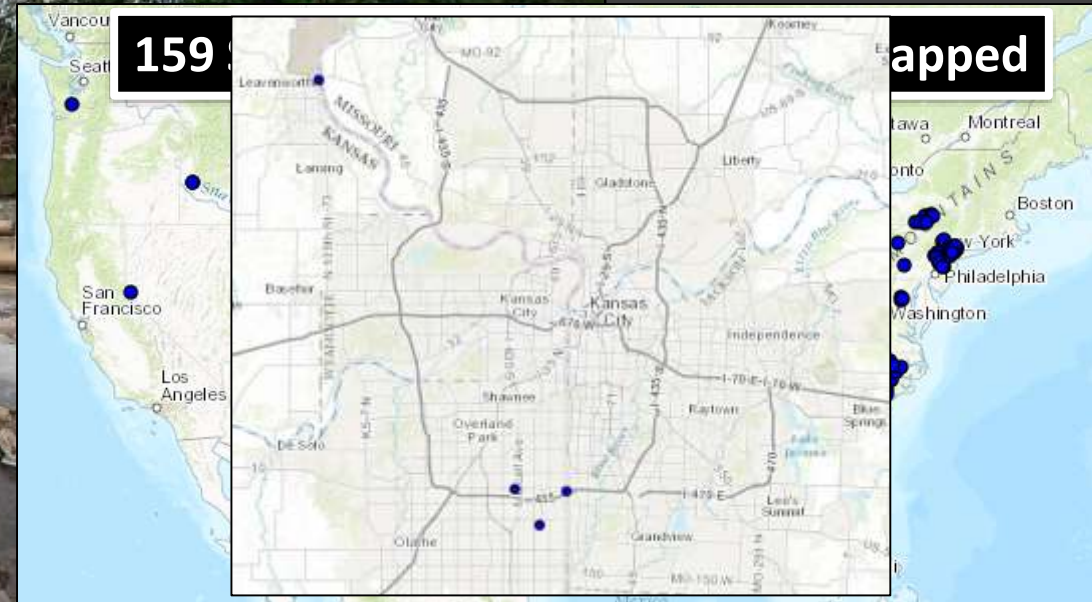
Flash Flood Fatalities Per County (1996-20



148 Flood Fatalities

ts of vacation home in Wirberley, TX

Cost vs. Time & Resources



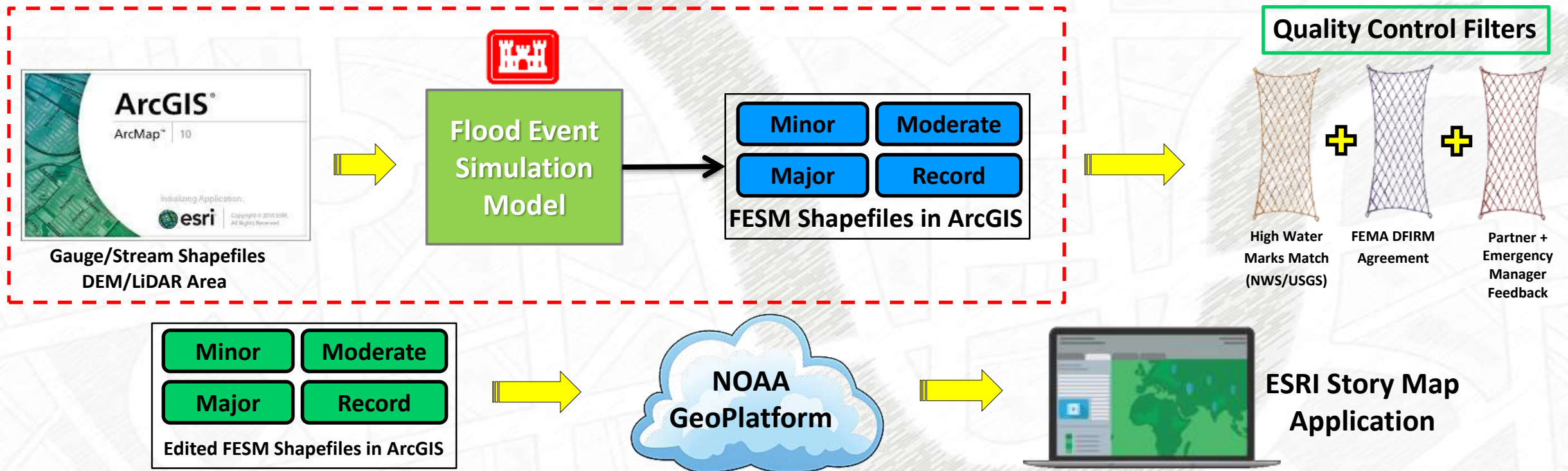
3 months to 12 months per site

\$20,000 - \$150,000 per site

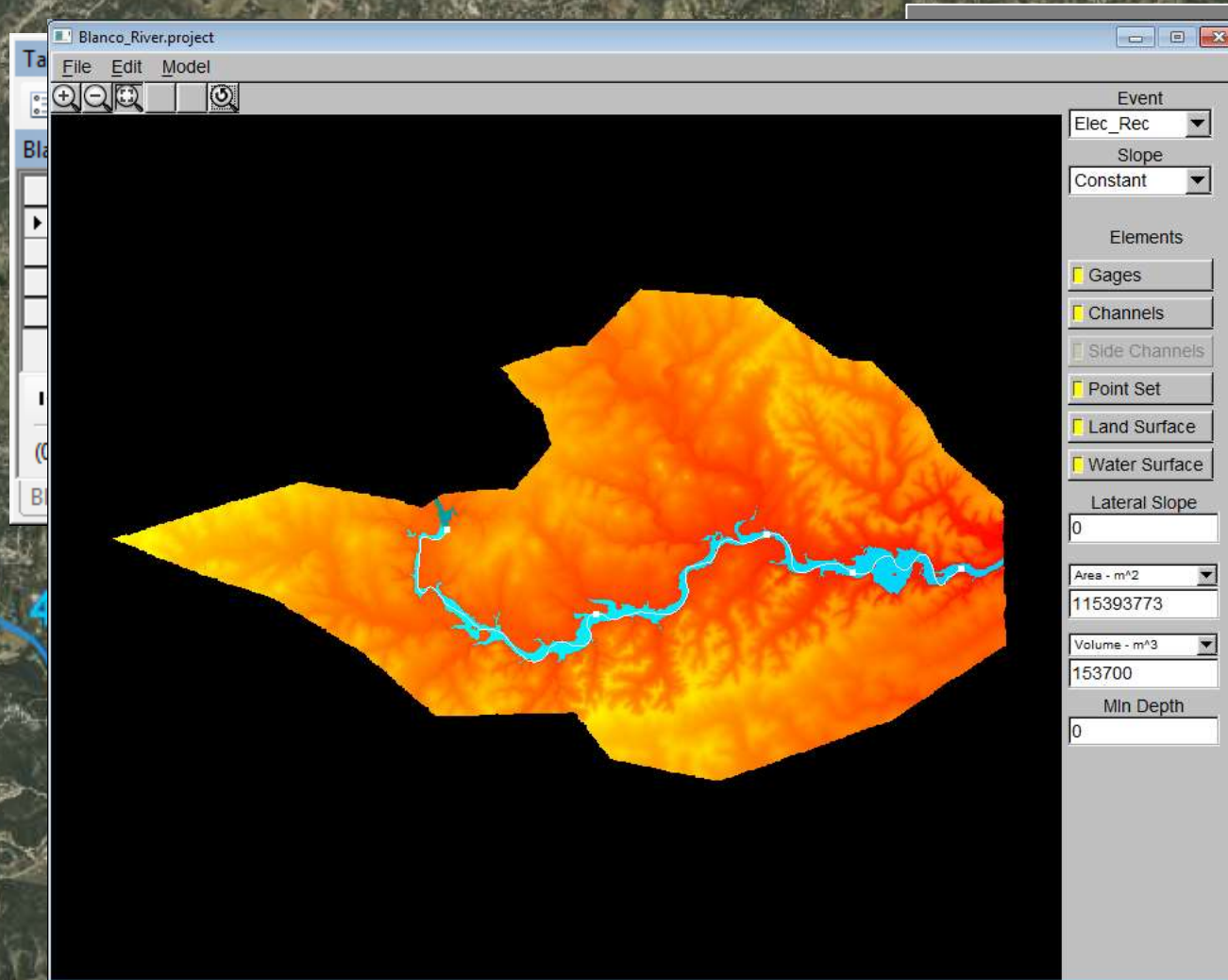
Goals: ↓ cost & ↑ flexibility

Flood SAF(ER) Development

- NWS & U.S. Corps of Engineers Partnership
 - Flood Event Simulation Model (FESM) – USACE Software Program
 - Developed a GIS workflow for NWS exploratory use

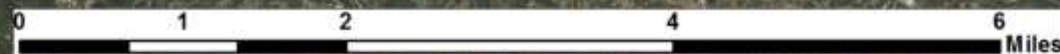


Blanco River near Wimberley, TX



in segments
downstream to
upstream

What's the
accuracy?
Can it be
improved?
Can this
work?



Results

- FESM/ArcGIS Methodology deemed spatially accurate: 6 sites tested
 - Effort vs. Cost Analysis
 - ***70-99% Flood Pixel Classification Accuracy & acceptable Kappa Coefficient statistic***
 - ***Site can be completed in a week or less (starting from scratch)***
 - ***With data in place & practice, can be done in 1-3 hours for raw flood area output & no QC***
- Mapping Accuracy & Kappa can be successfully increased through quality control measures:
 - Set to match current Impact Statements
 - FEMA DFIRM Data
 - River Forecast Center Agreement
 - Emergency Manager & Local Water Authority Agreement

Flood SAF(ER) Application



<http://arcg.is/1L00Wvm>

SAF(ER) Application Overview



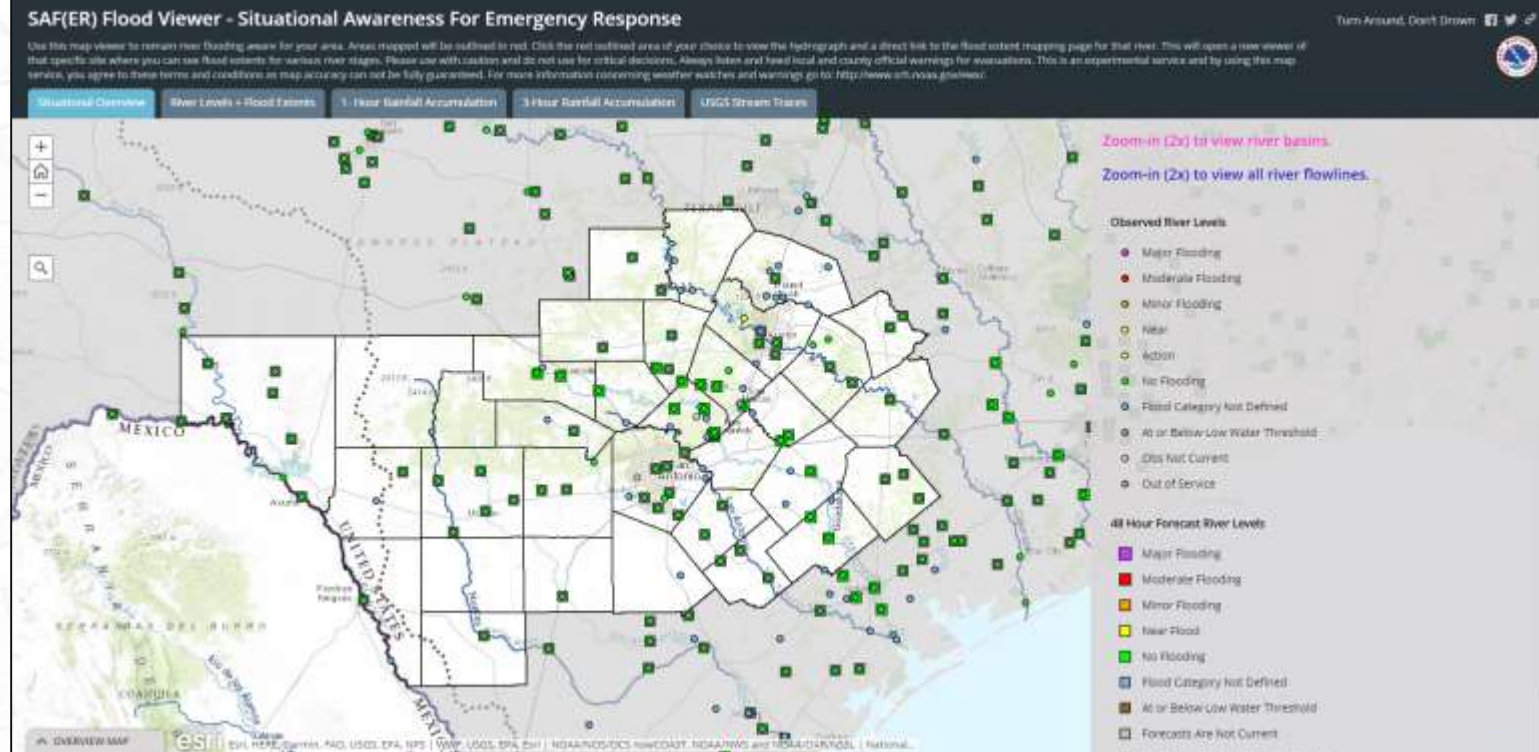
- ESRI ArcGIS Online Web Application
- Developed/Hosted by NOAA/NWS Austin-San Antonio, TX Office
- Link: arcg.is/1L00Wvm

• Current Version:

- Contains 5 Main Tabs
- Sub-Content & links exists on several of the tabs

1. Situational Overview Tab
2. River Levels + Flood Extents
3. 1-Hour Rainfall Accumulation
4. 3-Hour Rainfall Accumulation
5. USGS Stream Traces

Main Goal: Enhance internal and external river and flash flooding awareness, information, planning, and response



Situational Overview Tab



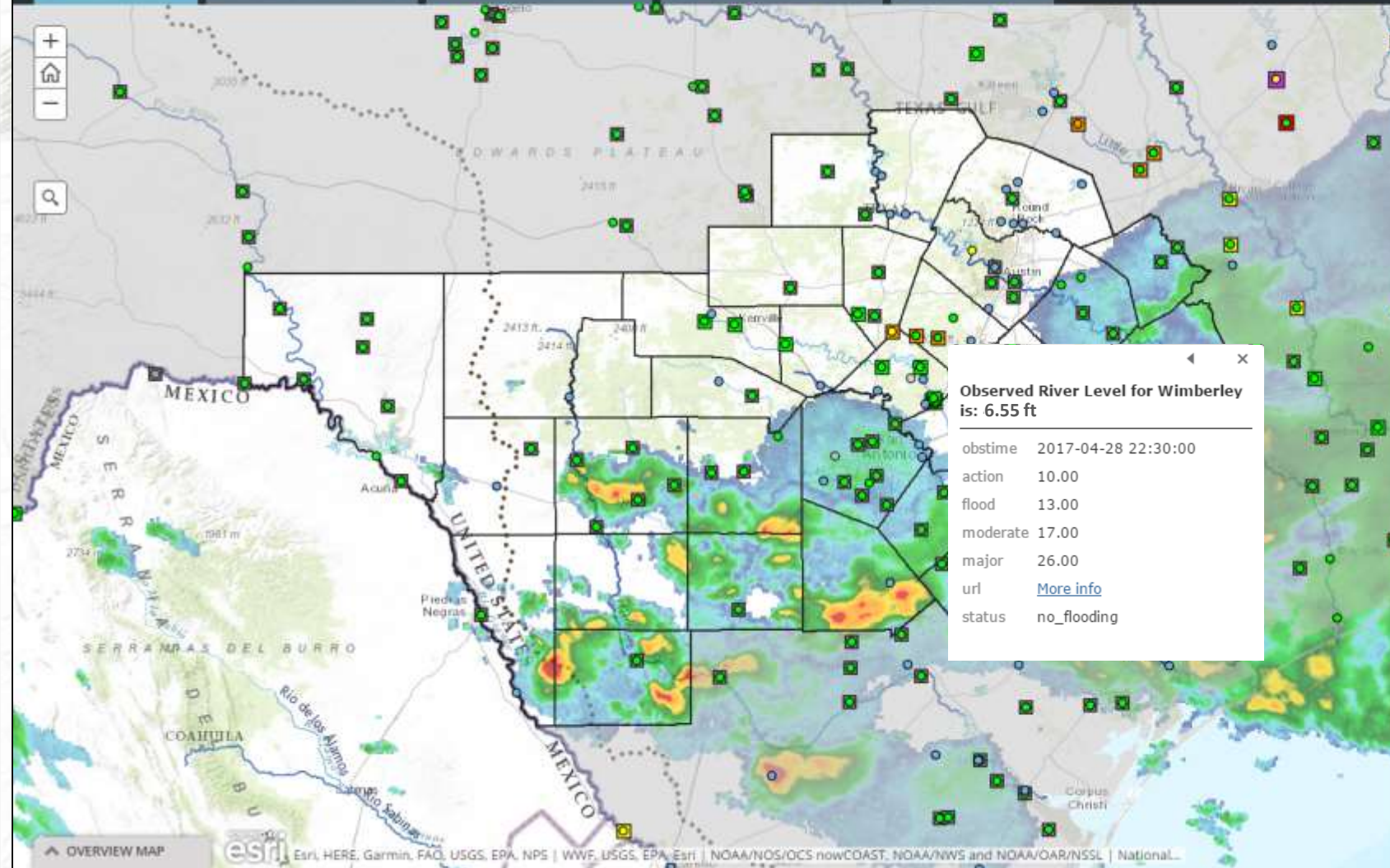
SAF(ER) Flood Viewer - Situational Awareness For Emergency Response

Use this map viewer to remain river flooding aware for your area. Areas mapped will be outlined in red. Click the red outlined area of your choice to view the hydrograph and a direct link to the flood extent mapping page for that river. This will open a new viewer of that specific site where you can see flood extents for various river stages. Please use with caution and do not use for critical decisions. Always listen and heed local and county official warnings for evacuations. This is an experimental service and by using this map service, you agree to these terms and conditions as map accuracy can not be fully guaranteed. For more information concerning weather watches and warnings go to: <http://www.srh.noaa.gov/eww/>.

Turn Around, Don't Drown! [f](#) [t](#) [l](#)



Situational Overview River Levels + Flood Extents 1-Hour Rainfall Accumulation 3-Hour Rainfall Accumulation USGS Stream Traces



- Default opening set-up
- Shows:
 - Latest Observed River Stages
 - 48-hour River Forecast
 - More information appears when clicked
 - HUC-12 Basin Overlay
 - Zoom-in for more info
 - NHD Plus Overlay
 - Zoom-in for more info
 - Radar Overlay

River Levels + Flood Extents Tab



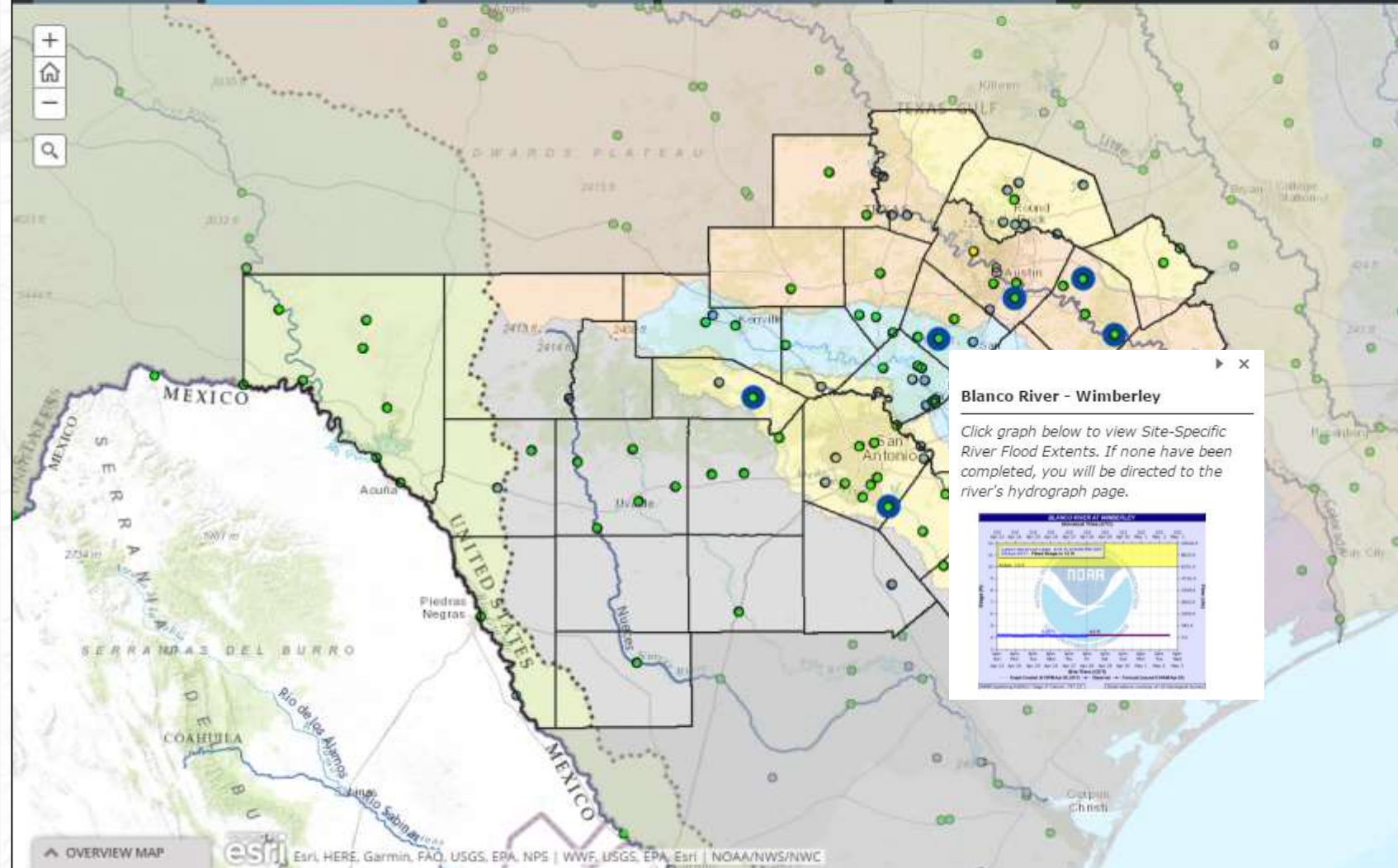
SAF(ER) Flood Viewer - Situational Awareness For Emergency Response

Use this map viewer to remain river flooding aware for your area. Areas mapped will be outlined in red. Click the red outlined area of your choice to view the hydrograph and a direct link to the flood extent mapping page for that river. This will open a new viewer of that specific site where you can see flood extents for various river stages. Please use with caution and do not use for critical decisions. Always listen and heed local and county official warnings for evacuations. This is an experimental service and by using this map service, you agree to these terms and conditions as map accuracy can not be fully guaranteed. For more information concerning weather watches and warnings go to: <http://www.srh.noaa.gov/eww/>.

Turn Around, Don't Drown!



Situational Overview | **River Levels + Flood Extents** | 1-Hour Rainfall Accumulation | 3-Hour Rainfall Accumulation | USGS Stream Traces



- Shows:
 - Latest Observed River Stages
 - More information appears when clicked
 - HUC-12 Basin Overlay
 - Zoom-in for more info
 - NHD Plus Overlay
 - Zoom-in for more info
- Links to individual river flood extent maps
 - Dark Blue Sites
 - Most not currently Public

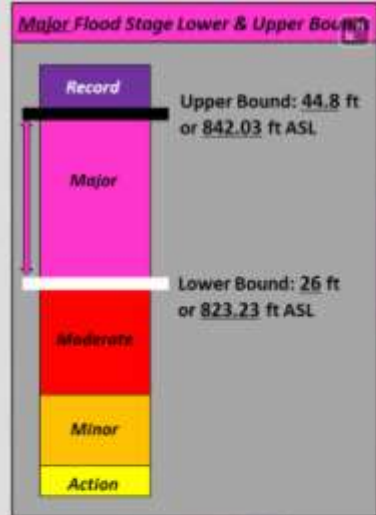
Blanco River at Wimberley Flood Extent Maps



River Flood Extents along Blanco River near Wimberley, TX

This map shows experimental lower and upper bound river flood extents along the Blanco River near Wimberley. Please use with caution and do not use for critical decisions. Always listen and heed local and county official warnings for evacuations. By using this map service, you agree to these terms and conditions as map accuracy can not be fully guaranteed. These flood extents were developed by National Weather Service Austin/San Antonio. For more information concerning weather watches and warnings go to: <http://www.srh.noaa.gov/eww/>. Usage Tips: Use your mouse or map buttons to zoom in/out or click and hold to pan. Flood

Minor Flood Stage Extent Moderate Flood Stage Extent **Major Flood Stage Extent** Record Flood Stage Extent 100 & 500 Year FEMA Flood Maps

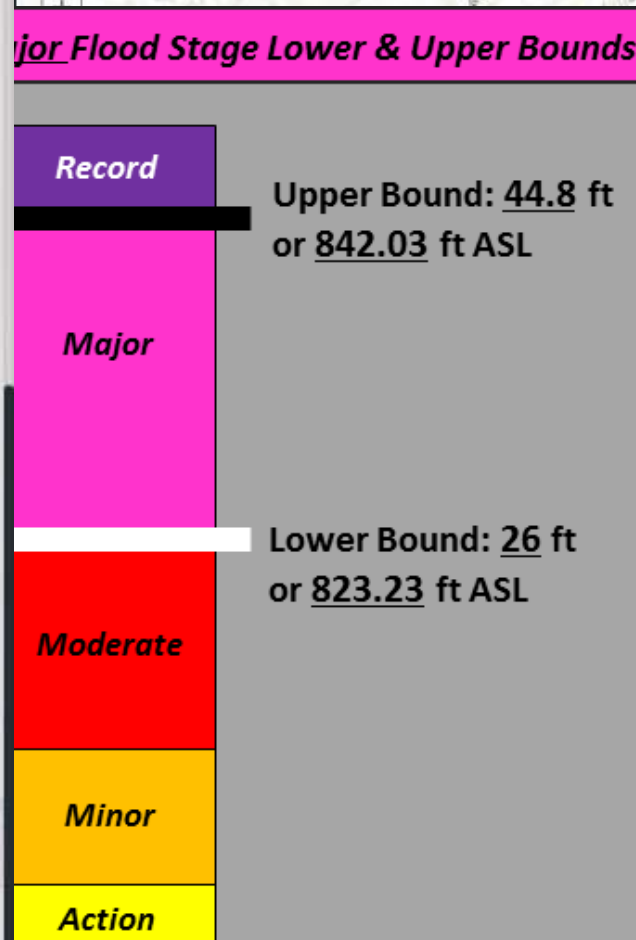


Blanco River Flooding Extent for Major Flood Stage near Wimberley

Scroll Down for Impact Statements

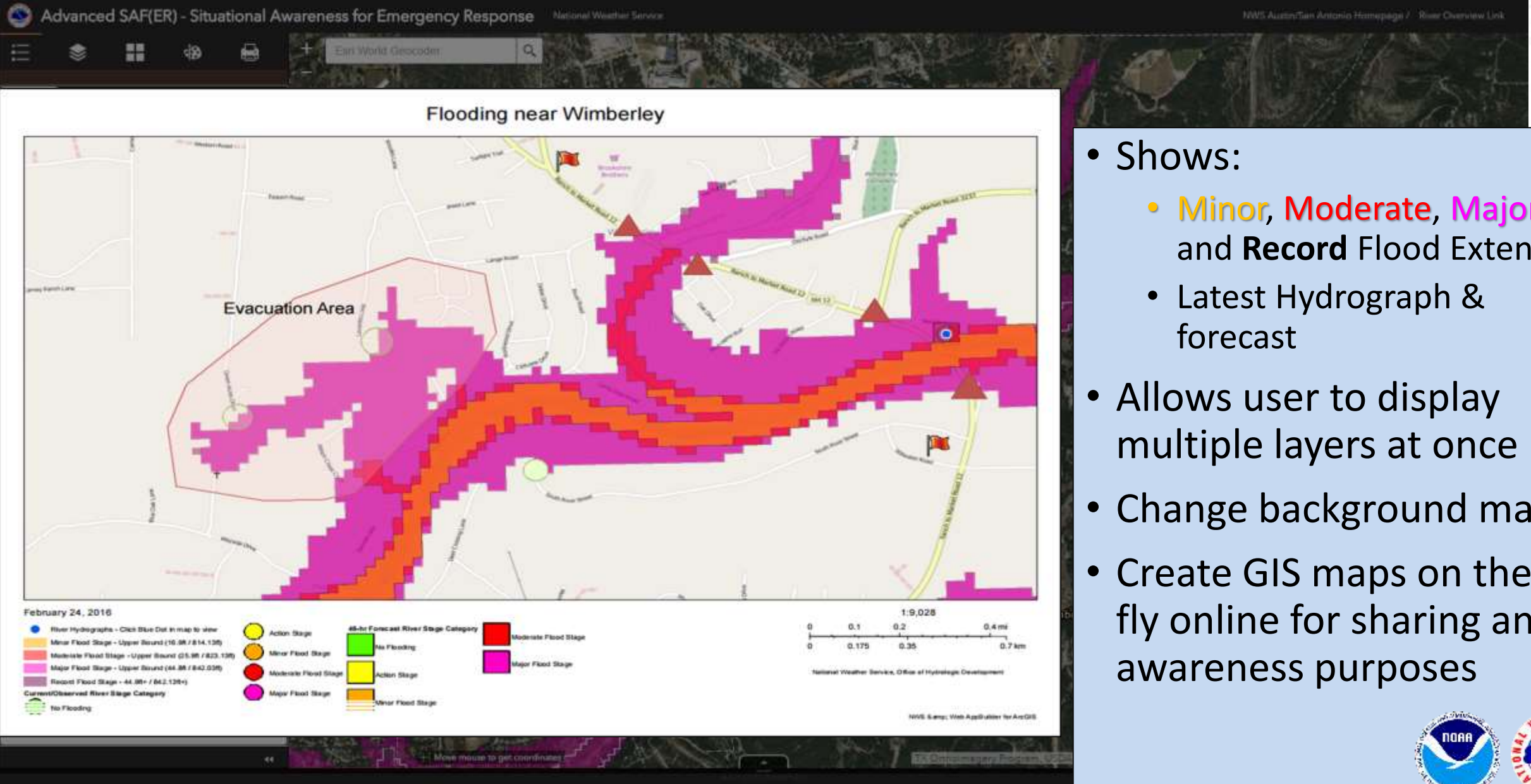
Major Flood Stage Impacts:

- 31 ft. Disastrous life threatening flooding will flood over a hundred homes and businesses in and near Wimberley in the Blanco River and Cypress Creek flood plains. Many homes flood severely downstream in the lower Blanco and San Marcos River flood plains near San Marcos. This level will reach lower rural homes in the flood plain above Blanco to below San Marcos and can trap and drown hundreds of livestock. Roads near the river are extremely dangerous.
- 29 ft. Many lowest homes in the Blanco River flood plain near Wimberley flood. Lowest homes and businesses in the Cypress Creek flood plain flood by backwater from the Blanco River and any runoff down Cypress Creek. Lowland flooding downstream in the lower Blanco and San Marcos Rivers severely floods lowest homes, roads and bridges near San Marcos. Livestock in the Blanco River flood plain above Blanco to the San Marcos River confluence are cut off and potentially drowned.
- 26 ft. Major flooding impacts several lowest homes on the Blanco River near Wimberley. Homes along Cypress Creek near Wimberley also are threatened by the Blanco River backwater and any flow down Cypress Creek. Major flooding of the lower Blanco River in northeast San Marcos floods lowest homes and inundates roads and low bridges with several feet of water near the river making them extremely dangerous. Livestock are cut off and potentially drowned.



- Shows:
 - Minor, Moderate, Major, and Record Flood Extents
 - 100 & 500 Year FEMA Flood extents
 - Latest Hydrograph + Forecast
 - Info-graphics showing river levels being viewed
 - Text Impact Statements
- Link to Advanced SAF(ER) Flood Extents

Blanco River at Wimberley Flood Extent Maps- Advanced Viewer



1-hour Rainfall Accumulation Tab



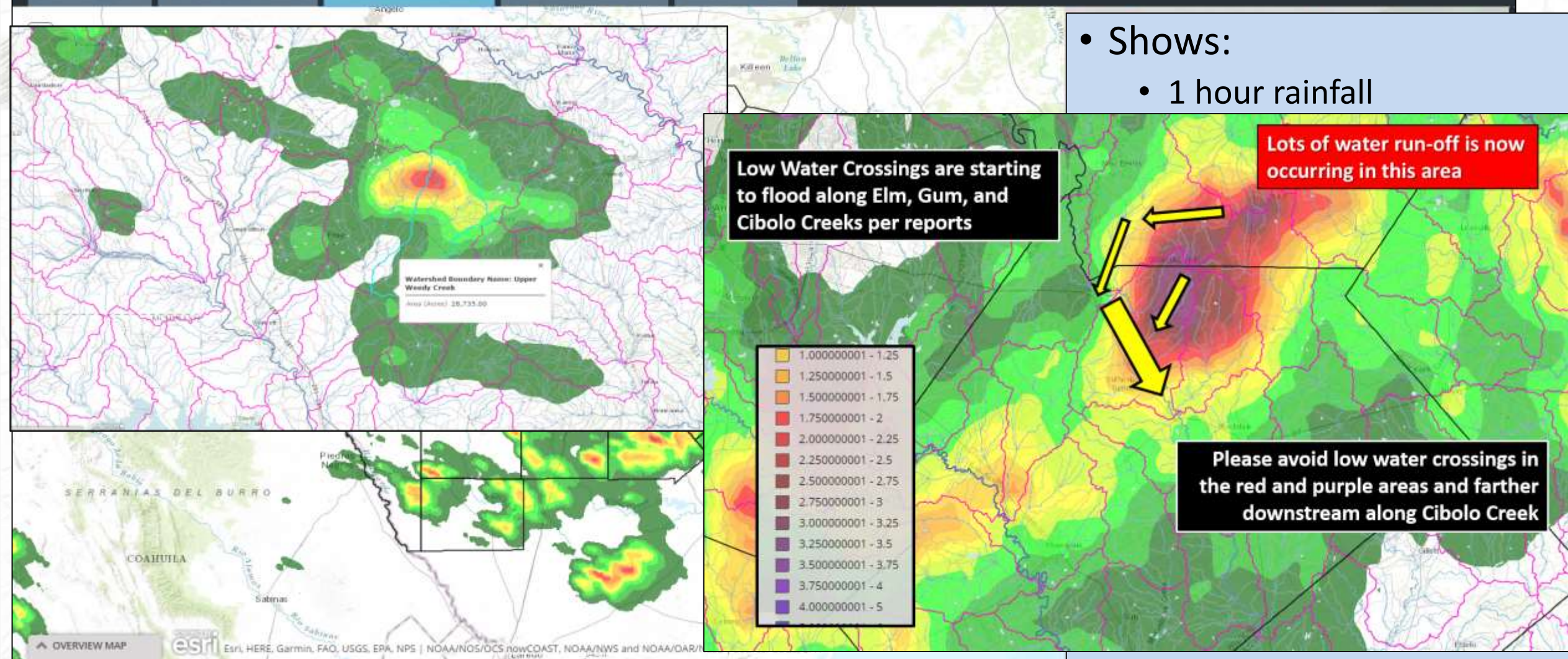
SAF(ER) Flood Viewer - Situational Awareness For Emergency Response

Use this map viewer to remain river flooding aware for your area. Areas mapped will be outlined in red. Click the red outlined area of your choice to view the hydrograph and a direct link to the flood extent mapping page for that river. This will open a new viewer of that specific site where you can see flood extents for various river stages. Please use with caution and do not use for critical decisions. Always listen and heed local and county official warnings for evacuations. This is an experimental service and by using this map service, you agree to these terms and conditions as map accuracy can not be fully guaranteed. For more information concerning weather watches and warnings go to: <http://www.srh.noaa.gov/ews/>.

Turn Around, Don't Drown



Situational Overview River Levels + Flood Extents **1-Hour Rainfall Accumulation** 3-Hour Rainfall Accumulation USGS Stream Traces



- Shows:
- 1 hour rainfall

3-hour Rainfall Accumulation Tab



SAF(ER) Flood Viewer - Situational Awareness For Emergency Response

Use this map viewer to remain river flooding aware for your area. Areas mapped will be outlined in red. Click the red outlined area of your choice to view the hydrograph and a direct link to the flood extent mapping page for that river. This will open a new viewer of that specific site where you can see flood extents for various river stages. Please use with caution and do not use for critical decisions. Always listen and heed local and county official warnings for evacuations. This is an experimental service and by using this map service, you agree to these terms and conditions as map accuracy can not be fully guaranteed. For more information concerning weather watches and warnings go to: <http://www.srh.noaa.gov/eww/>.

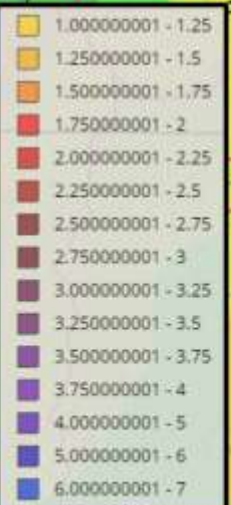
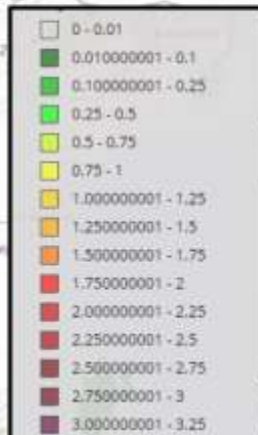
Turn Around, Don't Drown



Situational Overview River Levels + Flood Extents 1-Hour Rainfall Accumulation **3-Hour Rainfall Accumulation** USGS Stream Traces

Low Water Crossings are flooding in this area. Do not travel in this area for the next few hours. 2 high

3-Hour Rainfall Totals 10pm to 1am



- Shows:
 - 3 hour rainfall accumulation
 - Multi-Radar, Multi-Sensor Based (MRMS)
 - Updates every 5 minutes
 - Need to zoom-out and or in to force a refresh of the map for latest rainfall totals.
- Helps generate impact graphics and isolate river basins + streams/creeks at risk of flooding.

USGS Stream Trace Application Tab



SAF(ER) Flood Viewer - Situational Awareness For Emergency Response

Use this map viewer to remain river flooding aware for your area. Areas mapped will be outlined in red. Click the red outlined area of your choice to view the hydrograph and a direct link to the flood extent mapping page for that river. This will open a new viewer of that specific site where you can see flood extents for various river stages. Please use with caution and do not use for critical decisions. Always listen and heed local and county official warnings for evacuations. This is an experimental service and by using this map service, you agree to these terms and conditions as map accuracy can not be fully guaranteed. For more information concerning weather watches and warnings go to: <http://www.srh.noaa.gov/ews/>.

Turn Around, Don't Drown



Situational Overview River Levels + Flood Extents 1-Hour Rainfall Accumulation 3-Hour Rainfall Accumulation USGS Stream Traces



Track
Downstream

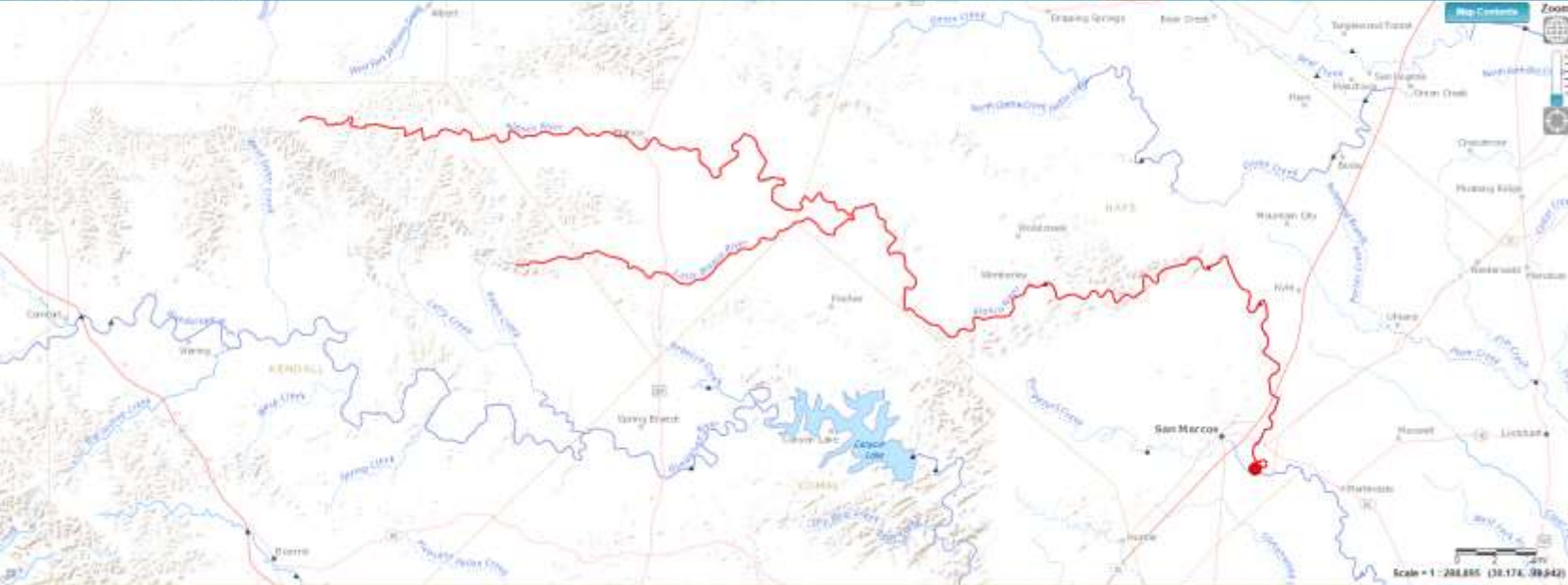
SAF(ER) Flood Viewer - Situational Awareness For Emergency Response

Use this map viewer to remain river flooding aware for your area. Areas mapped will be outlined in red. Click the red outlined area of your choice to view the hydrograph and a direct link to the flood extent mapping page for that river. This will open a new viewer of that specific site where you can see flood extents for various river stages. Please use with caution and do not use for critical decisions. Always listen and heed local and county official warnings for evacuations. This is an experimental service and by using this map service, you agree to these terms and conditions as map accuracy can not be fully guaranteed. For more information concerning weather watches and warnings go to: <http://www.srh.noaa.gov/ews/>.

Situational Overview River Levels + Flood Extents 1-Hour Rainfall Accumulation 3-Hour Rainfall Accumulation USGS Stream Traces



Track Downstream Track Upstream Clear Map Stream Report Print Map Home Help Location Search



About Streamer Quick Start FAQ Contact Us NEW! Trace API for Developers NEW! Map Services for Developers

Accessibility FCM Privacy Policies
URL: <https://pub.usgs.gov/dss/streamerweb/>
Last modified: December 18, 2015

Developed and powered by the USGS Texas Water Science Center

About Streamer Quick Start FAQ Contact Us NEW! Trace API for Developers NEW! Map Services for Developers

Accessibility FCM Privacy Policies
URL: <https://pub.usgs.gov/dss/streamerweb/>
Last modified: December 18, 2015

- Shows:
 - All selectable river and streams for upstream and downstream traces.
 - **Answer: Where is the water coming from and where is it going?**
- Can also get detailed reports based on stream traces
 - Census data
 - Potential impacts along river

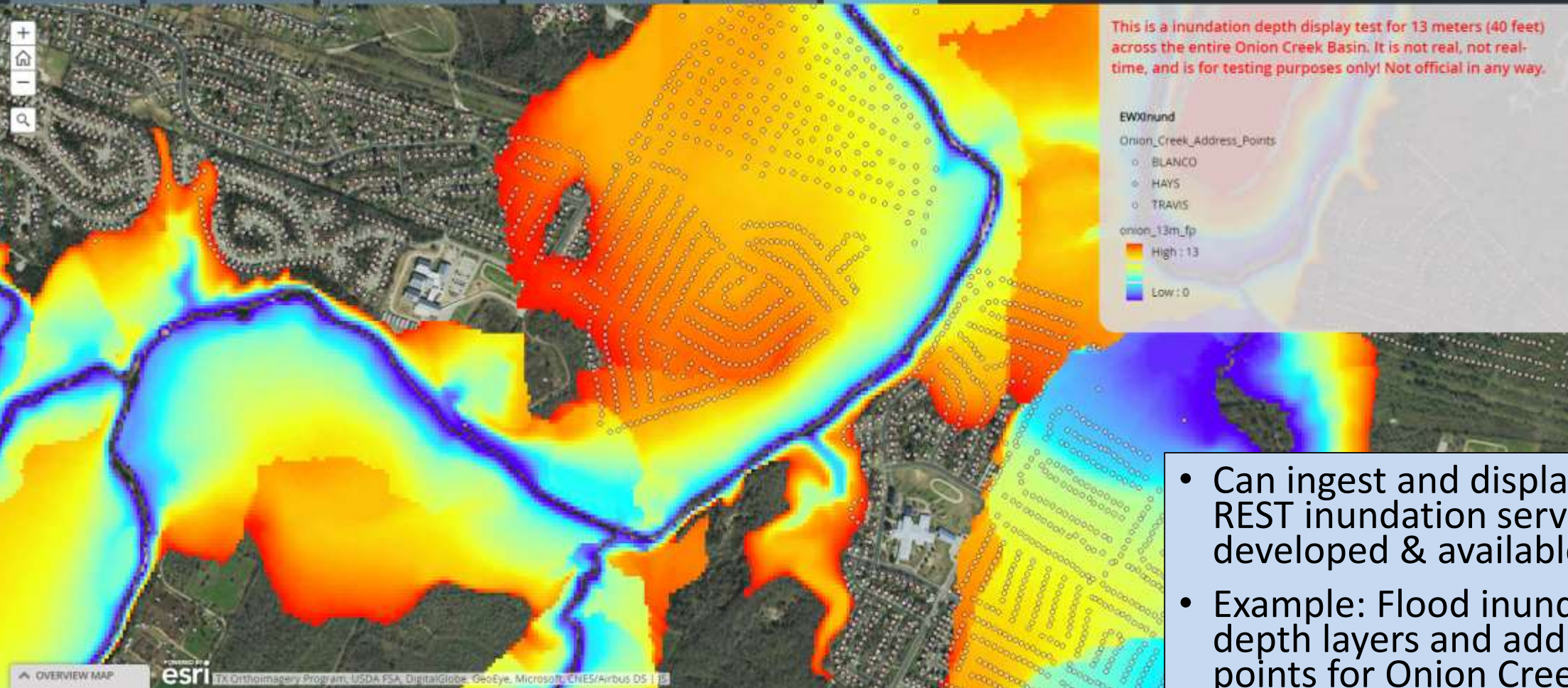
Additional SAF(ER) Capabilities



SAF(ER) Flood Viewer - Situational Awareness For Emergency Response

Use this map viewer to remain river flooding aware for your area. Areas mapped will be outlined in red. Click the red outlined area of your choice to view the hydrograph and a direct link to the flood extent mapping page for that river. This will open a new viewer of that specific site where you can see flood extents for various river stages. Please use with caution and do not use for critical decisions. Always listen and heed local and county official warnings for evacuations. This is an experimental service and by using this map service, you agree to these terms and conditions as map accuracy can not be fully guaranteed. For more information concerning weather watches and warnings go to: <http://www.srh.noaa.gov/ewu/>.

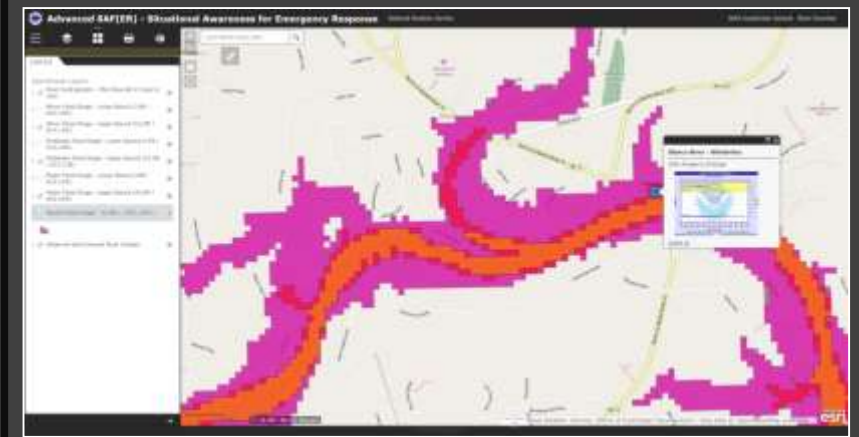
Situational Overview River Levels + Flood Extents 1-Hour Rainfall Accumulation 3-Hour Rainfall Accumulation USGS Stream Traces **Onion Creek TEST**



- Can ingest and display GIS REST inundation services (if developed & available)
- Example: Flood inundation depth layers and address points for Onion Creek Basin

Critical for:

- Preparation:
 - NWS sharing data before the next flood to GIS & EM partners
- Planning:
 - Key decision timelines
 - Communication of hazards
 - People and resource allocation
- Response & Recovery:
 - EOC awareness and service



Inter-agency Partnerships developed:



- **City/County Emergency Managers**
- **State Emergency Managers**
- **USGS Partnership**
- **Local River Authority Partnerships**
- **Local Community College Projects**



Thank You



Jared Allen

Email: Jared.Allen@noaa.gov

Twitter: Jarallen

NOAA/NWS Austin/San Antonio, TX

Cited Sources

1. Gall, M., Boruff, B., and Cutter, S. (2007). "Assessing Flood Hazard Zones in the Absence of Digital Floodplain Maps: Comparison of Alternative Approaches." *Nat. Hazards Rev.*, 8(1), 1–12.
2. Jeffrey D. Colby, Karen A. Mulcahy, and Yong Wang, 2000. Modeling flooding extent from Hurricane Floyd in the coastal plains of North Carolina. *Global Environmental Change Part B: Environmental Hazards*. 2(4), 157-168. [http://dx.doi.org/10.1016/S1464-2867\(01\)00012-2](http://dx.doi.org/10.1016/S1464-2867(01)00012-2).
3. Michener, William & Houhoulis Paula. "Identification and Assessment of Natural Disturbances in Forested Ecosystems: The Role in GIS and Remote Sensing." 1995 (http://www.ncgia.ucsb.edu/conf/SANTA_FE_CDROM/sf_papers/michener_william/michener.html)
4. Short, Nicholas. Accuracy Assessment. (http://www.fas.org/irp/imint/docs/rst/Sect13/Sect13_3.html)
5. Qi, S., Brown, D. G., Tian, Q., Jiang, L., Zhao, T., & Bergen, K. M. (2009). Inundation Extent and Flood Frequency Mapping Using LANDSAT Imagery and Digital Elevation Models. *GIScience & Remote Sensing*, 46(1), 101-127.
6. Viera, Anthony, MD & Garrett, Joanne, PhD. "Understanding Interobserver Agreement: The Kappa Statistic." *Family Medicine*. May 2005. (http://www1.cs.columbia.edu/~julia/courses/CS6998/Interrater_agreement.Kappa_statistic.pdf)
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.
8. Weiger, Ben. NWS Flood Inundation Mapping Services, 2008. Bayou Vermillion River Conference. (<http://www.srh.noaa.gov/media/lch/outreach/052808/6BenWeiger.pdf>)

<http://arcg.is/1L00Wvm>

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 LiDAR
Susquehanna River at Harrisburg, PA	30 Feet (10 meter) DEM
Kentucky River at Frankfort, KY	5 Feet LiDAR
Onion Creek at Austin, TX	30 Feet (10 Meter) DEM

- Spatial Statistical tests performed:
 - Cohen's Kappa Coefficient^{2,4}
 - Overall pixel classification accuracy⁶
 - 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 variables².

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

$Pr(a)$ = Relative Observed Agreement

$$20 + 15 = 35 \quad 35/50 = 0.7$$

$Pr(e)$ = Probability of Random Agreement

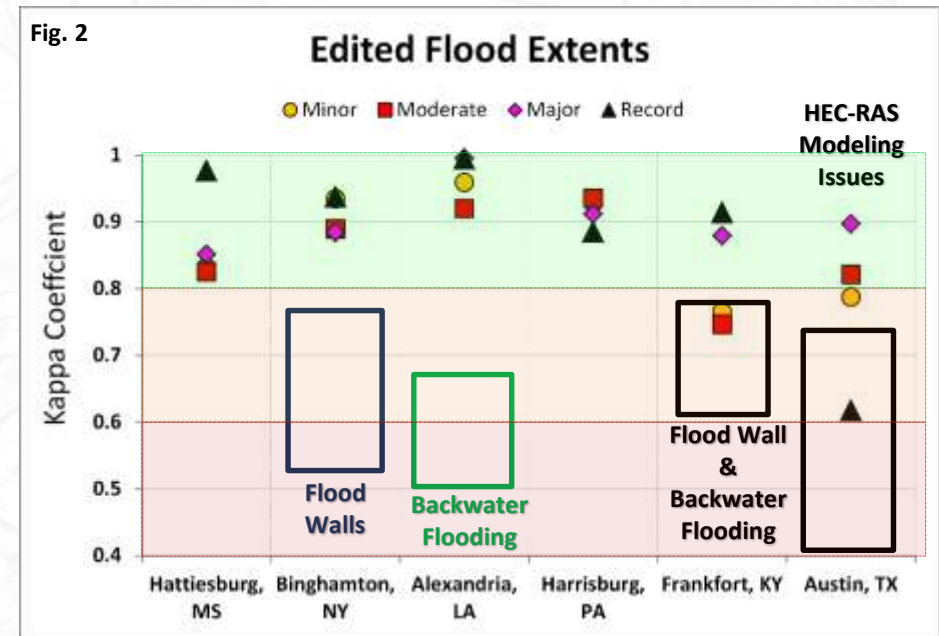
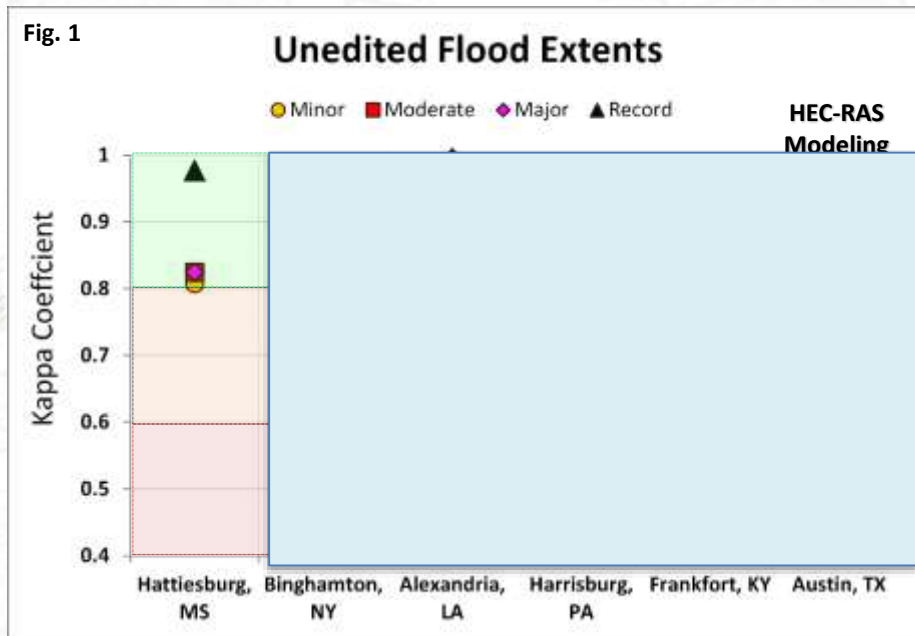
$$[(30/50) * (25/50)] + [(20/50) * (25/50)] = 0.5$$

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

B

Interpretation of Kappa	
	Poor Slight Fair Moderate Substantial Almost perfect
Kappa	0.0 .20 .40 .60 .80 1.0
<u>Kappa</u>	<u>Agreement</u>
< 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

Results



- Unedited FESM Flood Extents had substantial to near perfect agreement.
 - Record Stage performed the strongest on average across all sites (Austin, TX outlier)
 - Moderate Flood Stage was weakest on average across all 6 sites (moderate agreement)
- Using water impact location descriptions & FEMA DFIRM maps, edited flood extents (Fig. 2) had near perfect to substantial agreement.
 - Excluding the minor and moderate stages for Frankfort, KY (*High substantial agreement*)
 - Kappa could be raised further with local knowledge of Trumbo Bottom Area.
 - Significant improvement for Alexandria, LA site in Bayou Maria Basin
 - Moderate Flood Stage still lowest on average but above 0.8 (near perfect)

Flood Pixel Classification Accuracy

$$FCA = \frac{\text{Pixels of Flood}_{\text{Correct}}}{(\text{Pixels of Flood}_{\text{Correct}} + \text{Pixels of Flood}_{\text{Omission}} + \text{Pixels of Flood}_{\text{Commission}})}$$

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

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

