Deriving Flood Risk, Vulnerability, Loss Estimation, and Utilization of Statistical Applications for Decision and Regulatory Support from USGS products

U.S. Geological Survey – Central Midwest Water Science Center

Paul Rydlund - prydlund@usgs.gov
Chief: Hydraulics and Hydrology
Supervisory Hydrologist
Jason High - jhigh@usgs.gov
Physical Scientist

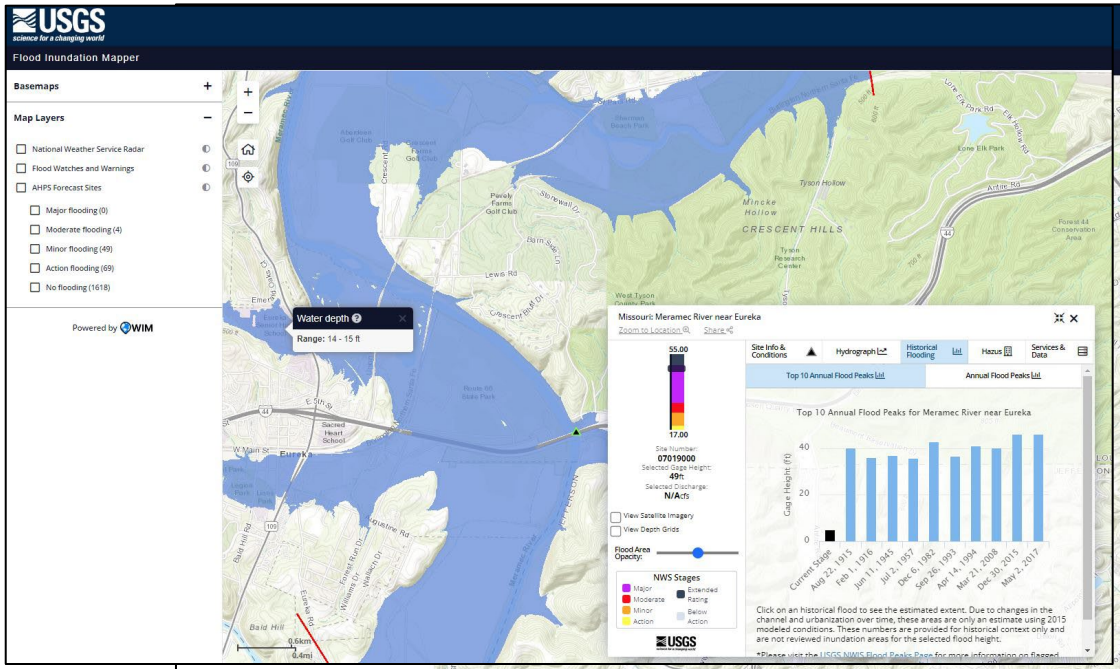
U.S. Department of the Interior
U.S. Geological Survey

USGS Flood Inundation Mapping

Stage-Based Deterministic Inundation Mapping

https://fim.wim.usgs.gov/fim/

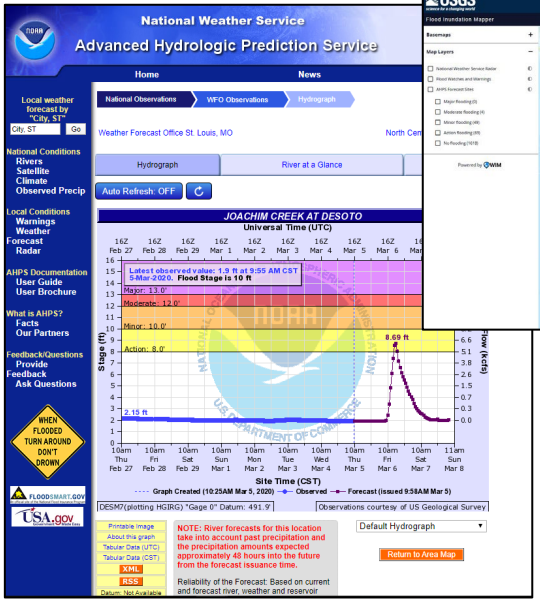
- Location Services
- Historic Flooding
- Flood Categories
- HAZUS Loss Estimation
- Backwater Considerations.

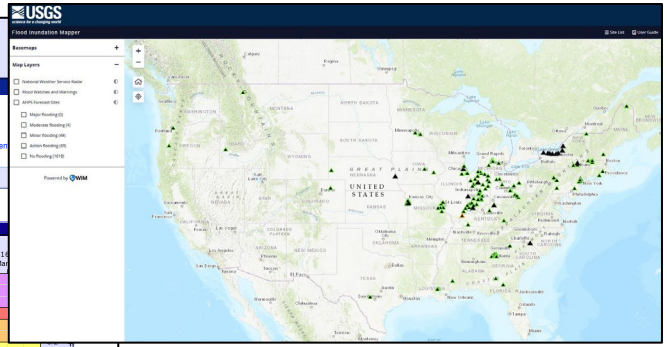


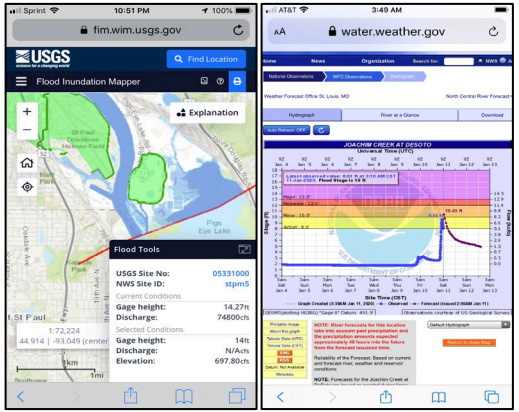
USGS

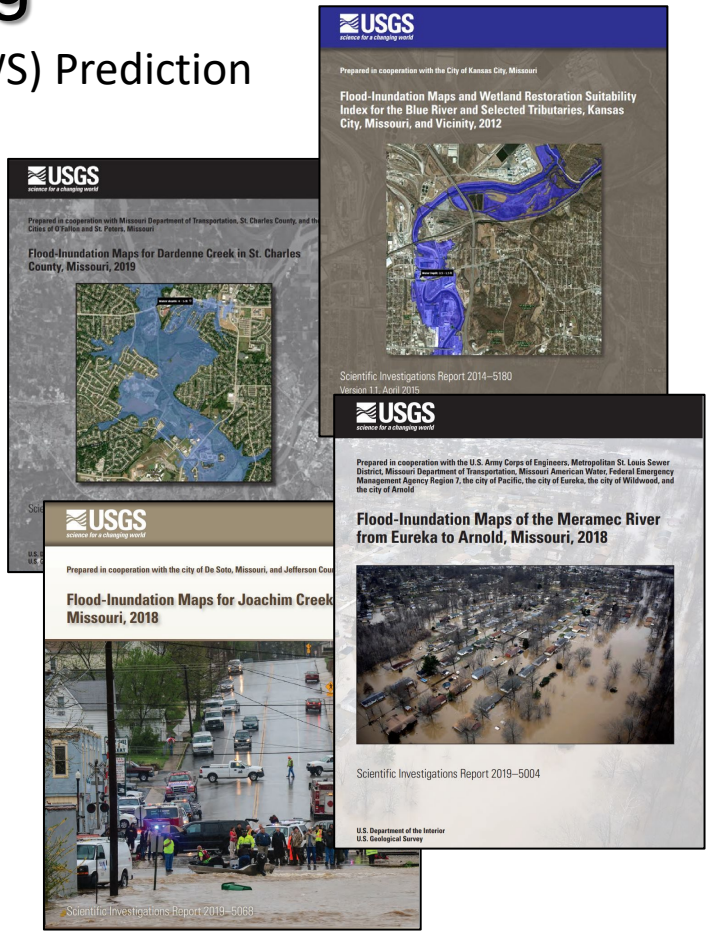
USGS Flood Inundation Mapping

State of Missouri National Weather Service (NWS) Prediction









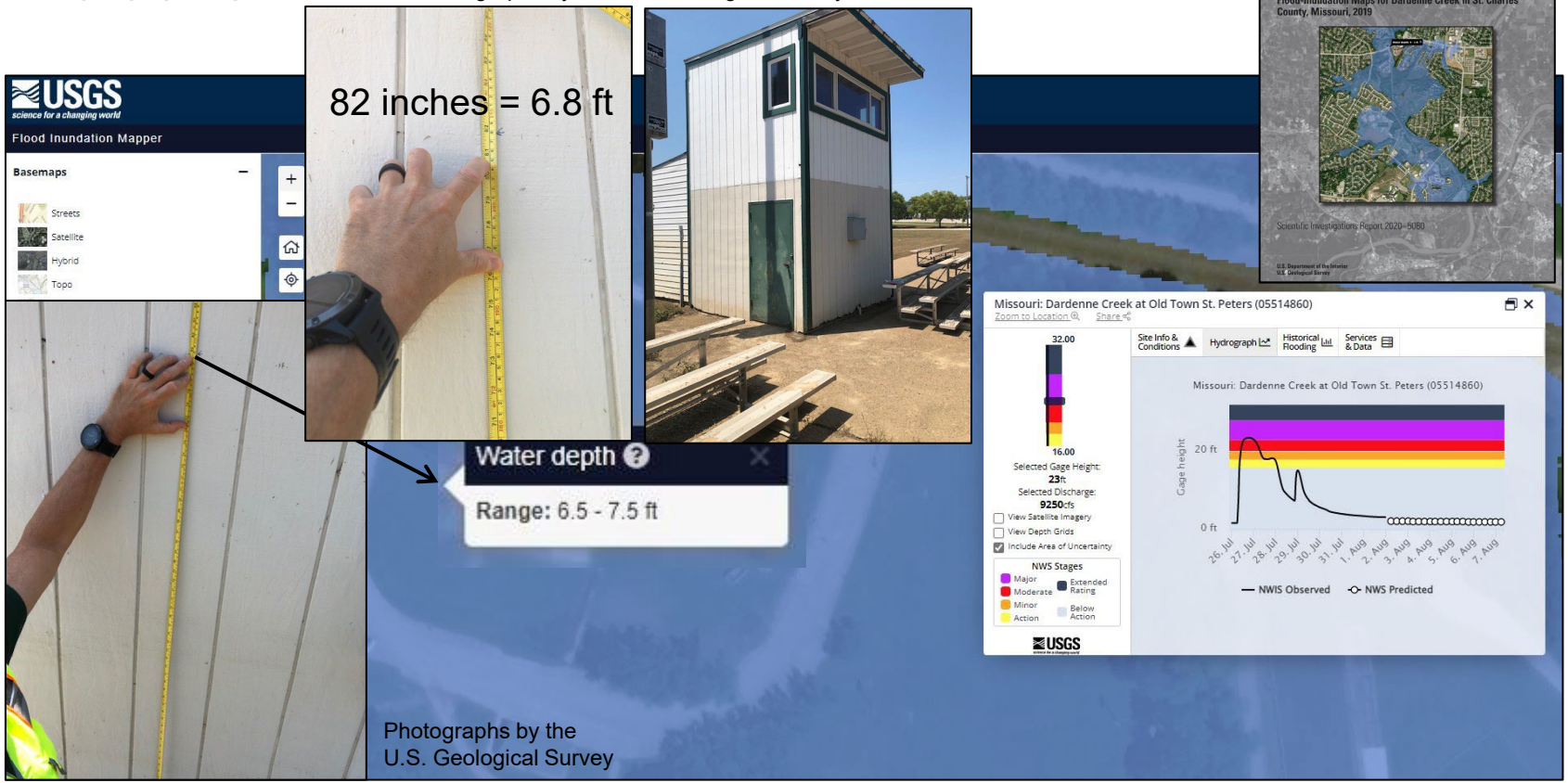
USGS

USGS Flood Inundation Mapping

Local Evaluation

https://pubs.er.usgs.gov/publication/sir20205060

Photographs by the U.S. Geological Survey



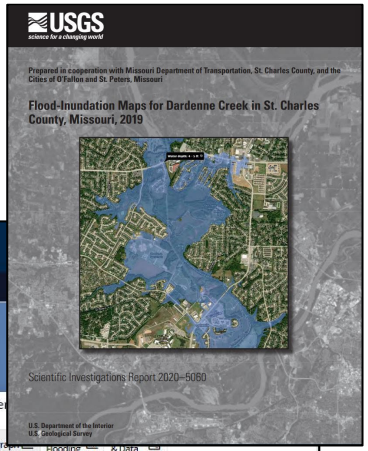
Photographs by the U.S. Geological Survey

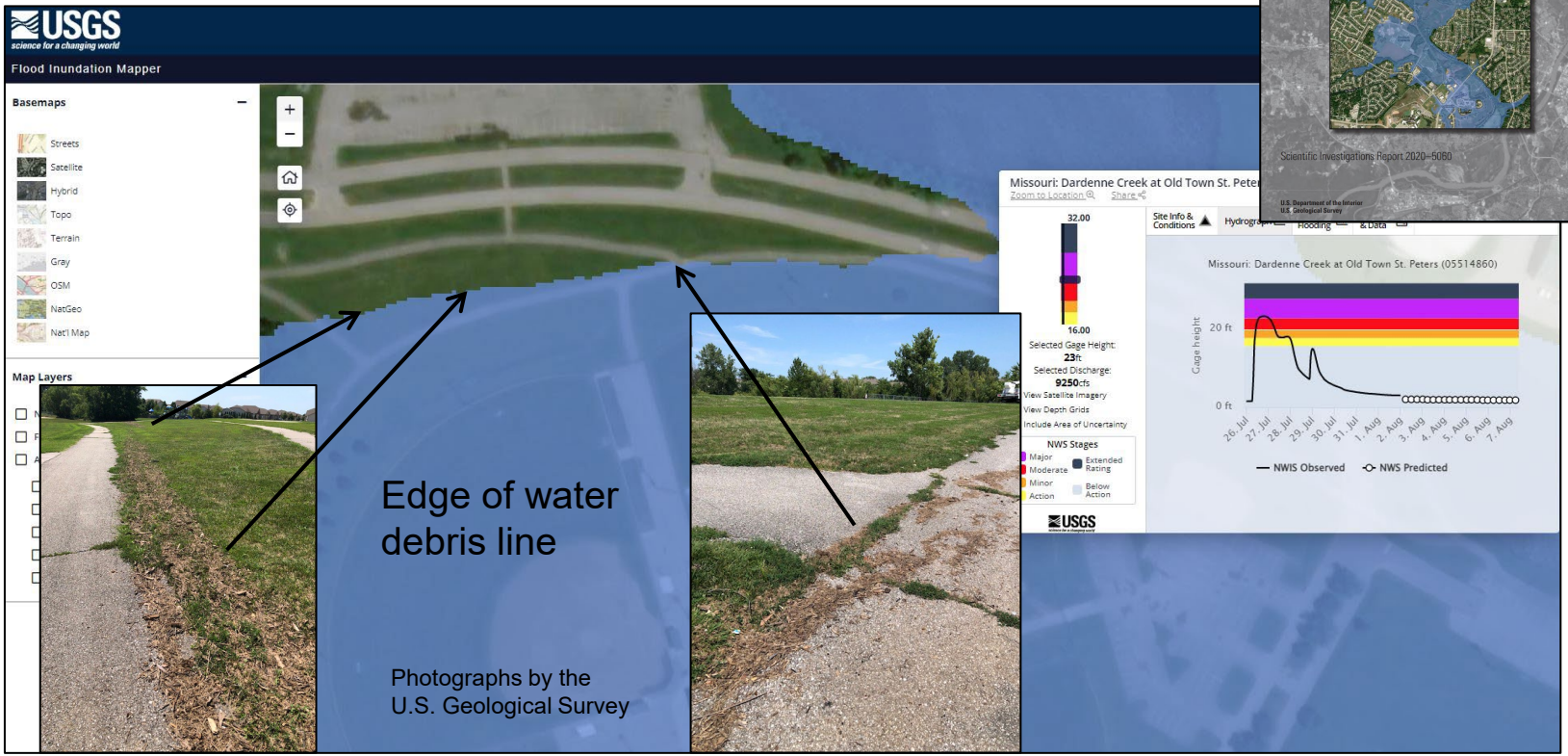
USGS

USGS Flood Inundation Mapping

Local Evaluation

https://pubs.er.usgs.gov/publication/sir20205060

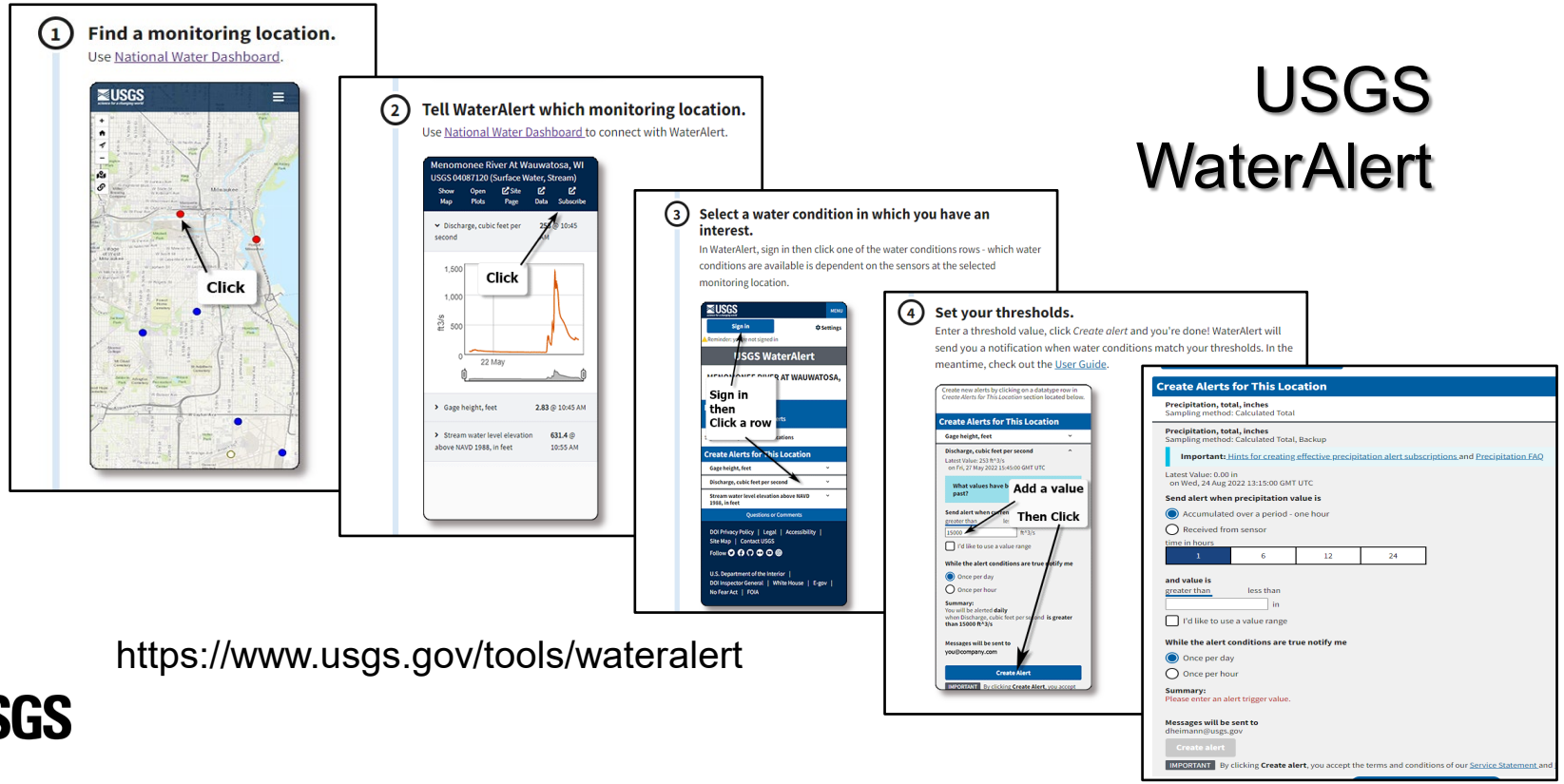




USGS

USGS Notifications – Decision / Regulatory Support

Enabling Text Message Alerts - Sensors and Data Dissemination



USGS WaterAlert

https://www.usgs.gov/tools/wateralert

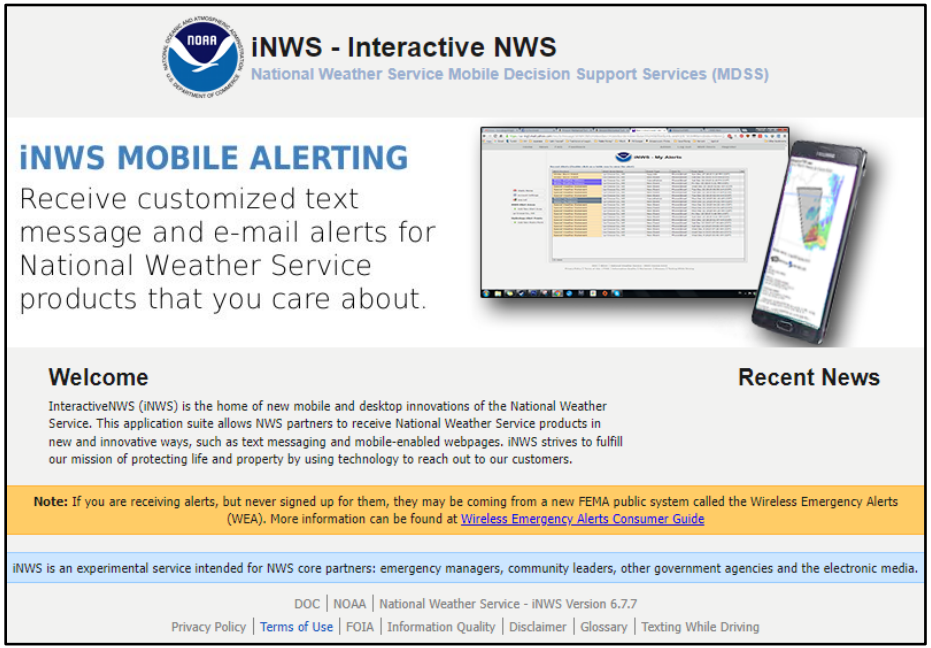
USGS

NWS Notifications – Decision / Regulatory Support

Enabling Text Message Alerts - Hydrology

- Flood Statements and Warnings
- Flash Flood Watches, Statements, and Warnings

https://inws.ncep.noaa.gov/



USGS

USGS Flood Inundation Mapping

Precipitation-Based Deterministic Inundation Mapping

Duration (hr.)	Incremental Magnitude (in)								
1	1.5	2.0	2.5	3.0	3.5				
2	2.0	2.5	3.0	3.5	4.0	4.5			
4	2.0	2.5	3.0	3.5	4.0	4.5	5.0		
6	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	

THE CITY OF HARRISONVILLE
WHERE TRADITION MEETS INNOVATION

Photograph by the U.S. Geological Survey

Precipitation Parameter(s): about this...

- 1 hour
- 2 hours
- 4 hours
- 6 hours
- 12 hours
- 24 hours

Alert Threshold Condition: about this...

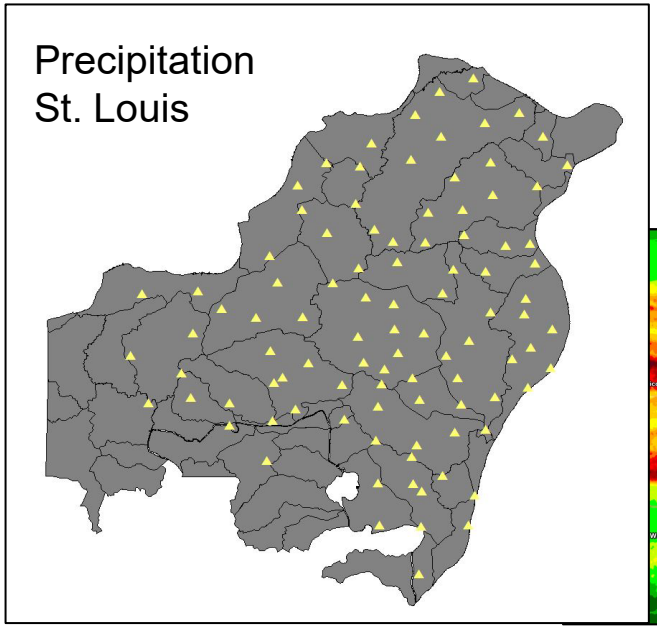
- Greater than (>)
- Less than (<)
- Outside a range (< or >)
- Inside a range (> and <)

Real-time value isgreater than: 6.0

USGS

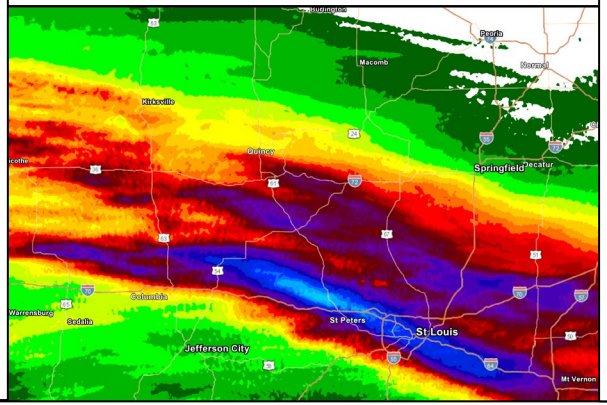
USGS Flood Inundation Mapping

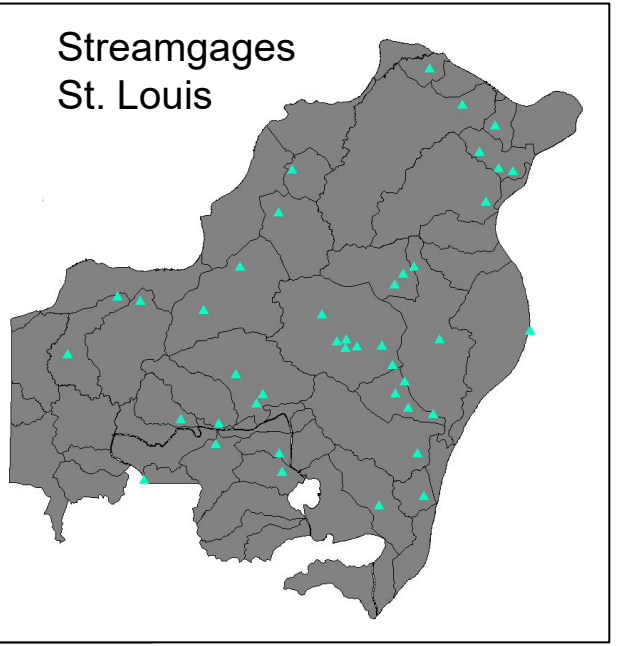
Precipitation-Based Deterministic Inundation Mapping



Potential Application

July 26th, 2022, Historic Flash Flooding in the St. Louis Metro Area





https://www.weather.gov/lsx/July262022Flooding

Multi-Radar Multi-Sensor (MRMS) 24hr Radar-Estimated Rainfall as of 12pm on July 26th.

USGS

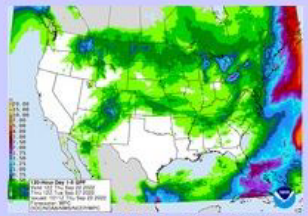
USGS Flood Inundation Mapping

Linking Precipitation Forecasts to Inundation Mapping

Quantitative Precipitation Forecasts

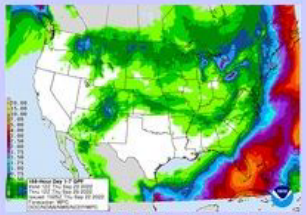
Day 1	Days 1-2	5- and 7-Day Totals
Day 2	Days 1-3	
Day 3	Days 4-5 and Days 6-7	

5-Day Total Precipitation



Valid 12z 09/22/22 - 12z 09/27/22
[contours only]

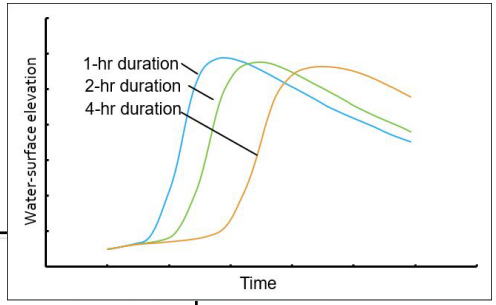
7-Day Total Precipitation



Valid 12z 09/22/22 - 12z 09/29/22
[contours only]

https://www.wpc.ncep.noaa.gov/qpf/qpf2.shtml

Forecasting is in 1-hr or 6-hr increments. How the precipitation is distributed will affect peak water-surface elevation.



Quantitative Precipitation Statement
Issued by NWS Missouri Basin, Pleasant Hill

Home | **Current Version** | Previous Version | Graphics & Text | Print | Product List | Glossary On
Versions: **1** 2 3

```
:  *****  EAX HSA  *****
1612       0.04 /   0.00 /   0.00 /   0.00 /   0.04  : FAIRFAX LWR
1619       0.02 /   0.00 /   0.00 /   0.00 /   0.02  : BURLINGTON JCT
1621       0.02 /   0.00 /   0.00 /   0.00 /   0.02  : MARYVILLE
1622       0.09 /   0.00 /   0.00 /   0.00 /   0.09  : ROSENDALE
1624       0.10 /   0.00 /   0.00 /   0.00 /   0.10  : AGENCY
1625       0.13 /   0.00 /   0.00 /   0.00 /   0.13  : CASTLE CREEK
1626       0.17 /   0.00 /   0.00 /   0.00 /   0.17  : SMITHVILLE RES INF
1627       0.18 /   0.00 /   0.00 /   0.00 /   0.18  : WILKERSON SECOND CR
1628       0.17 /   0.00 /   0.00 /   0.00 /   0.17  : PLATTE CITY
1634       0.05 /   0.00 /   0.00 /   0.00 /   0.05  : MILL CR
1635       0.06 /   0.00 /   0.00 /   0.00 /   0.06  : GRAHAM
1640       0.06 /   0.00 /   0.00 /   0.00 /   0.06  : BOLCKOW
1641       0.12 /   0.00 /   0.00 /   0.00 /   0.12  : PLATTSBURG
1701       0.18 /   0.06 /   0.00 /   0.00 /   0.24  : BANNISTER ROAD
1702       0.18 /   0.06 /   0.00 /   0.00 /   0.24  : LONGVIEW RES INF
1703       0.18 /   0.06 /   0.00 /   0.00 /   0.24  : BLUE SPGS RES INF
```

https://forecast.weather.gov/product.php?site=NWS&issuedby=KRF&product=QPS

USGS

USGS Flood Inundation Mapping

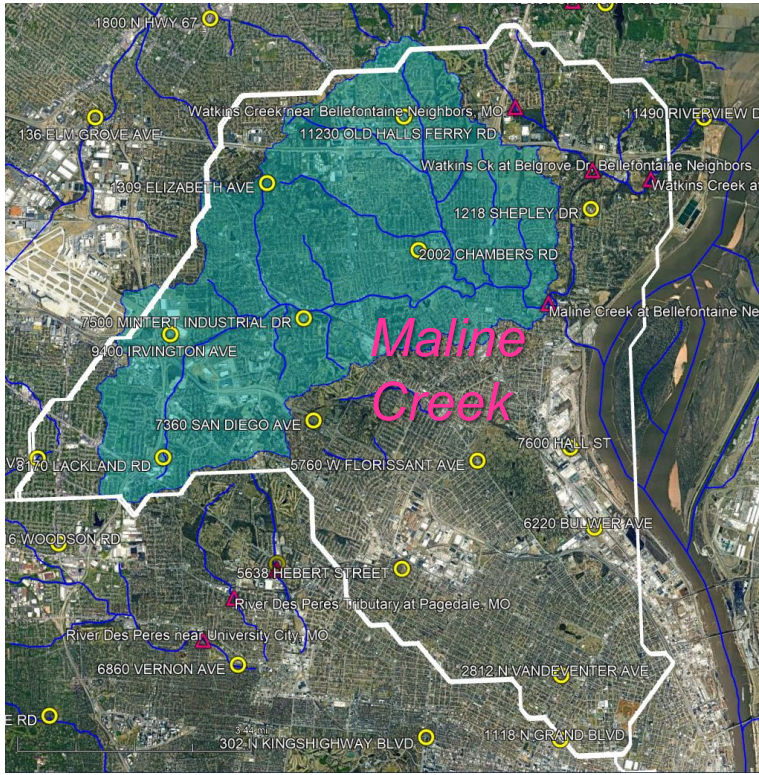
Linking Precipitation Forecasts to Inundation Mapping

6 – Hour Subbasin EADM7URB

```
.ER EADM7URB 20221109 Z DH1800/DC202211091435/PPQFM  /DIH06
.E1  0.000/0.000/0.000/0.000/0.000/0.000/0.000/0.002/
.E2  0.000/0.000/0.000/0.000/0.000/0.000/0.000/0.000/
.E3  0.000/0.000/0.000/0.000/0.000/0.000/0.000/0.000/
.E4  0.000/0.000/0.000/0.000/
```

https://www.wpc.ncep.noaa.gov/qpf/qpf2.shtml

Image taken from Google Earth version 7.3.6



- Streamgages
- Precipitation Gages
- Forecasting Subbasin Boundary

USGS

USGS Flood Inundation Mapping

Linking Precipitation Forecasts to Inundation Mapping

Response of 6-hr forecast values above threshold* are simulated and available for display

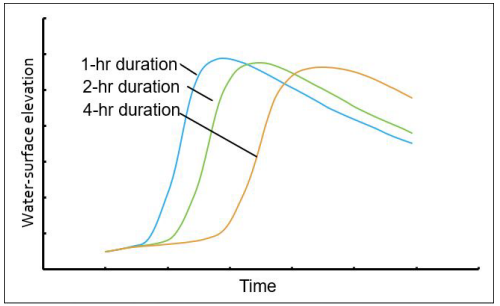
6 – Hour Subbasin EADM7URB

** Identified based on simulated effects of both magnitude and duration*

Example:

```
.E1    0.259/0.590/1.204/2.524/6.537/1.576/0.316/0.056
```

Hydrologic response determined for 1.2 inches distributed over 30 min, 1hr, 2hr, 3hr, 4hr, and 6 hr.



USGS

USGS Flood Inundation Mapping

Linking Precipitation Forecasts to Inundation Mapping

Response of 6-hr forecast values above threshold* are simulated and available for display

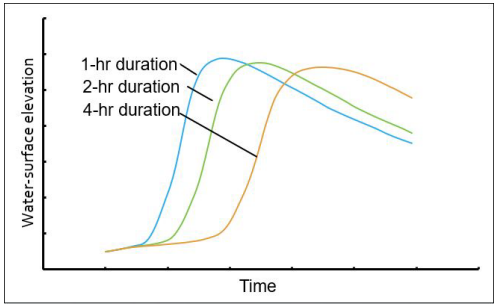
6 – Hour Subbasin EADM7URB

** Identified based on simulated effects of both magnitude and duration*

Example:

```
.E1    0.259/0.590/1.204/2.524/6.537/1.576/0.316/0.056
```

Hydrologic response determined for 2.5 inches distributed over 30 min, 1hr, 2hr, 3hr, 4hr, and 6 hr.



USGS

USGS Flood Inundation Mapping

Linking Precipitation Forecasts to Inundation Mapping

```
KSTL   NBM V4.1 NBH GUIDANCE    2/06/2023  1000 UTC
UTC  11 12 13 14 15 16 17 18 19 20 21 22 23 00 01 02 03 04 05 06 07 08 09 10 11
```
4:00AM

```
KSTL   NBM V4.1 NBH GUIDANCE    2/06/2023  1100 UTC
UTC  12 13 14 15 16 17 18 19 20 21 22 23 00 01 02 03 04 05 06 07 08 09 10 11 12
```
5:00AM

```
KSTL   NBM V4.1 NBH GUIDANCE    2/06/2023  1200 UTC
UTC  13 14 15 16 17 18 19 20 21 22 23 00 01 02 03 04 05 06 07 08 09 10 11 12 13
```
6:00AM

```
KSTL   NBM V4.1 NBH GUIDANCE    2/06/2023  1300 UTC
UTC  14 15 16 17 18 19 20 21 22 23 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14
```
7:00AM

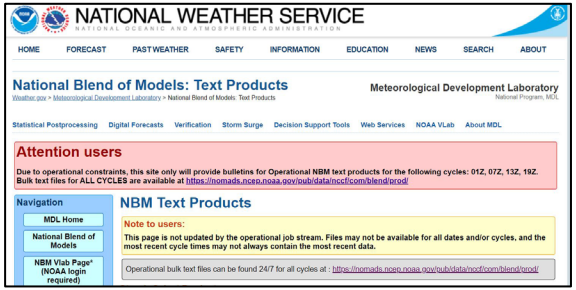
```
KSTL   NBM V4.1 NBH GUIDANCE    2/06/2023  1400 UTC
UTC  15 16 17 18 19 20 21 22 23 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
```
8:00AM

From 6-hour precipitation forecasts to 1-hour precipitation forecasts

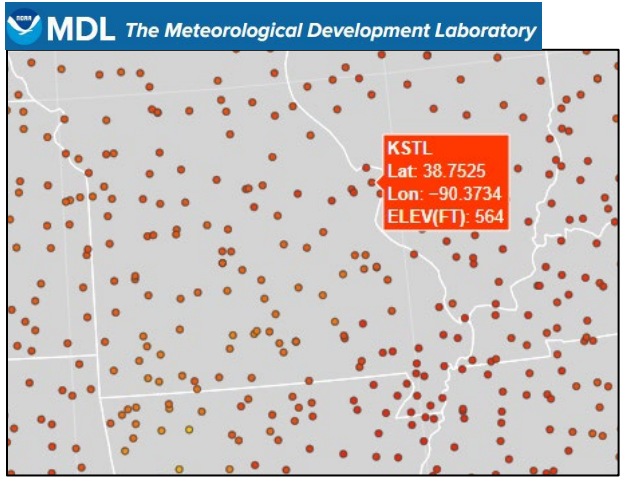
9:00AM…

Why? How do we know where the bulk of the rain fell in 6 hours….

USGS



https://www.weather.gov/mdl/nbm_text?ele=nbh,nbs&sta=klxt&download=yes



USGS Flood Inundation Mapping

Precipitation-based Visualization for Decision and Regulatory Support

THE CITY OF HARRISONVILLE
WHERE TRADITION MEETS INNOVATION

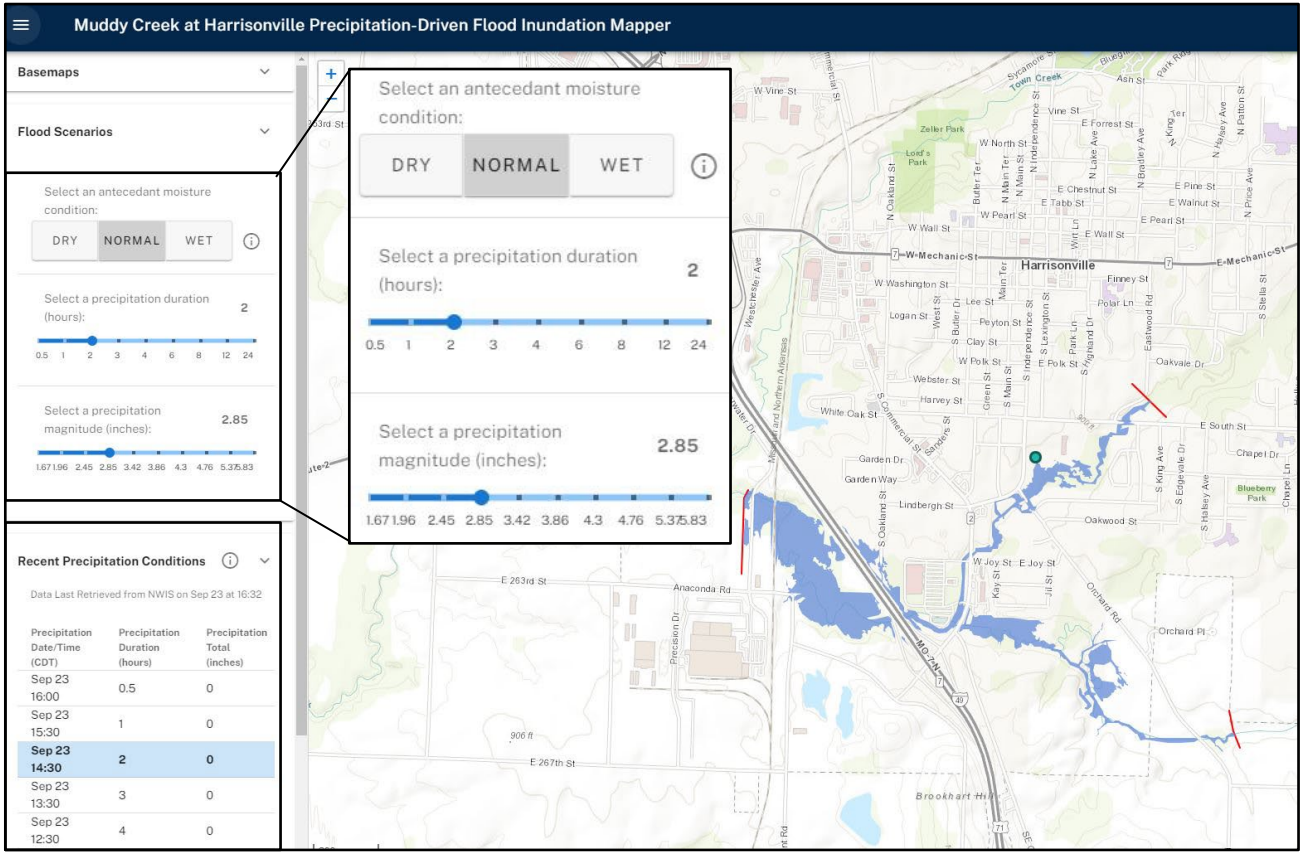
https://fim.wim.usgs.gov/fim/

USGS
science for a changing world
Web Informatics & Mapping

Web Informatics & Mapping

Modern Web Development in support of delivering the best of the USGS to the public.

USGS



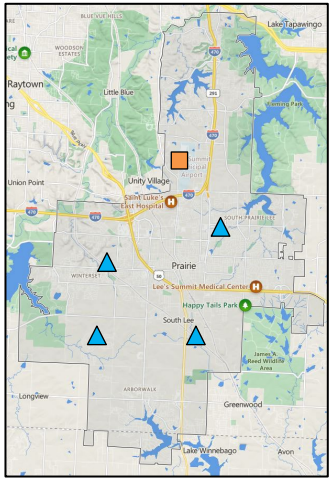
USGS Flood Inundation Mapping

Precipitation-based Visualization for Decision and Regulatory Support

Interactive and Automated

Precipitation Gages
Illustrative purposes only

National Weather Service (NWS) Forecast location
KLXT



USGS

Conceptual

```
NBH TEXT BULLETIN - STATION KLXT
#
 KLXT   NBM V4.0 NBH GUIDANCE   12/08/2022  1300 UTC
 UTC  14 15 16 17 18 19 20 21 22 23 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14
```

Basemaps

Flood Scenarios

Select an antecedant moisture condition:
DRY | NORMAL | WET

Select a precipitation duration (hours): 2
0.5 1 2 3 4 6 8 12 24

Select a precipitation magnitude (inches): 2.85
1.67 1.96 2.45 2.85 3.42 3.86 4.3 4.76 5.37 5.83

Recent Precipitation Conditions

Data Last Retrieved from NWIS on Sep 23 at 16:32

Precipitation Date/Time (CDT)	Precipitation Duration (hours)	Precipitation Total (inches)
Sep 23 16:00	0.5	0
Sep 23 15:30	1	0
Sep 23 14:30	**2**	**0**
Sep 23 13:30	3	0
Sep 23 12:30	4	0

Select an antecedant moisture condition:
DRY | NORMAL | WET

Select a precipitation duration (hours):
0.5 1 2 3 4 6 8 12

Select a precipitation magnitude (inches): 2.85
1.67 1.96 2.45 2.85 3.42 3.86 4.3 4.76 5.37 5.83

1-hour precipitation forecast updated every 6 hours

"At a glance" 24-hr forecast with potential flooding in hours 9 and 10.

1	2	3	4	5	6
7	8	**9**	**10**	11	12
13	14	15	16	17	18
19	20	21	22	23	24

15-min	30-min	1-hr	2-hr	3-hr	4-hr	6-hr
986 ft	982 ft	980 ft				

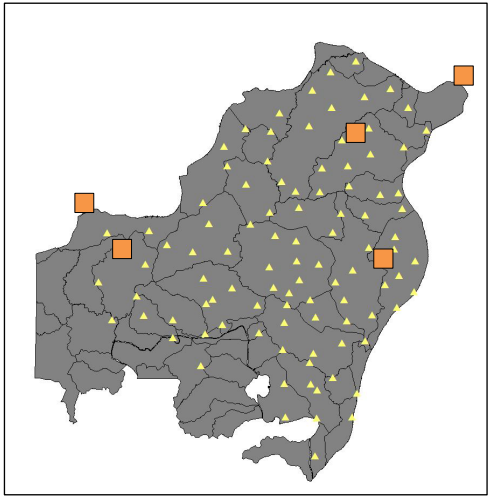
USGS Flood Inundation Mapping

Precipitation-based Visualization for Decision and Regulatory Support

Interactive and Automated

Precipitation Gages
Illustrative purposes only ▲

National Weather Service
(NWS) Forecast locations ■



USGS

Conceptual

```
NBH TEXT BULLETIN - STATION KLXT
#
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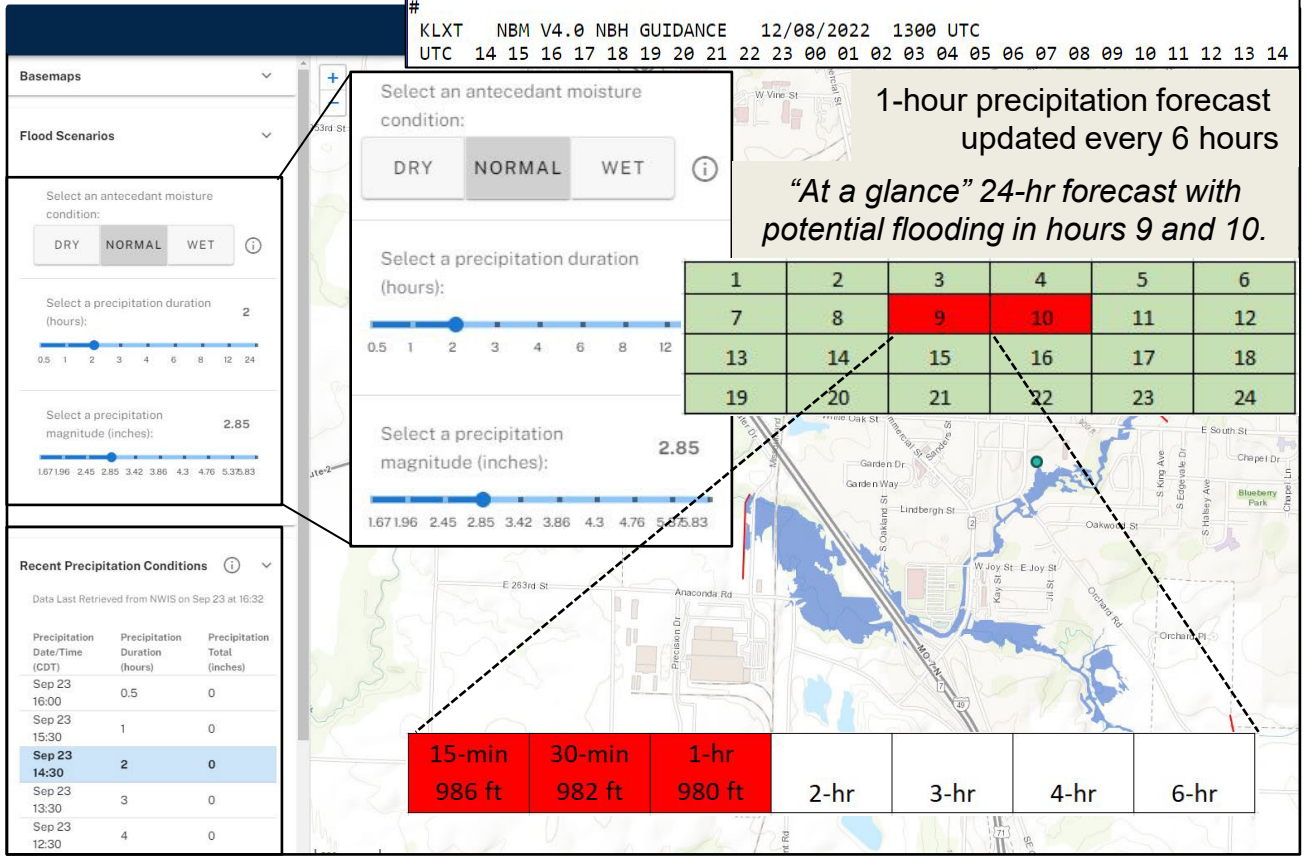


1-hour precipitation forecast updated every 6 hours

"At a glance" 24-hr forecast with potential flooding in hours 9 and 10.

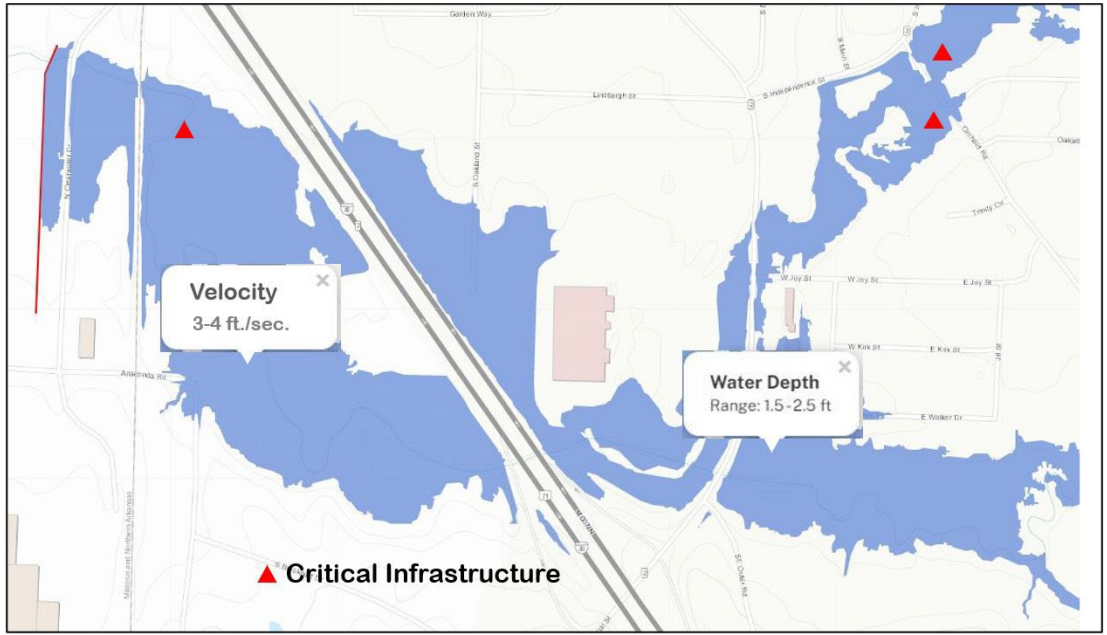
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24

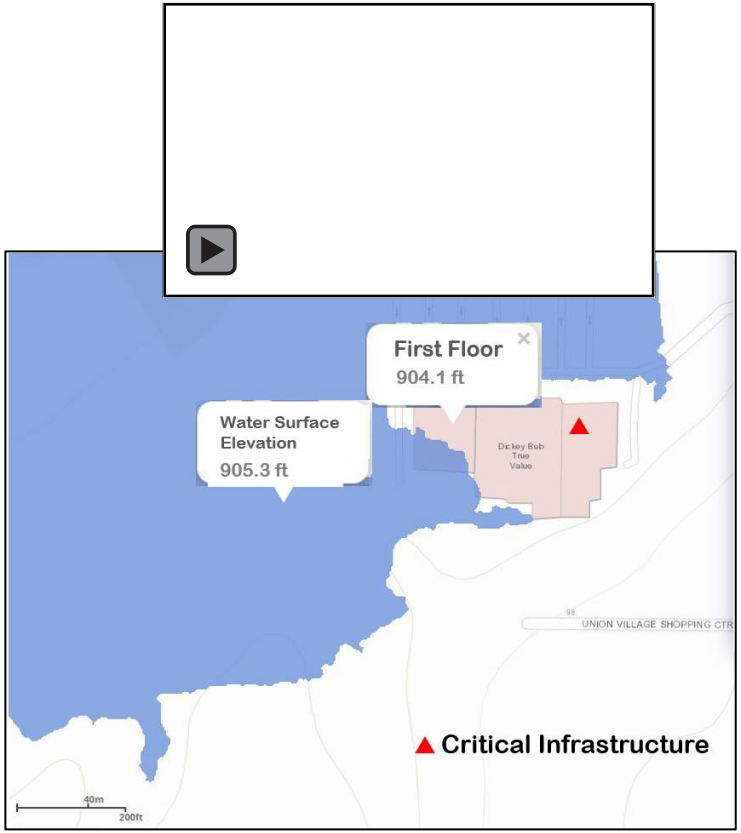
15-min 986 ft	30-min 982 ft	1-hr 980 ft	2-hr	3-hr	4-hr	6-hr

USGS Flood Inundation Mapping

Precipitation-based Visualization for Decision and Regulatory Support

Value-added Data Analytics





USGS

https://fim.wim.usgs.gov/fim/

USGS Flood Inundation Mapping

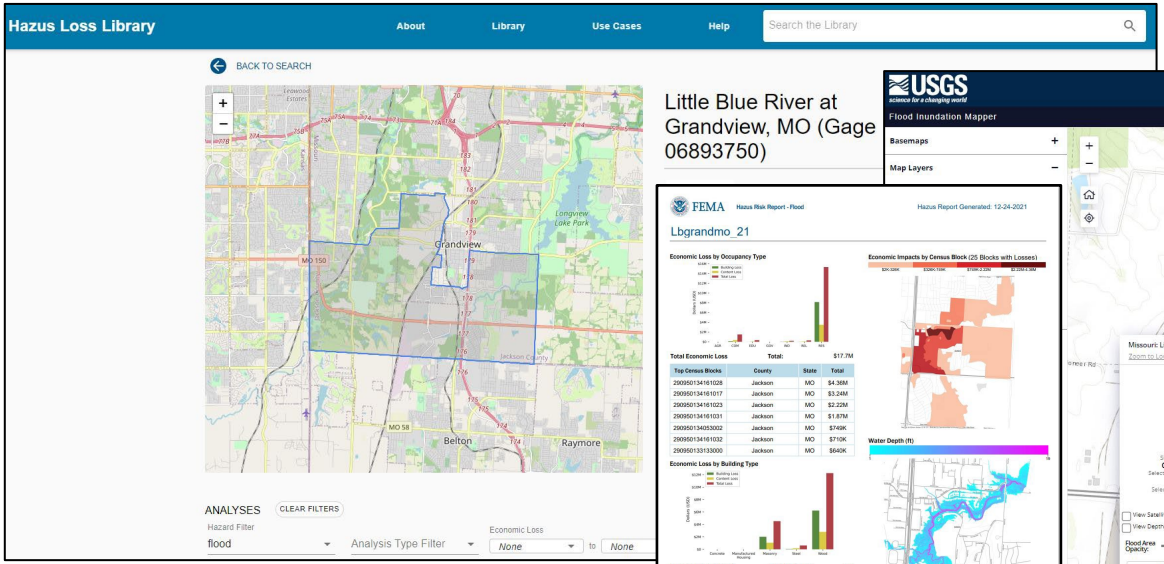
USGS – FEMA Partnership *Loss estimation*

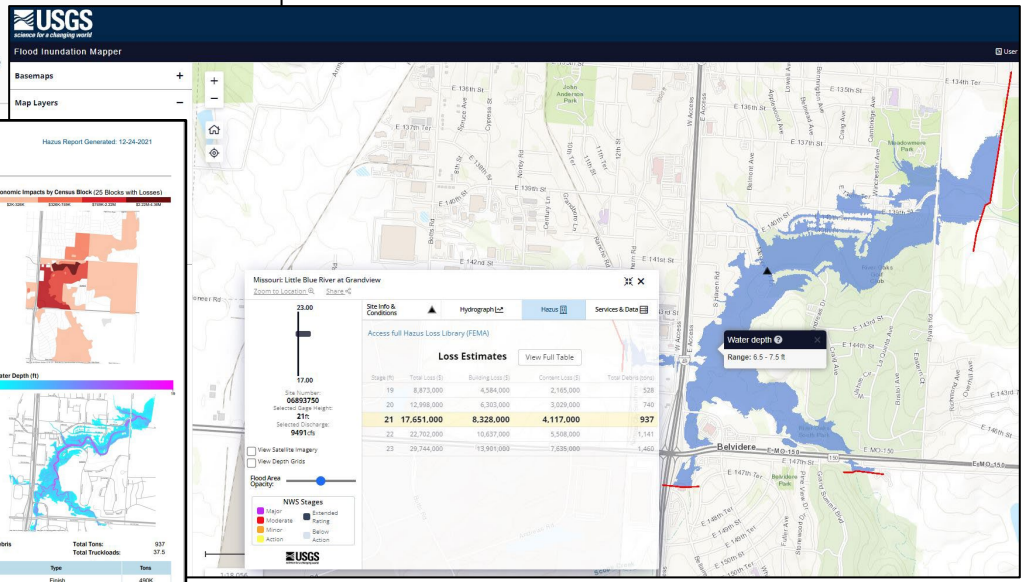
HAZUS
EARTHQUAKE • WIND • FLOOD • TSUNAMI

https://fim.wim.usgs.gov/fim/

USGS
science for a changing world

FEMA



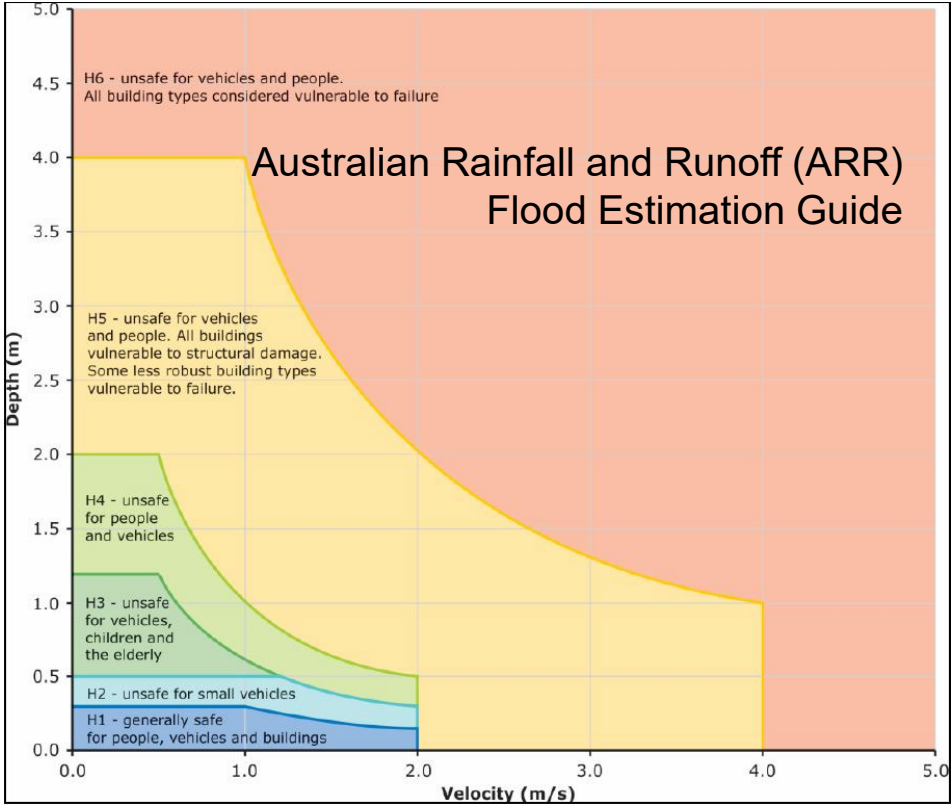


USGS

USGS Flood Inundation Mapping

Visualization for Decision and Regulatory Support

People, Vehicles, and Buildings

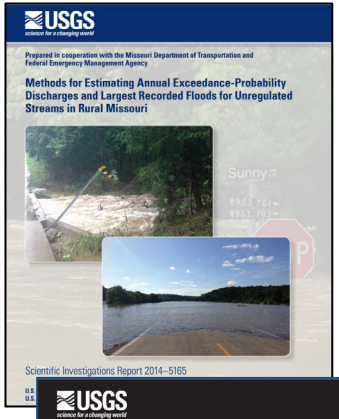


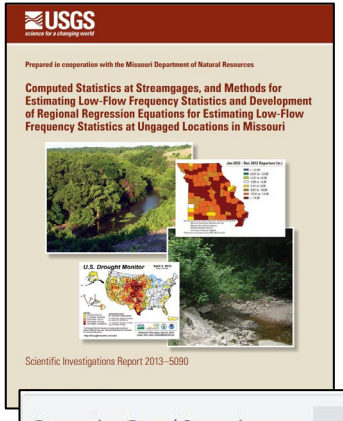
https://arr.ga.gov.au/home

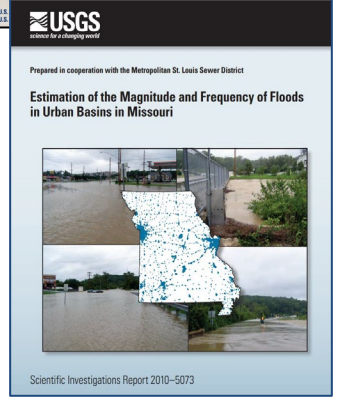
USGS

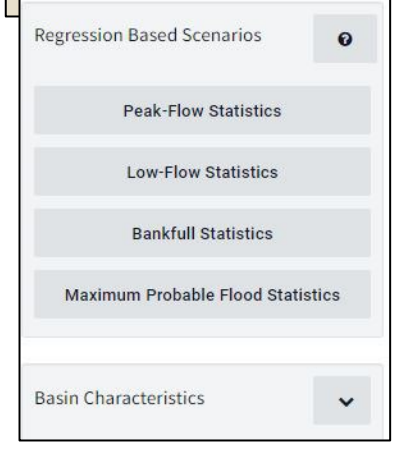
USGS Streamstats

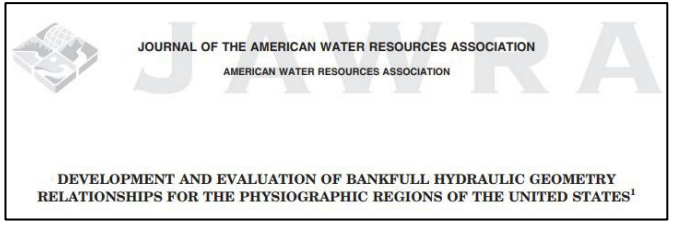
Core Function: Basin Characteristics => State-based Regional Regression Equations => Streamflow Statistics



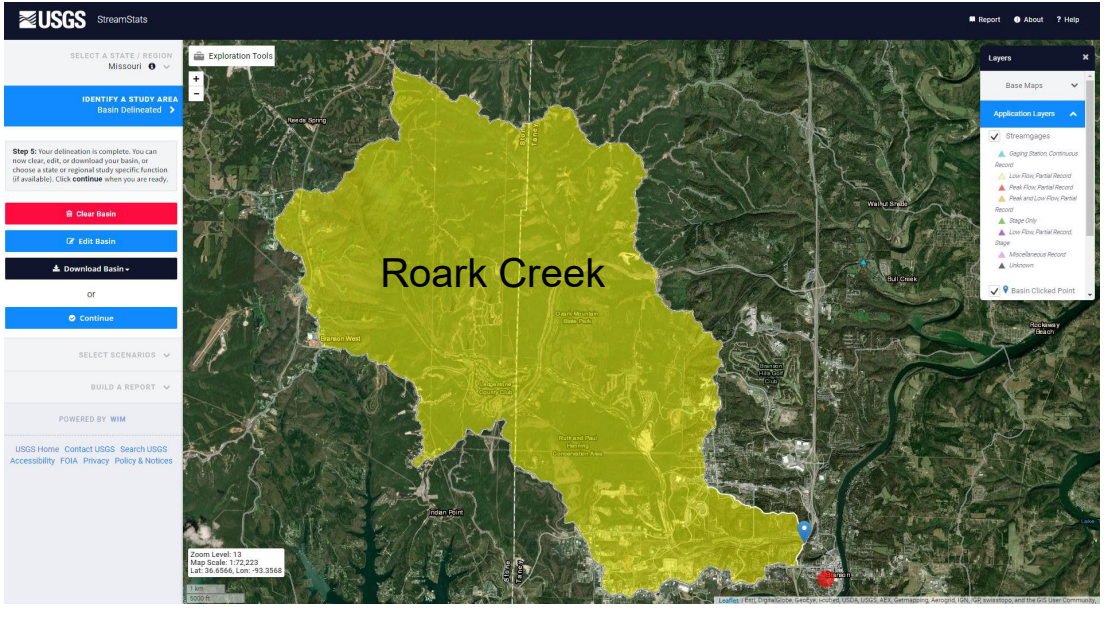








https://streamstats.usgs.gov/ss/



USGS Streamstats

Customizations: Bankfull Statistics

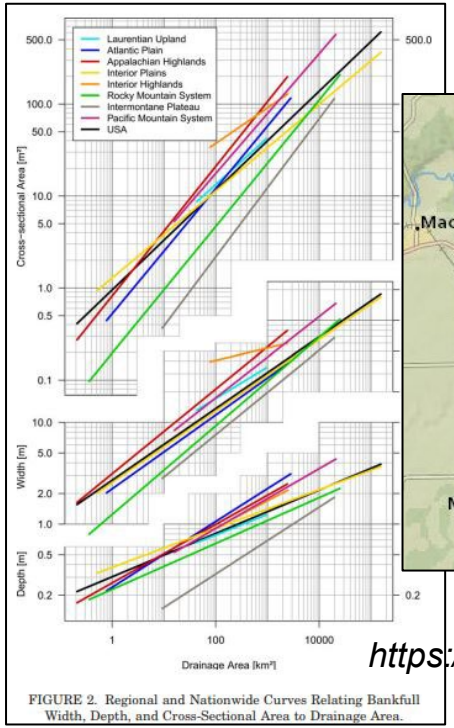
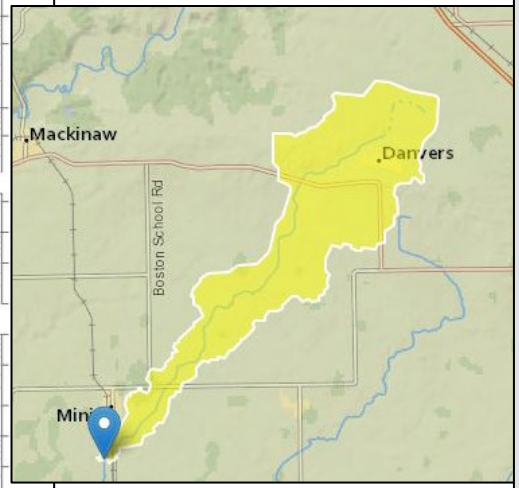


FIGURE 2. Regional and Nationwide Curves Relating Bankfull Width, Depth, and Cross-Sectional Area to Drainage Area.



https://streamstats.usgs.gov/ss/

Bankfull Statistics Parameters [USA Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	23.16	square miles	0.07722	59927.7393

Bankfull Statistics Flow Report [Interior Plains D Bieger 2015]

Statistic	Value	Unit
Bieger_D_channel_width	35.3	ft
Bieger_D_channel_depth	2.73	ft
Bieger_D_channel_cross_sectional_area	95.1	ft^2

Bankfull Statistics Flow Report [Central Lowland P Bieger 2015]

Statistic	Value	Unit
Bieger_P_channel_width	39.3	ft
Bieger_P_channel_depth	3.16	ft
Bieger_P_channel_cross_sectional_area	88.4	ft^2

Bankfull Statistics Flow Report [USA Bieger 2015]

Statistic	Value	Unit
Bieger_USA_channel_width	37.4	ft
Bieger_USA_channel_depth	2.35	ft
Bieger_USA_channel_cross_sectional_area	93.3	ft^2

Bankfull Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
Bieger_D_channel_width	35.3	ft
Bieger_D_channel_depth	2.73	ft
Bieger_D_channel_cross_sectional_area	95.1	ft^2
Bieger_P_channel_width	39.3	ft
Bieger_P_channel_depth	3.16	ft
Bieger_P_channel_cross_sectional_area	88.4	ft^2
Bieger_USA_channel_width	37.4	ft
Bieger_USA_channel_depth	2.35	ft
Bieger_USA_channel_cross_sectional_area	93.3	ft^2

USGS

Bieger, Katrin; Rathjens, Hendrik; Allen, Peter M.; and Arnold, Jeffrey G.,2015, Development and Evaluation of Bankfull Hydraulic Geometry Relationships for the Physiographic Regions of the United States, Publications from USDA-ARS / UNL Faculty. 17p.

USGS Streamstats

Customizations: Bankfull Statistics

Missouri Nationwide Regional Permitting Regional Conditions (2021)

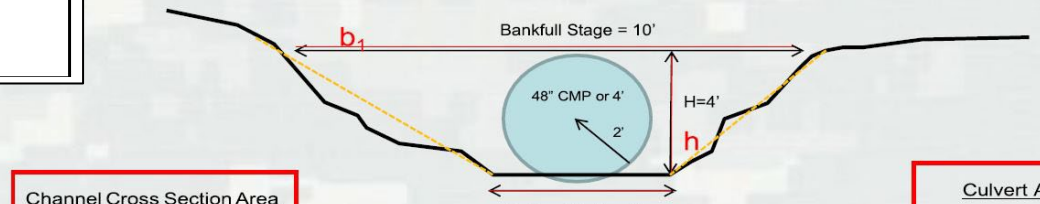
Stream Type	% of crossing profile that shall remain open
Perennial	Designed to allow an 85% opening to include the culvert(s) and area above the crossing up to the bankfull area.
Intermittent	Designed to allow a 50% opening to include the culvert(s) and area above the crossing up to the bankfull area.

https://www.mvs.usace.army.mil/Portals/54/docs/regulatory/permits/2021MONWPRC.pdf?ver=2GGFgQfT4aJgycG0OVU4Ig%3d%3d

Regional Condition 1 – Stream Crossings

Intermittent Stream
Approximate Minimum Area

Culvert cross-sectional area must be ~50% of stream x-sectional area



Channel Cross Section Area

$$A = \frac{(b_1 + b_2) \cdot h}{2}$$

$$\text{Area} = \frac{(10 + 4) * 4}{2} = 28\text{ft}^2$$

$28\text{ft}^2 \times 50\% = 14\text{ft}^2$

~50% ?

Culvert Area

$$A = \pi \cdot r^2$$

Area = $3.14(2)^2 = 12.6\text{ft}^2$

Graphic is not to scale

BUILDING STRONG®

USGS Streamstats - Iowa

Customizations: Flow Anywhere – Flow Duration Curve Transfer

Flow-Duration Statistics Flow Report [Statewide Flow Duration 2012 5232]

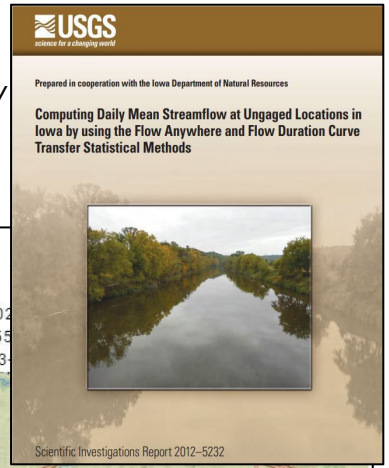
PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	ASEp
1 Percent Duration	1800	ft^3/s	23.5
5 Percent Duration	608	ft^3/s	23.6
10 Percent Duration	324	ft^3/s	24.2
15 Percent Duration	251	ft^3/s	24.6
20 Percent Duration	188	ft^3/s	22.1
30 Percent Duration	126	ft^3/s	17.1
40 Percent Duration	84.8	ft^3/s	14.9
50 Percent Duration	61.1	ft^3/s	16.4
60 Percent Duration	41.9	ft^3/s	22.1
70 Percent Duration	25.7	ft^3/s	32.4
80 Percent Duration	9.66	ft^3/s	40.1
85 Percent Duration	6.97	ft^3/s	42.5
90 Percent Duration	4.86	ft^3/s	51
95 Percent Duration	2.45	ft^3/s	74.9
99 Percent Duration	1.15	ft^3/s	

Flow-Duration Statistics Citations

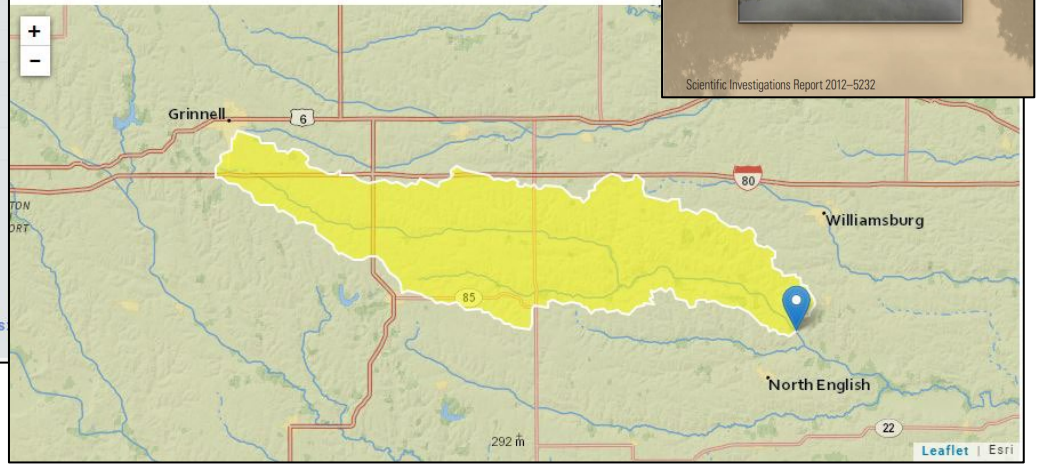
Linhart, S.M., Nania, J.F., Sanders, C.L., Jr., and Archfield, S.A.,2012, Computing daily mean streamflow at ungaged locations in Iowa by using the Flow Anywhere and Flow Duration Curve Transfer statistical methods: U.S. Geological Survey Scientific Investigations Report 2012–5232, 50 p.

https://pubs.usgs.gov/sir/2012/5232/sir2012-5232.pdf



StreamStats Report

Region ID: IA
Workspace ID: IA202
Clicked Point (Latitude, Longitude): 41.55
Time: 2023-



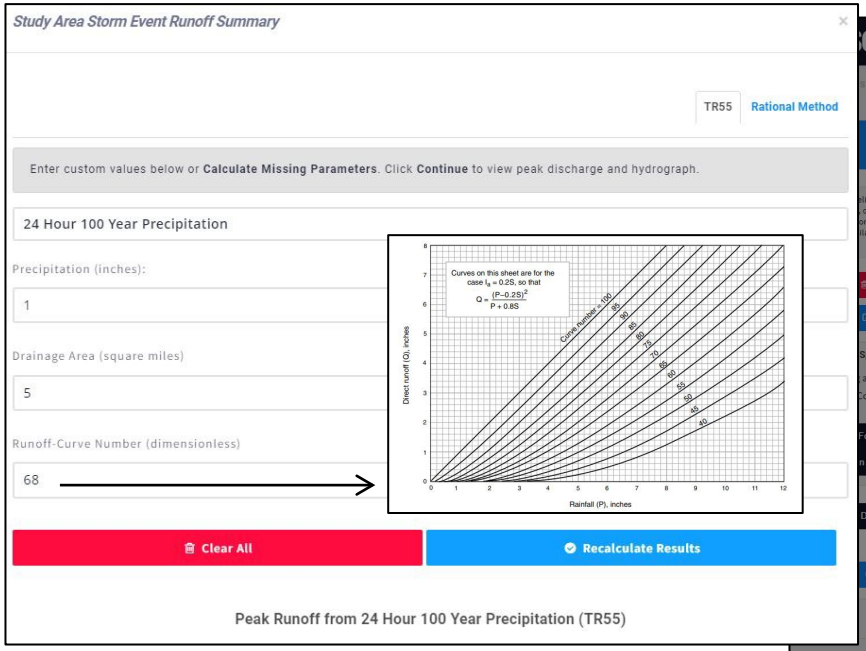
USGS

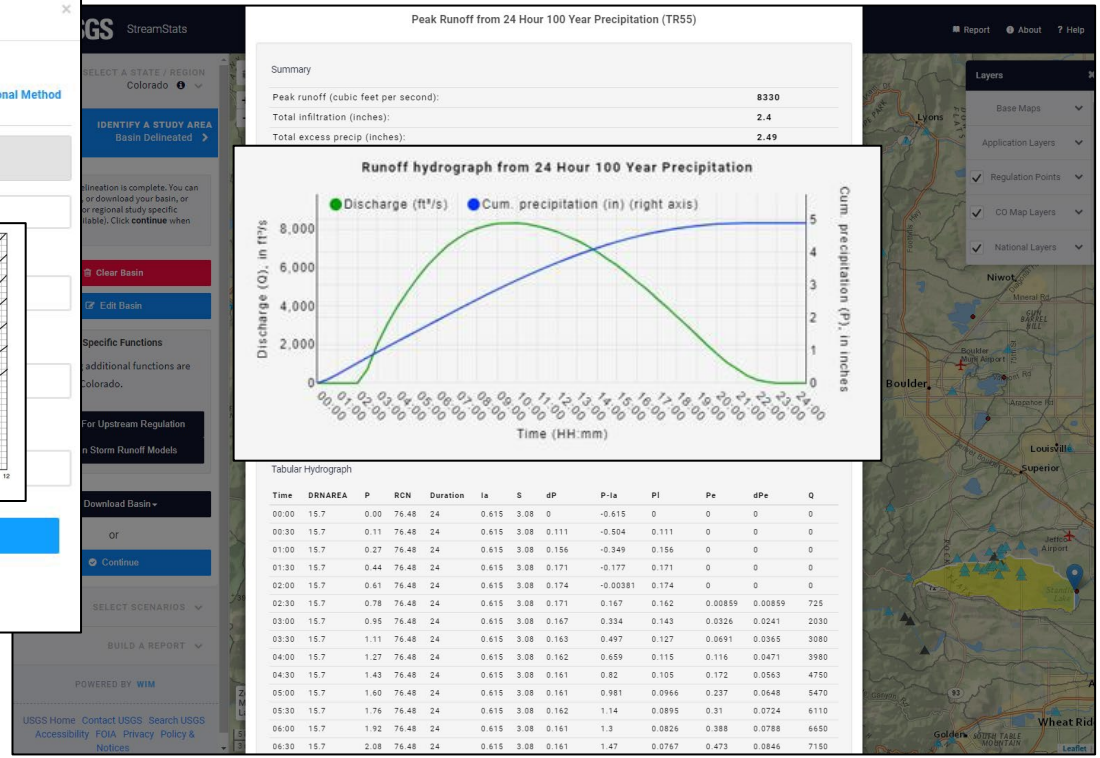
https://streamstats.usgs.gov/ss/

USGS Streamstats - Colorado

Customizations: Peak flow for small basins/storm runoff tools

Implementation of TR-55 and Rational Methods





USGS

https://streamstats.usgs.gov/ss/

USGS Streamstats - Colorado

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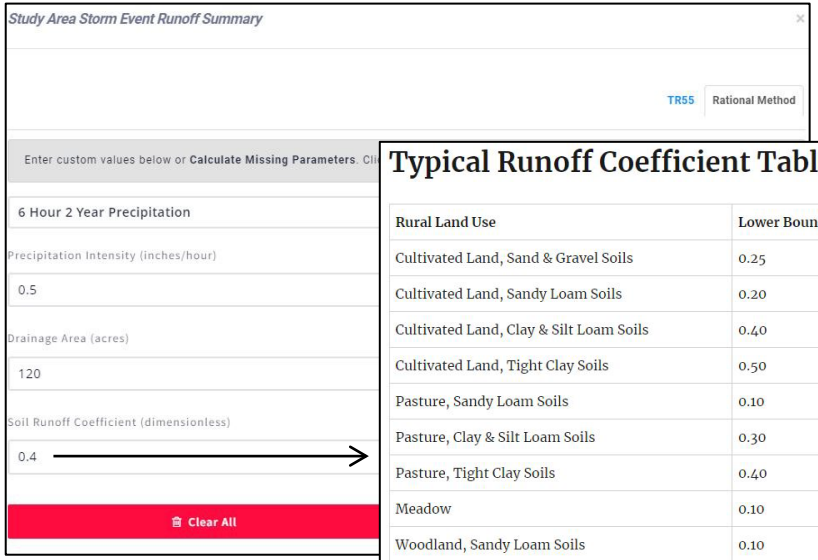
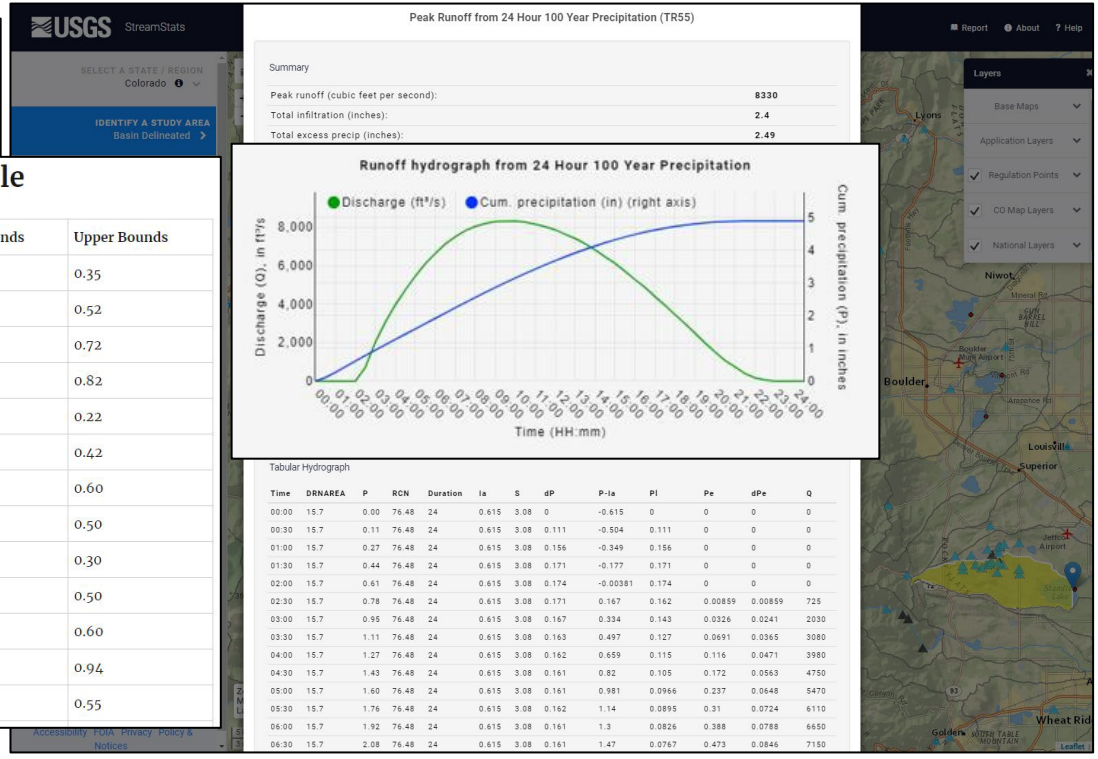


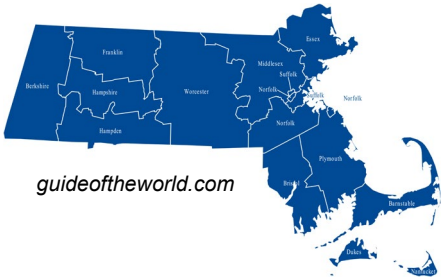
Typical Runoff Coefficient Table

Rural Land Use	Lower Bounds	Upper Bounds
Cultivated Land, Sand & Gravel Soils	0.25	0.35
Cultivated Land, Sandy Loam Soils	0.20	0.52
Cultivated Land, Clay & Silt Loam Soils	0.40	0.72
Cultivated Land, Tight Clay Soils	0.50	0.82
Pasture, Sandy Loam Soils	0.10	0.22
Pasture, Clay & Silt Loam Soils	0.30	0.42
Pasture, Tight Clay Soils	0.40	0.60
Meadow	0.10	0.50
Woodland, Sandy Loam Soils	0.10	0.30
Woodland, Clay & Silt Loam Soils	0.30	0.50
Woodland, Tight Clay Soils	0.40	0.60
Bare Rock	0.82	0.94
Desert	0.30	0.55



USGS Streamstats

Massachusetts: Statewide Hydraulic Modeling Pilot



Goal:

To give communities the ability to create a preliminary design for a new or existing stream crossing replacement.

Proposed MA Statewide Hydraulic Modeling Tool:

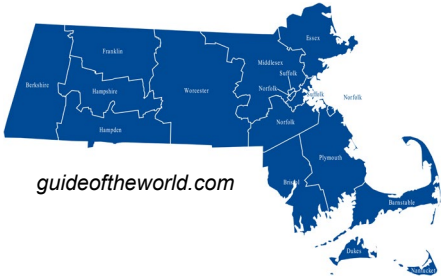
Help communities facilitate permitting of replacement projects that will meet Wetlands Protection Act requirements while minimizing associated adverse impacts.

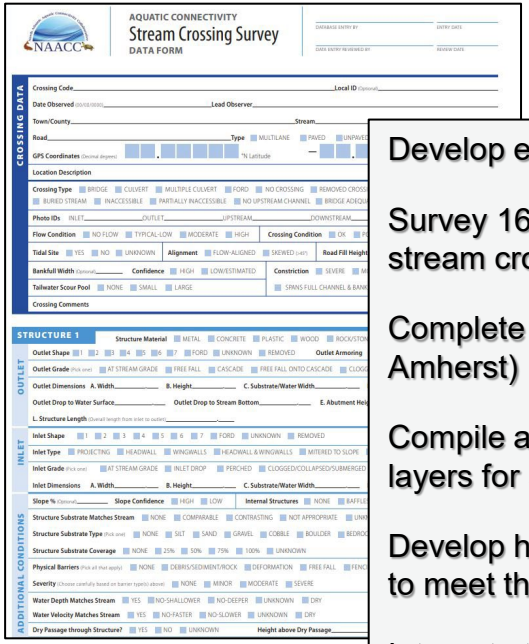
Provide preliminary evaluation of hydrology and hydraulics and ecological conditions for potential replacements projects.

USGS

USGS Streamstats

Massachusetts: Statewide Hydraulic Modeling Pilot





Develop elevation derived DEMs from Quality Level 2 (QL-2) lidar

Survey 16 culverts/bridges and associated stream channel elevations and complete stream crossing assessments

Complete NAACC stream crossing assessments in pilot watershed (UMass Amherst)

Compile a GIS aquatic habitat quality and connectivity restoration potential data layers for stream crossing locations (UMass Amherst)

Develop hydraulic model runs for a selected MassDOT hydraulic design flow(s) and to meet the Massachusetts Stream Crossing Standards

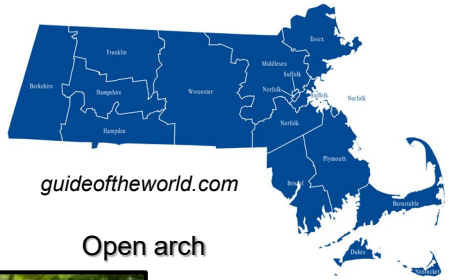
Integrate the hydraulic modeling tool developed for the pilot watershed into the USGS StreamStats web application

USGS

North Atlantic Aquatic Connectivity Collaborative
NAACC

USGS Streamstats

Massachusetts: Statewide Hydraulic Modeling Pilot



guideoftheworld.com

Large span, 1.2x bankfull width

0.82 Openness ratio

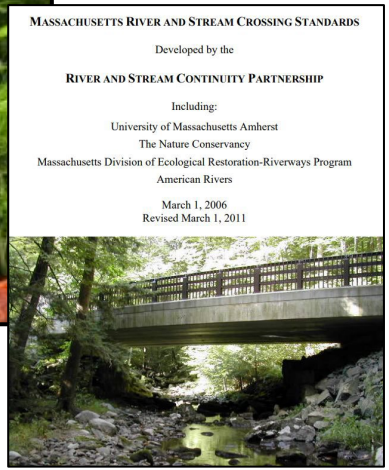
Open arch

Embedment

Natural substrate

Banks, dry passage

Comparable depth and velocity, up & downstream



MASSACHUSETTS RIVER AND STREAM CROSSING STANDARDS

Developed by the

RIVER AND STREAM CONTINUITY PARTNERSHIP

Including:

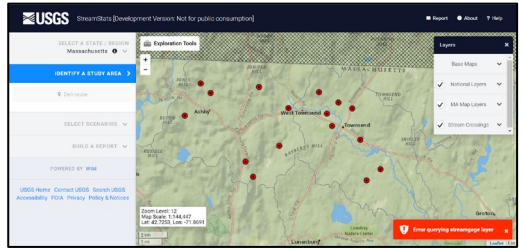
University of Massachusetts Amherst
The Nature Conservancy
Massachusetts Division of Ecological Restoration-Riverways Program
American Rivers

March 1, 2006
Revised March 1, 2011

USGS

USGS Streamstats

Massachusetts: Statewide Hydraulic Modeling Pilot



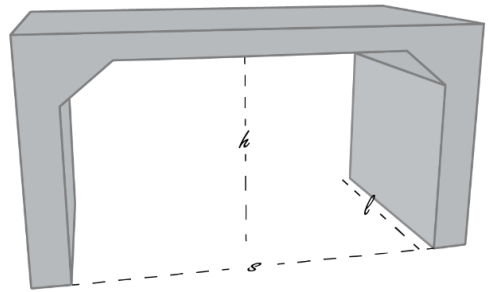
Summary:

- Site location
- North Atlantic Aquatic Connectivity Collaborative (NAACC)
- Aquatic habitat quality, stream connectivity restoration potential, and Maximum Extent Practicable (MEP) scores
- MassDOT highway functional classification and hydraulic design flow
- USGS peak flow and bankfull channel geometry equations
- Preliminary box, arch, and pipe culvert dimensions and relation to MRSCS

USGS

https://dev.streamstats.usgs.gov/ma-culverts/

Preliminary 3-Sided Box Culvert Design meeting the 10- and 25-Year Flood Flows and Stream Crossing Standards



Parameter Name	10-Yr Flow	25-Yr Flow	Meets SCS	Unit
Box Culvert Span	12.0		17	Feet
Box Culvert Height	2.0		2	Feet
Box Culvert Length	42.6	42.6	42.6	Feet
Box Culvert Area	24.0		34	Square Feet
Box Culvert Material	Concrete	Concrete	Concrete	
Box Culvert Upstream Channel Invert Elevation	978.2	978.2	978.2	Feet - NAVD88
Box Culvert Downstream Channel Invert Elevation	977.2	977.2	977.2	Feet - NAVD88
Box Culvert Road Deck Elevation	981.7	981.7	981.7	Feet - NAVD88
Box Culvert Maximum Flow to Pass Through	10		10	Year
Box SCS Culvert Type	3-sided Box	3-sided Box	3-sided Box	
Box SCS Embedment	None	None	None	Feet
Box SCS Substrate	Natural	Natural	Natural	
Box Water Depth and Velocity Ratio				
Box SCS Span Ratio	0.9		1.2	
Box SCS Openness Ratio	0.60		0.8	

Hydraulic Model Citations

Massachusetts Department of Fish and Game, Division of Ecological Restoration, 2012, Massachusetts stream crossing handbook, 2nd edition, accessed August 1, 2021 at https://www.mass.gov/doc/massachusetts-stream-crossing-handbook/download.

Questions?

Thank you….

USGS Presentation Photos
Teams Conference
Circa 2007 ☺

TEAM Transportation Engineers Association of Missouri

MoDOT

USGS

Paul Rydlund - prydlund@usgs.gov
Chief: Hydraulics and Hydrology
Supervisory Hydrologist
Jason High - jhigh@usgs.gov
Physical Scientist