Operational Flood Inundation Mapping in Kansas & Implications for Water Infrastructure

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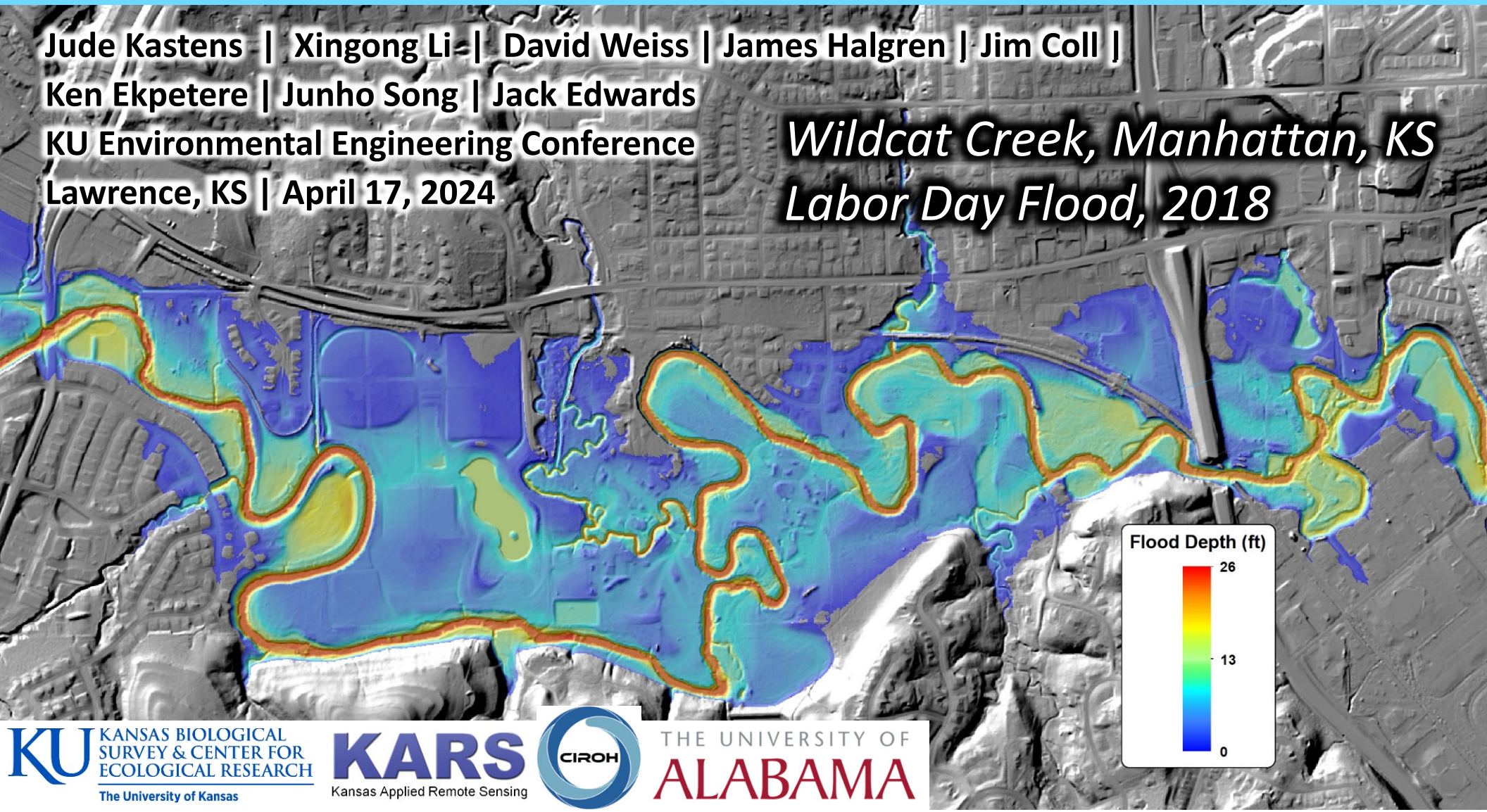
KU Environmental Engineering Conference
Lawrence, KS | April 17, 2024



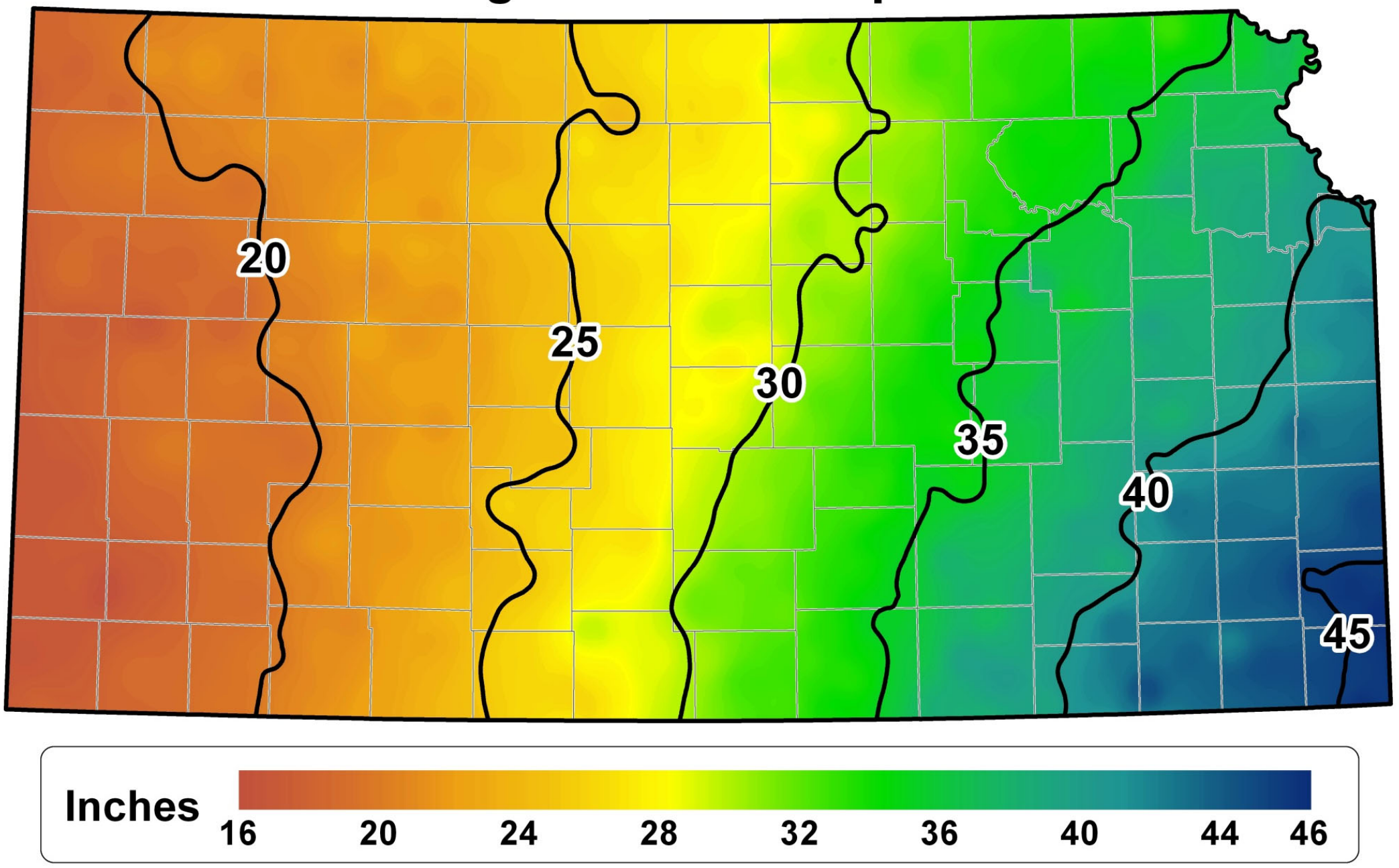
KU KANSAS BIOLOGICAL SURVEY & CENTER FOR ECOLOGICAL RESEARCH
The University of Kansas
KARS Kansas Applied Remote Sensing
CIROH
THE UNIVERSITY OF ALABAMA

Republican River Flood Crest

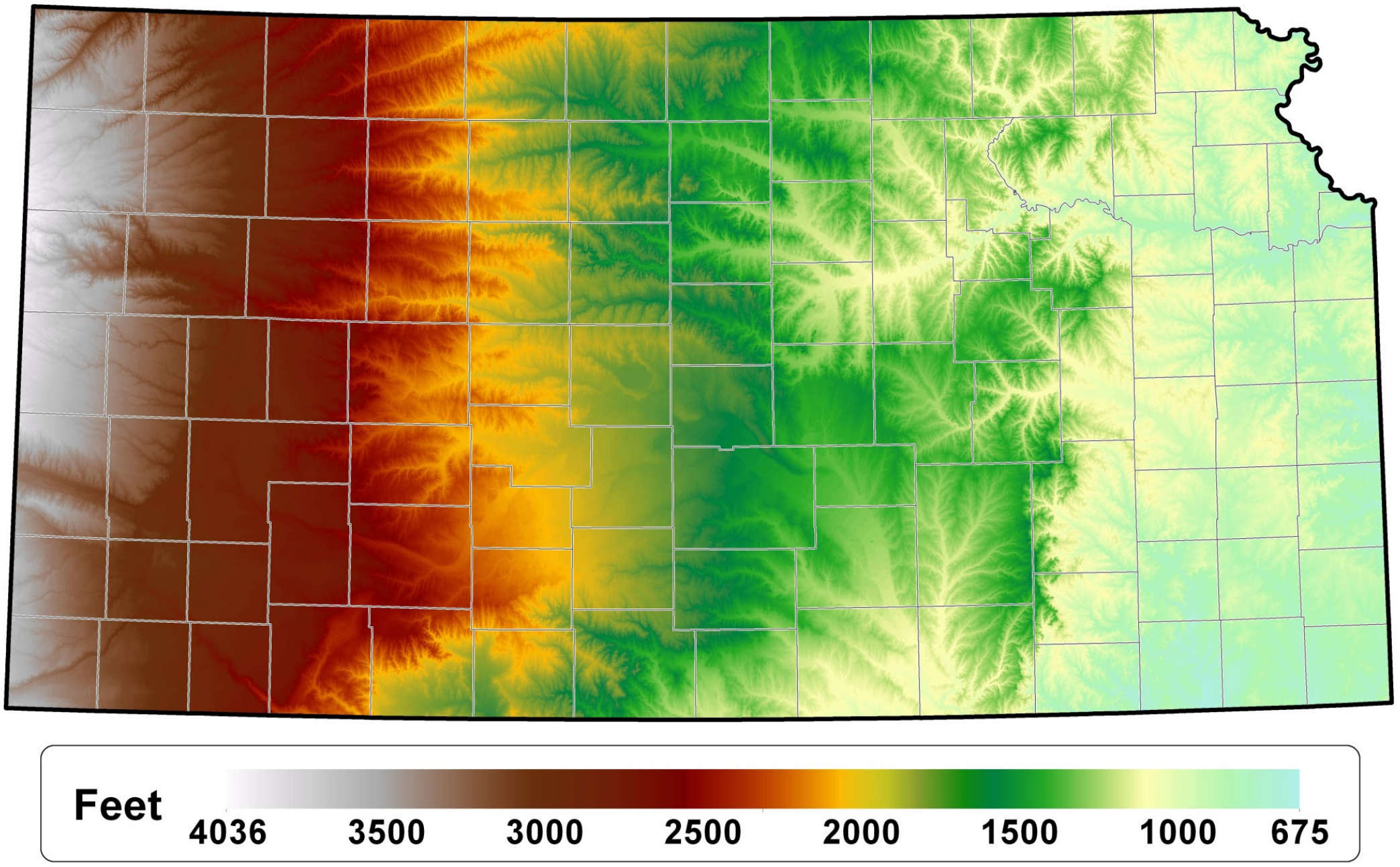
Stratton, NE

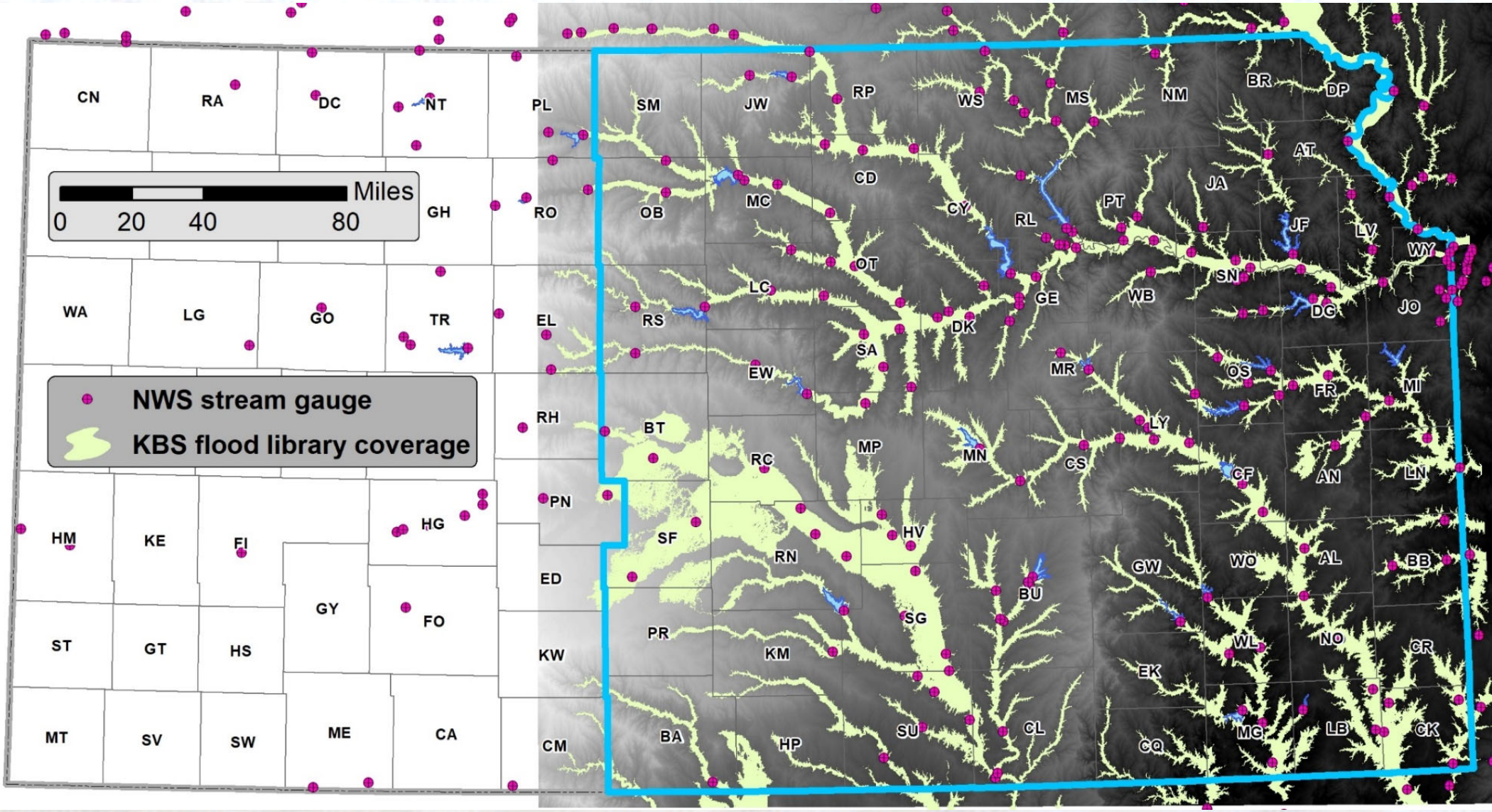
July 26, 2020

Average Annual Precipitation (1981-2010)



Elevation





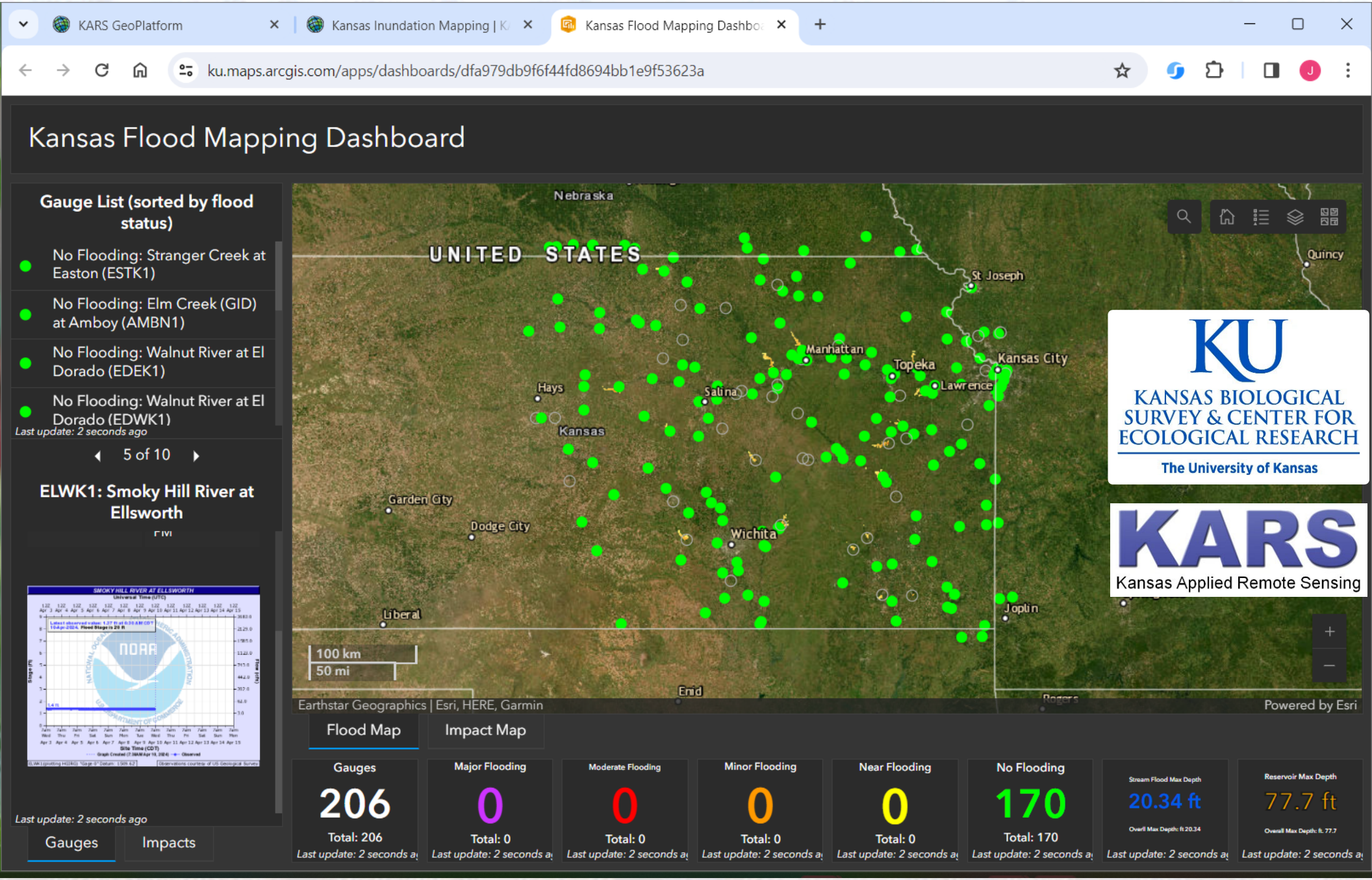
Kansas Inundation Library Coverage

Background

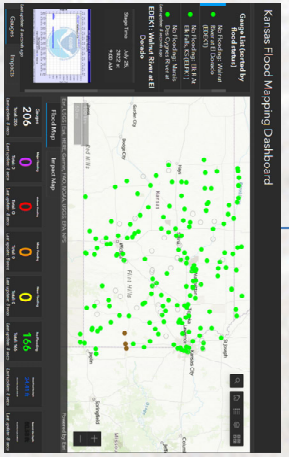
- Inundation library coverage developed for gaged stream network spanning greater eastern Kansas (GIS-PB funding 08, 09, 11, 13)
- Library put into action during record 2019 flooding
- Funding for mapping tool development provided by KWO (2020-2024) & KDEM (2020)
- **Future directions:**
  - Improved mapping capabilities, statewide coverage
  - Enhanced functionality, such as impacts to roads and other critical infrastructure

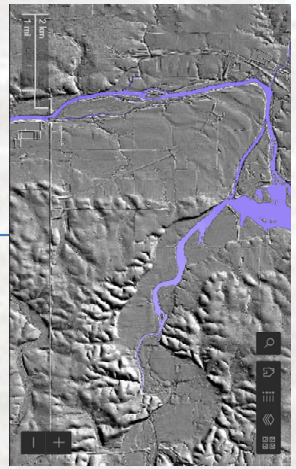
Kansas Real-Time Flood Mapping Dashboard

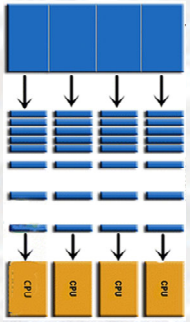
https://kars.geoplatform.ku.edu/pages/kansas-inundation-mapping

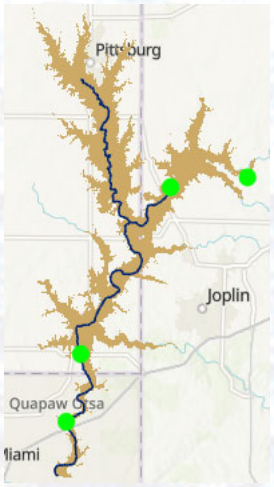


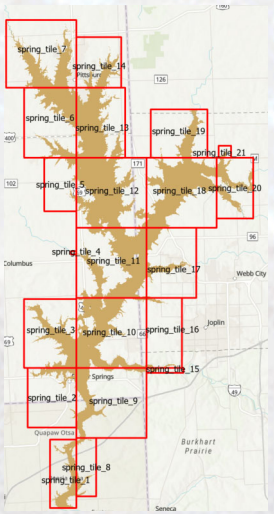
System Structure

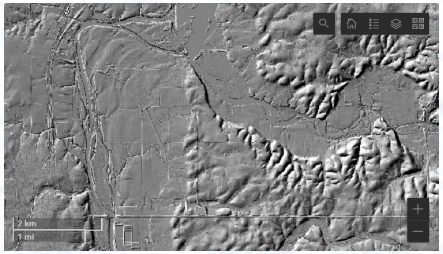


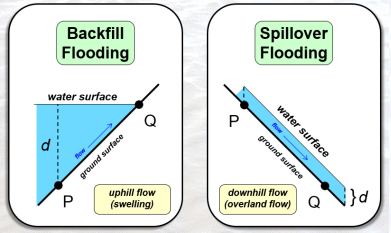




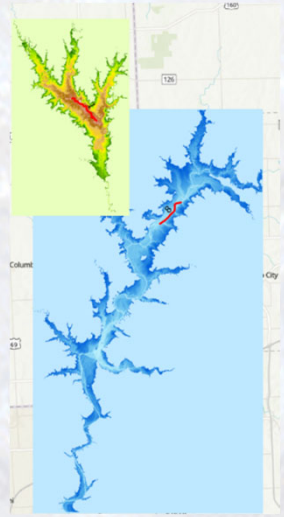




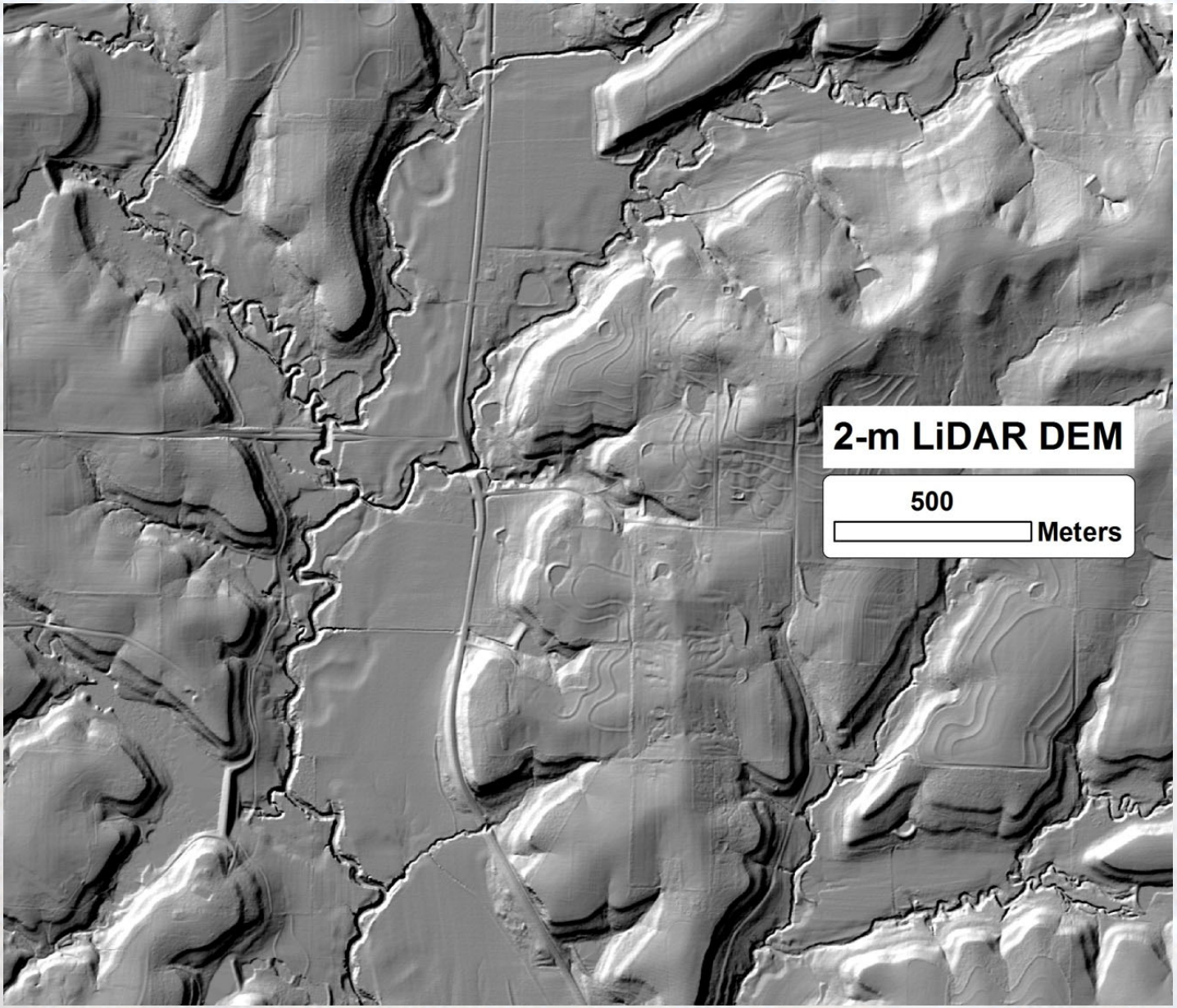




FLDPLN



Terrain Processing: ***DEM*** *(Digital Elevation Model)*

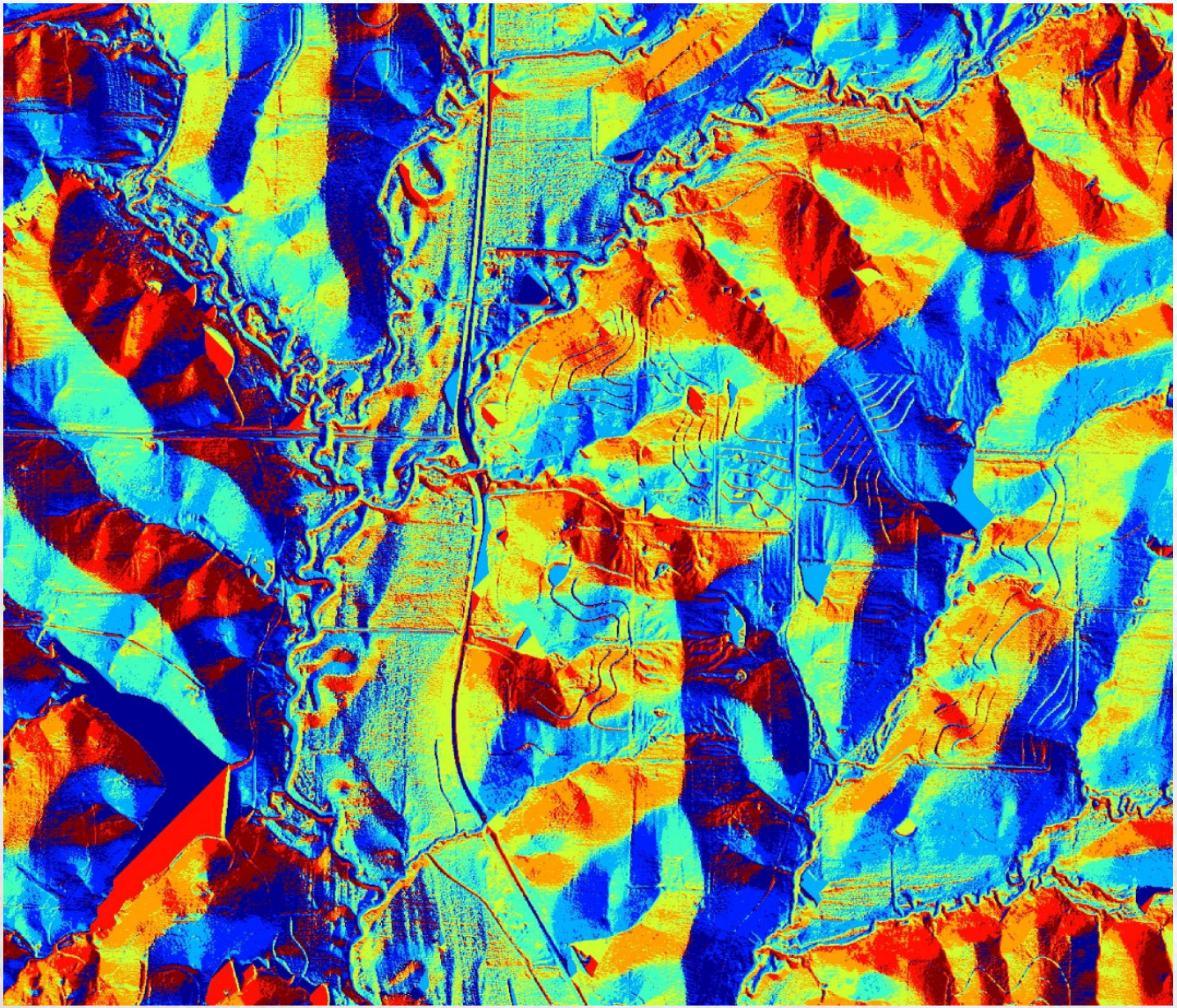


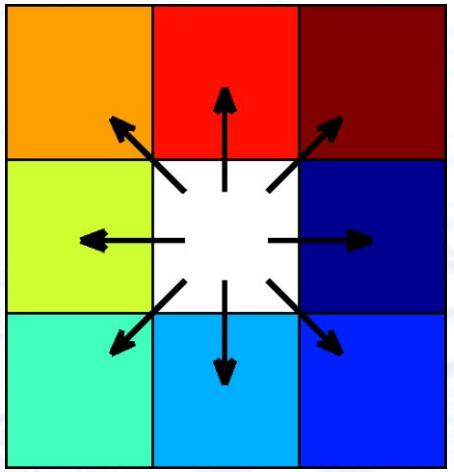
DEM (shown in shaded relief)

This DEM was created using LiDAR data.

Shown is a portion of the river valley for Mud Creek in Jefferson County, Kansas.

Terrain Processing: ***Flow Direction*** *(derived from filled DEM)*



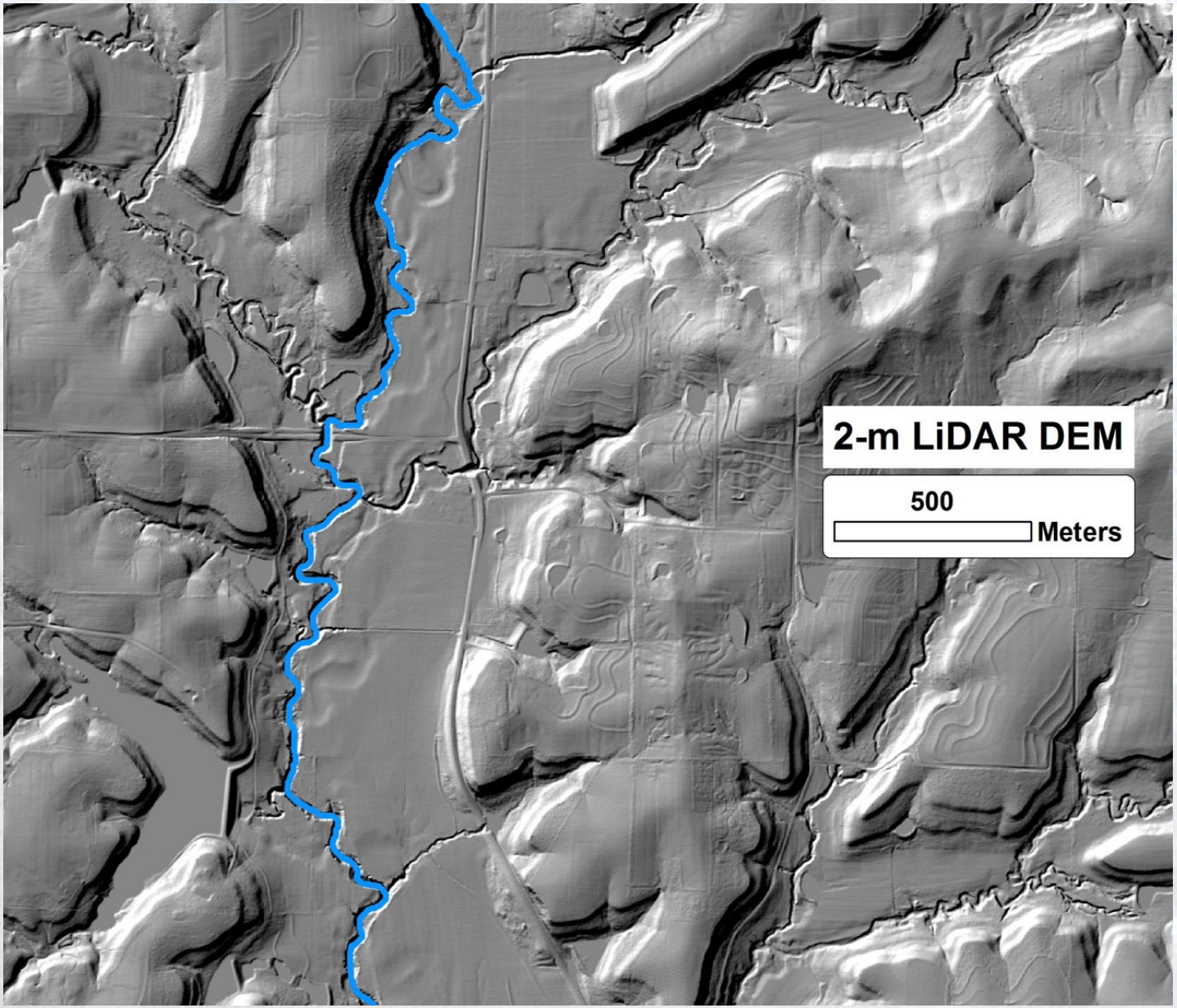


Each pixel is colored based on its flow direction.

Navigating by flow direction, every pixel has a single *exit path* out of the image.

Flow direction map (gradient direction approximation)

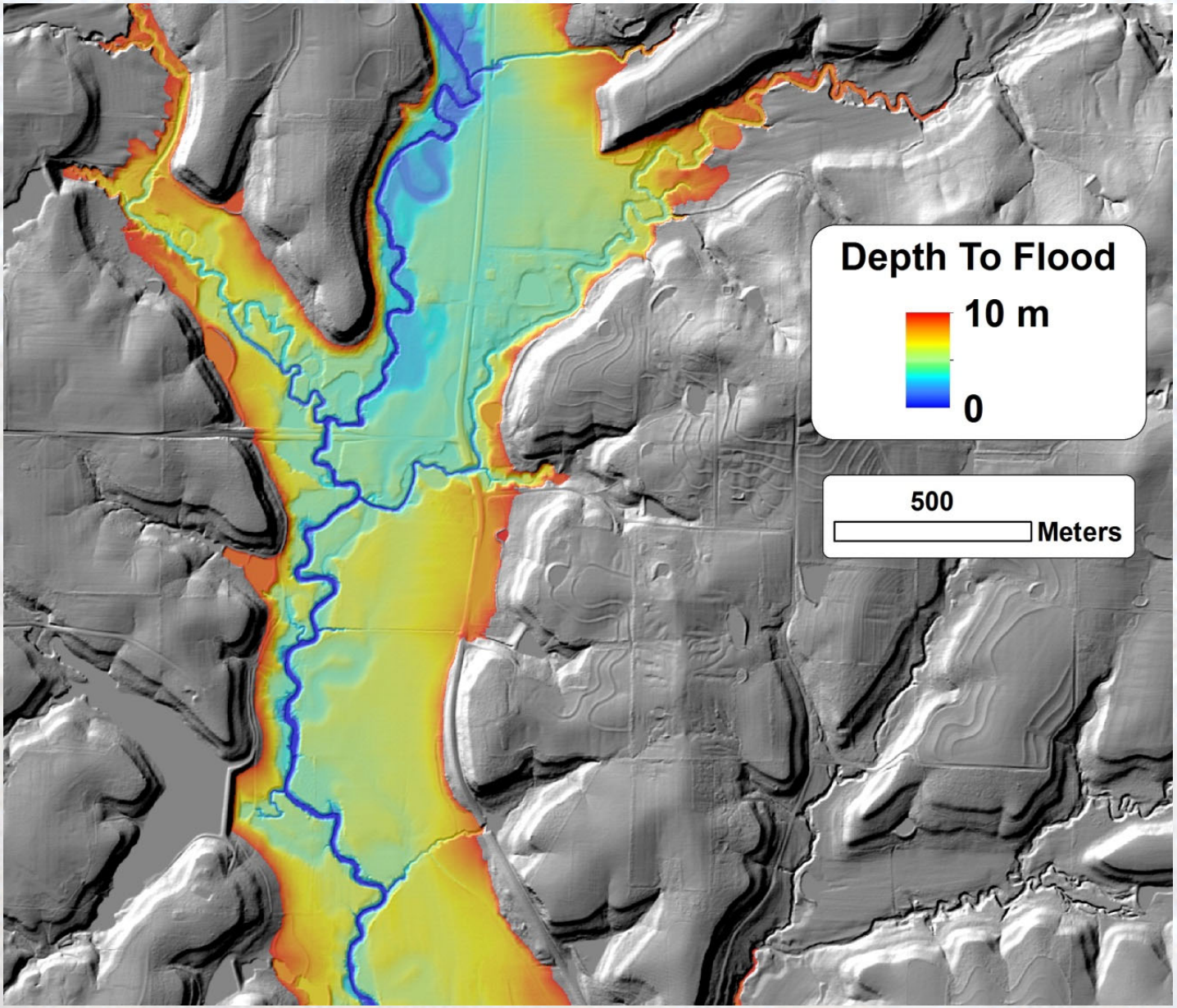
Terrain Processing: *Stream Delineation* *(from Flow Direction)*



"Synthetic Stream Network"

The Mud Creek streamline is identified (shown in blue) using an appropriate flow accumulation threshold or starting point.

Terrain Processing: *Floodplain Mapping*



10-m Floodplain (DTF Map)

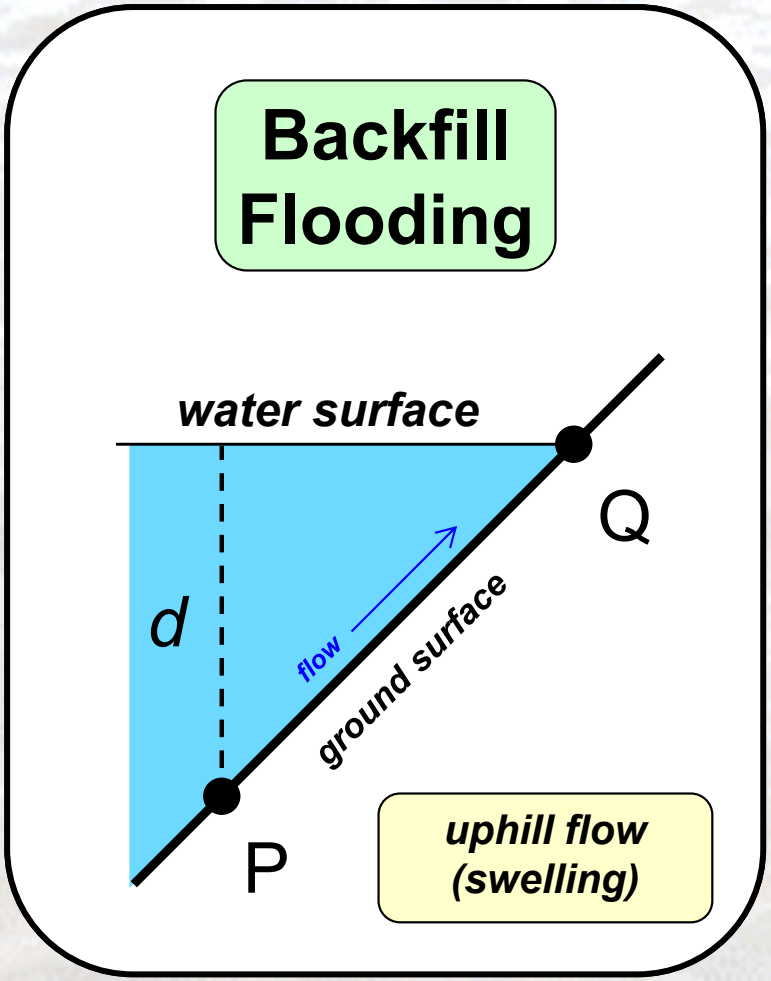
The 10-m floodplain was computed *for Mud Creek* using the FLDPLN model.

FLDPLN is a static, 2D hydrologic model that requires only DEM data as input.

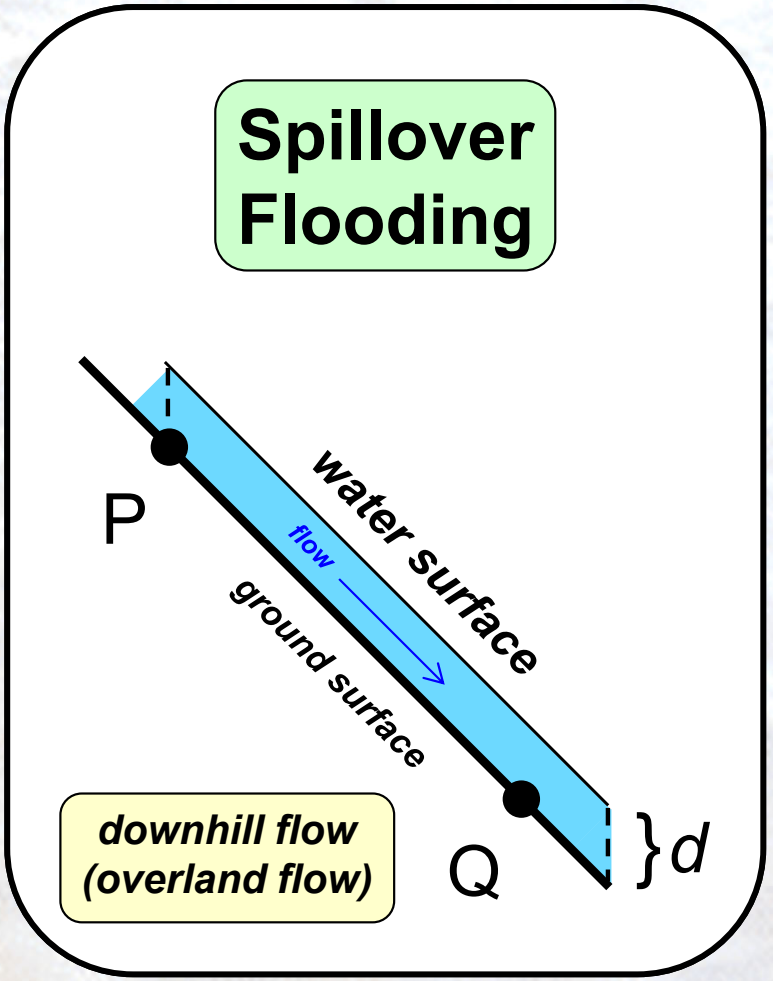
Using simple surface flow properties, FLDPLN identifies the depth-varying floodplain in reference to the input stream network (floodwater source).

The FLDPLN ("Floodplain") Model—

There are two ways that point **Q** can be flooded by water originating from point **P**:

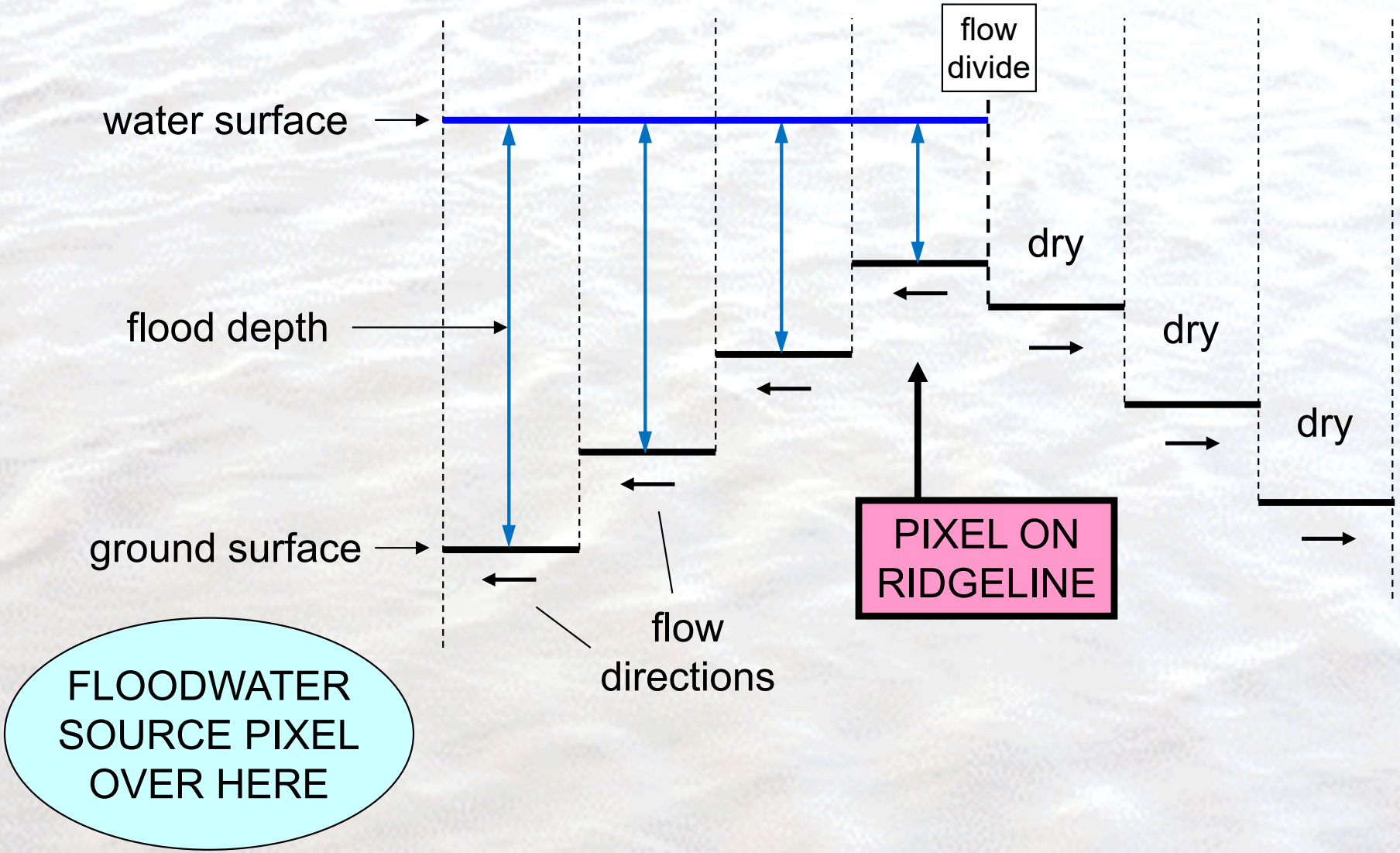


"Water seeks its own level"

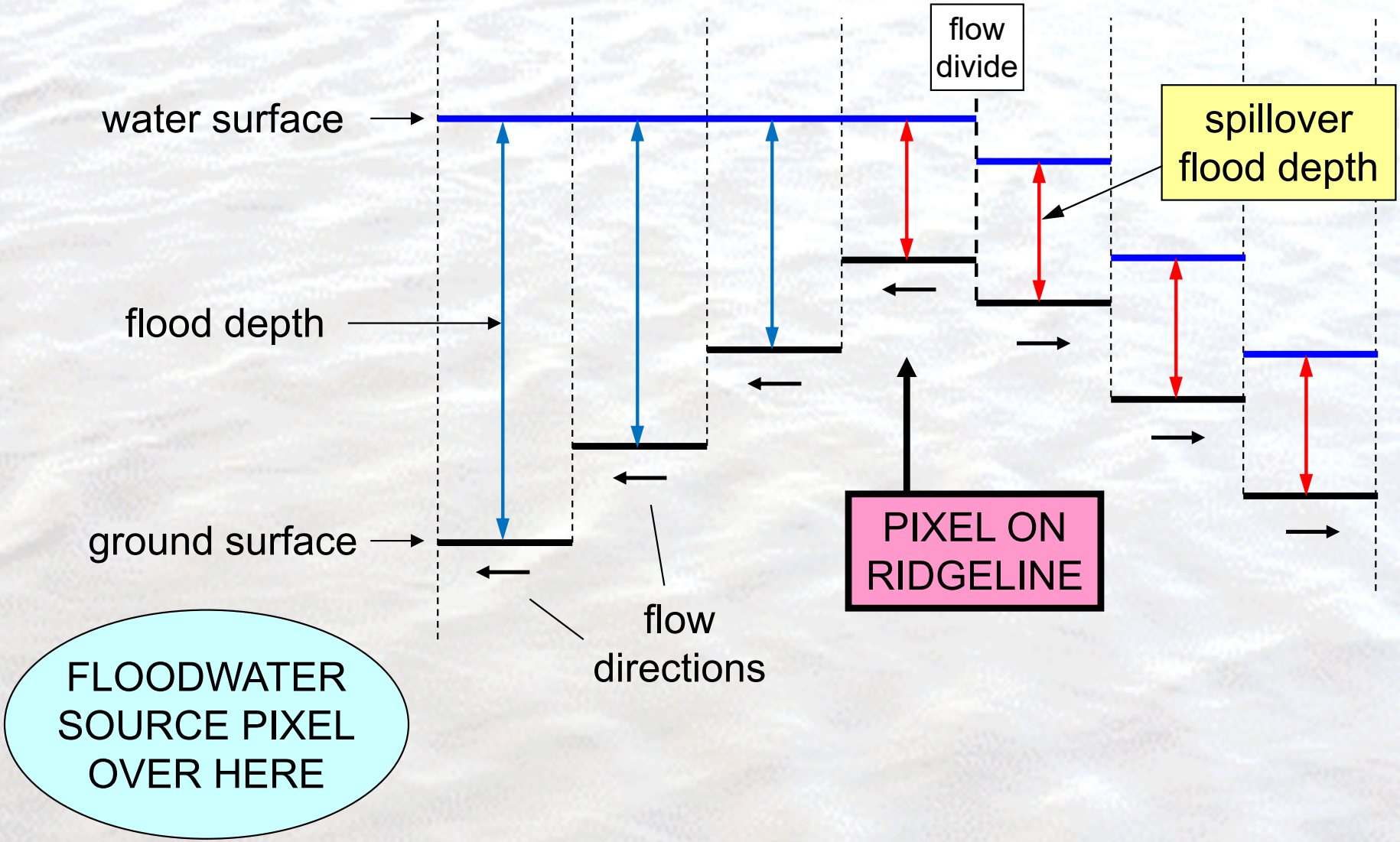


"Water flows downhill"

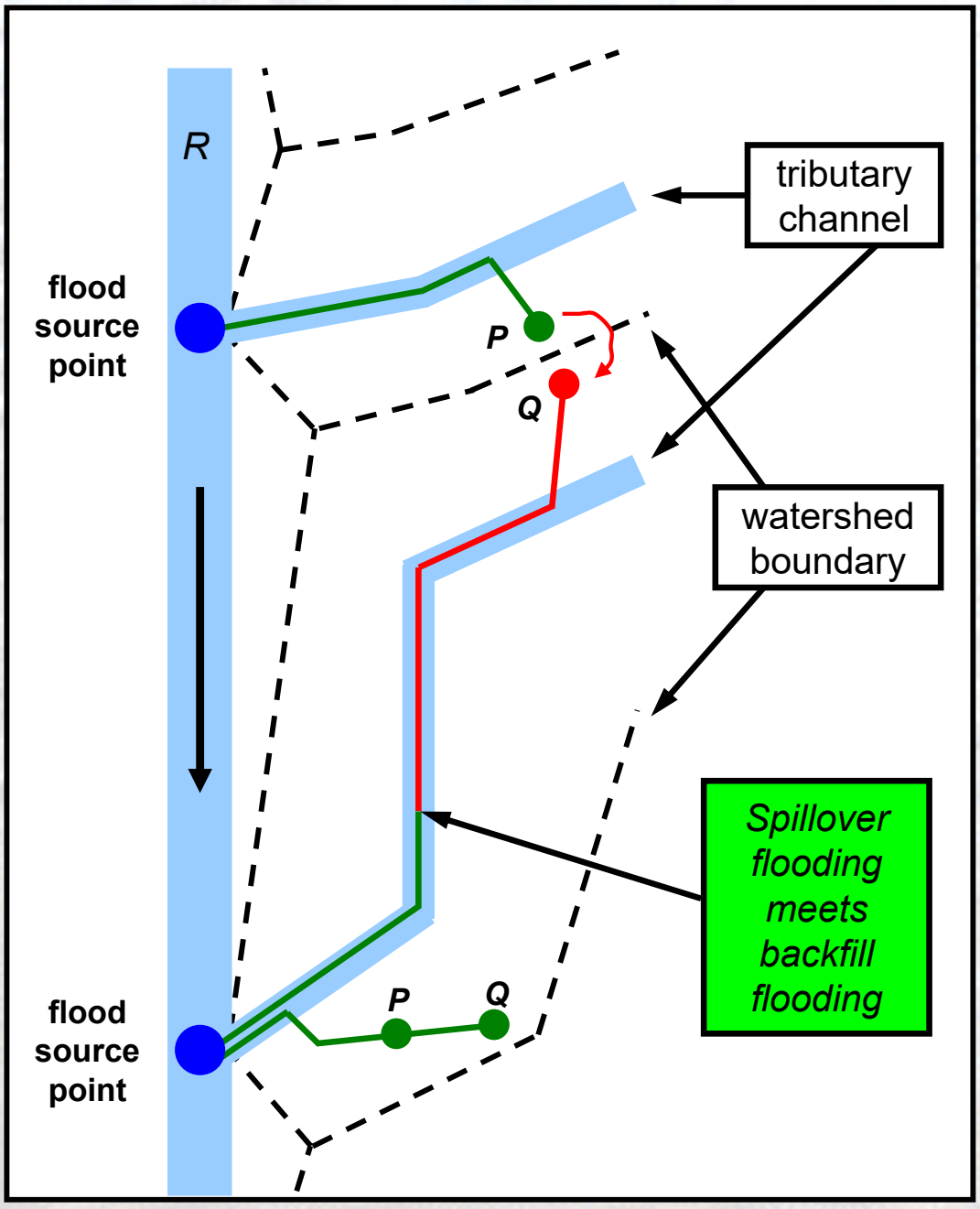
Backfill Flooding—accounts for floodwater expansion due to swelling processes

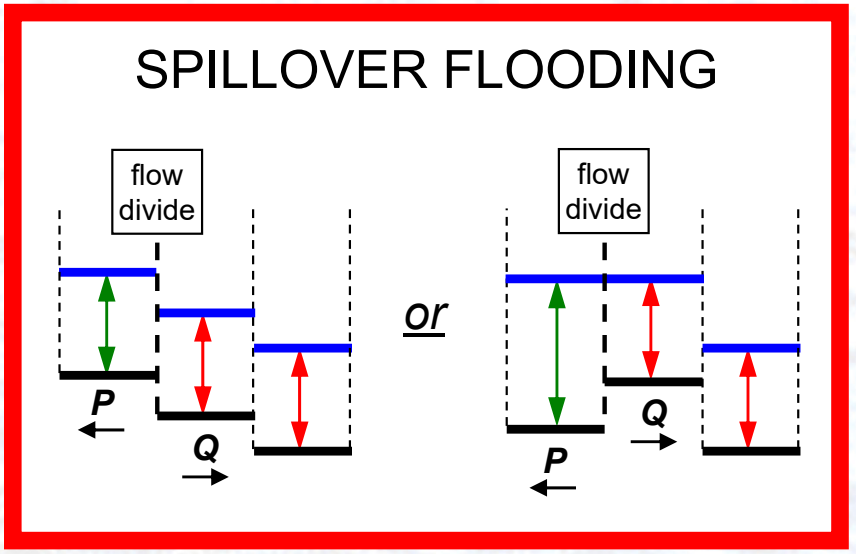


Spillover Flooding—accounts for floodwater rerouting (new flow path development)

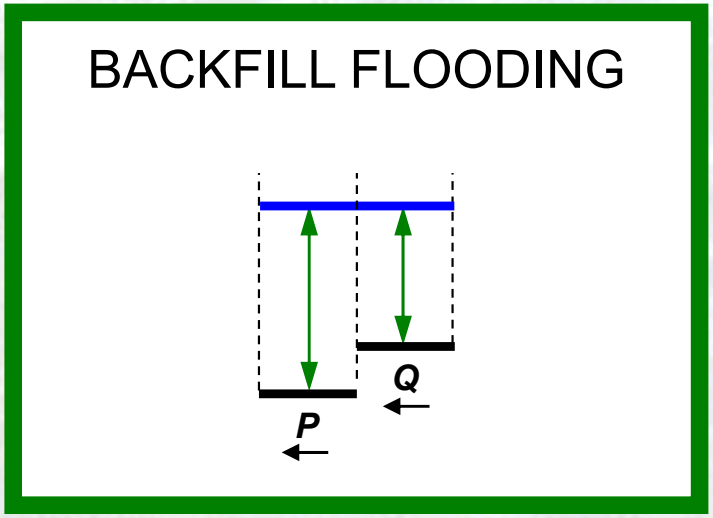


PLAN VIEW illustrating backfill and spillover flooding





Depth To Flood (DTF) Contour

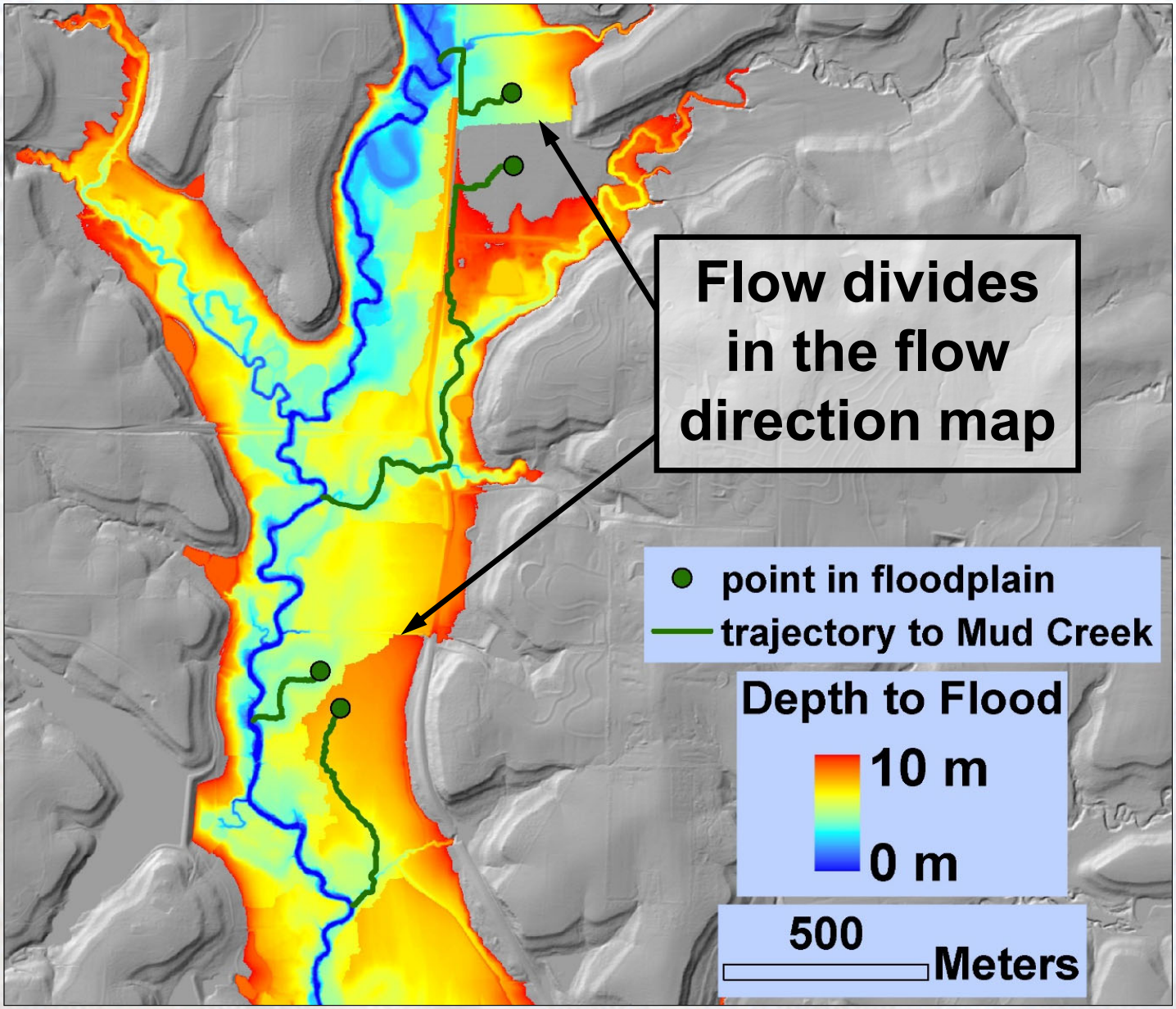


Backfill Flooding Is Not Sufficient

Here is what a DTF map looks like determined using only backfill flooding.

Note the erroneous discontinuities.

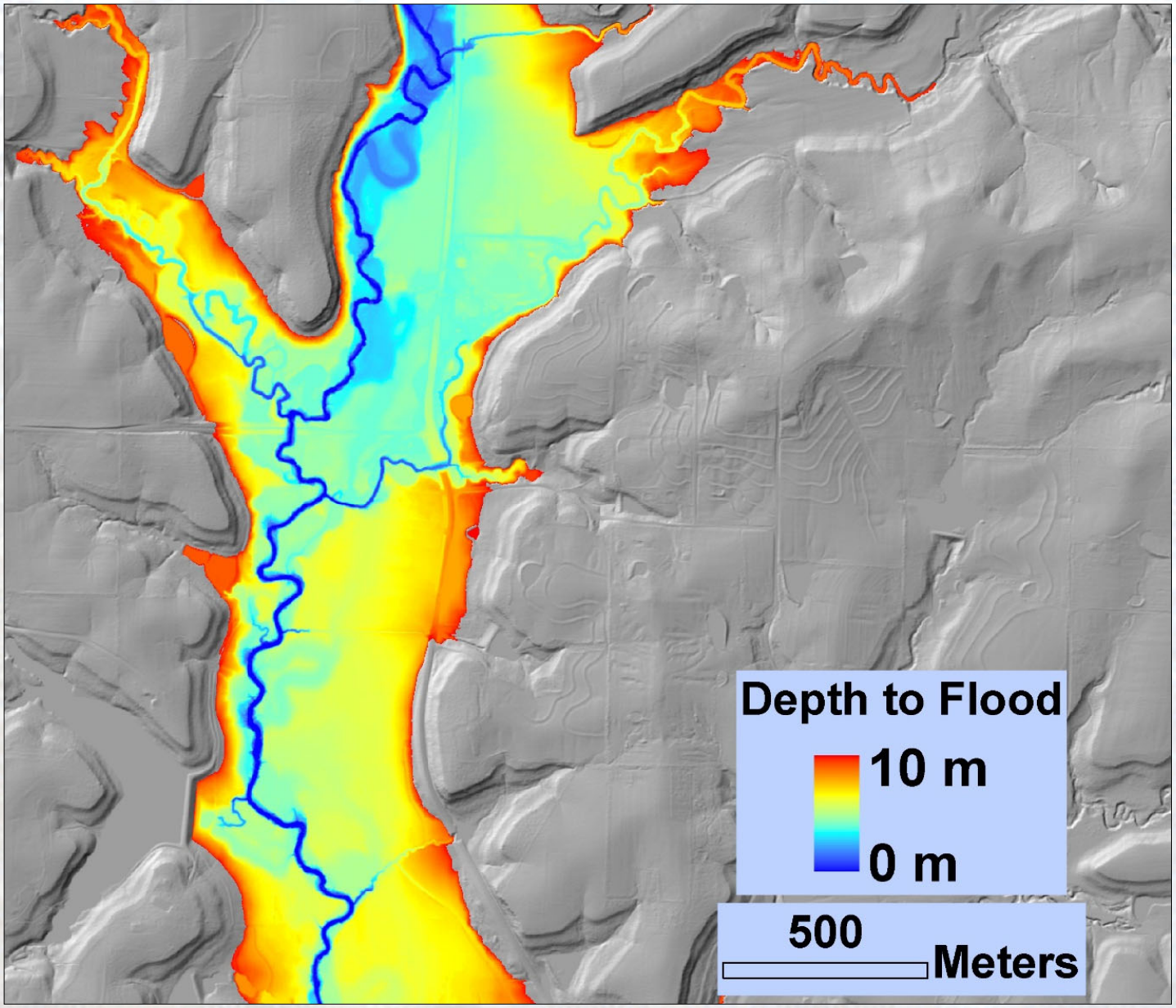
These are caused by ridgelines in the DEM.



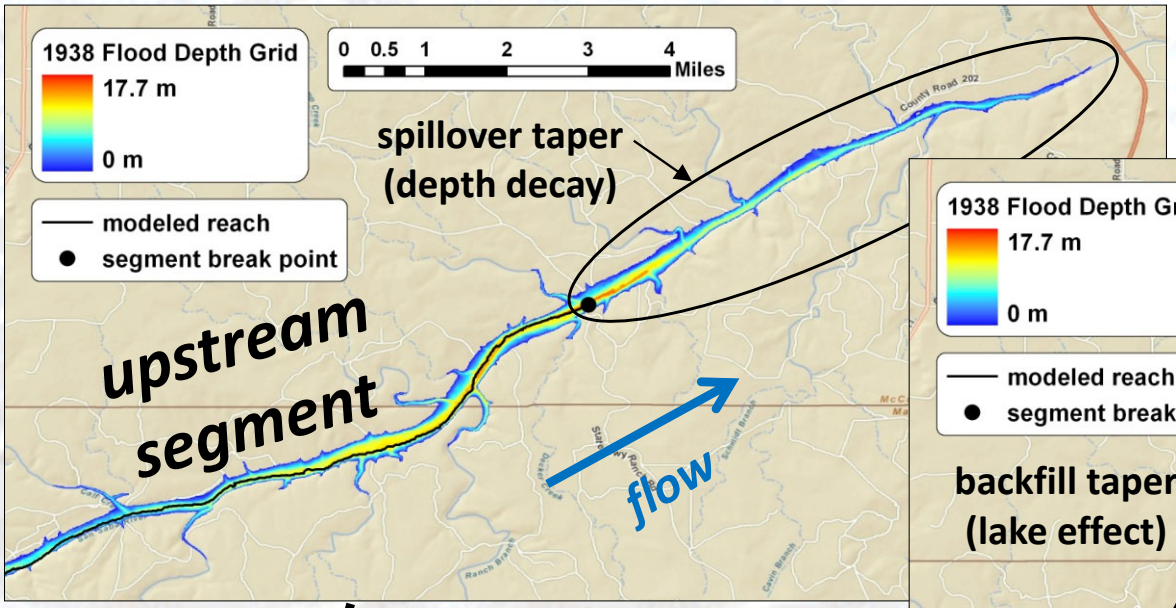
Backfill + Spillover Flooding

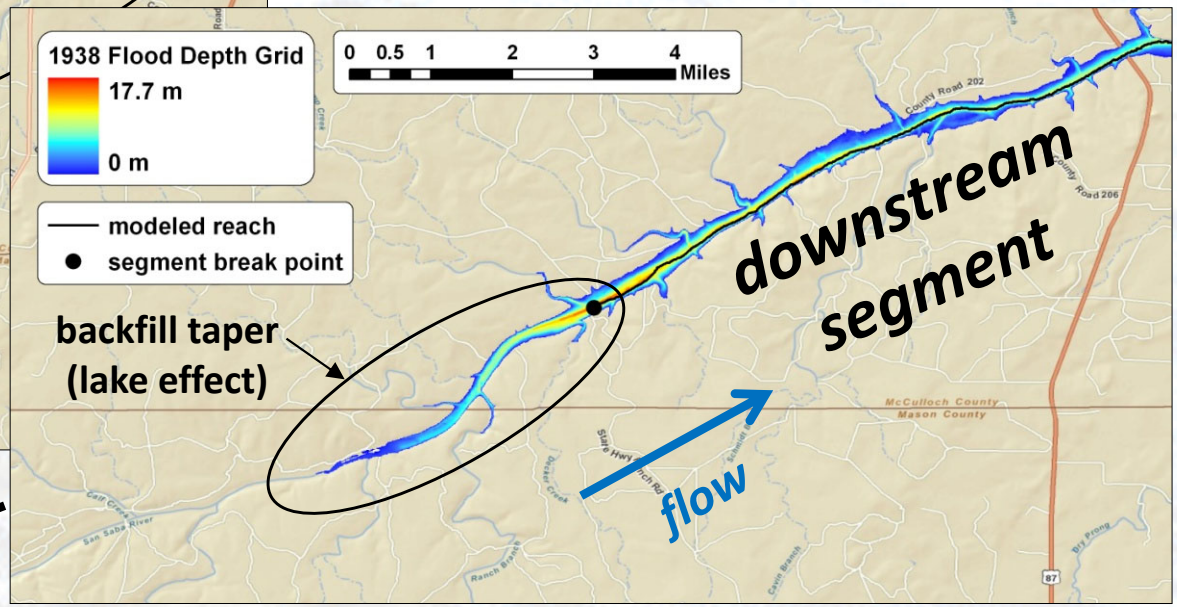
By backfill flooding using small flood depth increments, and allowing spillover flooding to occur on the floodplain boundary between iterations, the DTF discontinuity problem is mostly resolved.

The 10-m steady state floodplain is shown, computed using the FLDPLN model and 0.5 m increments.

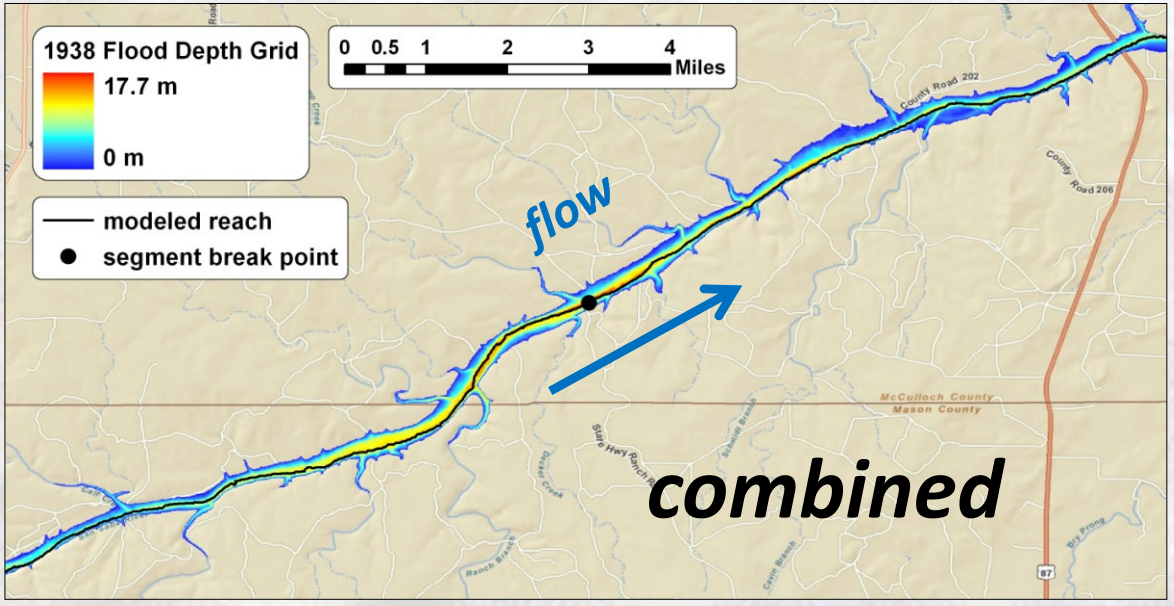


Seamless modeling with FLDPLN



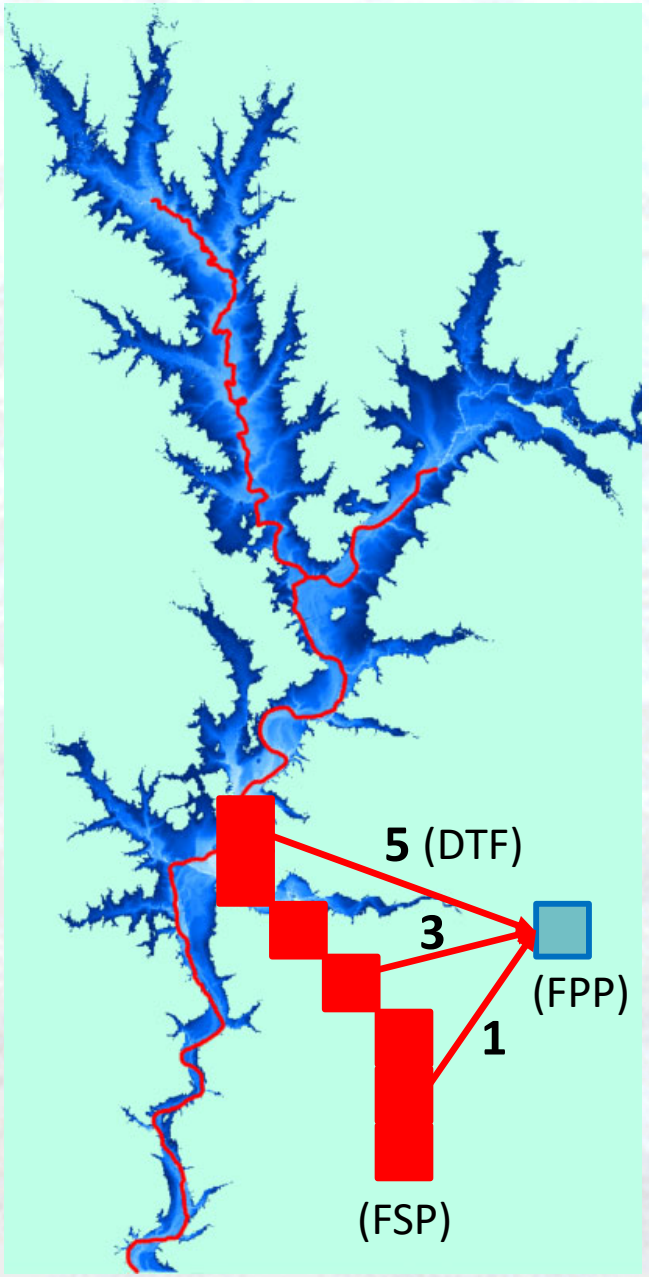


maximum value composite



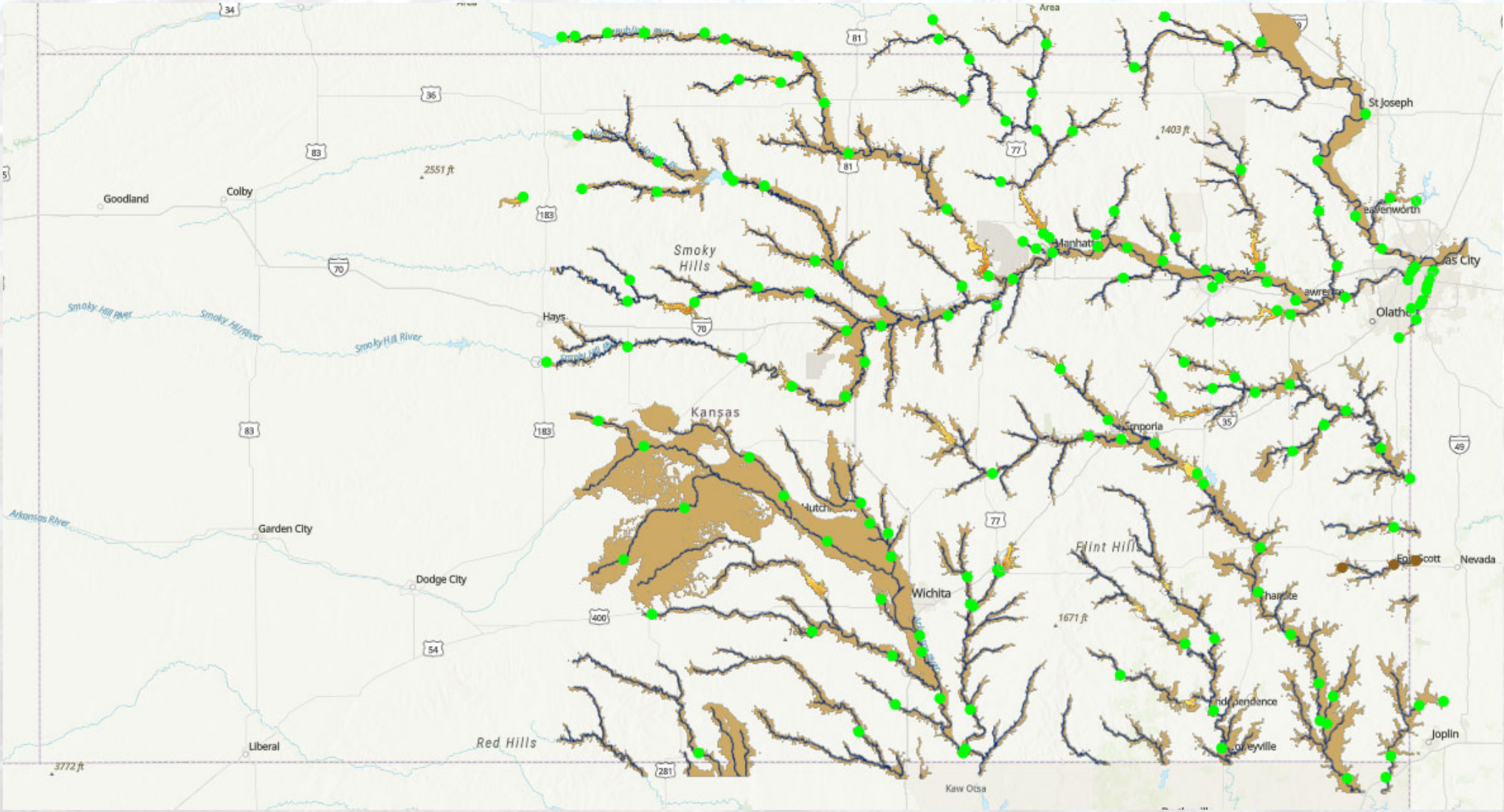
FLDPLN Model

- A floodplain pixel (FPP) can be flooded by the water originated from flood source (stream) pixels (FSPs) through backfill and spillover flooding
  - FSP-FPP flood relation
  - many-to-many relation
- Depth to flood (DTF)
  - Minimum depth at a FSP needed to flood a FPP
  - Attribute associated with a FSP-FPP relation
- FLDPLN model identifies the FSP-FPP flooding relations and their associated DTFs
  - Iterative process



FLDPLN Libraries for Eastern Kansas

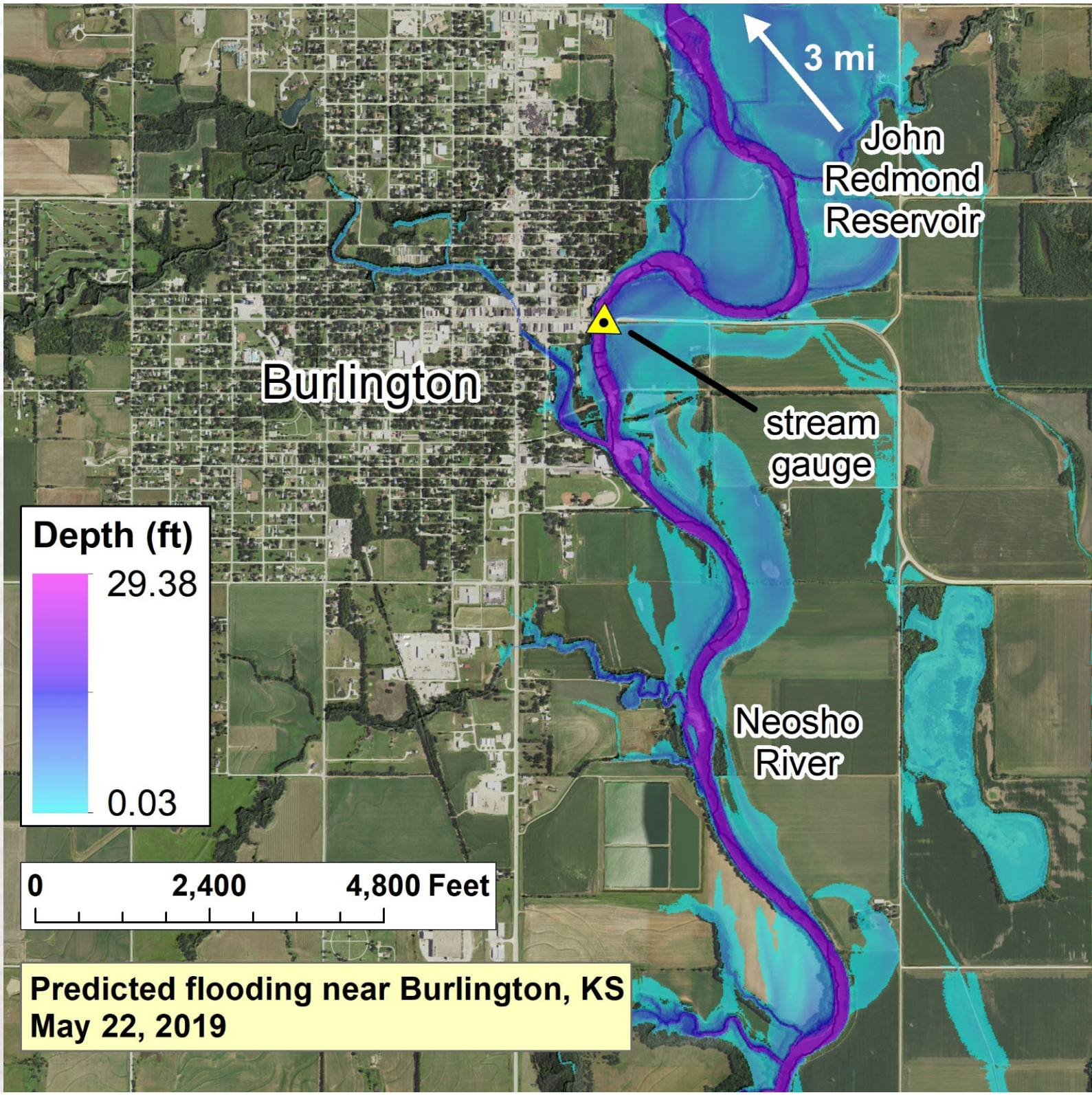
- 25 libraries cover eastern Kansas (~100 GB file size)
- Based on 5-m LiDAR DEM



Tool in Action:

Coffey Co, KS

May 2019



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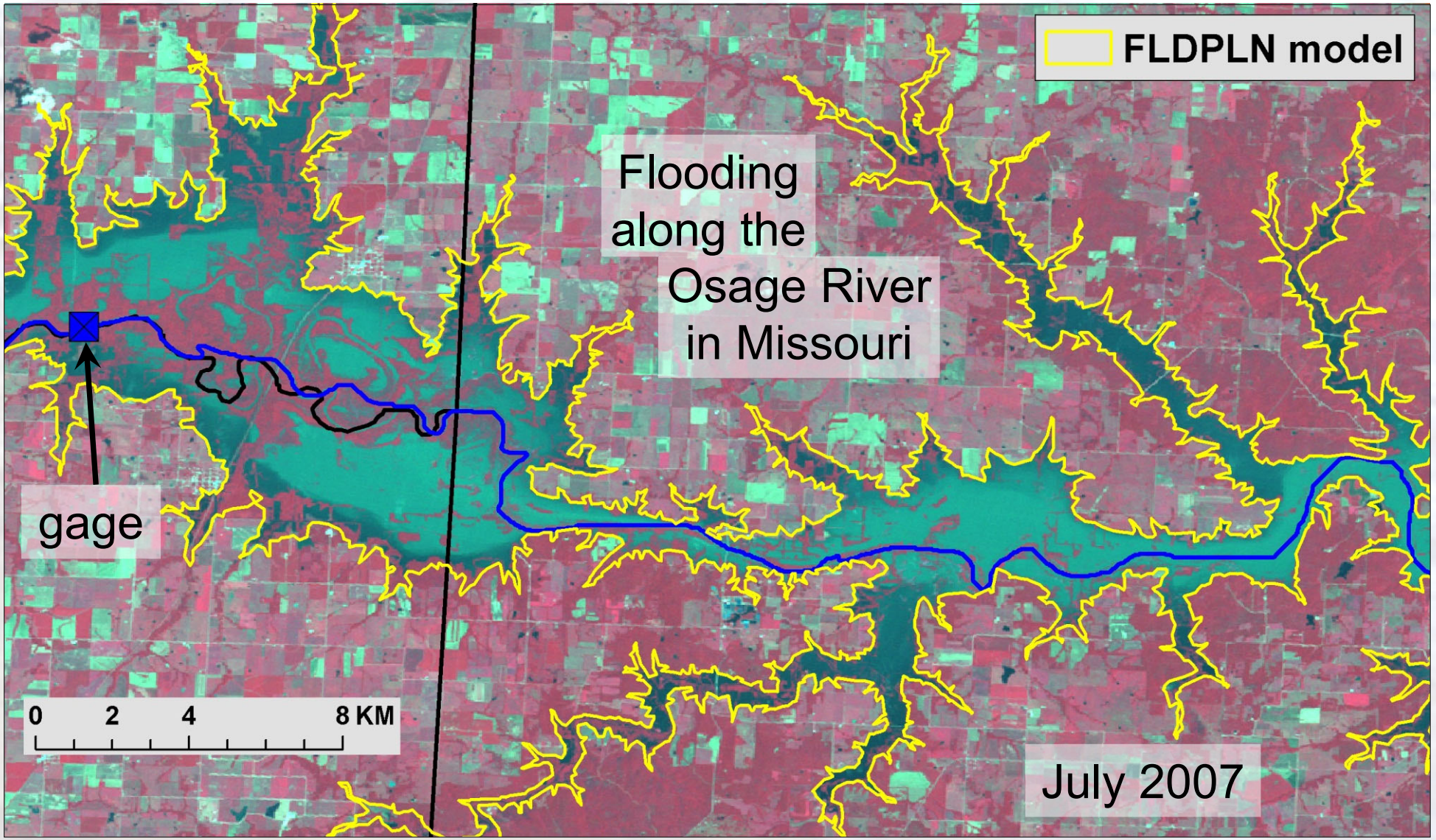
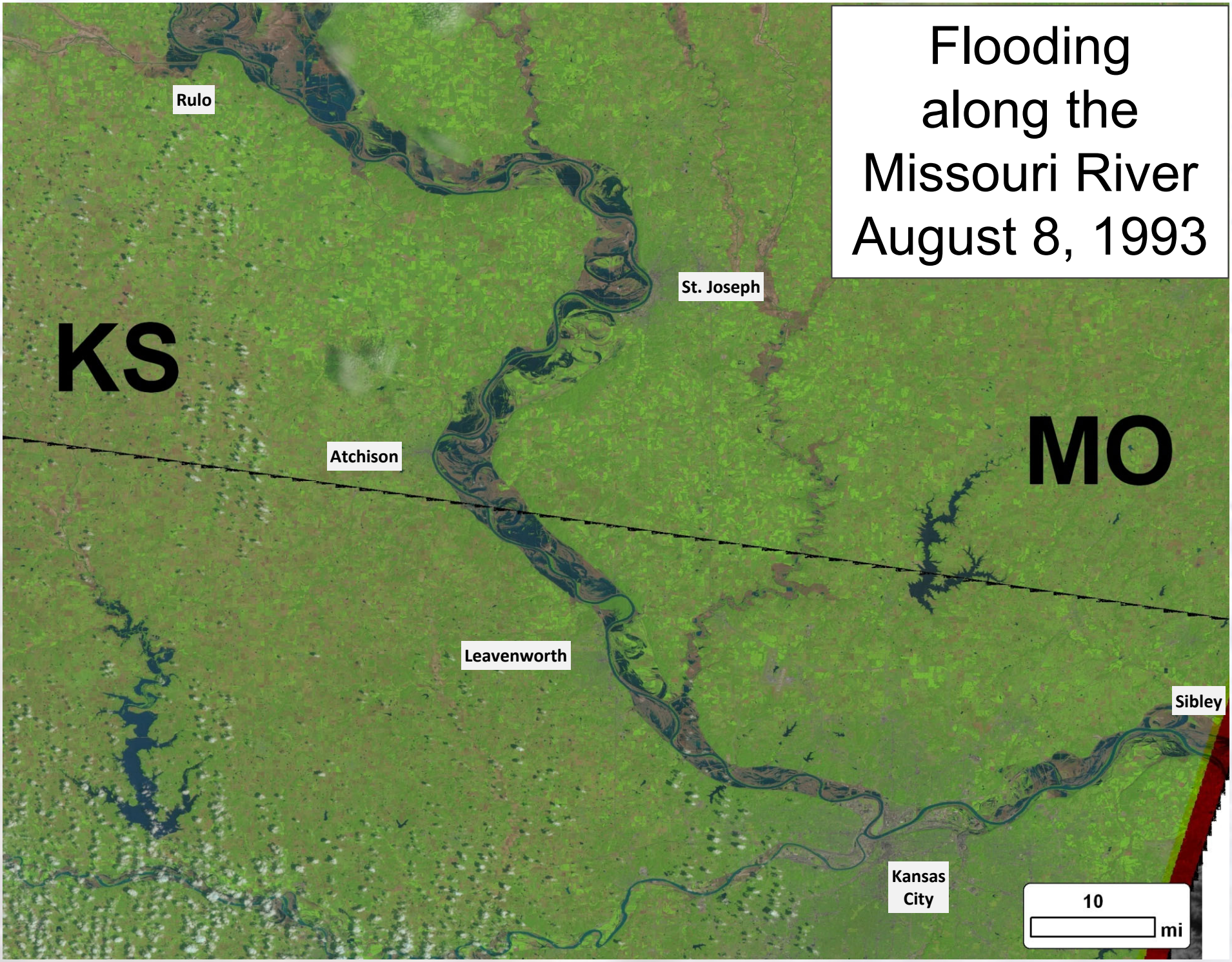
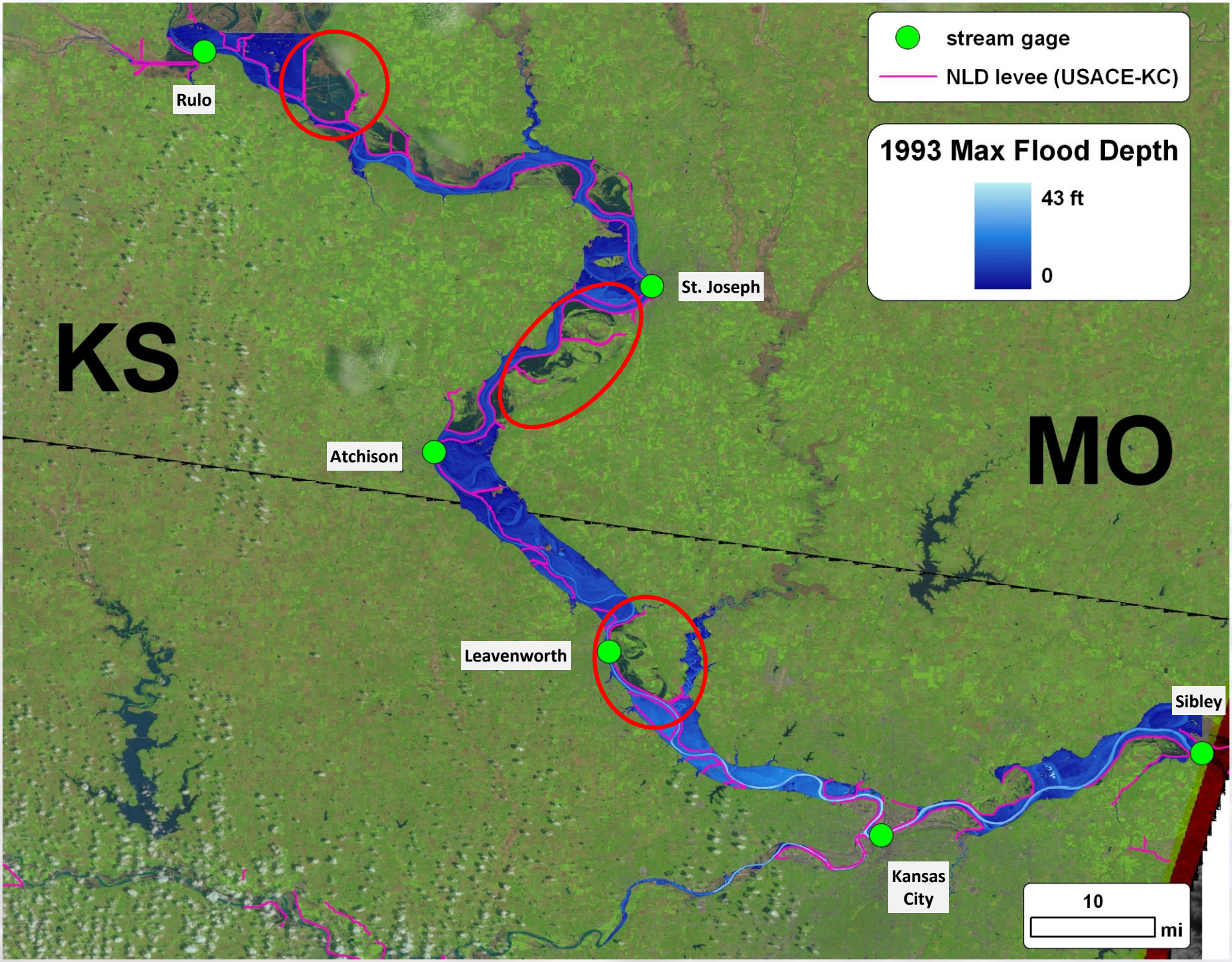
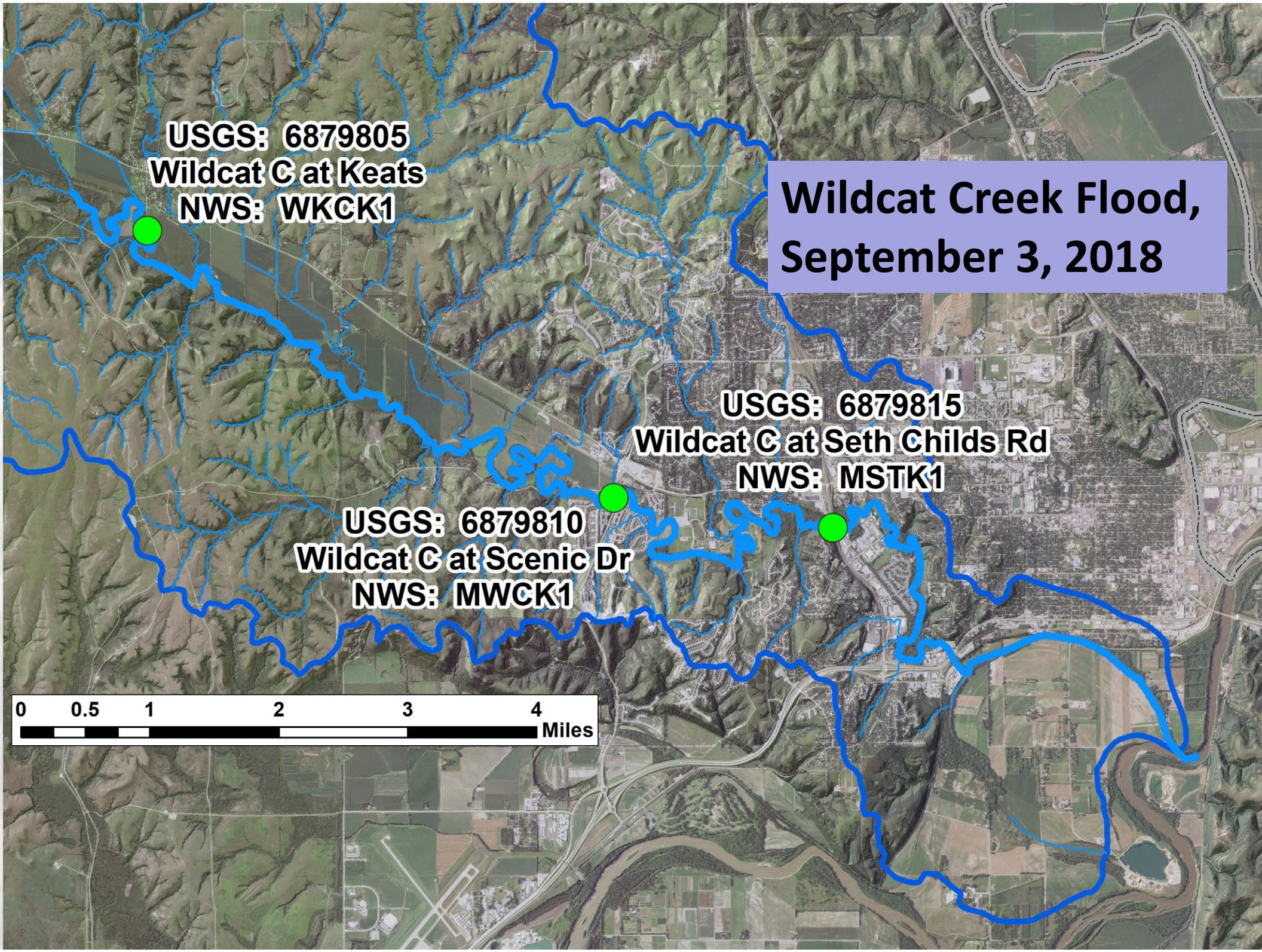
Kansas Applied Remote Sensing

Flood mapping examples using FLDPLN

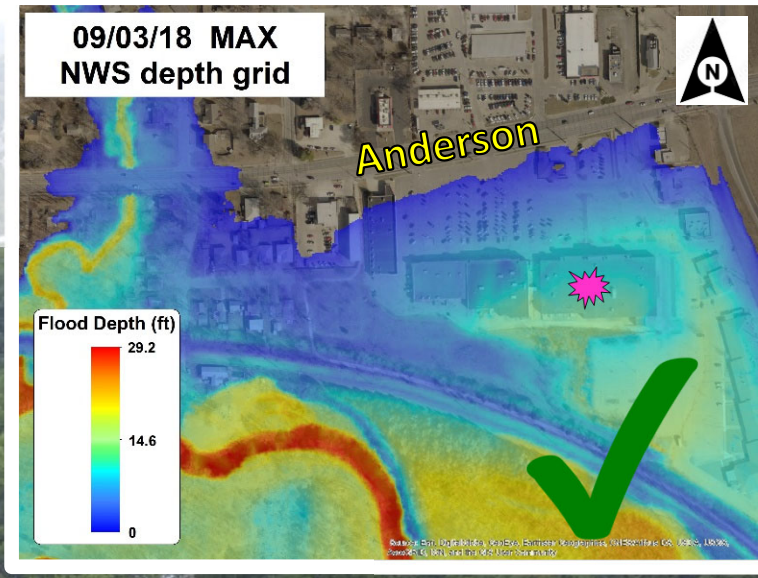


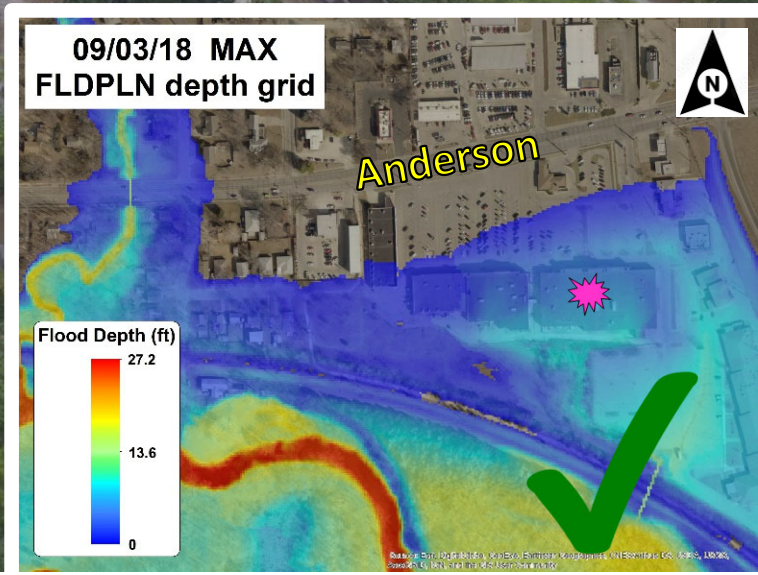

Flooding
along the
Missouri River
August 8, 1993
Rulo
St. Joseph
KS
MO
Atchison
Leavenworth
Sibley
Kansas
City
10
mi


stream gage
NLD levee (USACE-KC)
1993 Max Flood Depth
43 ft
0
Rulo
St. Joseph
Atchison
Leavenworth
Sibley
Kansas City
KS
MO
10
mi


USGS: 6879805
Wildcat C at Keats
NWS: WKCK1
Wildcat Creek Flood,
September 3, 2018
USGS: 6879815
Wildcat C at Seth Childs Rd
NWS: MSTK1
USGS: 6879810
Wildcat C at Scenic Dr
NWS: MWCK1
0 0.5 1 2 3 4
Miles

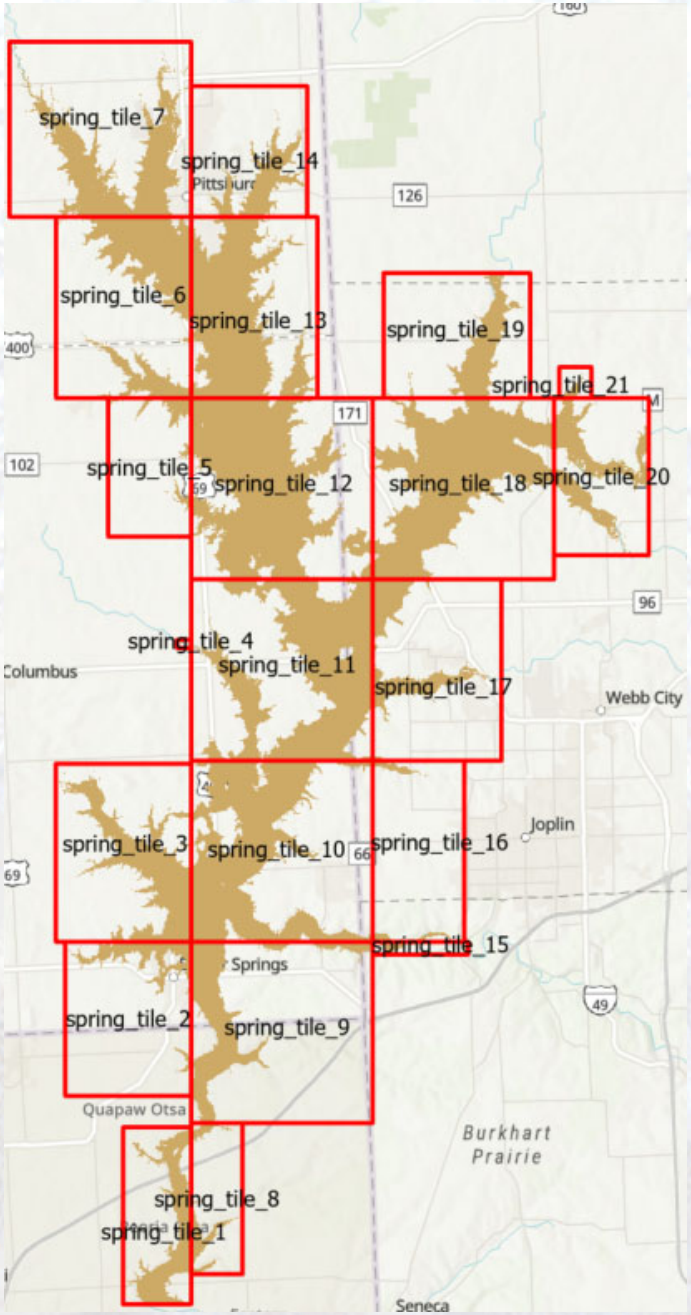
Anderson Ave & Meadowbrook Ln (looking east)





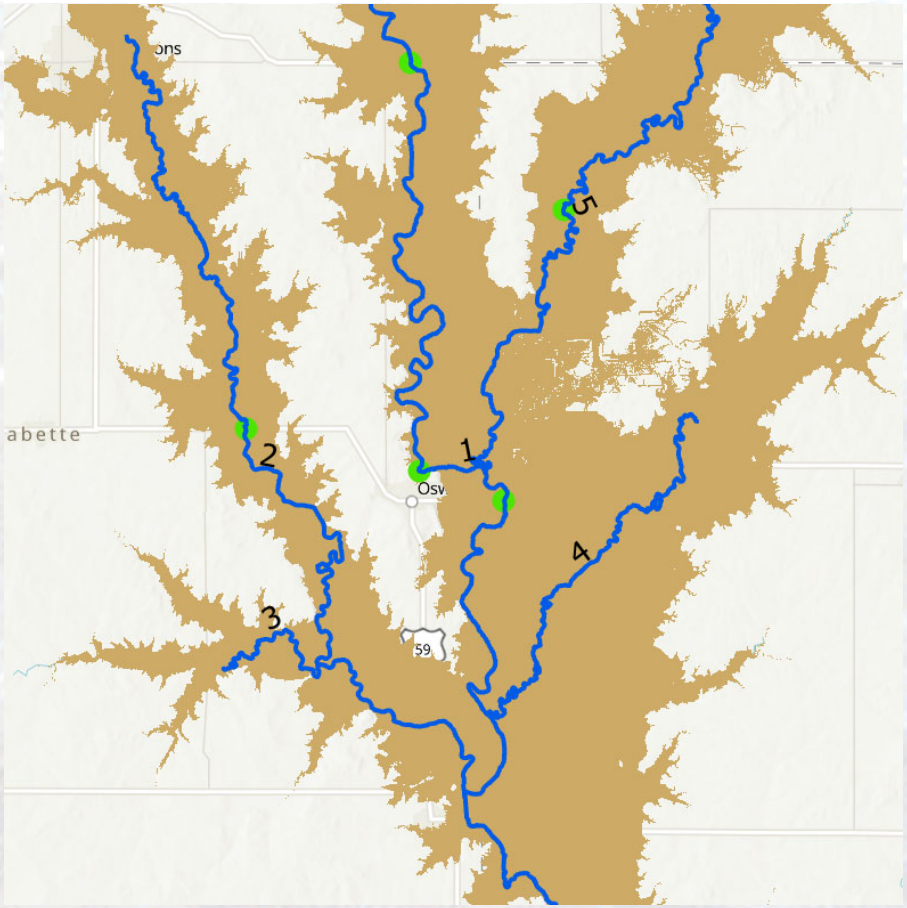
Tile FSP-FPP Relations

- Organize relations by tiles
  - Each tile stores **all the FSPs** that can flood the FPPs in the tile
- Flood mapping by tiles
  - Avoid memory overflow with a proper tile size
  - Only one file I/O is needed to map a tile
  - Scalable
    - Mapping tiles in parallel
    - Each tile can be mapped independently



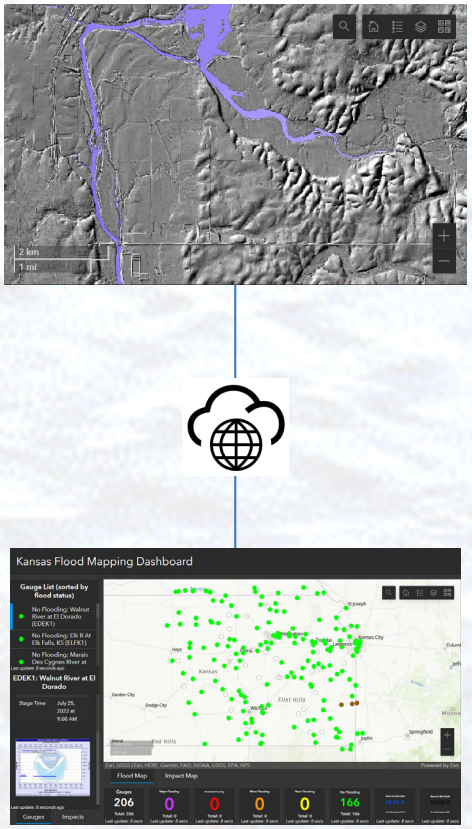
Gauge and Stage

- Reliable means for flood tracking
- Estimate FSP depth of flow (DOF)
  - Snap gauges to FSPs
  - Based on steam orders
    - From low to high
  - Linear interpolation using distance or elevation
  - Better yet, use the 100-year flood profile to interpolate stage values between gauges
- Sources
  - NWS AHPS and USGS
  - State and local networks
  - Bridge gauges



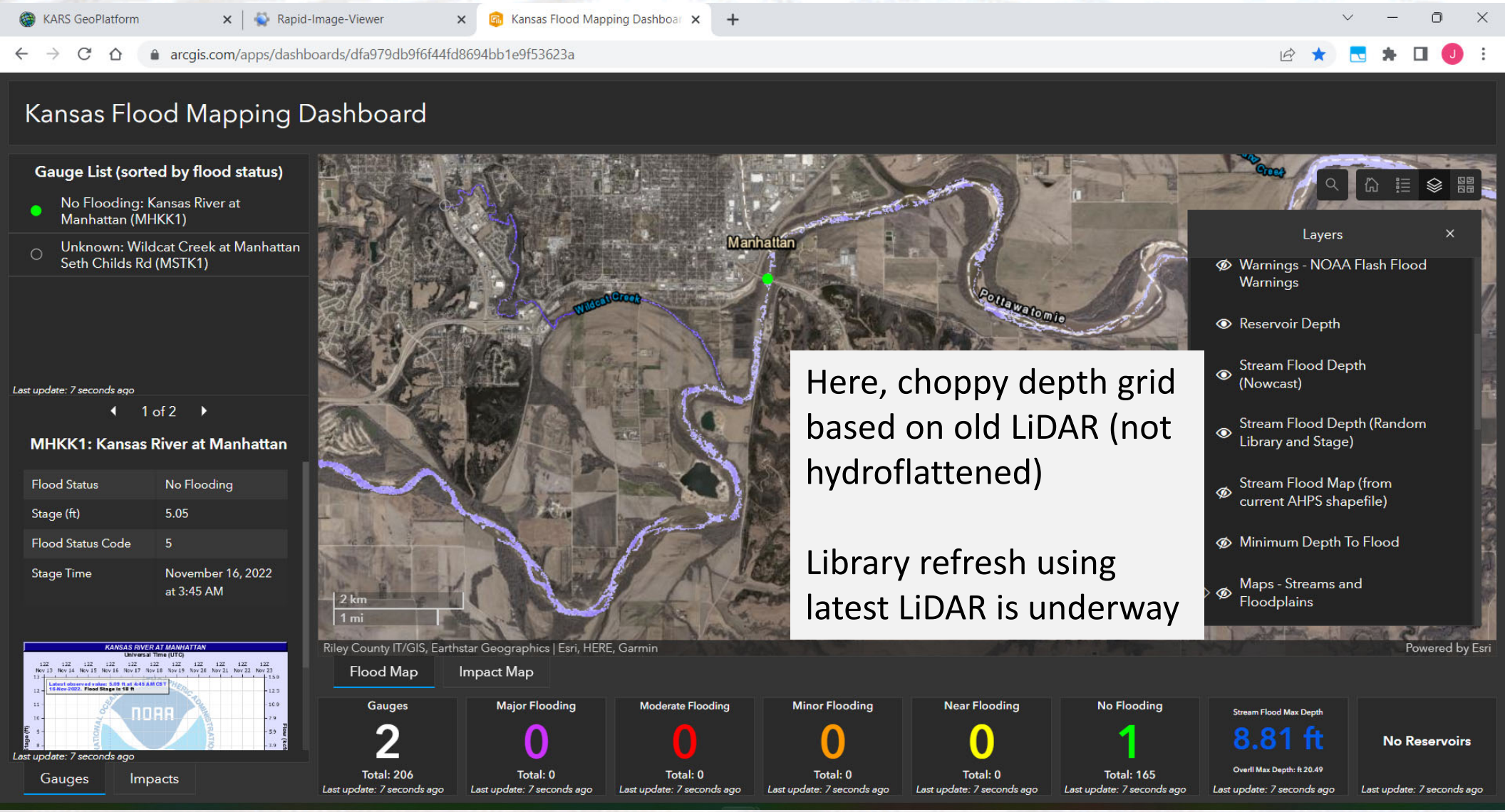
Serve Flood Maps on Web

- Accessible to KDEM and the general public
  - Don’t need to run flood mapping locally
  - Available through the dashboard or as a service
  - Take advantage (scalable) of cloud cyber infrastructure
- Flood maps are served using ArcGIS Server
  - Tiled flood maps (COGs) are served as ArcGIS image services using mosaic datasets
  - Base maps are served as ArcGIS map or image services
- Stream flood maps are updated hourly
- Reservoir flood maps are updated every 6 hours



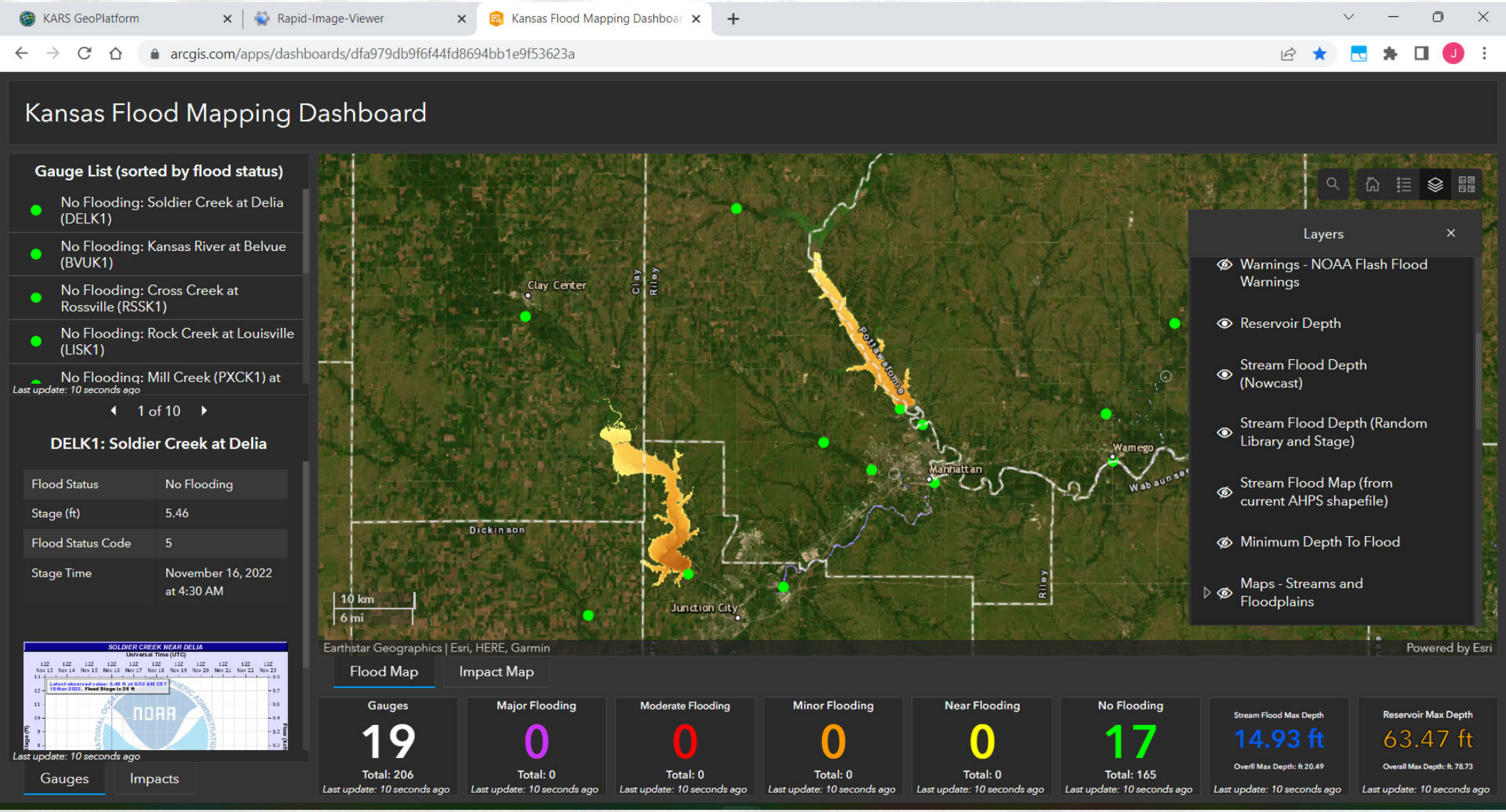
Kansas Flood Mapping Dashboard

Stream Flood Depth (Nowcast) (1-hr refresh)



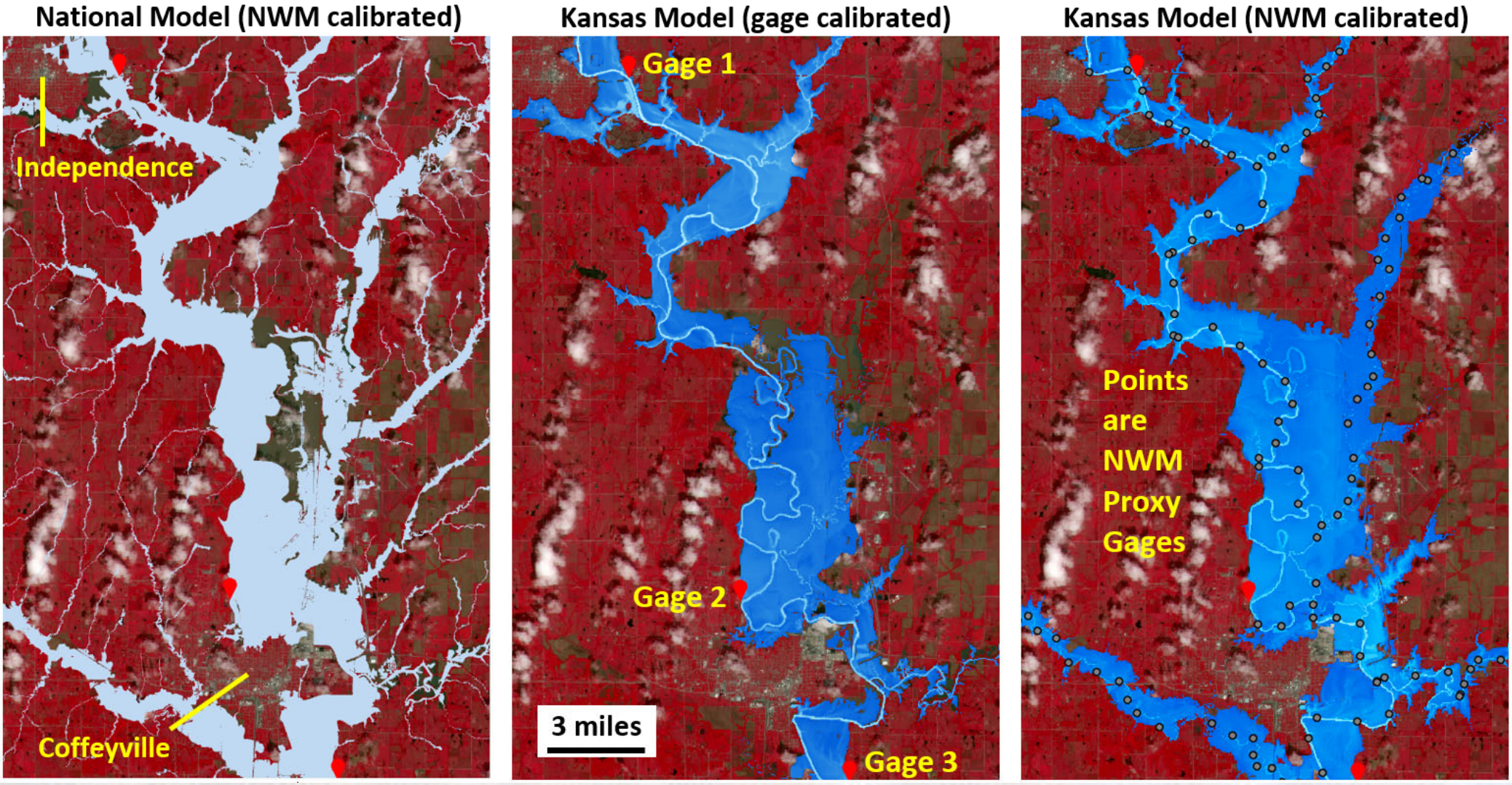
Kansas Flood Mapping Dashboard

Reservoir Depth (bathymetry + LiDAR, 6-hr refresh)



Better model, better calibration…better map

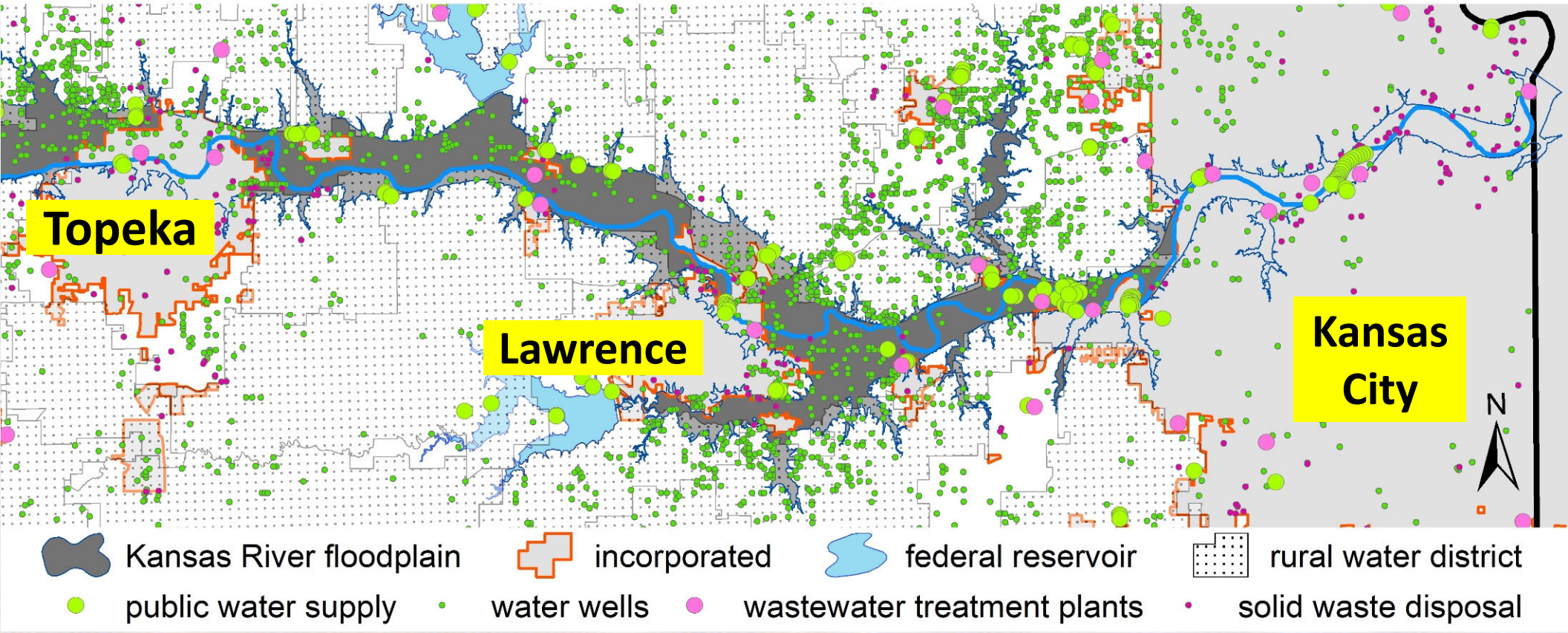
Simulation of peak 2019 flooding along the Verdigris River in Montgomery County, Kansas



Exploration of National Water Model (NWM) output for operational use in Kansas is underway

Highlighting Water Infrastructure Impacts

A sample of water infrastructure in the Kansas River floodplain

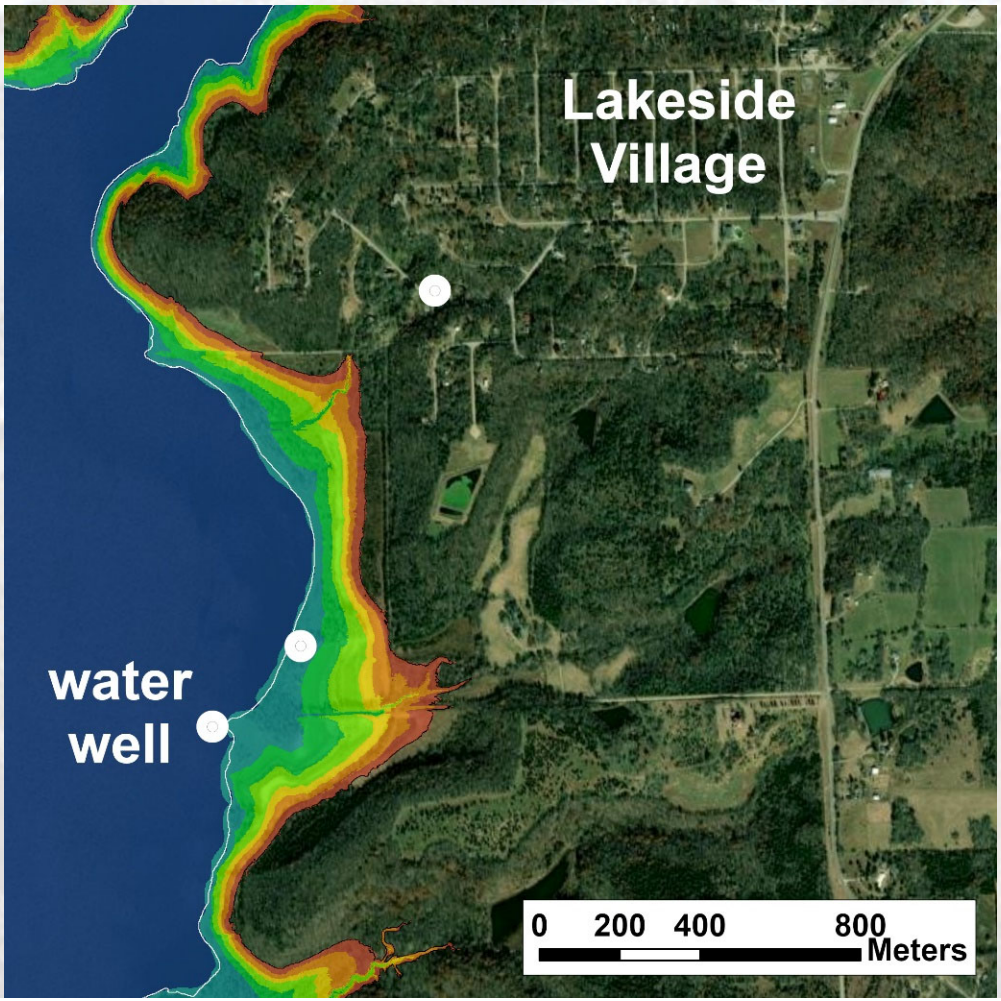


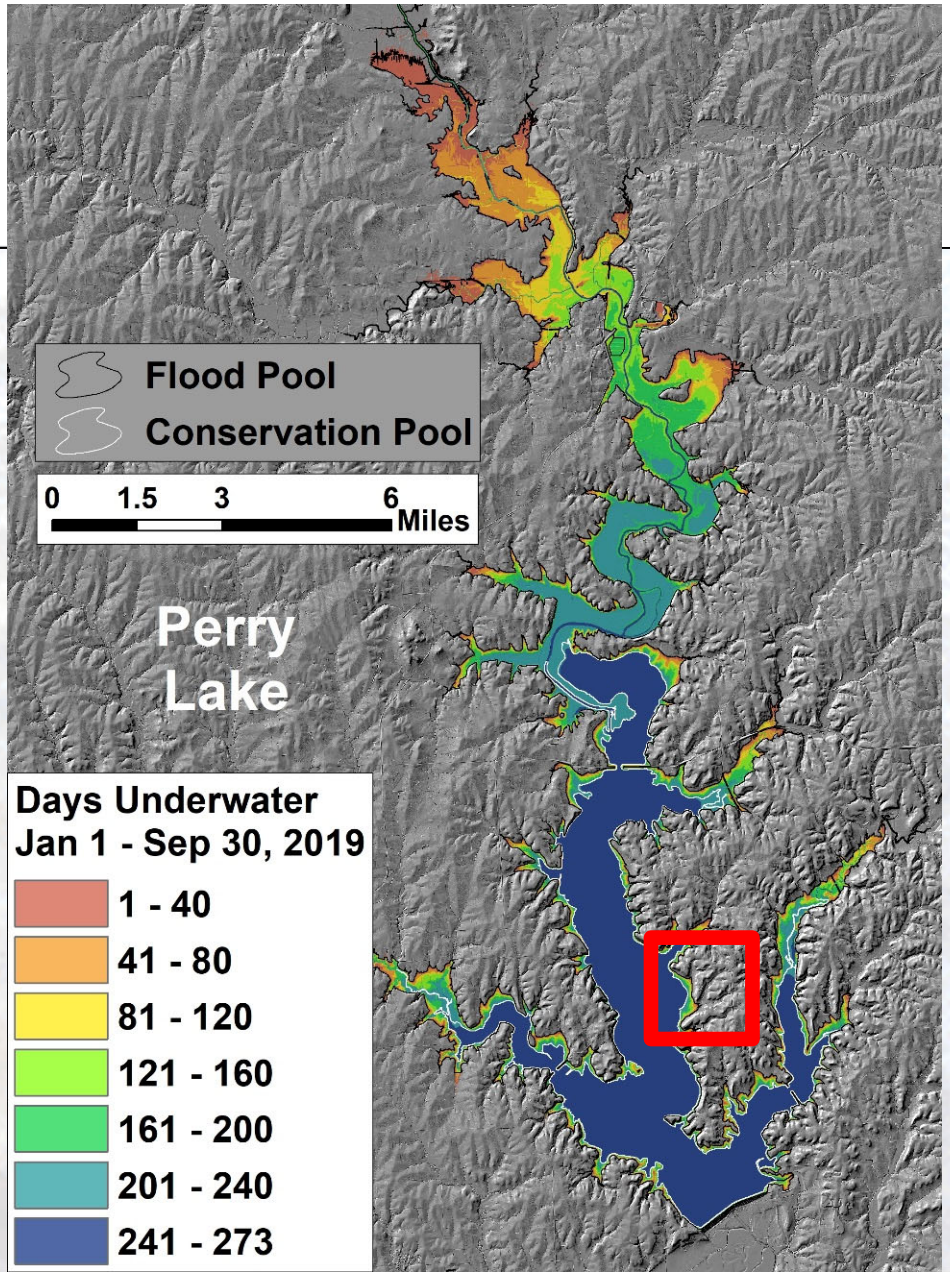
Flood Impacts: Public Water Wells

Guard still hauling water to residents near Perry Lake

By Associated Press · Thursday, July 25, 2019

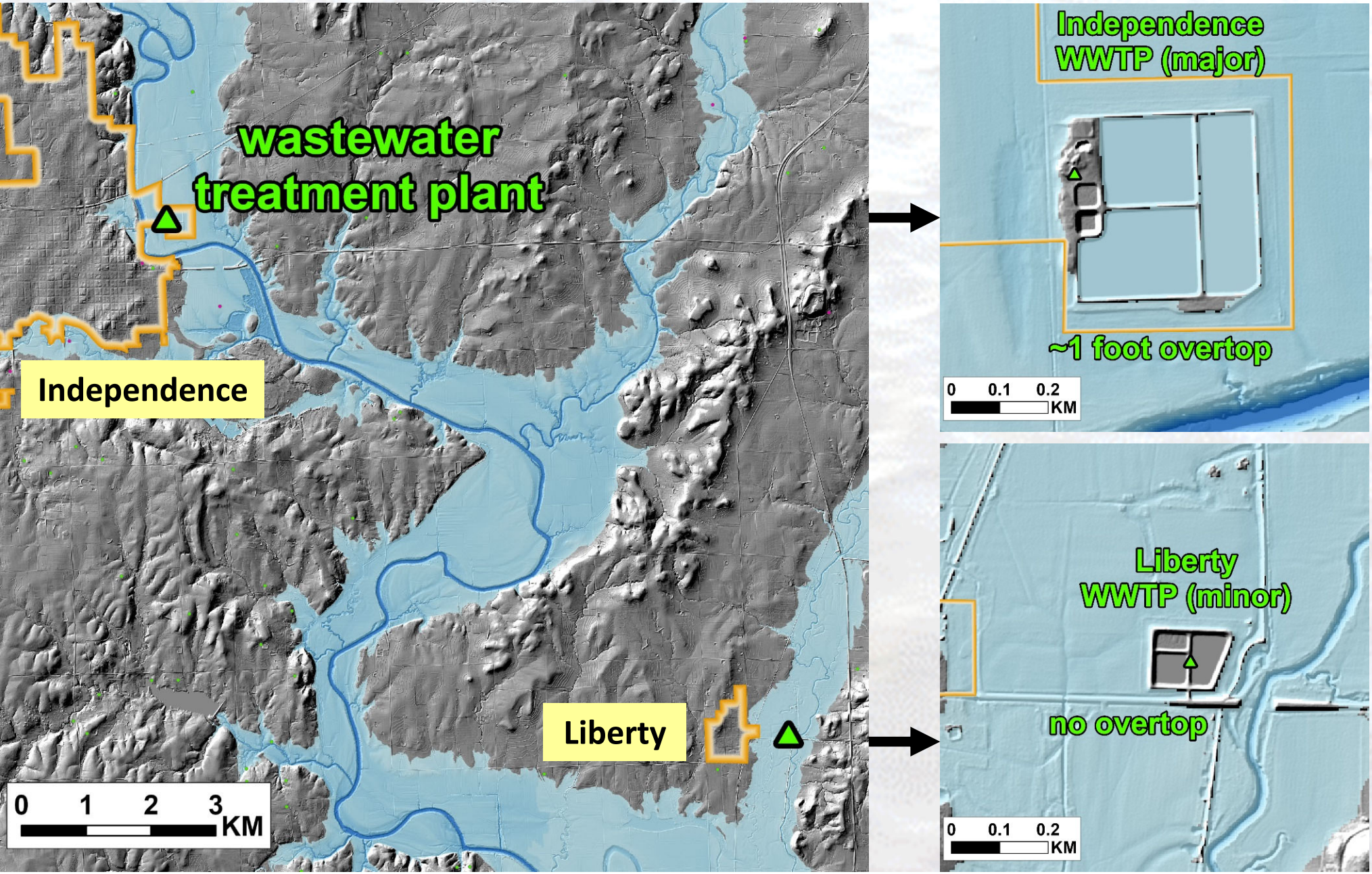
2 months after flood





Flood Impacts: Wastewater Treatment Plants

Simulation of peak 2019 flooding along the Verdigris River in Montgomery County, Kansas



Examples of Other Floodplain Assets that Could Pose a Risk to Water Quality During Extreme Flooding

- **Industrial hazardous waste holdings**
- **Landfills**
- **Manure lagoons**

With geospatial inventory for such features integrated into the mapping tools, flood forecasts could provide early warning & help assess impacts.


Thanks for Listening…
Any Questions?
FLOOD
THEY MIGHT BE GIANTS
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