2D Modeling and Regulations

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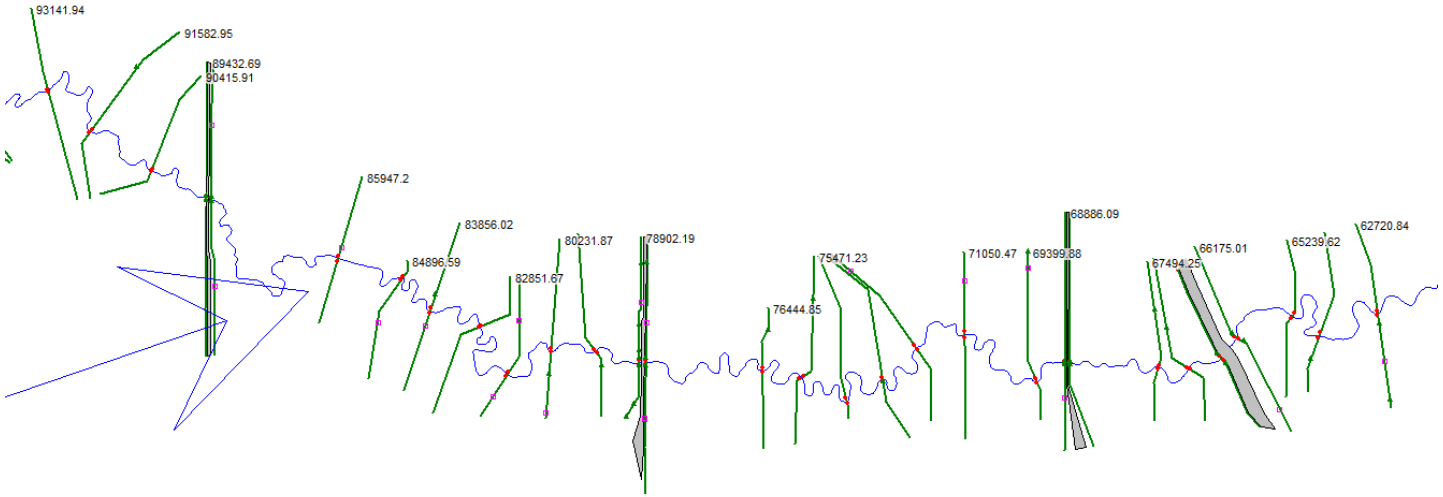
DEPARTMENT OF NATURAL RESOURCES

1D versus 2D

1D Modeling

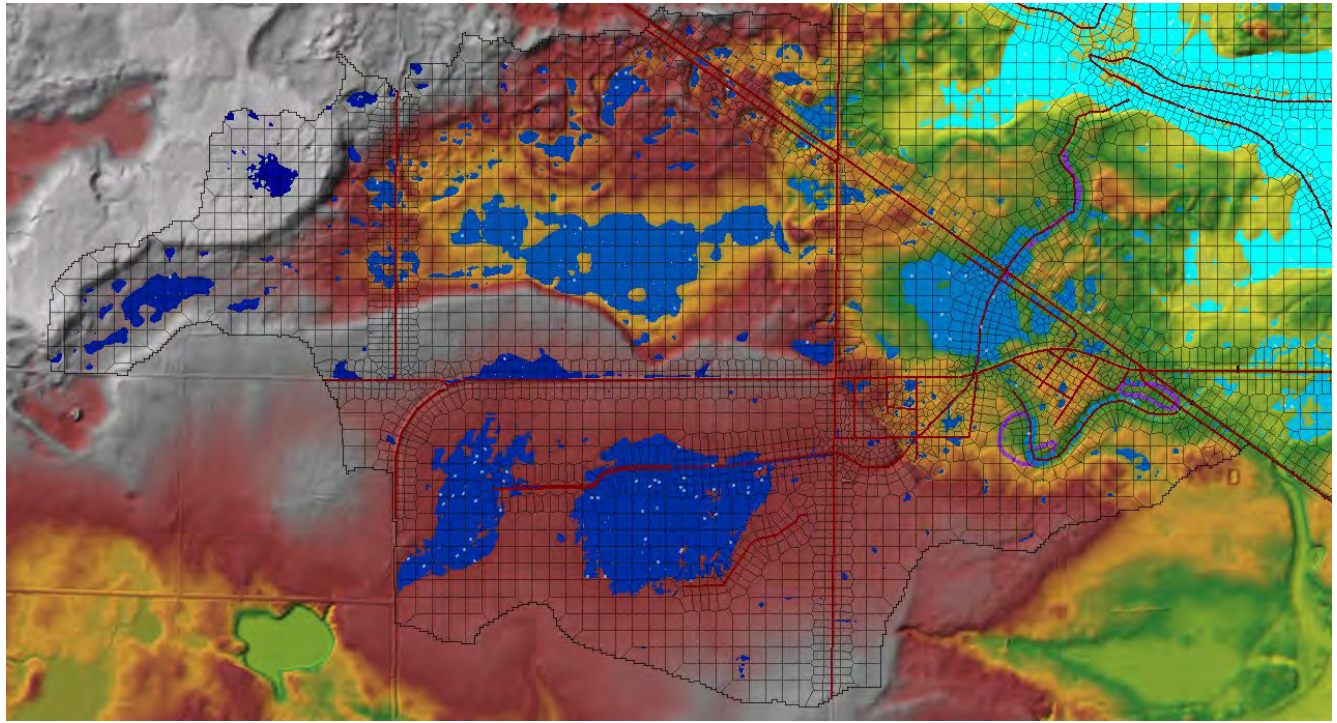
- One directional flow from XS to XS
- Single water surface at each cross section
- Use for typical riverine systems



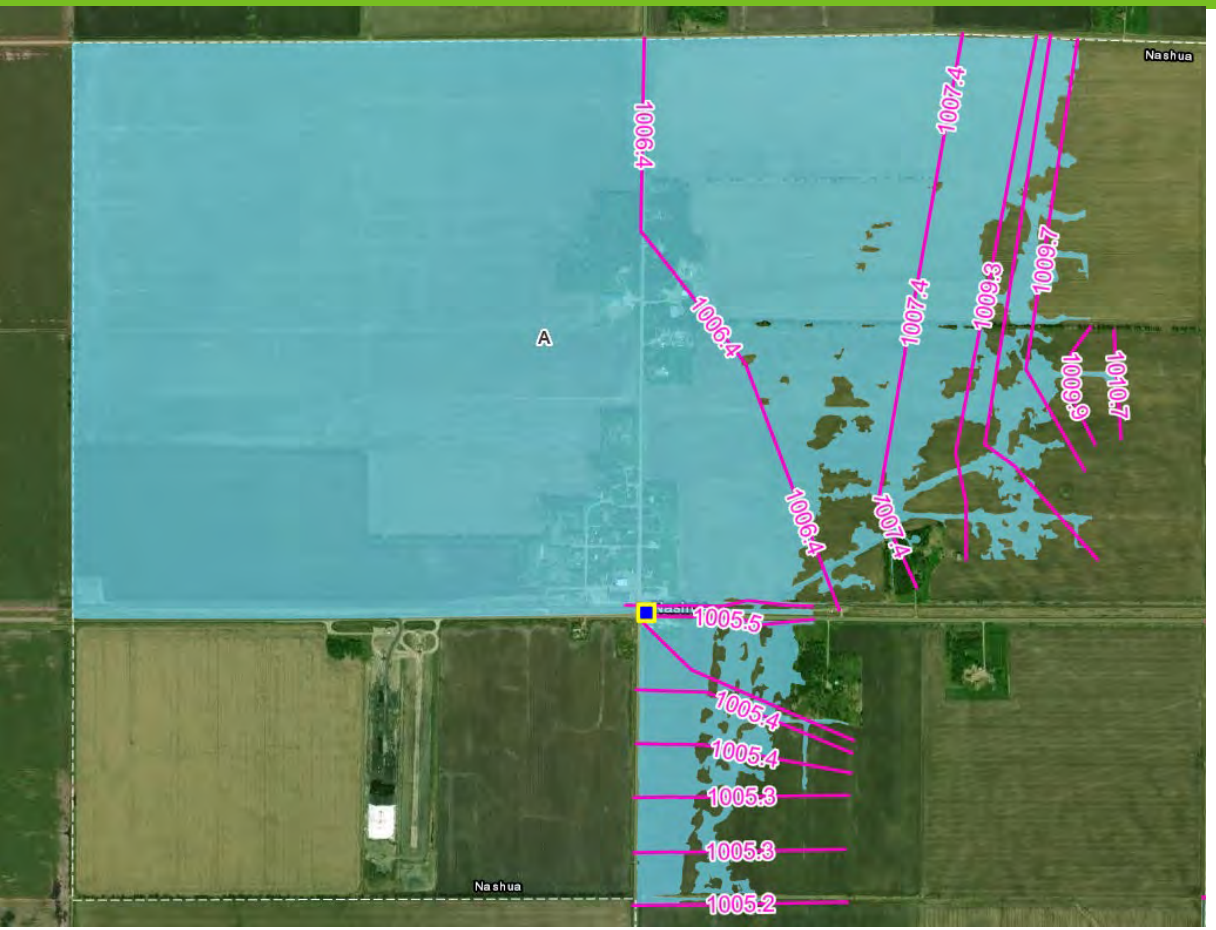
1D versus 2D

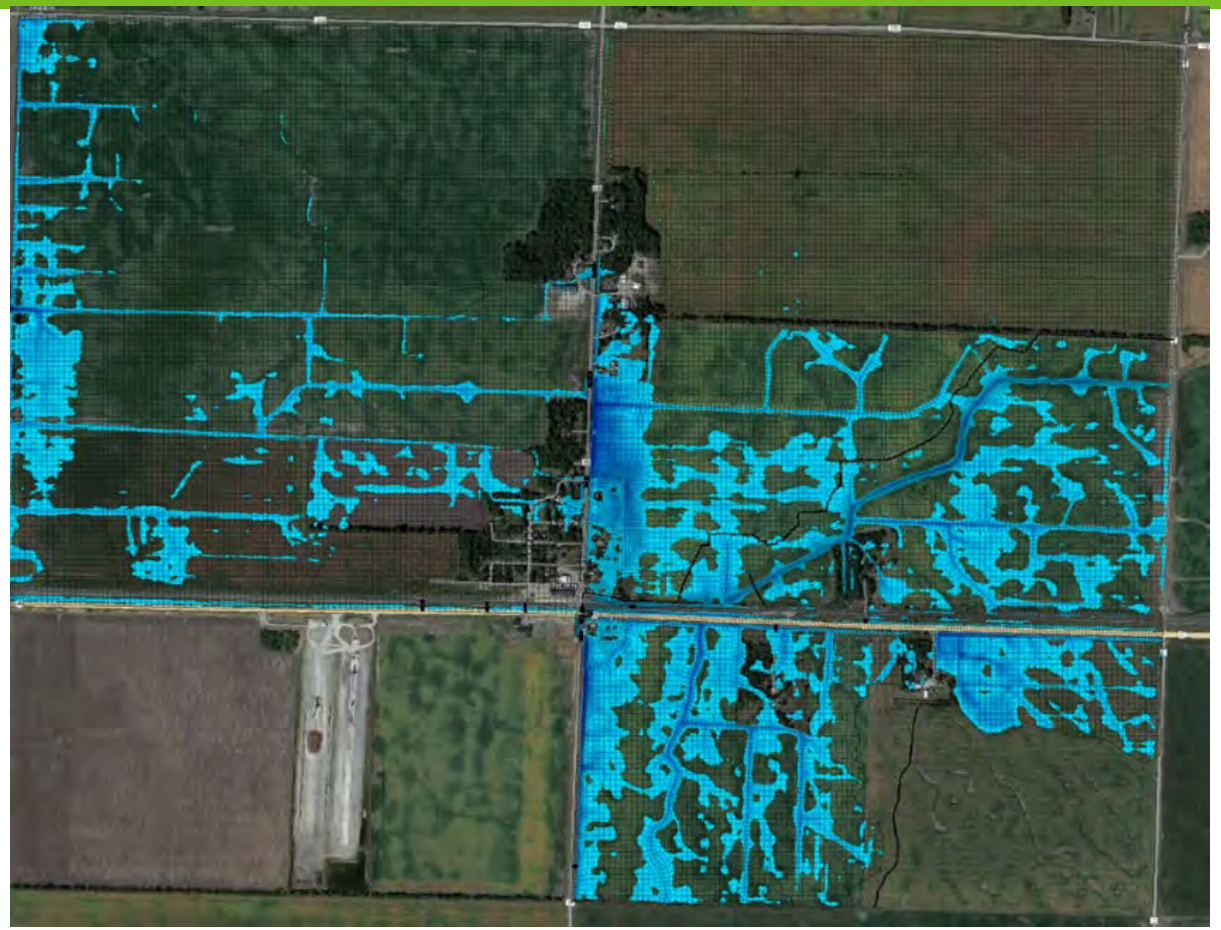
2D Modeling

- Unique water surface elevation at every cell
- Use for levees, breakout flow, complex flow
- Allows water to go different directions
- Allows the model to figure out the results with fewer judgement-based inputs.



2D Map Revision Recently Completed





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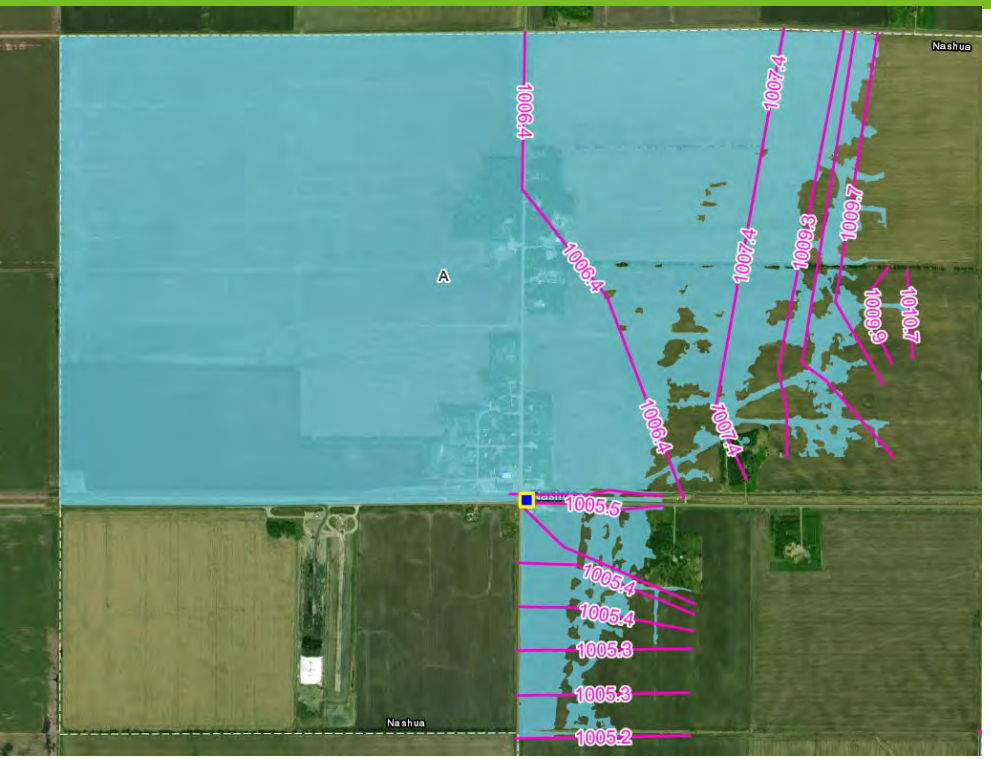

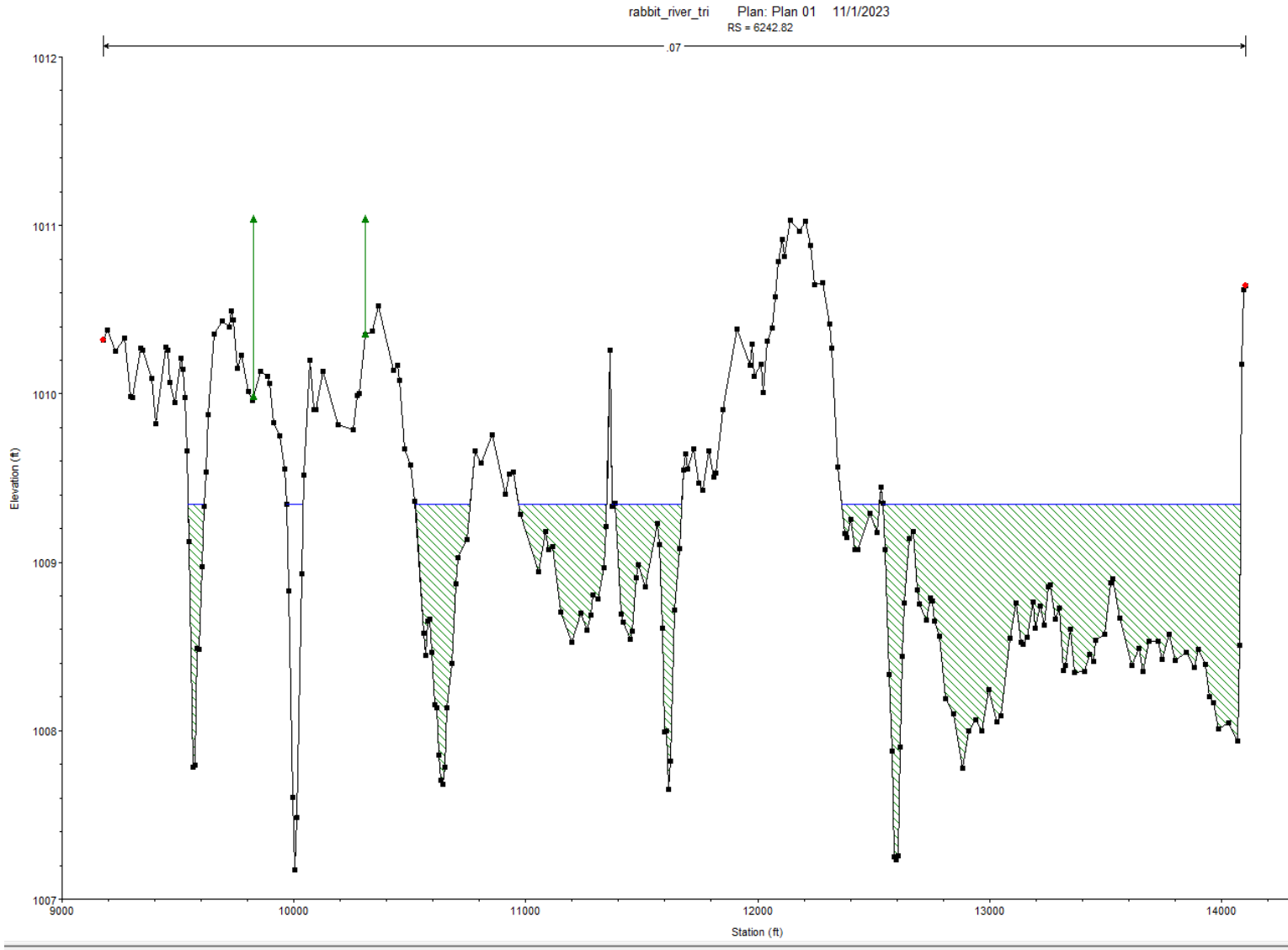

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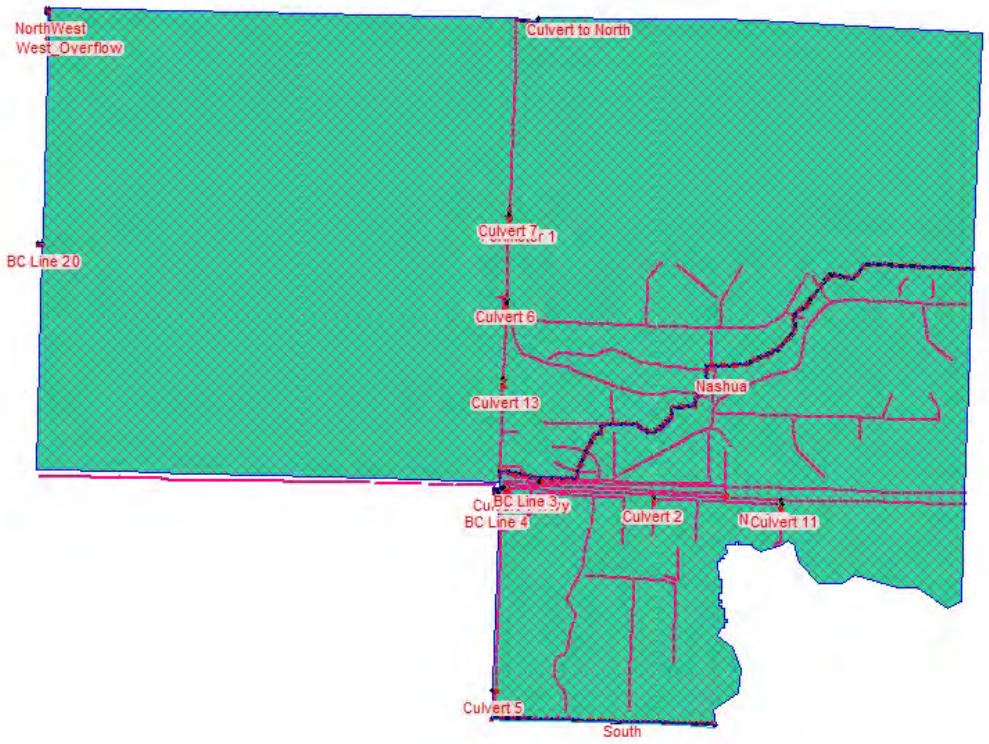
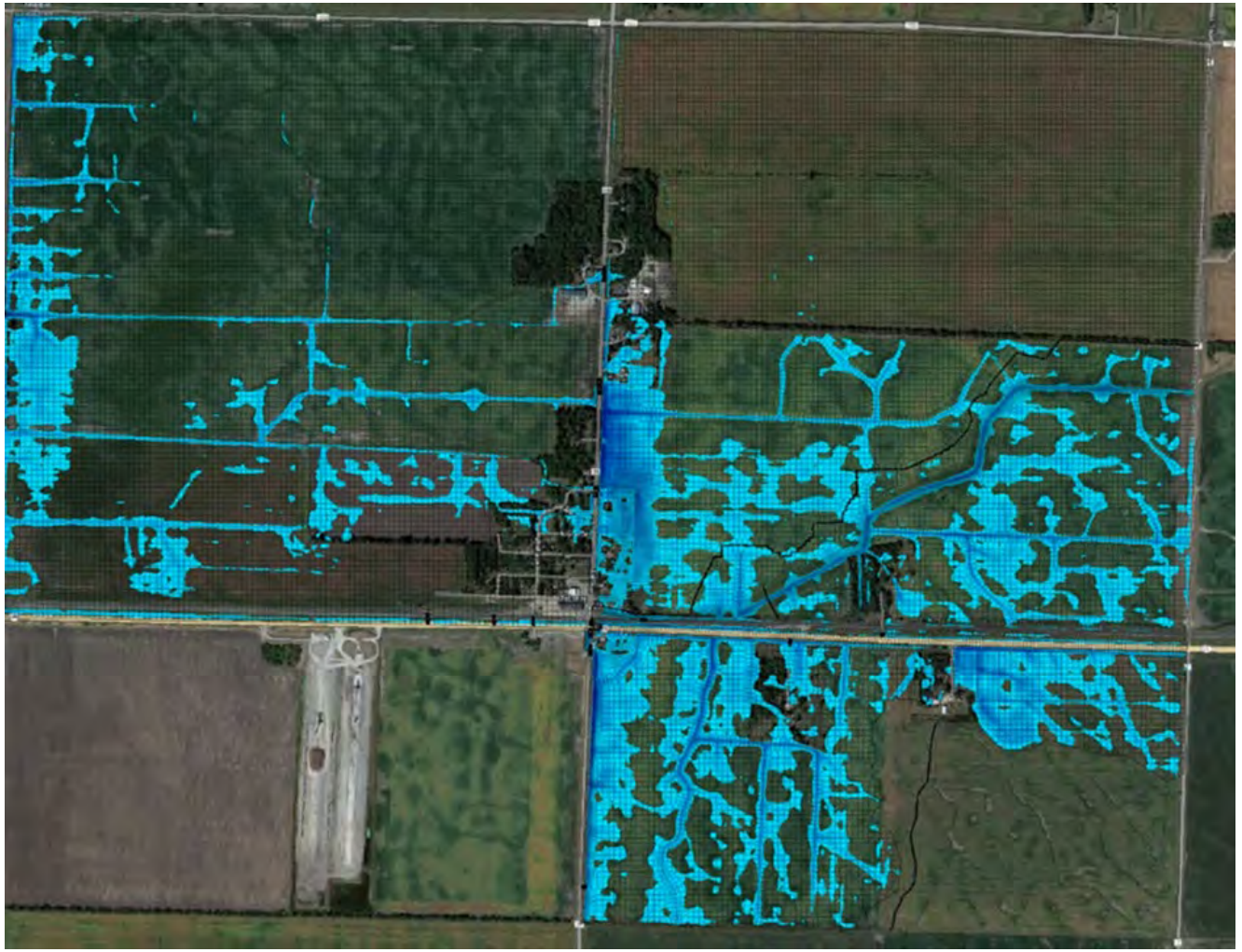
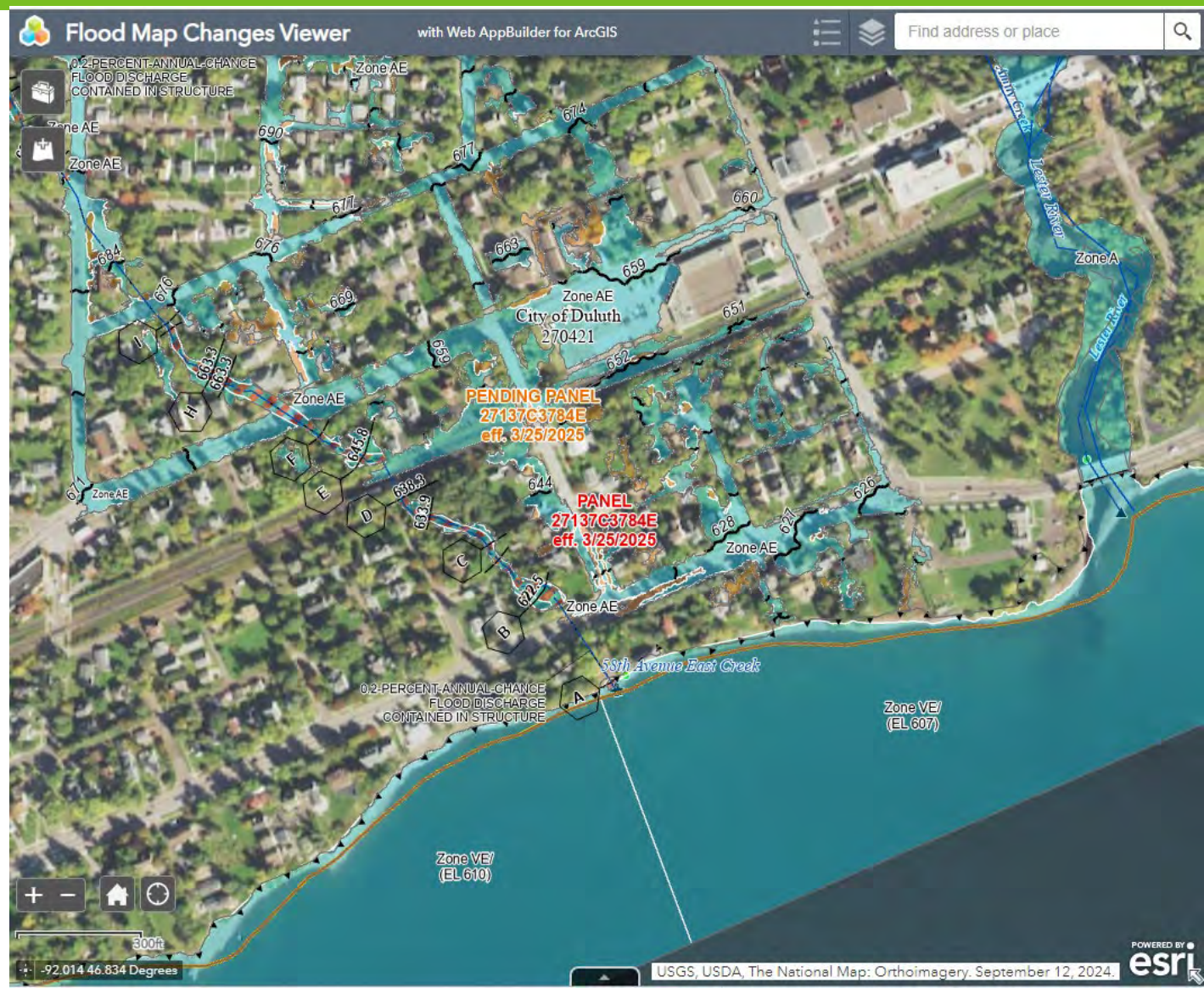




1D (left) Versus 2D (right) Modeling & Mapped Areas

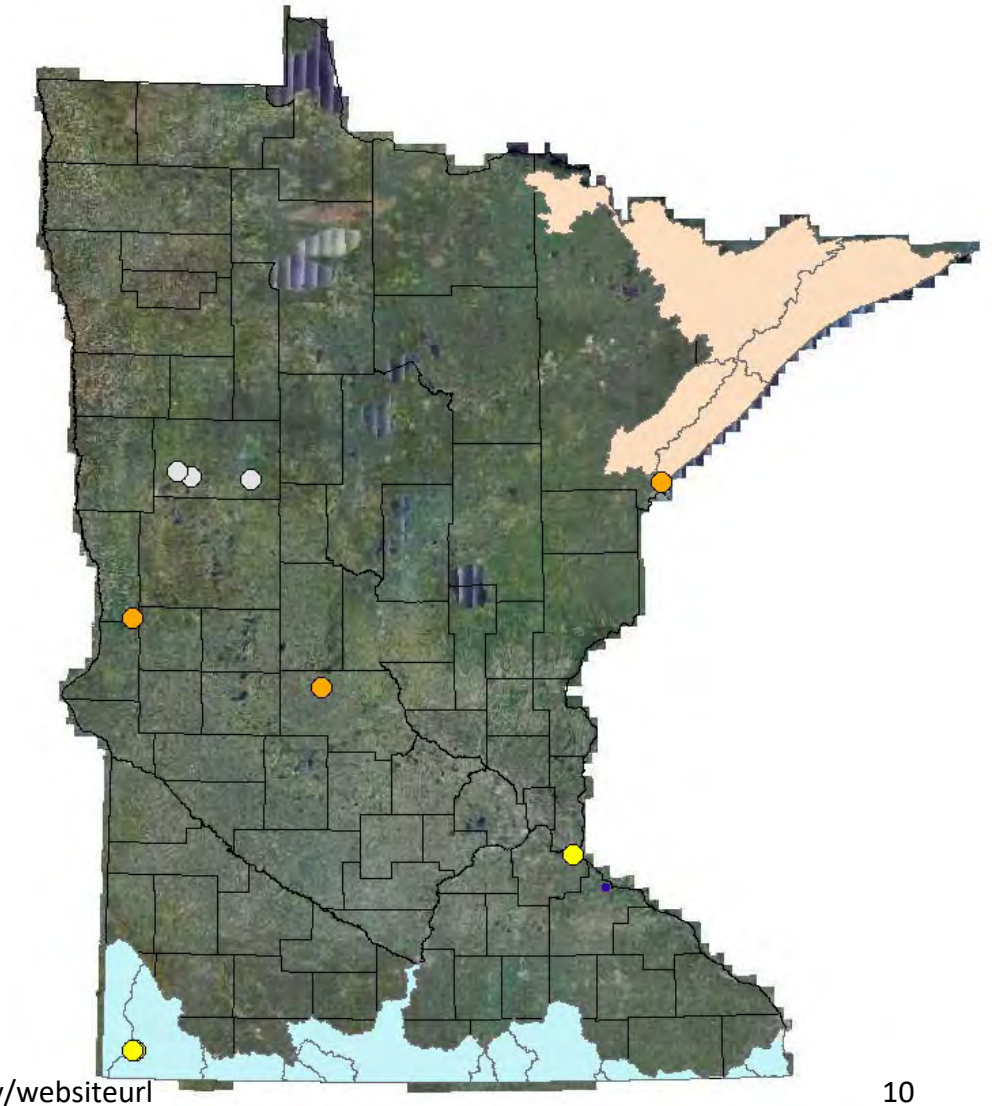
1D (left) Versus 2D (right) Modeling & Mapped Areas

New Coastal Zones in St. Louis County (as of March 25, 2025)



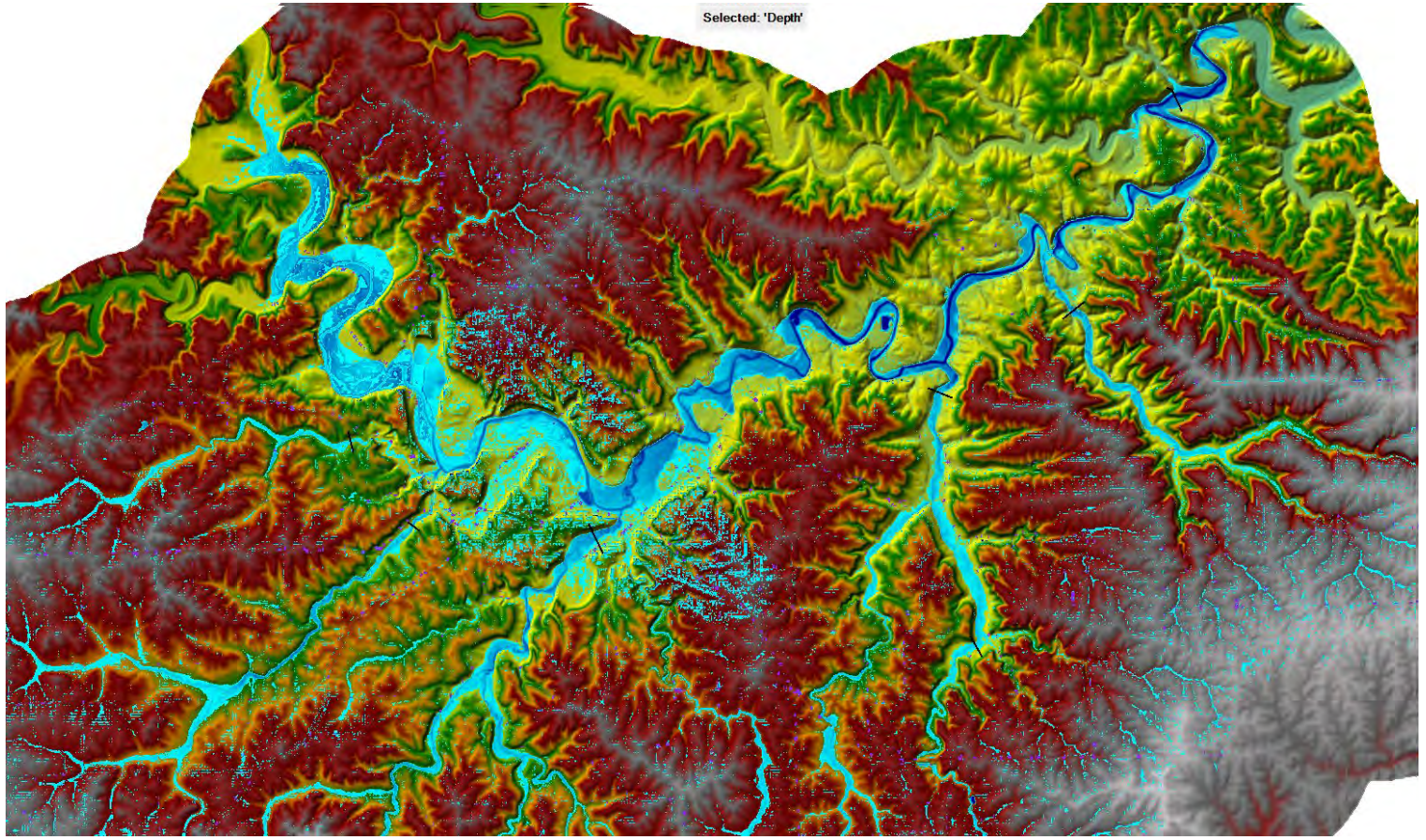
2D regulatory-to-be models in MN

- **Orange** Dots – Existing 2D regulatory models (Nashua, Melrose, Duluth)
- **Yellow** Dots – 2D regulatory models in the works – Luverne, Mississippi River (Twin Cities)
- **Gray** Dots – “Best Available” 2D models
- **Light Blue** watersheds – 2D BLE modeling done for Iowa-wide effort
- **Brown** watersheds – 2D BLE modeling in the works in Cook/Lake Counties



FEMA mapping is changing

- 1D→2D
- 2D Base Level Engineering



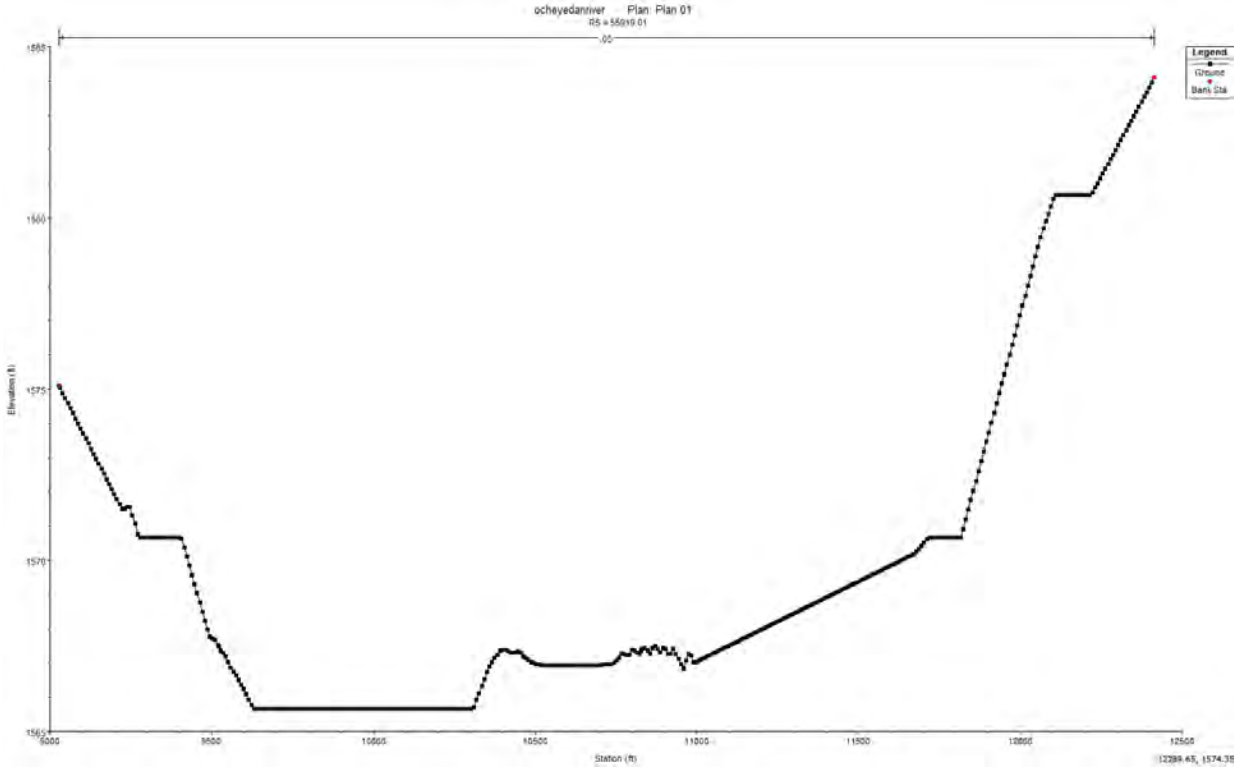
Regulatory issues

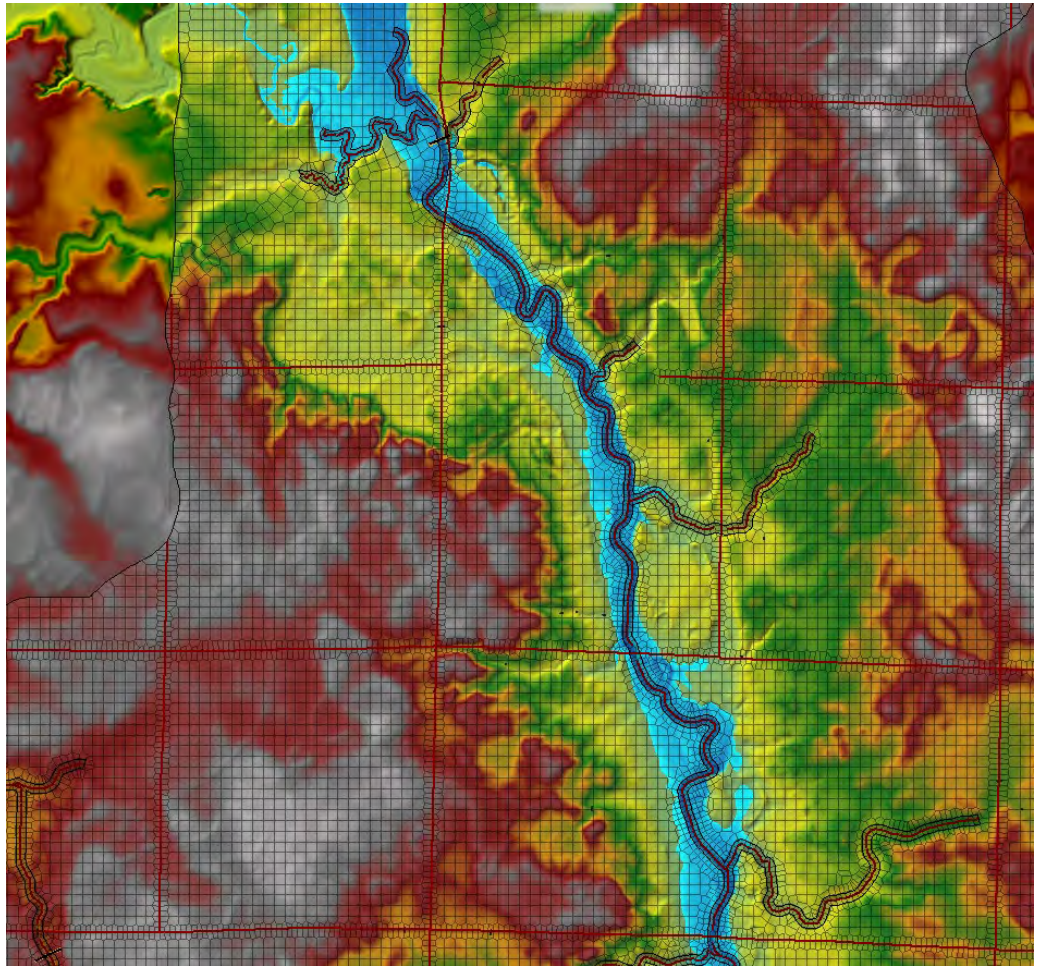
- Best available data
- BFEs

What Counts as Best Available Data?

- Zone AE: Need to use the effective model in most situations
- Zone A:
  - Newer isn’t always better
  - Mn DNR is happy to help make a judgement call
- Unmapped:
  - Any model may be the best available
  - Up to you to determine if it’s useful

What Counts as Best Available Data?





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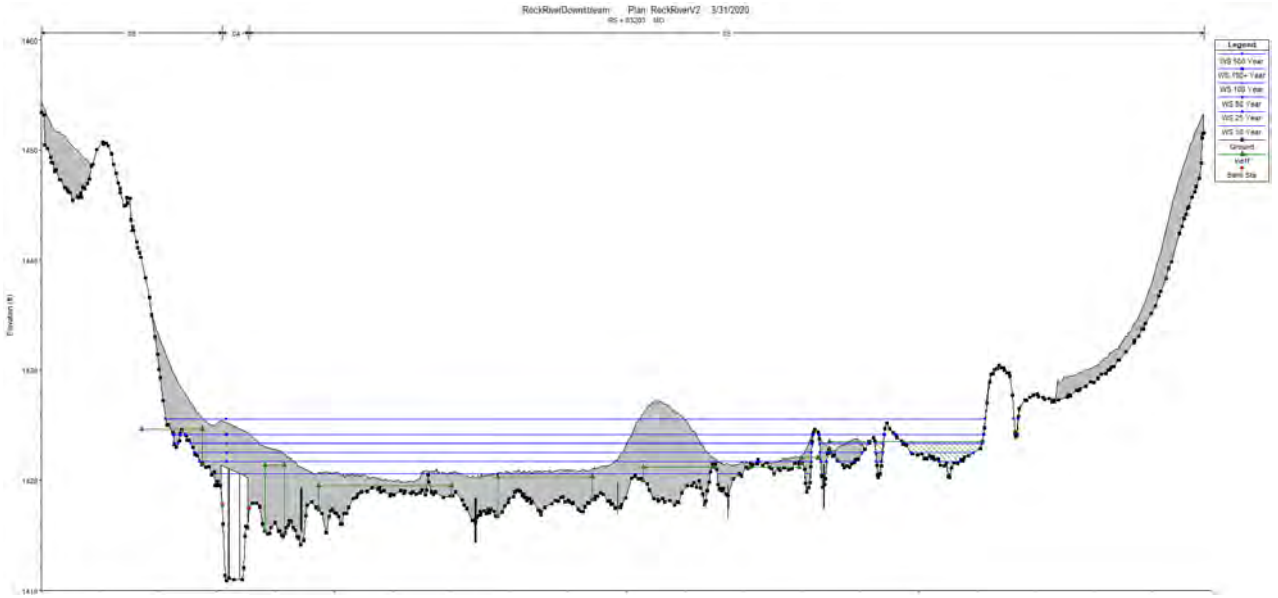
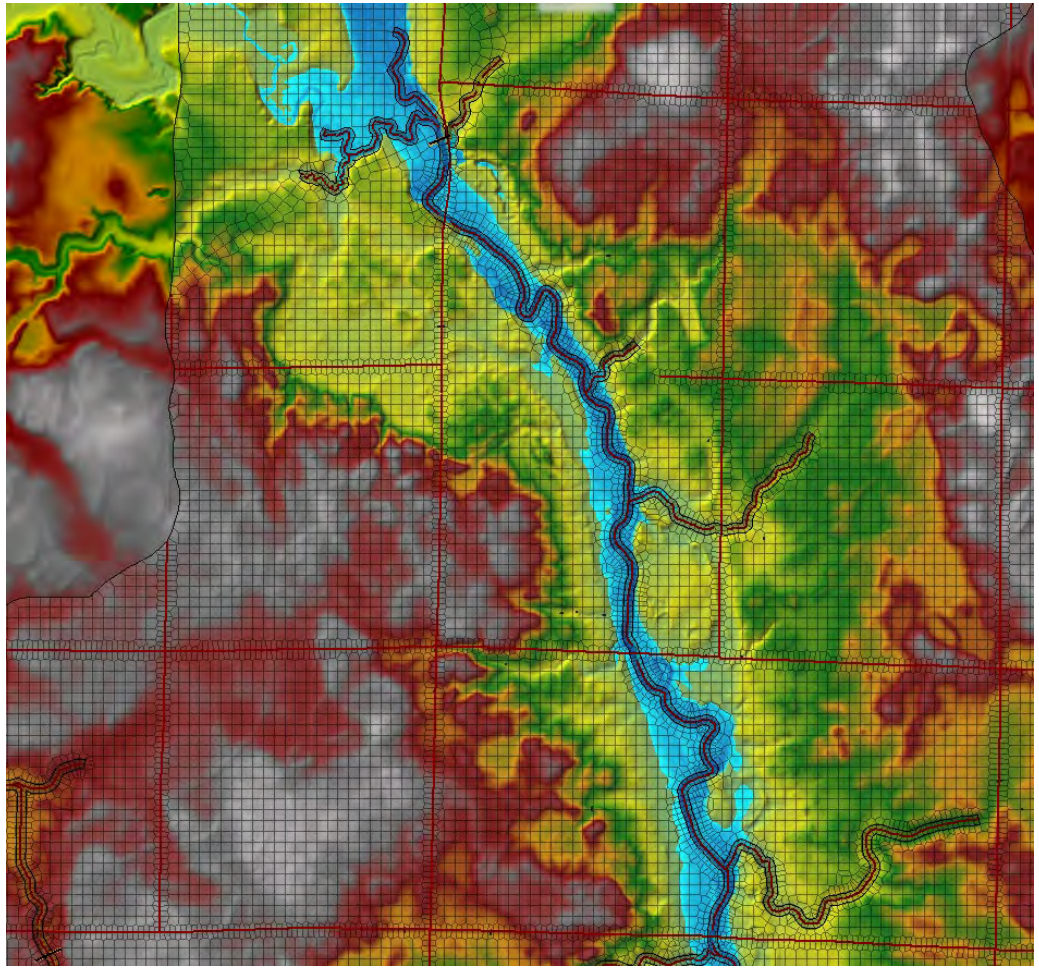
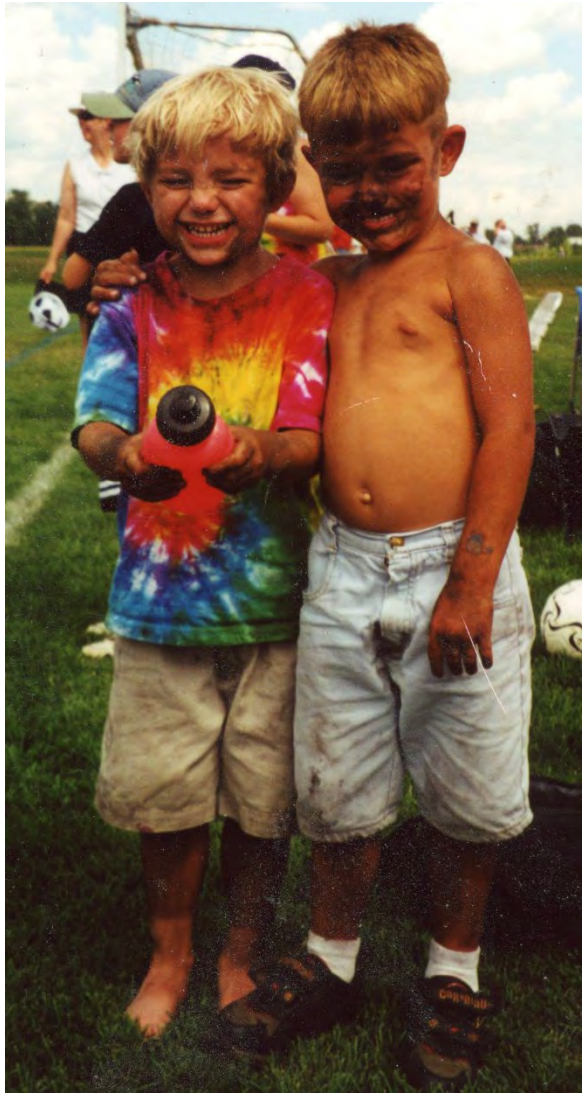




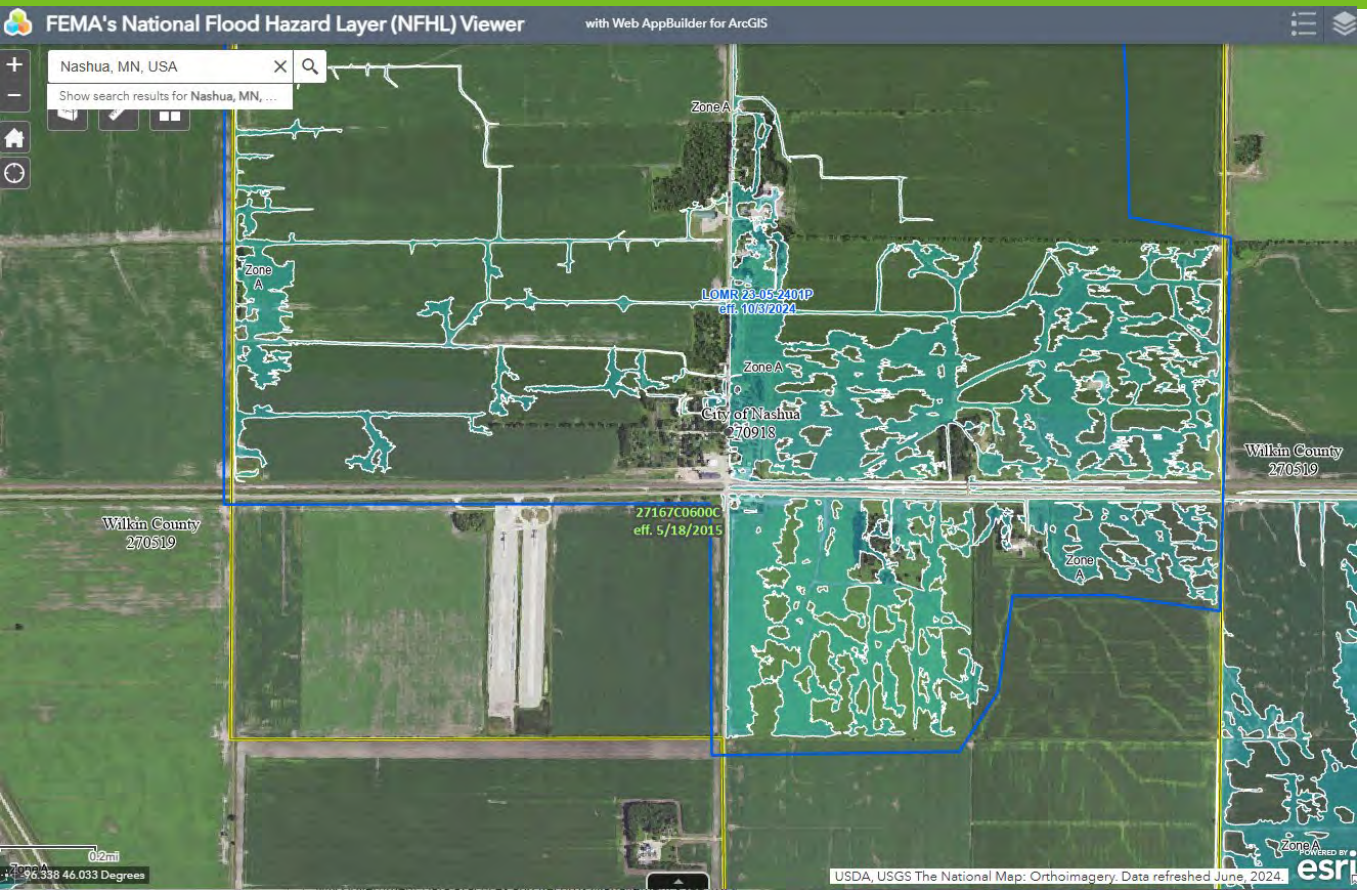
Regulating 2D Mapped Areas- Can be Messy Situations

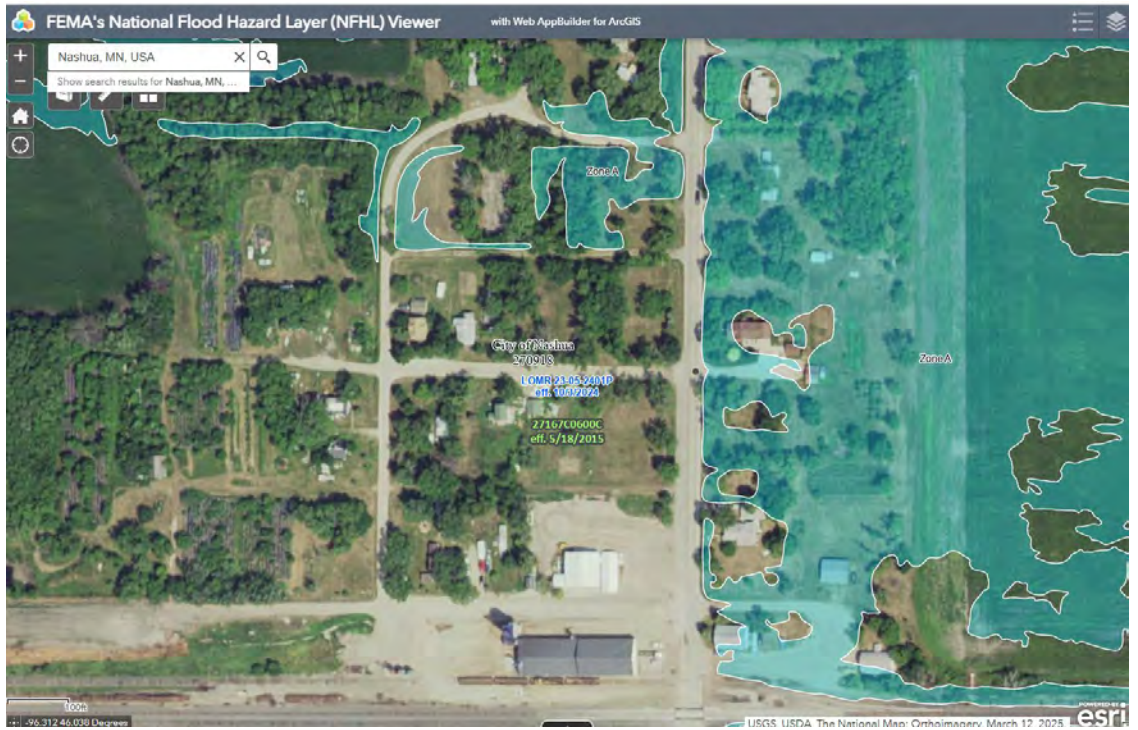


More Recent Use of 2D Modeling; Way of Future Need to Retain Storage Areas

- Some studies assume storage areas will be retained (i.e., XP-SWMM)
- Those storage areas are shown as “Administrative Floodway” on the FIRMs and are administered with the more restrictive floodway ordinance standards.

Nashua Example





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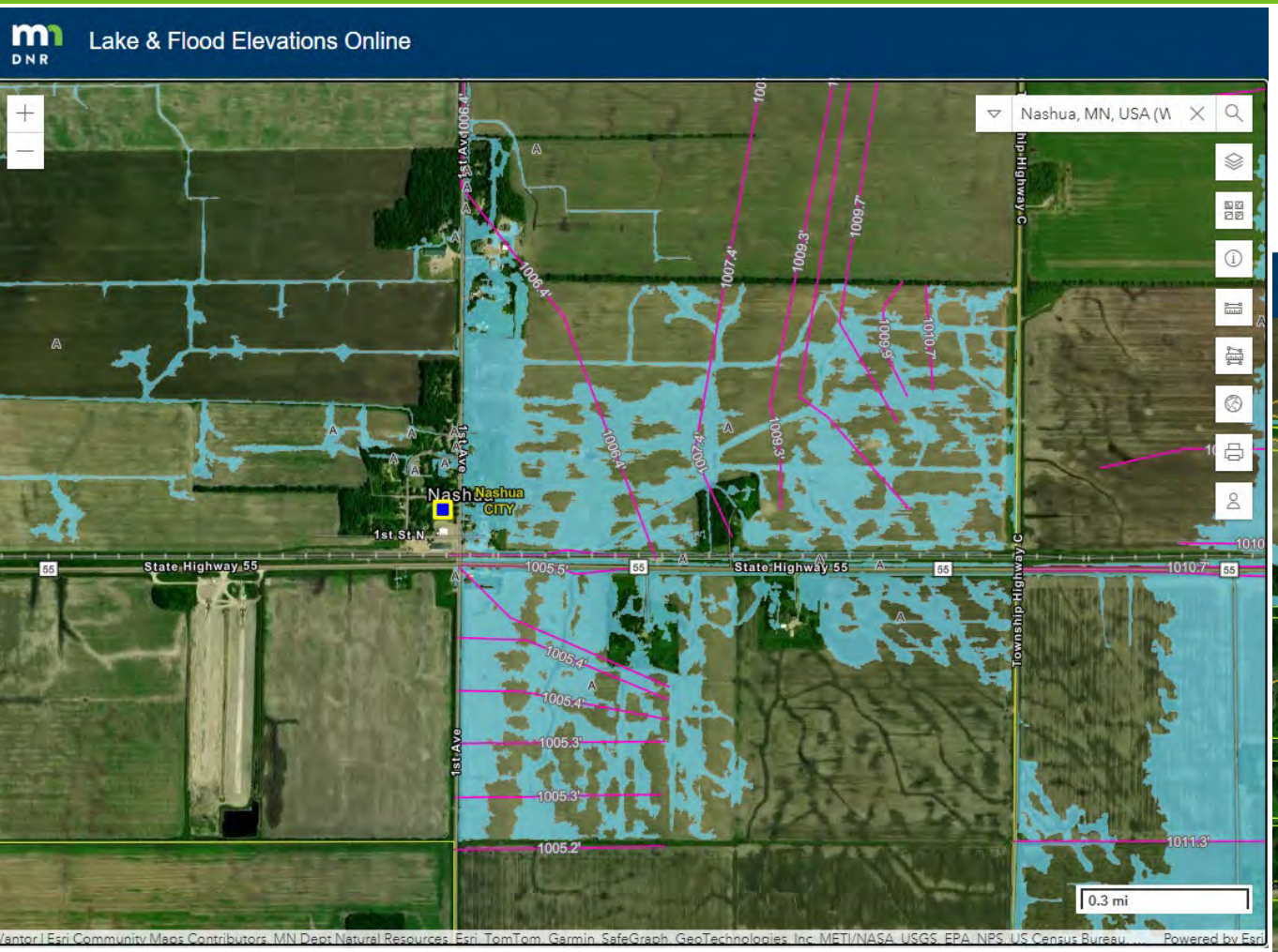
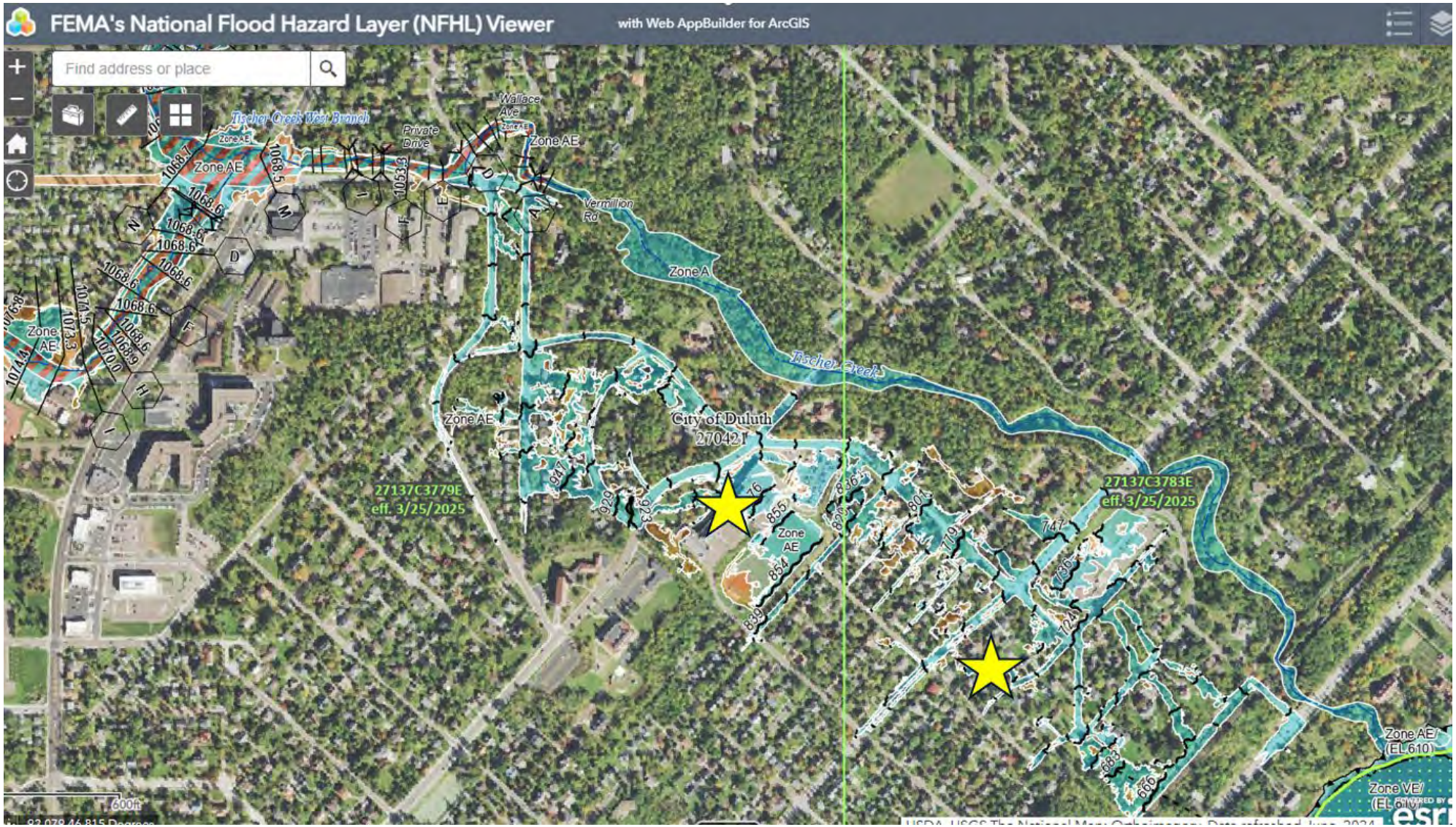


Disconnected Zone AEs

Disconnected Zone AEs

OK to fill?

Two More Duluth Examples in Tischer Creek Area



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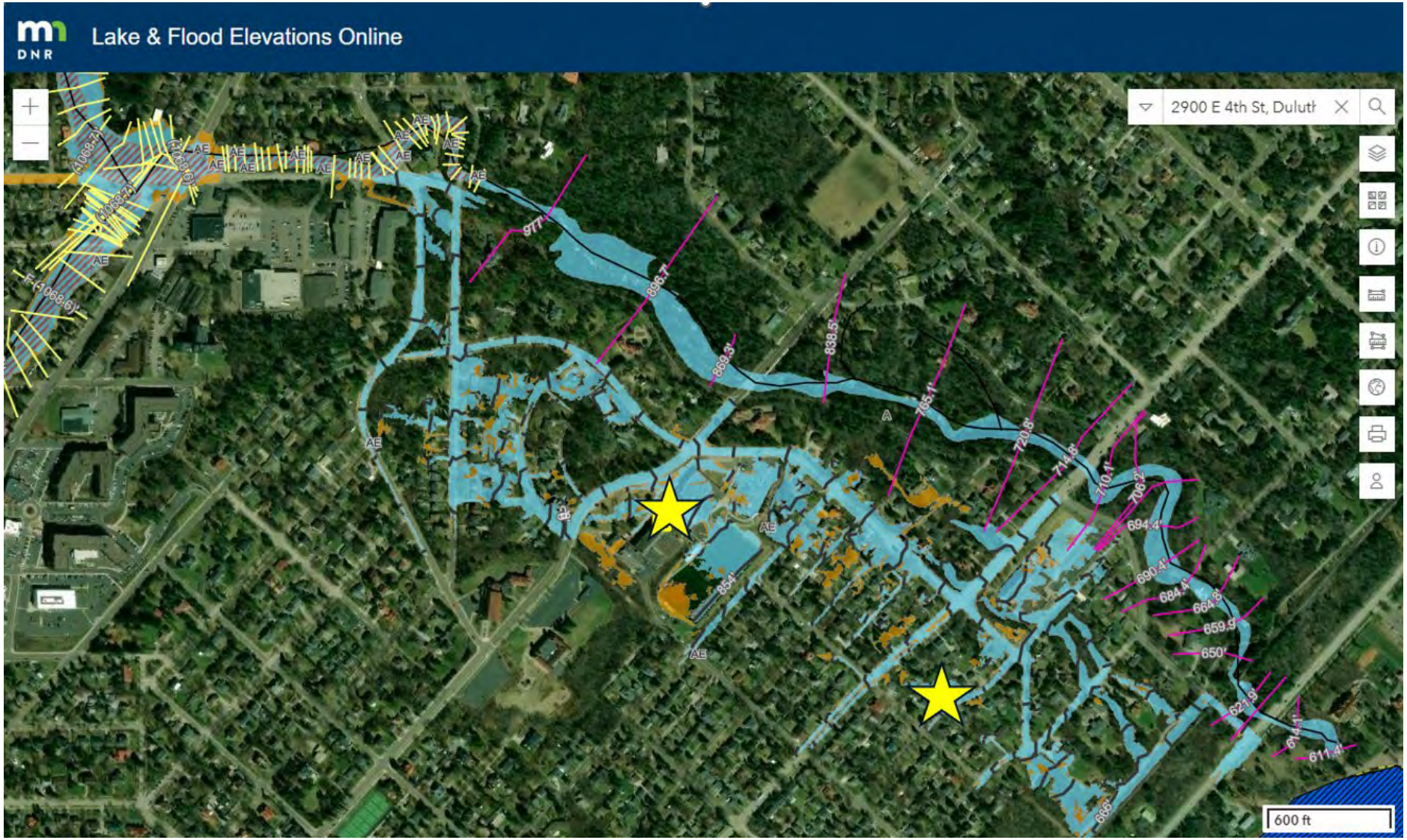

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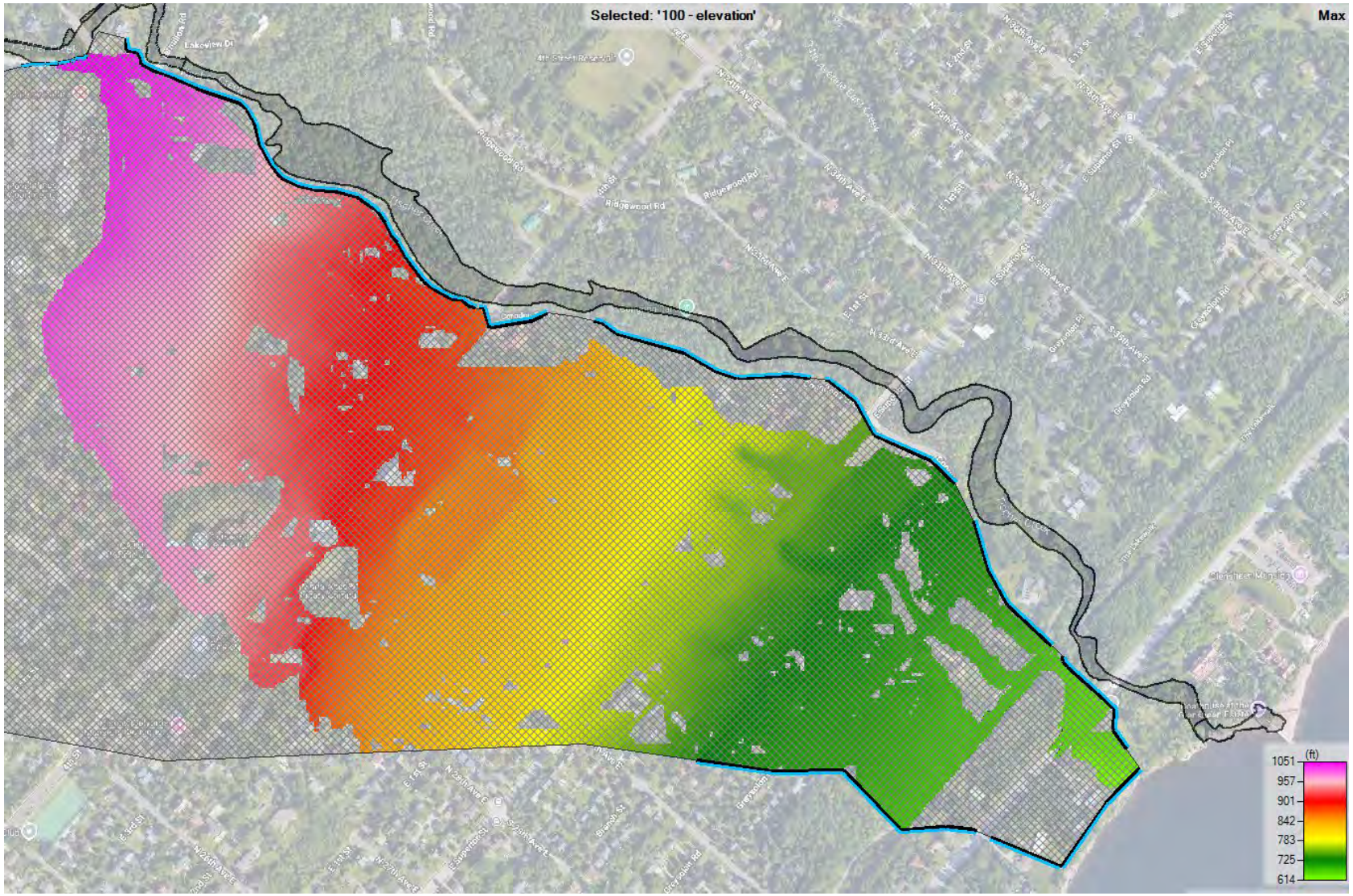
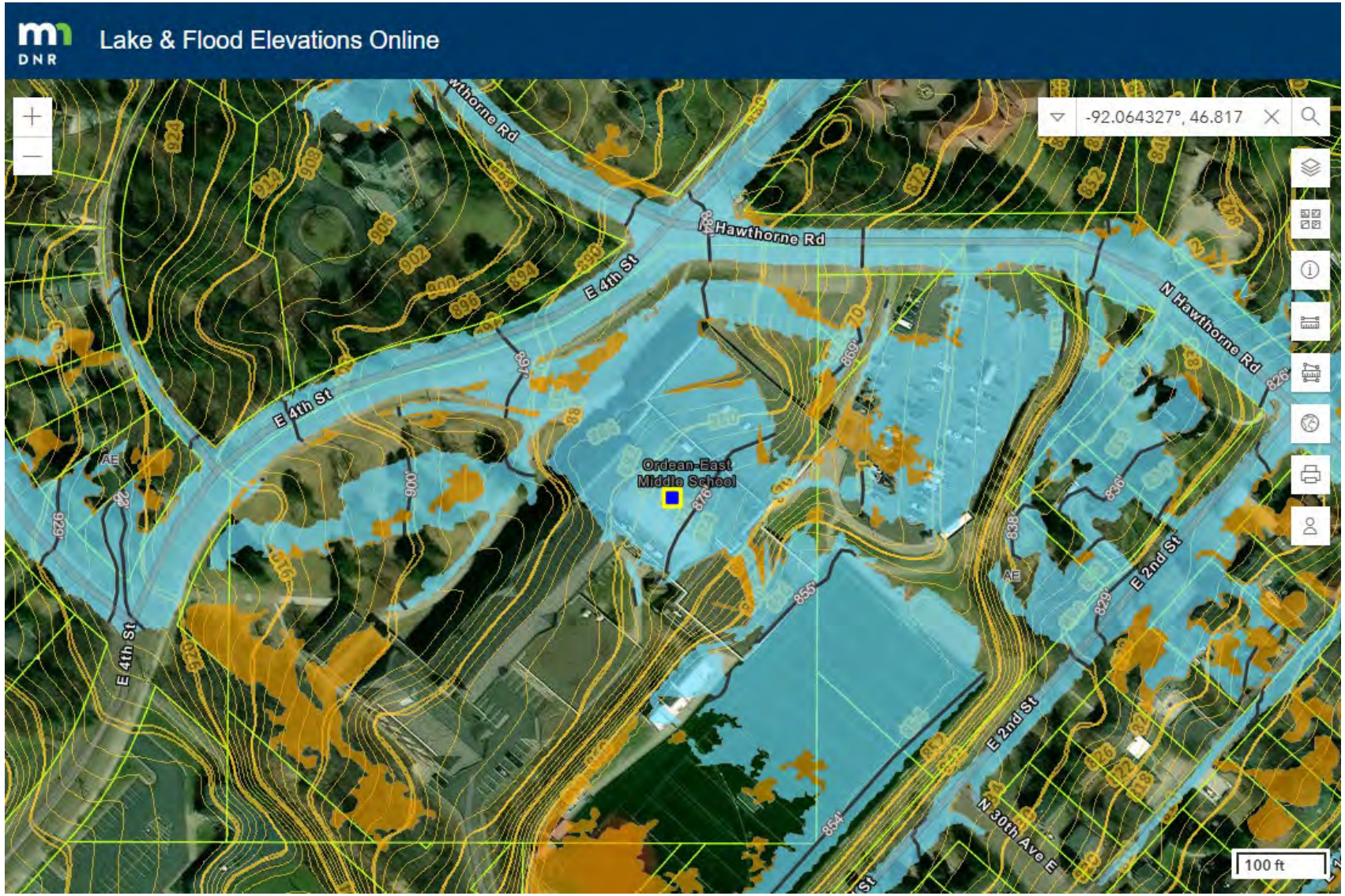


- Main reach for Tischer Creek is 1D model
- Separate 2D model for the breakout flood flow
- Clip shows the 2D mesh boundary
- Blue line on the north/northeast boundary is the boundary condition for water flowing out of 2D model into Tischer Creek 1D
- HEC-RAS 2D version 5.0

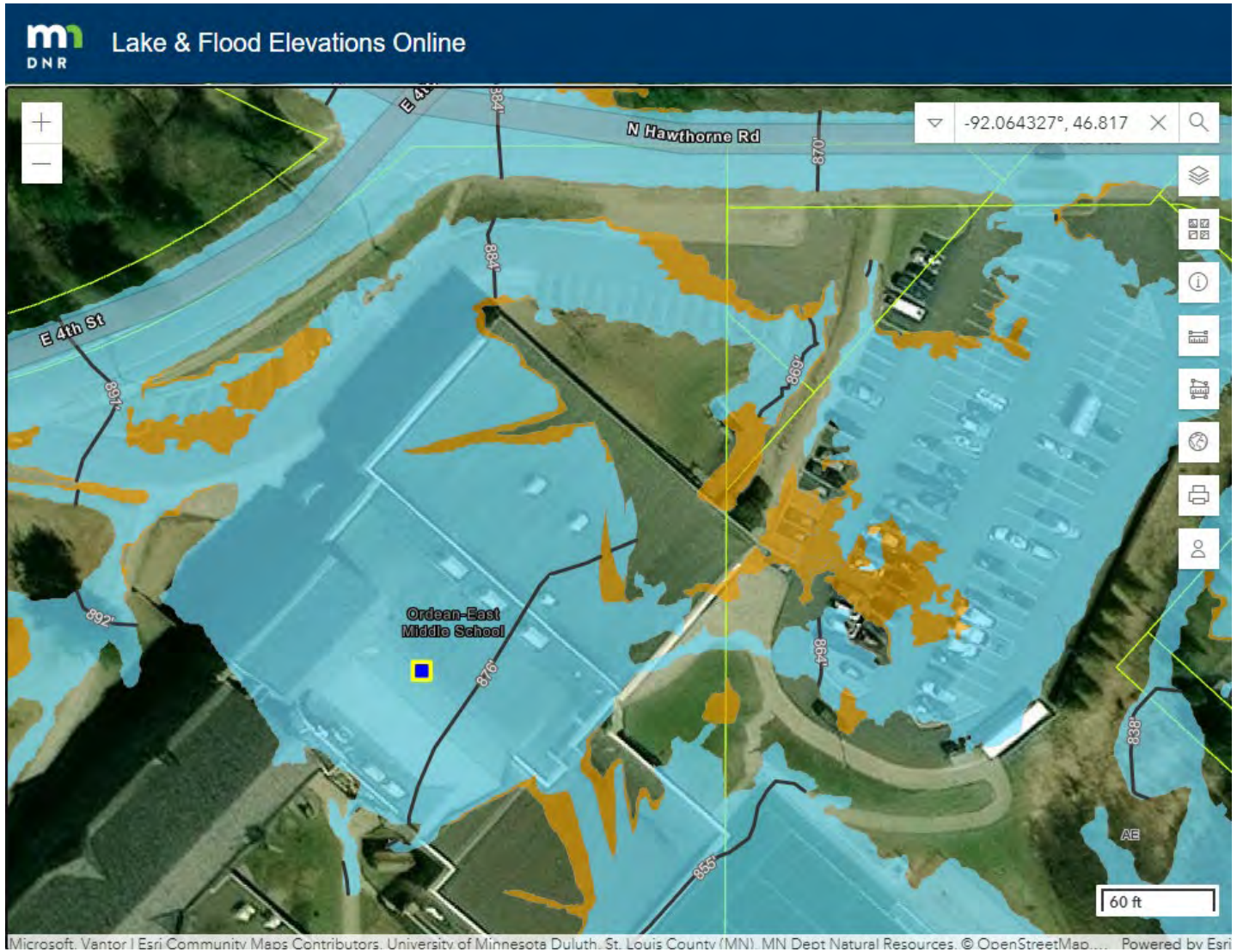
Middle School Example



Middle School Example

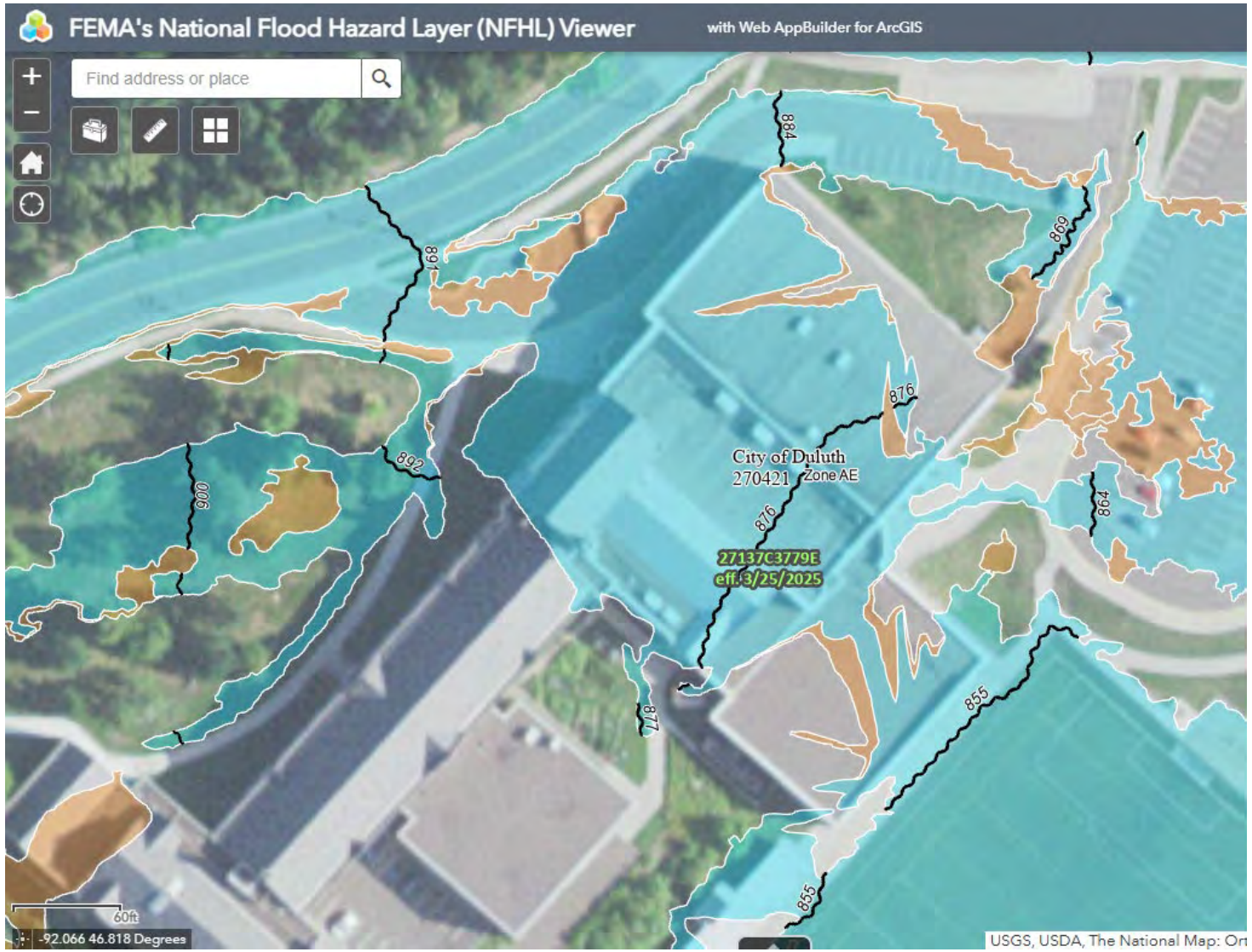
On 4th Street looking south at building

Determine BFE for a Public Building – In LFEO



- Middle School in Duluth
- Flood elevations on school – 876’ NAVD88
- Flood elevations near school – 864’, 884, 891’

Determine BFE for a Public Building (Middle School) – In NFHL



- Middle School in Duluth
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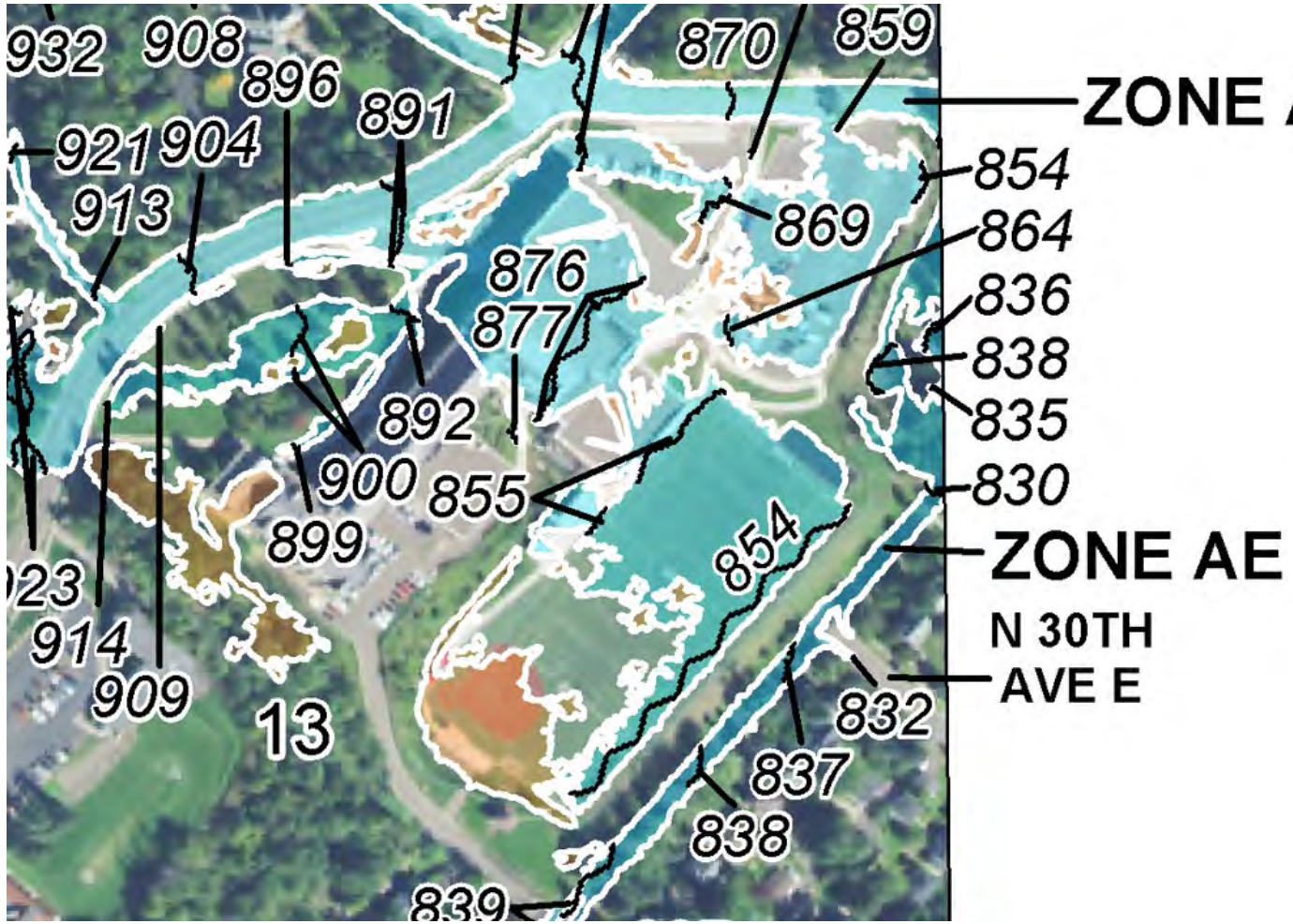
Determine BFE for a Public Building – On Map Panel (no help)



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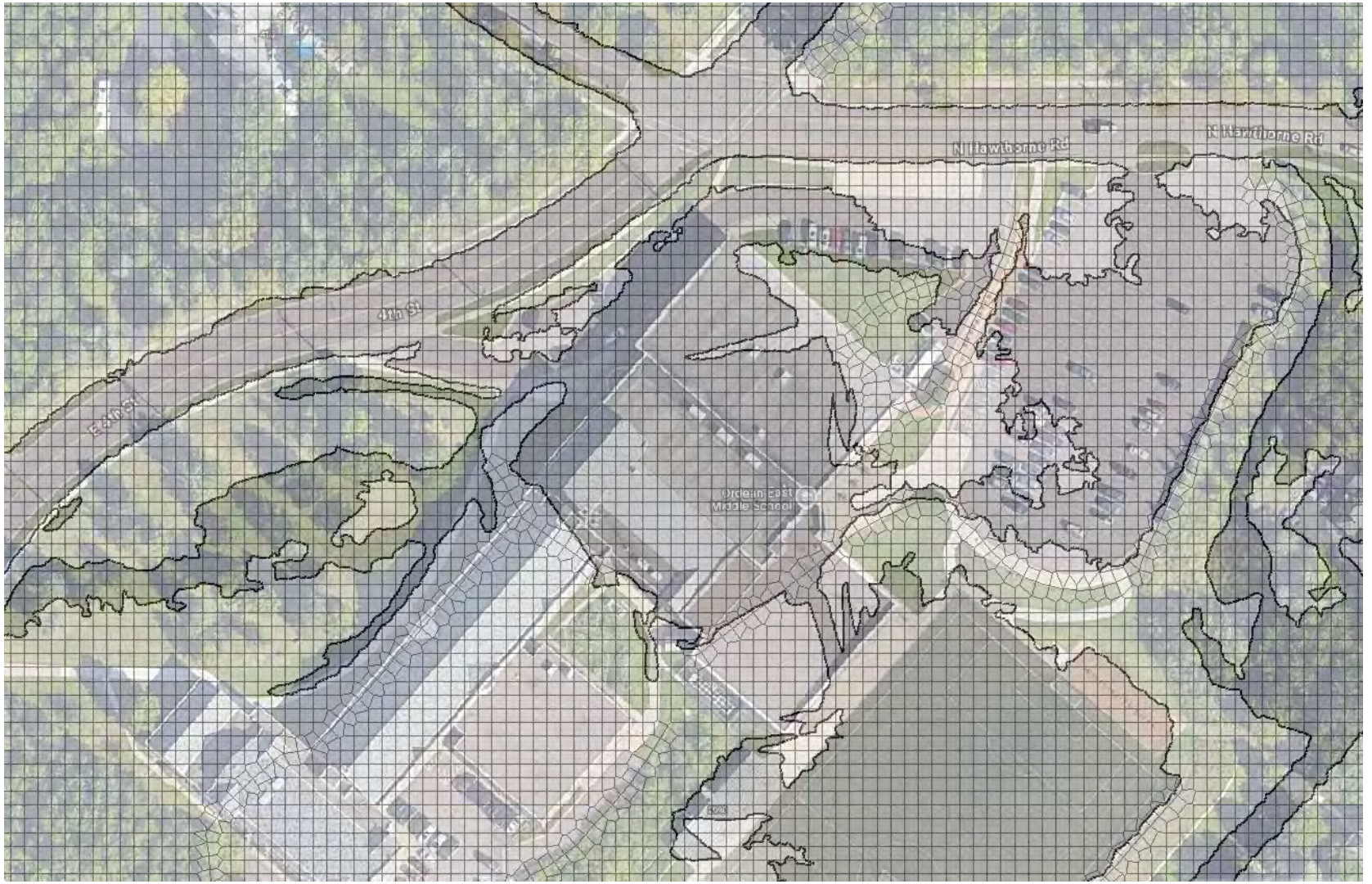
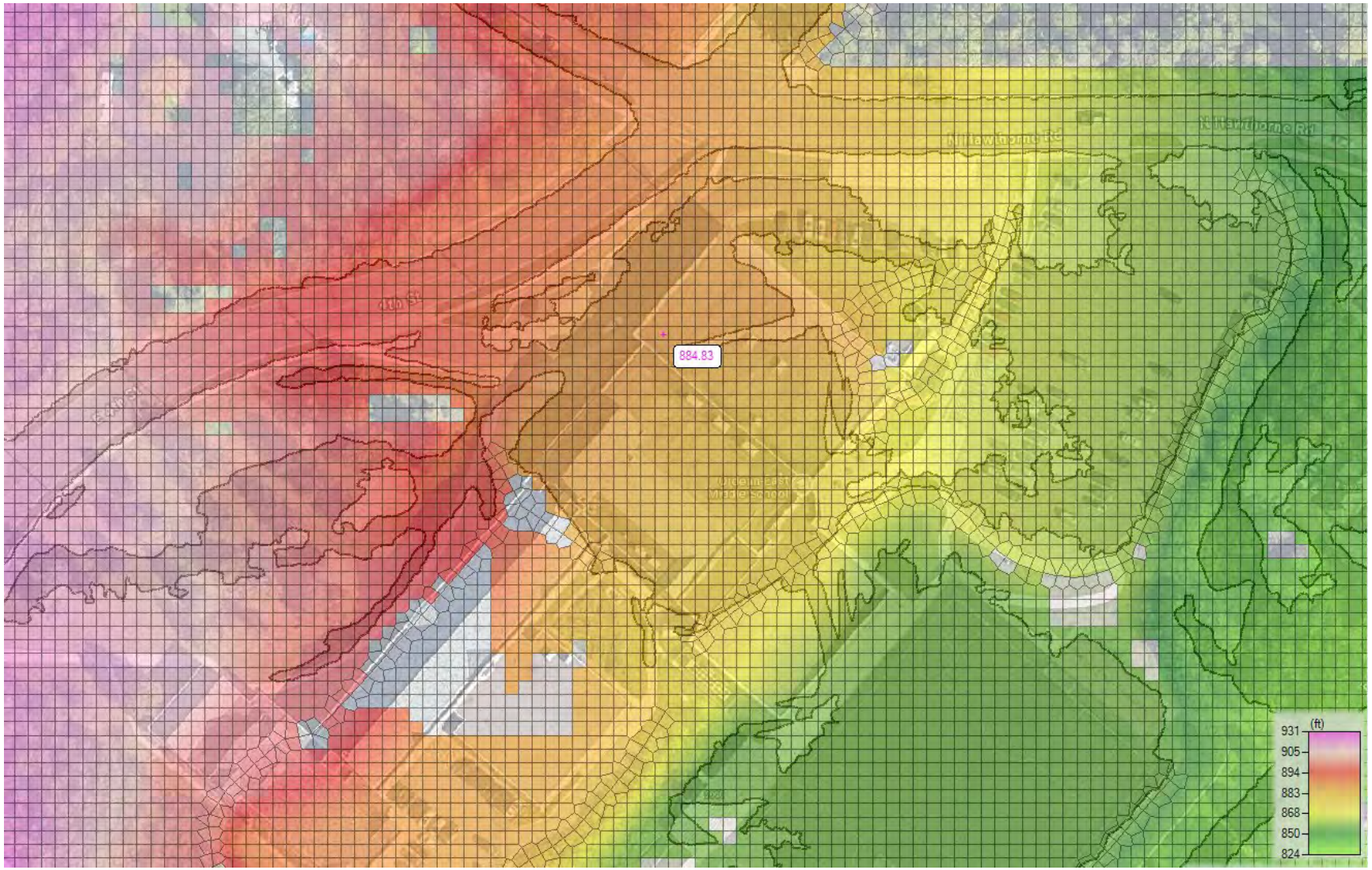
Determine BFE for a Public Building – 2D Modeling



- 2D mesh with 10 x 10-foot cells
- Outline of FEMA Special Flood Hazard Area

Determine BFE for a Public Building – 2D Modeling

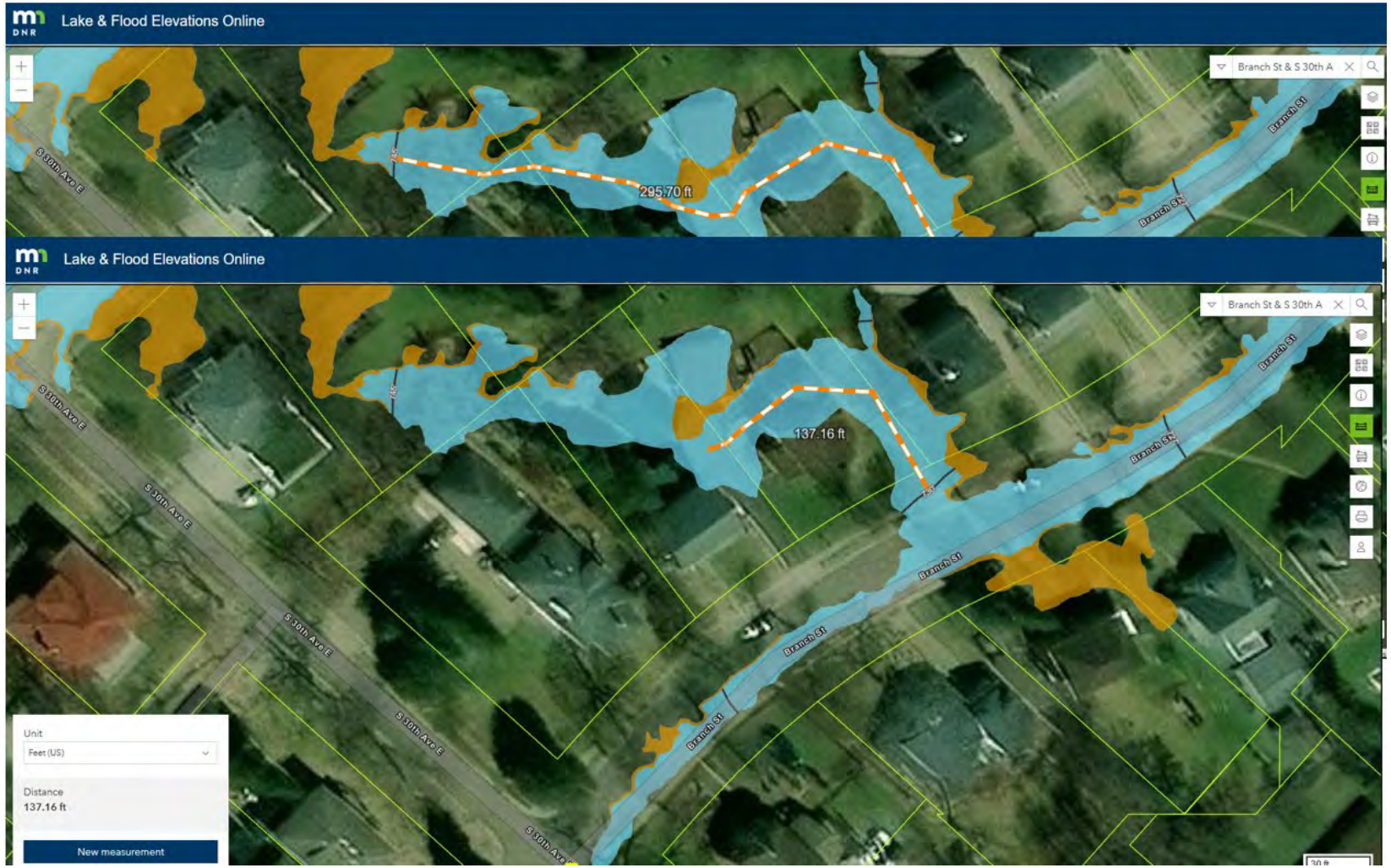


- Adding Water Surface Layer
- Set it to the “Max”
- Hover over cells to see max water surface elevations within that cell
- Elevation 884.8 was the highest cell elevation

Determine BFE for a Letter of Map Amendment (LOMA) Request

- Special Flood Hazard Area (SFHA) clips house
- Flood elevations range from 730’ to 745’ NAVD88
- MT-1 staff stated they would prorate to get BFE

Determine BFE for a Letter of Map Amendment (LOMA) Request



- Full length = 296’
- Distance from 730 XS to site = 137’

137/296 = X/15’

X = 137/296 x 15 = 6.9’

So BFE at house is 730 + 6.9 = 736.9’ NAVD88

Determine BFE for a Letter of Map Amendment (LOMA) Request

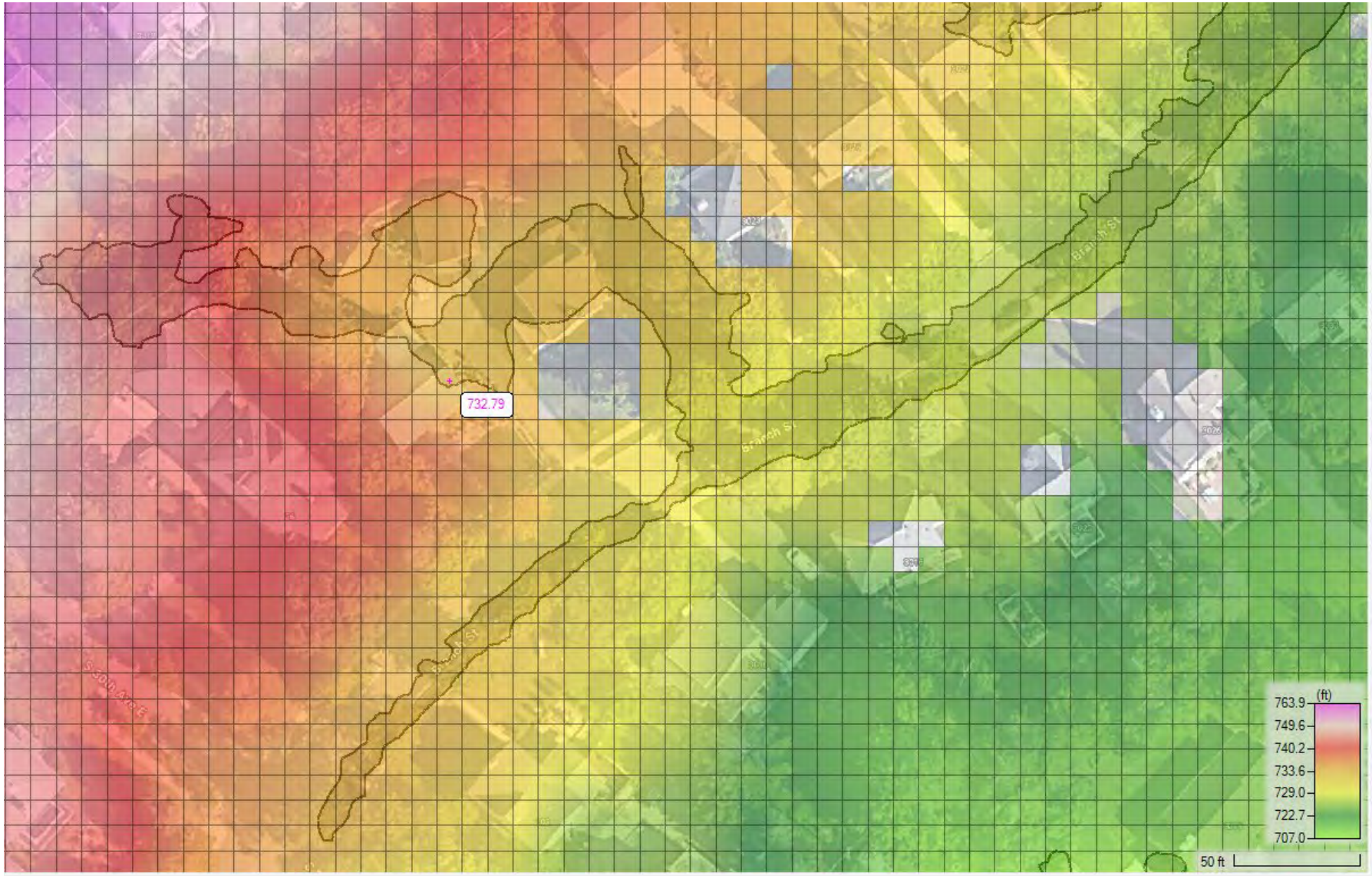
BFE based on prorating = 736.9’ NAVD88

BFE based on contour at house = 734’ NAVD88

Determine BFE at Residence – 2D Modeling

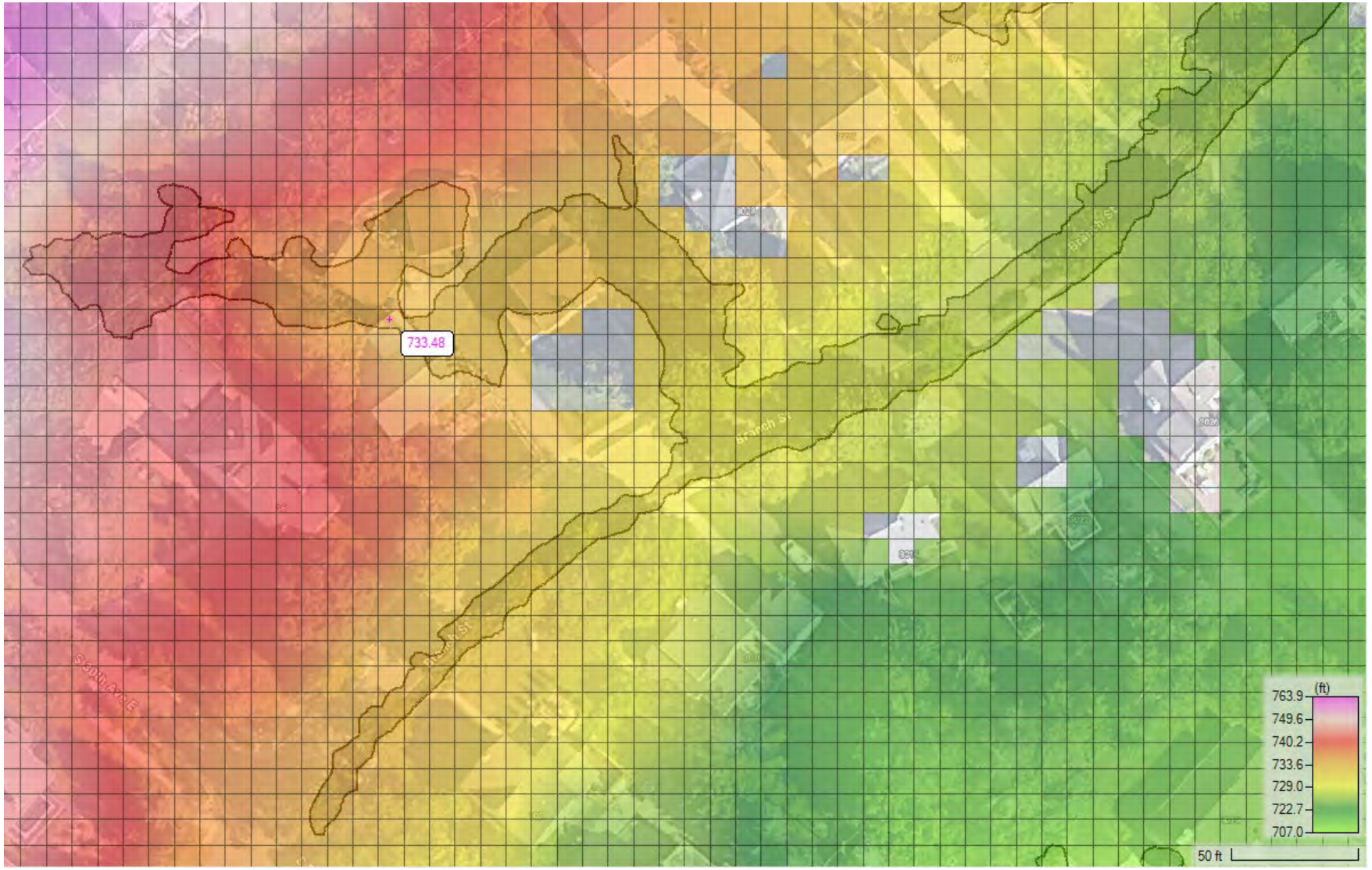
- 2D mesh with 10 x 10-foot cells
- Outline of FEMA Special Flood Hazard Area

Determine BFE at Residence – 2D Modeling



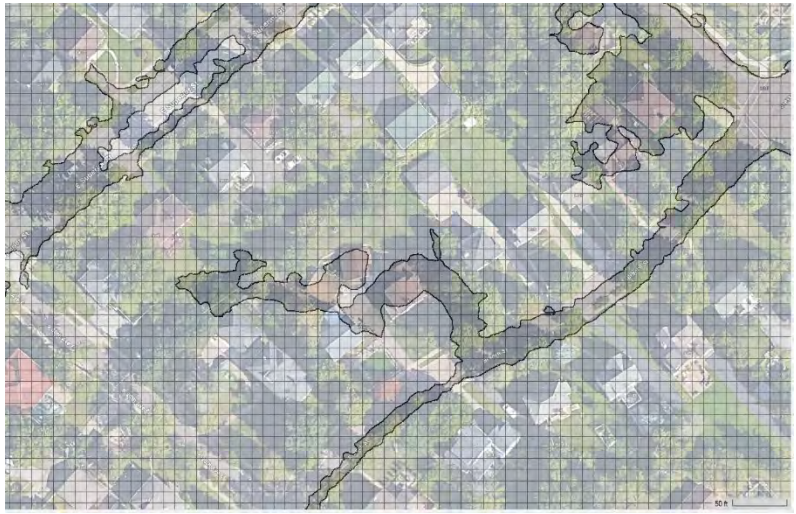
- Adding Water Surface Layer
- Set it to the “Max”
- Hover over cells to see max water surface elevations within that cell
- 732.79 was the max elevation on one cell

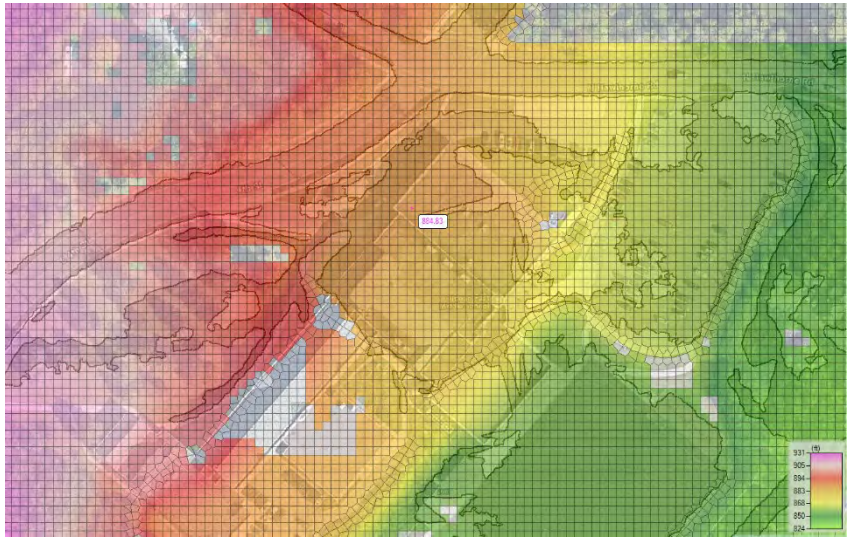
Determine BFE at Residence – 2D Modeling



- 733.48 was the max elevation on other cell (vs 732.79 on first)
- Use the highest cell max elevation of 733.48 as 2D model BFE estimate
- This data from the model is the most accurate, so use 733.48, but round to nearest tenth (733.5’ NAVD88) for LOMA or LOMR-F application (or development)

Future Training on Using HEC-RAS 2D Models to Find BFEs?





- HEC-RAS 2D is a free publicly available program (vs XPSWMM and some other programs)
- There are a few steps required to set up the model to see those BFEs in the cells.
- DNR floodplain staff thinking of offering a virtual training on the steps required and showing some examples – interest?

Questions?

DEPARTMENT OF NATURAL RESOURCES

Thank You!

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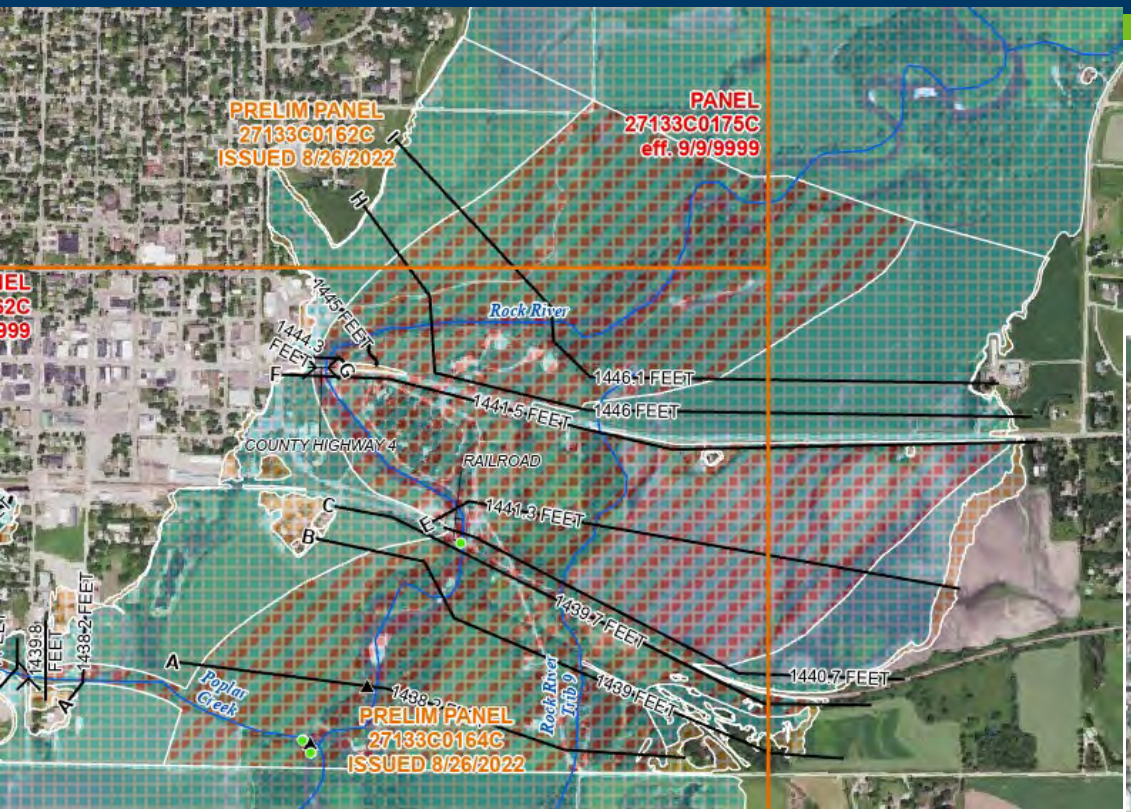
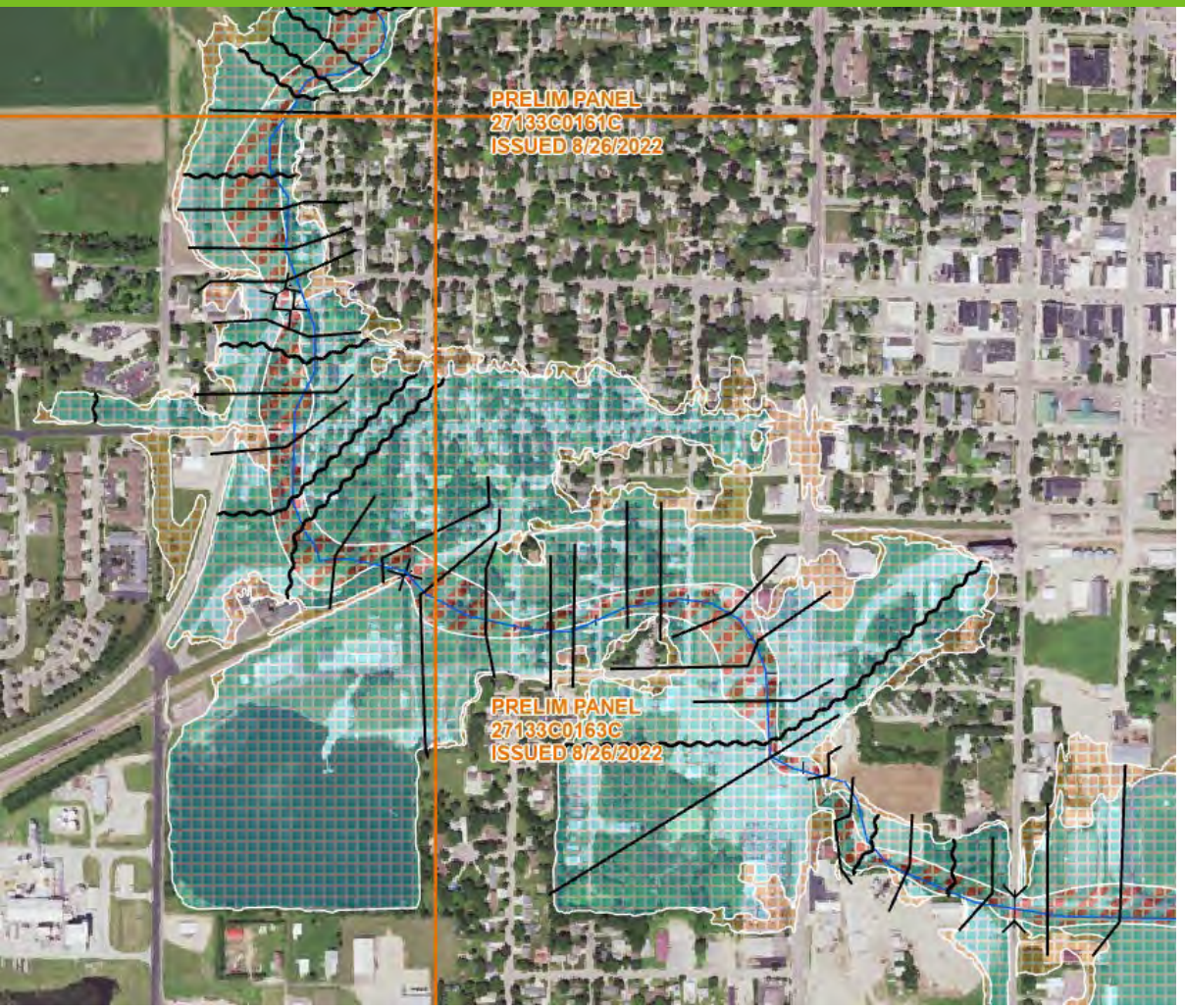
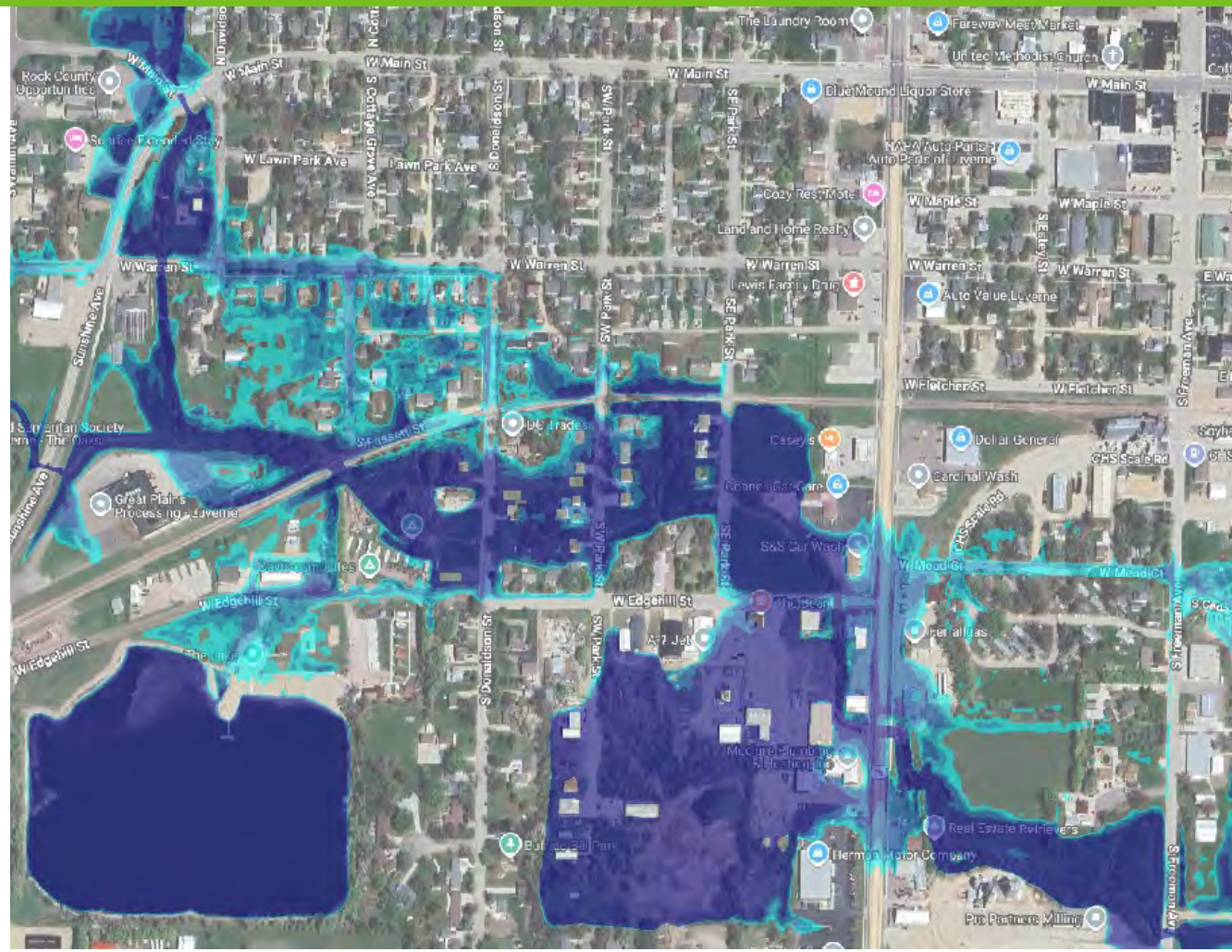
2D regulatory models in MN

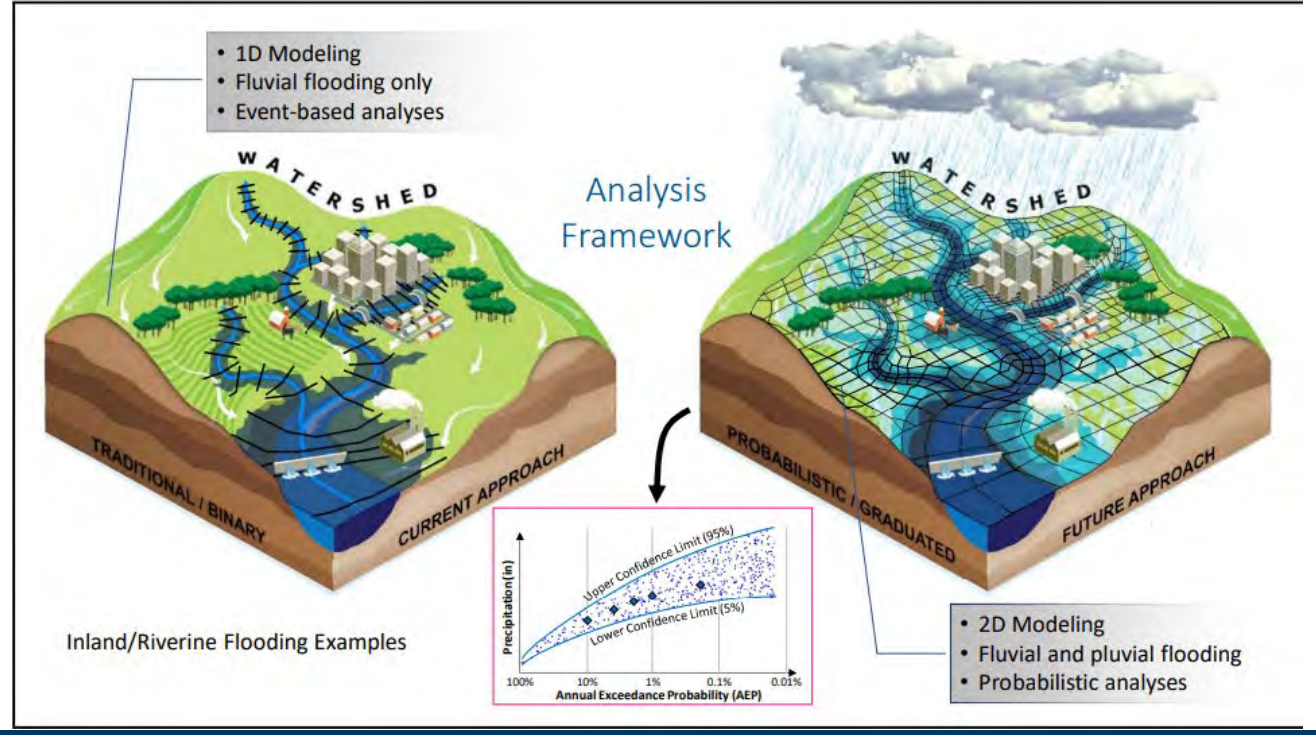
2D regulatory models in MN in the works



2D regulatory models in MN in the works







Future of Flood Risk Data

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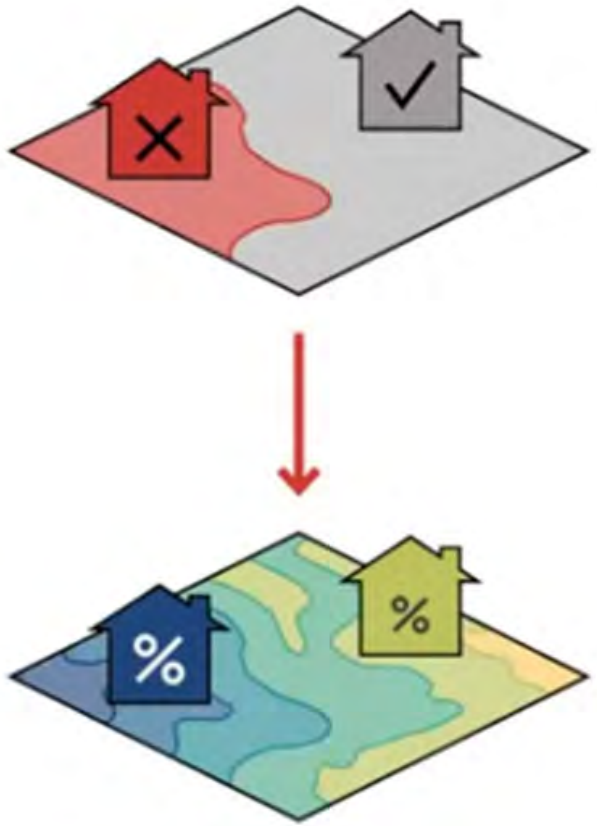
DEPARTMENT OF NATURAL RESOURCES

Future of Flood Risk Data - Overview

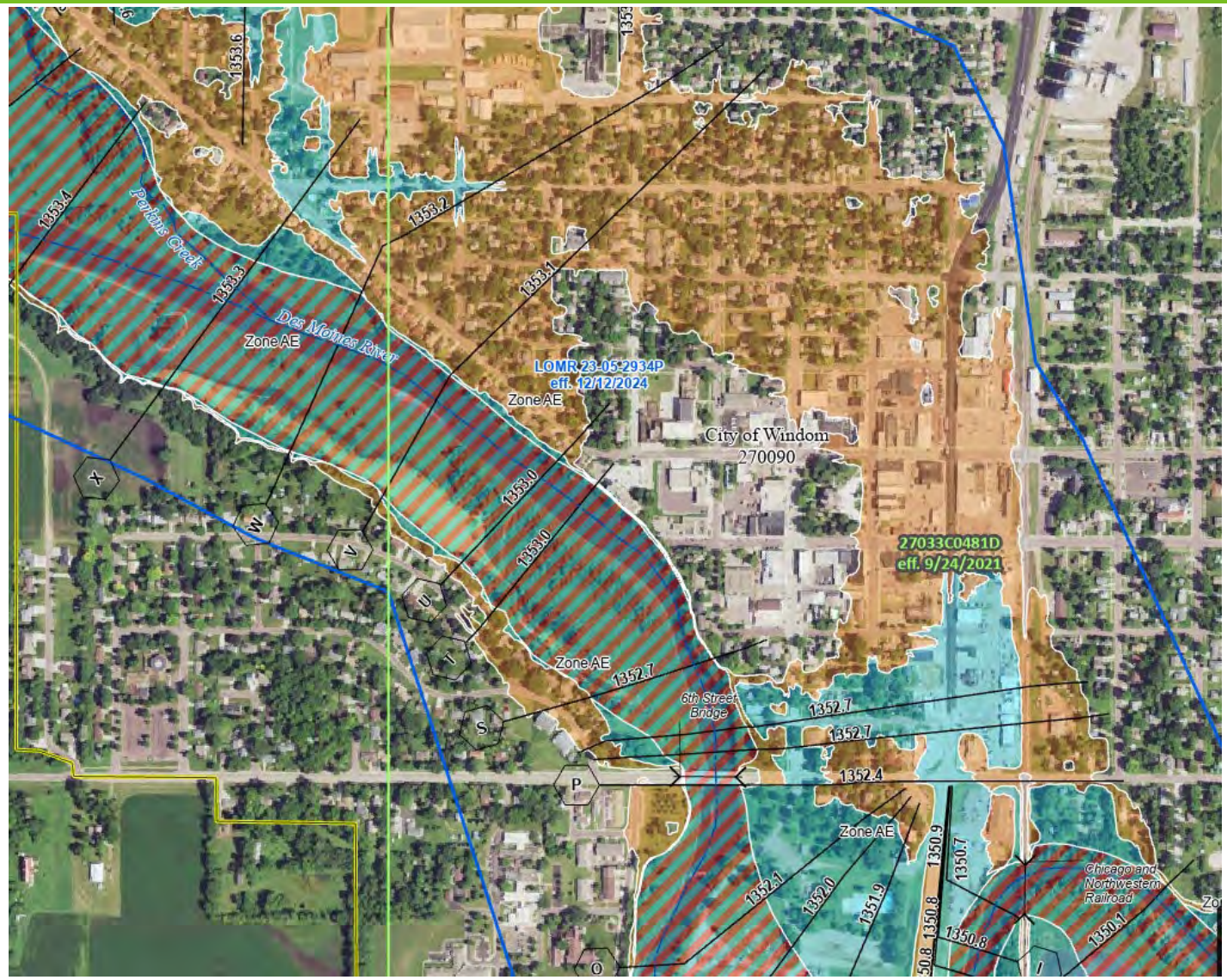
Objectives

- Shift from binary to probabilistic analysis
- Modernize data management
- Drive risk-informed actions

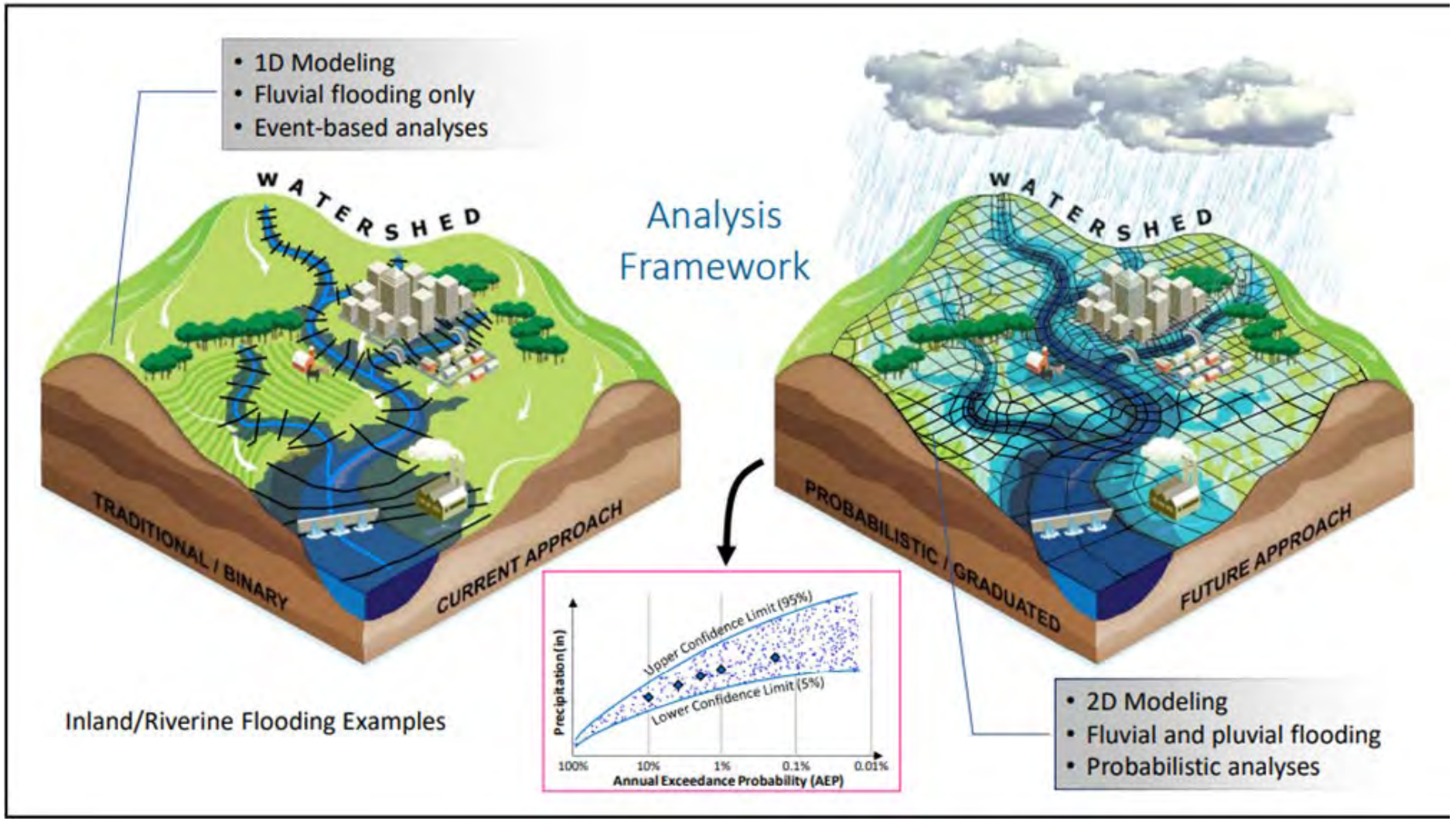


- Key Sources:
  - https://asfpm-library.s3.us-west-2.amazonaws.com/FSC/CTP/CTP_Webinar_ASFPM_Lindemer.pdf
  - https://www.hec.usace.army.mil/confluence/hecnews/spring-2023/fema-s-future-of-flood-risk-data-initiative
  - https://floodsciencecenter.org/event/ctp-webinar-femas-future-of-flood-risk-data-initiative/

Current FEMA maps



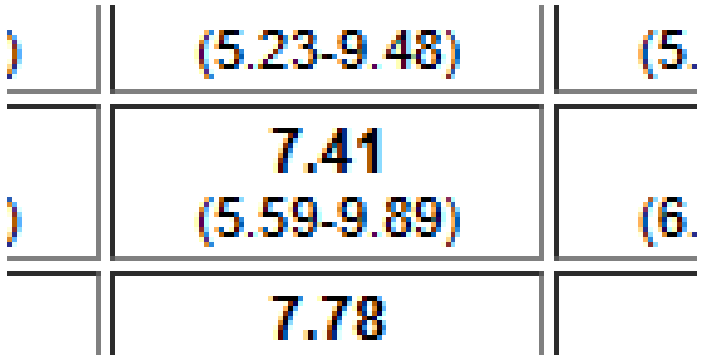
Traditional to FFRD



Account for Uncertainty

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.360 (0.284-0.468)	0.425 (0.334-0.552)	0.535 (0.420-0.697)	0.630 (0.491-0.824)	0.767 (0.580-1.04)	0.878 (0.646-1.20)	0.992 (0.704-1.38)	1.11 (0.756-1.58)	1.28 (0.834-1.85)	1.41 (0.892-2.06)
10-min	0.527 (0.415-0.685)	0.622 (0.490-0.809)	0.783 (0.614-1.02)	0.923 (0.720-1.21)	1.12 (0.849-1.52)	1.28 (0.946-1.75)	1.45 (1.03-2.02)	1.63 (1.11-2.31)	1.87 (1.22-2.71)	2.06 (1.31-3.02)
15-min	0.643 (0.506-0.836)	0.758 (0.597-0.987)	0.955 (0.749-1.24)	1.12 (0.878-1.47)	1.37 (1.04-1.85)	1.57 (1.15-2.14)	1.77 (1.26-2.46)	1.99 (1.35-2.82)	2.28 (1.49-3.31)	2.52 (1.59-3.68)
30-min	0.893 (0.704-1.16)	1.06 (0.837-1.38)	1.35 (1.06-1.76)	1.60 (1.24-2.09)	1.95 (1.47-2.63)	2.24 (1.64-3.04)	2.53 (1.80-3.51)	2.84 (1.93-4.02)	3.26 (2.12-4.72)	3.59 (2.28-5.25)
60-min	1.17 (0.919-1.52)	1.37 (1.08-1.79)	1.75 (1.37-2.28)	2.10 (1.64-2.74)	2.62 (2.00-3.58)	3.07 (2.27-4.22)	3.55 (2.53-4.97)	4.07 (2.78-5.82)	4.82 (3.15-7.02)	5.42 (3.44-7.93)
2-hr	1.44 (1.15-1.84)	1.69 (1.34-2.16)	2.15 (1.71-2.77)	2.60 (2.05-3.36)	3.30 (2.55-4.48)	3.91 (2.93-5.33)	4.58 (3.30-6.35)	5.31 (3.67-7.53)	6.38 (4.22-9.22)	7.26 (4.64-10.5)
3-hr	1.61 (1.29-2.05)	1.87 (1.50-2.38)	2.39 (1.91-3.05)	2.91 (2.31-3.72)	3.75 (2.93-5.08)	4.49 (3.40-6.11)	5.32 (3.88-7.38)	6.26 (4.36-8.85)	7.63 (5.09-11.0)	8.78 (5.65-12.6)
6-hr	1.89 (1.54-2.37)	2.18 (1.77-2.74)	2.78 (2.25-3.50)	3.40 (2.74-4.29)	4.42 (3.52-5.95)	5.35 (4.11-7.21)	6.39 (4.72-8.78)	7.57 (5.34-10.6)	9.33 (6.30-13.3)	10.8 (7.02-15.4)
12-hr	2.12 (1.74-2.61)	2.48 (2.04-3.06)	3.19 (2.61-3.95)	3.88 (3.16-4.82)	4.98 (3.98-6.56)	5.95 (4.61-7.87)	(5.23-9.48)	8.22 (5.85-11.4)	9.98 (6.80-14.1)	11.4 (7.51-16.1)
24-hr	2.45 (2.04-2.98)	2.80 (2.33-3.40)	3.49 (2.90-4.25)	4.18 (3.45-5.12)	5.29 (4.30-6.89)	6.29 (4.94-8.23)	7.41 (5.59-9.89)	8.66 (6.24-11.8)	10.5 (7.23-14.7)	12.0 (7.99-16.8)
2-day	2.85 (2.41-3.41)	3.17 (2.68-3.80)	3.83 (3.22-4.60)	4.51 (3.77-5.44)	5.63 (4.63-7.22)	6.64 (5.28-8.58)	7.78	9.08 (6.62-12.3)	11.0 (7.66-15.2)	12.6 (8.46-17.4)
3-day	3.14 (2.67-3.72)	3.44 (2.93-4.09)	4.09 (3.47-4.87)	4.76 (4.01-5.70)	5.88 (4.88-7.49)	6.90 (5.53-8.84)	8.06 (6.20-10.6)	9.37 (6.88-12.6)	11.3 (7.95-15.6)	13.0 (8.76-17.8)
4-day	3.36 (2.88-3.97)	3.68 (3.15-4.35)	4.35 (3.70-5.14)	5.03 (4.26-5.97)	6.15 (5.12-7.77)	7.18 (5.78-9.13)	8.33 (6.44-10.8)	9.64 (7.11-12.9)	11.6 (8.16-15.8)	13.2 (8.96-18.1)
7-day	3.90 (3.37-4.54)	4.31 (3.73-5.03)	5.10 (4.39-5.96)	5.85 (5.01-6.87)	7.02 (5.86-8.67)	8.04 (6.51-10.0)	9.16 (7.13-11.7)	10.4 (7.72-13.7)	12.2 (8.65-16.5)	13.7 (9.36-18.6)
10-day	4.39 (3.82-5.06)	4.89 (4.26-5.66)	5.80 (5.03-6.72)	6.61 (5.70-7.70)	7.84 (6.55-9.53)	8.86 (7.20-10.9)	9.95 (7.77-12.6)	11.1 (8.28-14.5)	12.8 (9.11-17.1)	14.1 (9.74-19.1)
20-day	5.94 (5.25-6.75)	6.64 (5.86-7.56)	7.81 (6.86-8.91)	8.78 (7.67-10.1)	10.1 (8.53-12.0)	11.2 (9.18-13.5)	12.3 (9.67-15.2)	13.4 (10.0-17.1)	14.9 (10.7-19.6)	16.0 (11.1-21.4)
30-day	7.34 (6.54-8.26)	8.20 (7.30-9.24)	9.58 (8.49-10.8)	10.7 (9.41-12.1)	12.2 (10.3-14.2)	13.3 (11.0-15.8)	14.4 (11.4-17.6)	15.5 (11.7-19.6)	16.9 (12.2-22.0)	17.9 (12.6-23.9)
45-day	9.19 (8.25-10.2)	10.3 (9.20-11.5)	11.9 (10.7-13.4)	13.3 (11.8-14.9)	15.0 (12.7-17.2)	16.2 (13.4-19.0)	17.3 (13.8-20.9)	18.4 (13.9-23.0)	19.7 (14.3-25.4)	20.6 (14.5-27.3)
60-day	10.8 (9.77-12.0)	12.1 (10.9-13.4)	14.0 (12.6-15.6)	15.5 (13.9-17.4)	17.4 (14.9-19.9)	18.8 (15.6-21.9)	20.0 (15.9-23.9)	21.0 (16.0-26.1)	22.3 (16.2-28.6)	23.1 (16.4-30.4)

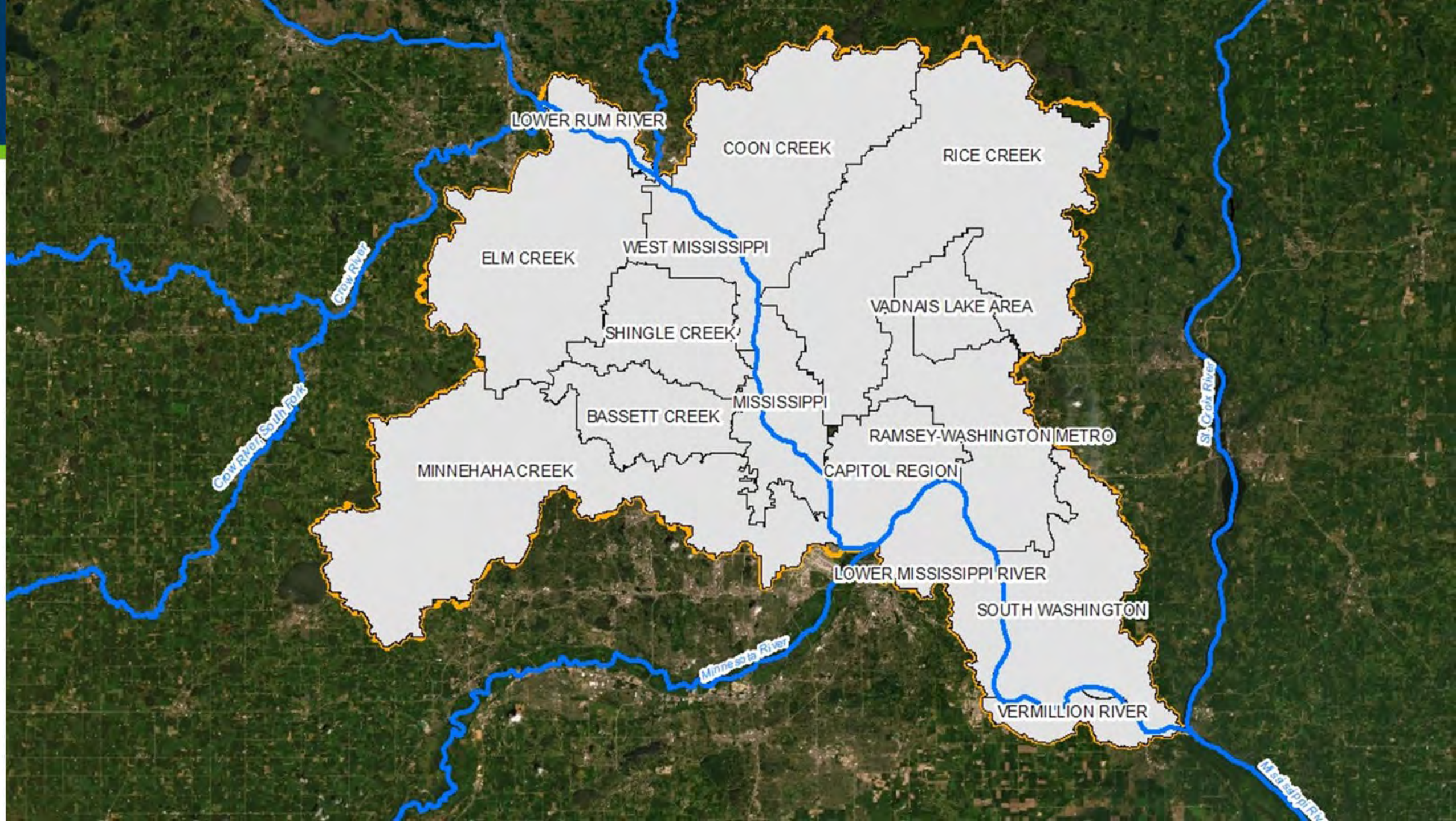


Account for Uncertainty

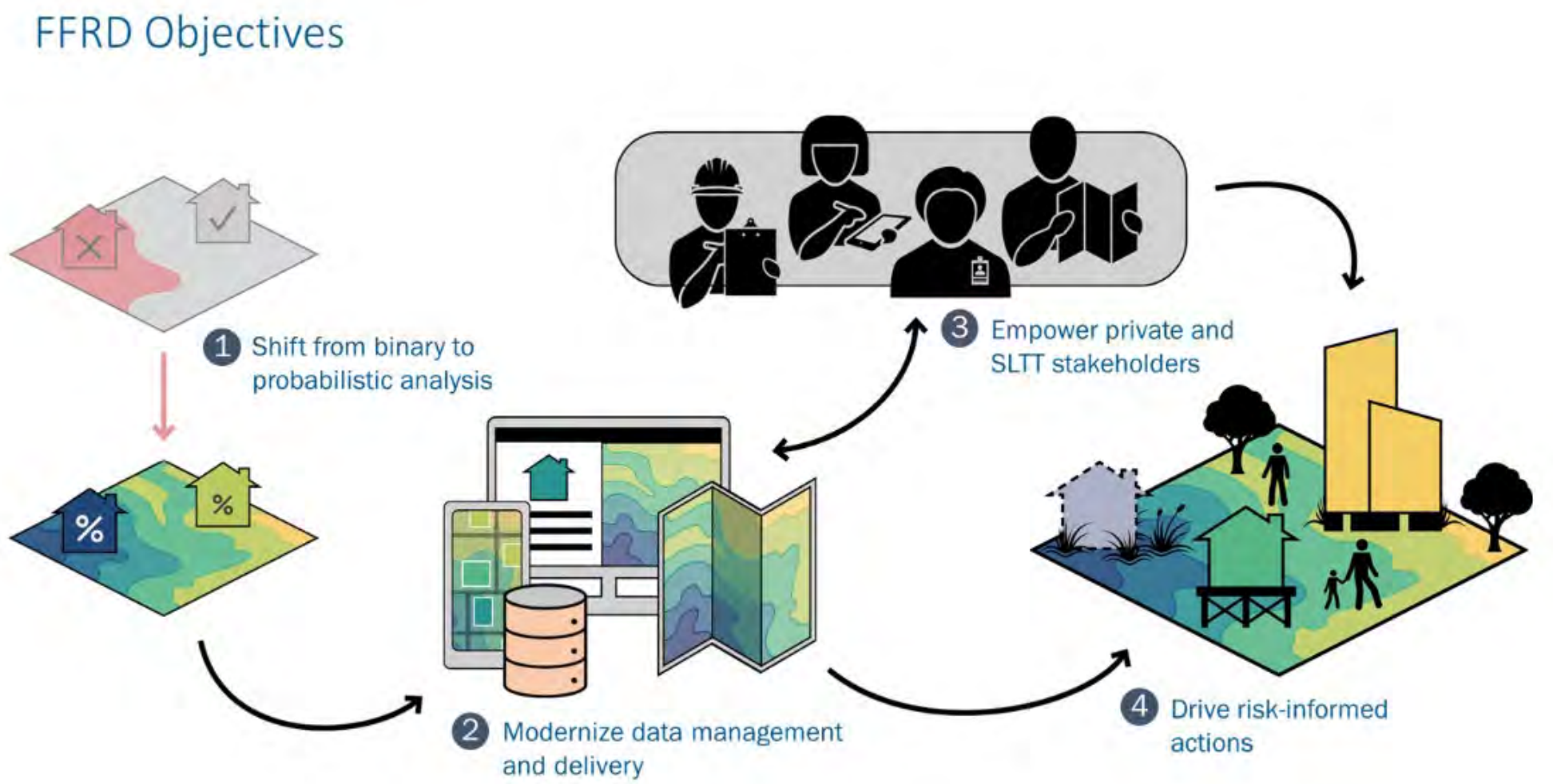
Peak-Flow Statistics Flow Report [Minnesota Peakflow D 2023 5079]

PIL: Lower 90% Prediction Interval, PIU: Upper 90% Prediction Interval, ASEp: Average Standard Error of Prediction, SE: Standard Error, PC: Percent Correct, RMSE: Root Mean Squared Error, PseudoR^2: Pseudo R Squared (other -- see report)

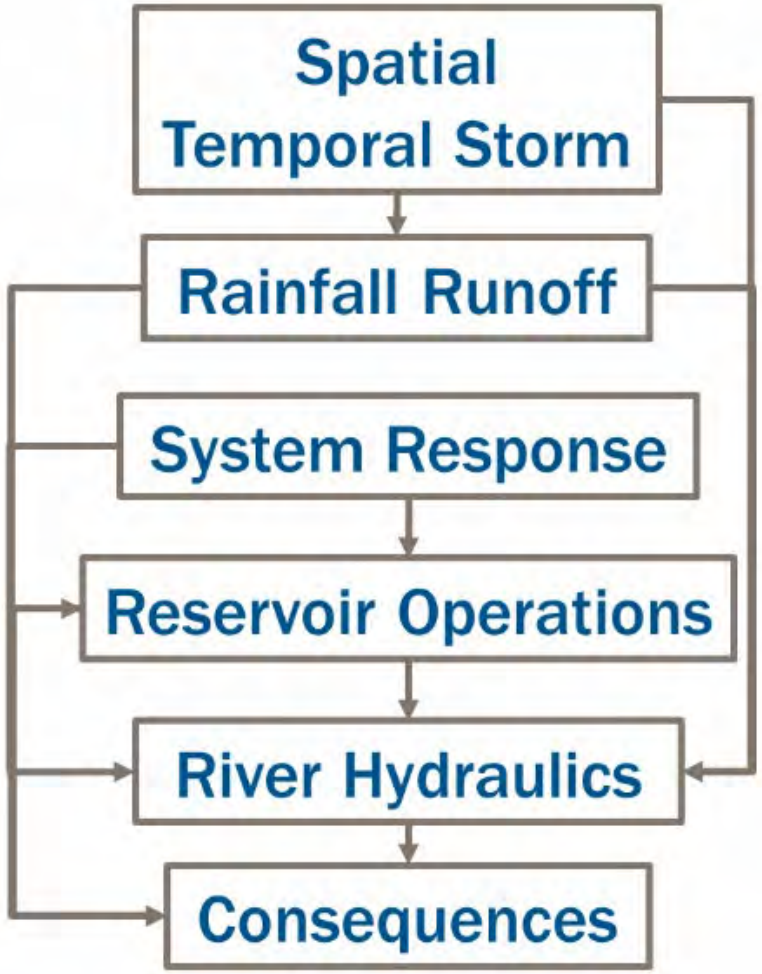
Statistic	Value	Unit	PIL	PIU	SE	ASEp
66.7-percent AEP flood	573	ft^3/s	251	1310	51.7	53.8
50-percent AEP flood	818	ft^3/s	391	1710	45.7	47.6
20-percent AEP flood	1620	ft^3/s	844	3110	40.3	42.2
10-percent AEP flood	2290	ft^3/s	1170	4500	41.2	43.2
4-percent AEP flood	3260	ft^3/s	1600	6630	43.8	46.1
2-percent AEP flood	4090	ft^3/s	1930	8670	46.4	48.9
1-percent AEP flood	4970	ft^3/s	2230	11100	49.8	52.5
0.2-percent AEP flood	7350	ft^3/s	2940	18400	58.1	61.4


LOWER RUM RIVER
COON CREEK
RICE CREEK
ELM CREEK
WEST MISSISSIPPI
Crow River
VADNAIS LAKE AREA
SHINGLE CREEK
Crow River, South Fork
MISSISSIPPI
BASSETT CREEK
RAMSEY-WASHINGTON METRO
St. Croix River
MINNEHAHA CREEK
CAPITOL REGION
LOWER MISSISSIPPI RIVER
SOUTH WASHINGTON
Minnesota River
VERMILLION RIVER

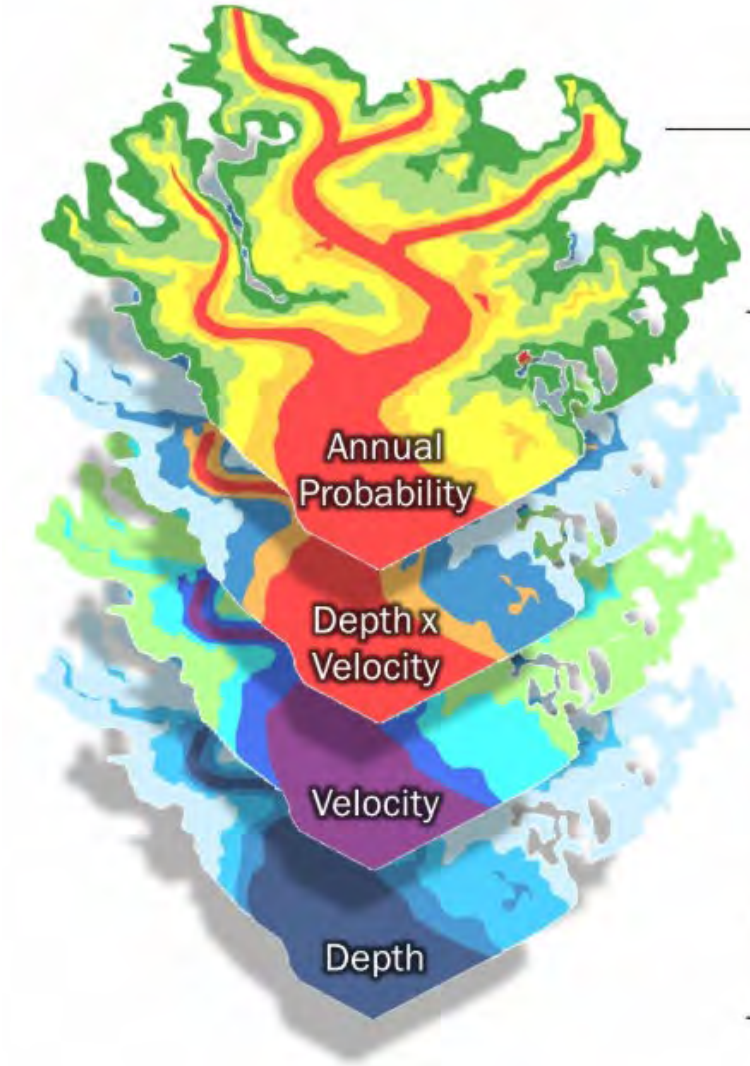
FFRD Objectives



FFRD Conceptual Layout

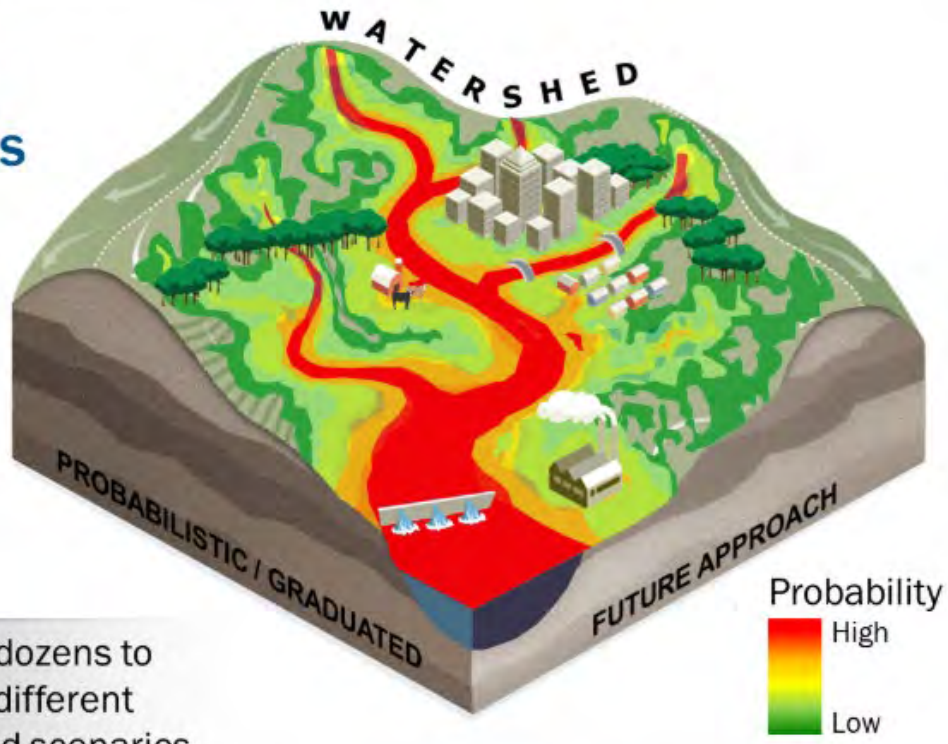


FFRD Outputs



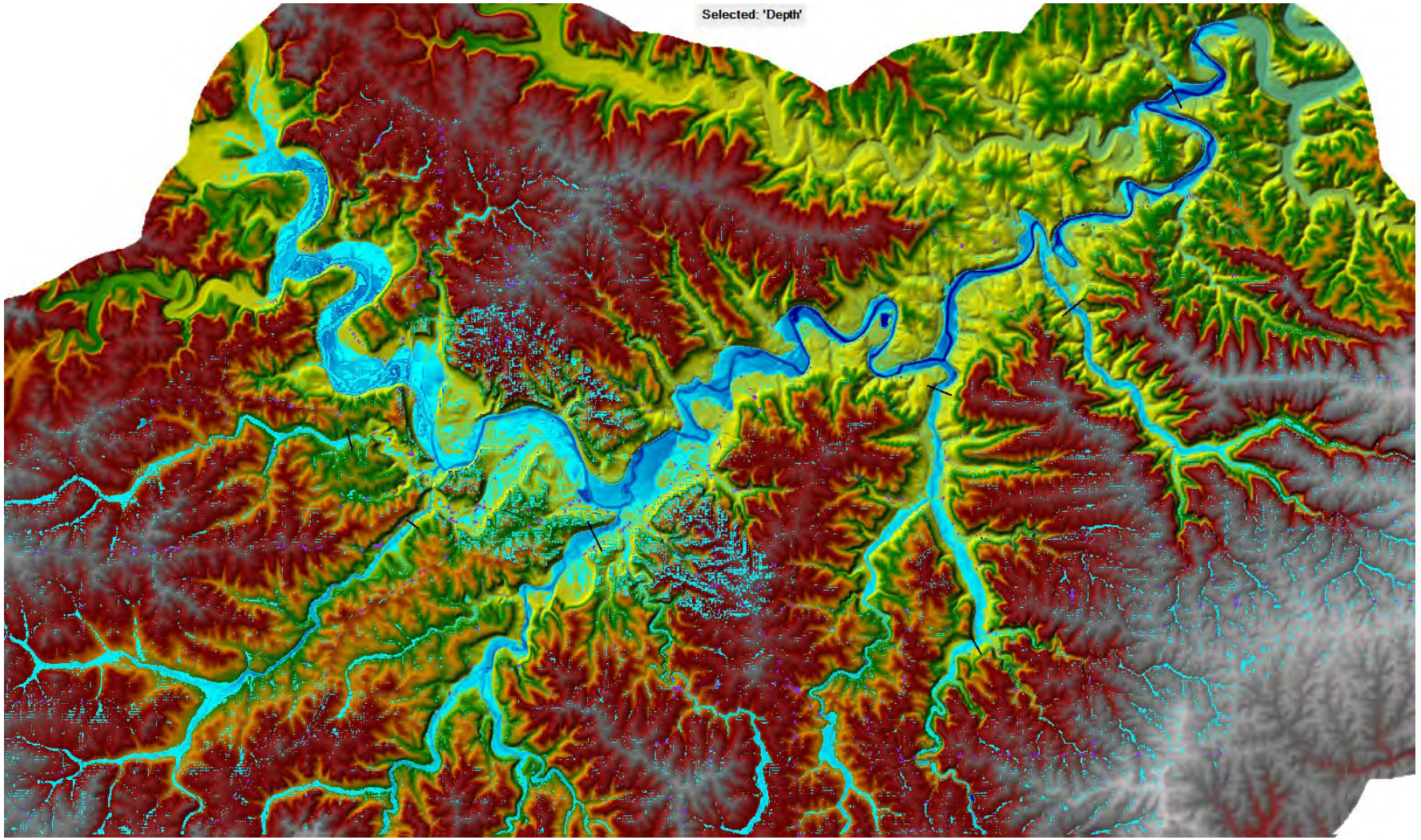
Probabilistically-derived from the extensive range of flood scenarios analyzed

Key Outputs



Available for dozens to hundreds of different modeled flood scenarios

FEMA mapping is changing



FFRD Timing

- FEMA has been talking about this for a couple of years
- USACE is a key partner
- No specific news yet on when

Questions?

DEPARTMENT OF NATURAL RESOURCES

Thank You!

Jeff Weiss

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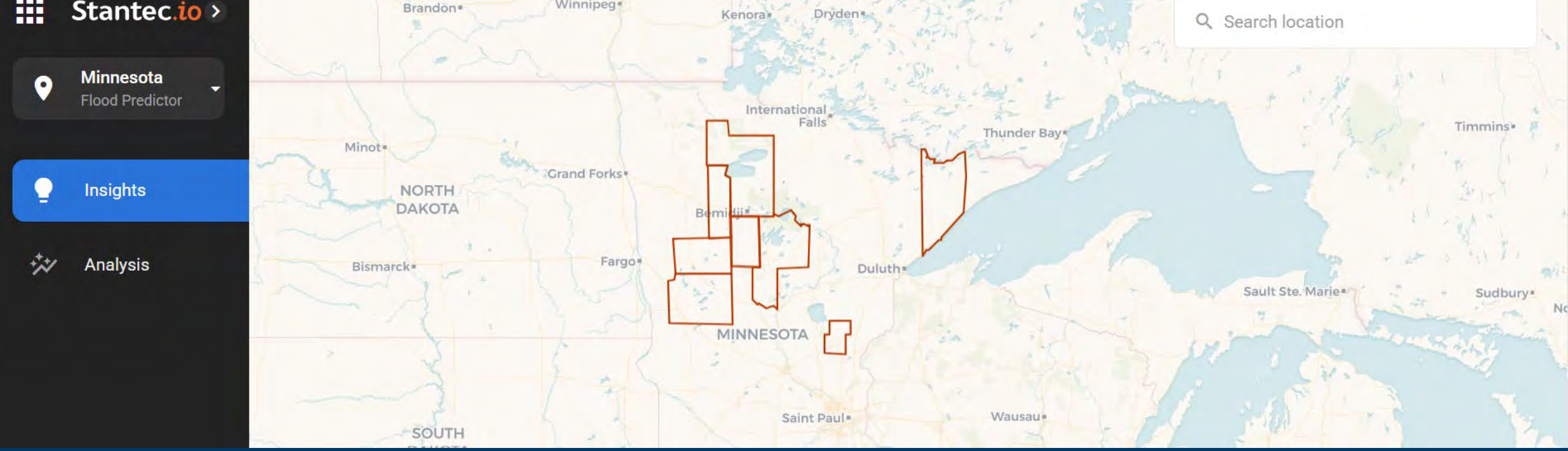
651-259-5802



Stantec Flood Predictor Tool

December 17, 2025

Jeff Weiss, State Floodplain Engineer | Garry Bennett, Floodplain Hydrologist

DEPARTMENT OF NATURAL RESOURCES

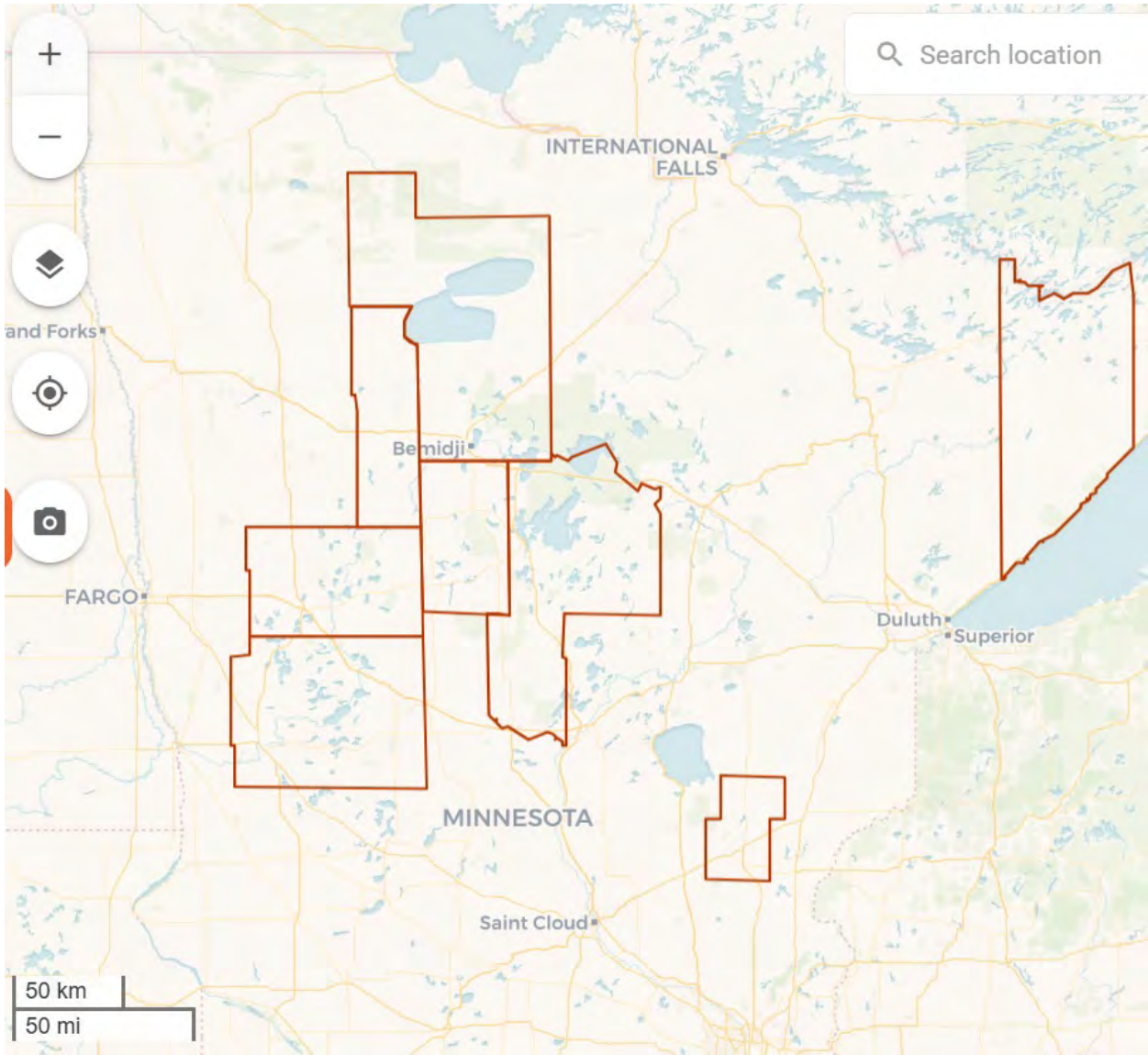
Flash Flood Assessment, the Why

- Understanding flash flood exposure is vital, especially the increasing frequency and intensity of extreme weather events.
- **Flash floods can strike suddenly causing severe damage to infrastructure, community disruption, and loss of life.**
- By thoroughly assessing flash flood exposure, we can better prepare and implement effective mitigation strategies, reducing the vulnerability of at-risk populations and enhancing resilience against future extreme weather disasters.

Included Counties

Unmapped counties, included in the tool:

- **Becker**
- **Beltrami**
- **Cass**
- **Clearwater**
- **Hubbard**
- **Lake**
- **Otter Tail**
- **…and Kanabec (is mapped)**



Source Data

The following source data were used as input into Flood Predictor:

- USGS National Hydrography Dataset (NHD).
- USGS National Land Cover Database(NLCD).
- USGS Digital Elevation Model(DEM). The National Map.
- Soil Survey Geographic Database (SSURGO).
- Daymet. Annual Averages.

The source data was reprojected into the WGS84 Web Mercator coordinate system (meters) and used to create the data derivatives and dimensionless engineering features for use in Flood Predictor.

The Flood Predictor modelling was optimized using data from:

- NOAA Atlas 14 Historical Extremes

Based on HUC-12

Otter Tail County MN

Flood Predictor

Simulations

ADD NEW SIMULATION

Search...

Selected Watersheds (0)

12-Digit HUC Value or Map Selection

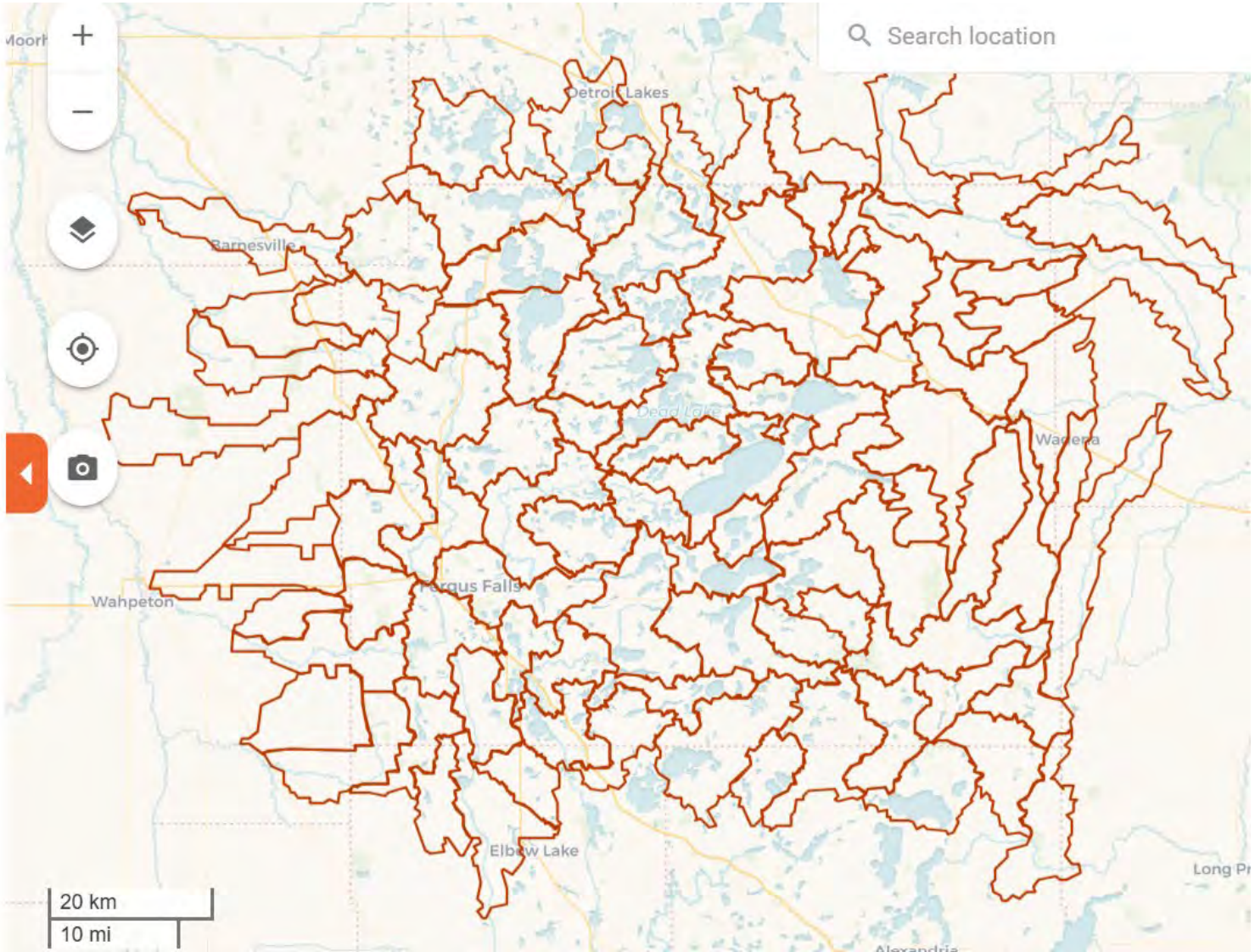
Flash Flood | Otter Tail County 100 Year

Custom | 06/12/2025 09:56 CST | User Email

jodi.lindsey@stantec.com

Rainfall 5.89 - 6.61 in | Runoff 1.63 - 4.38 in

1



1% Annual Chance Flood Probability

Probability (Confidence Level) – This represents the probability that a given model simulation will result with an inundated cell. The flood probability is the predicted probability that an area will experience flooding based on the selected simulation. The probability is shown as a percentage from 10-100% that an area is likely to flood for that scenario.

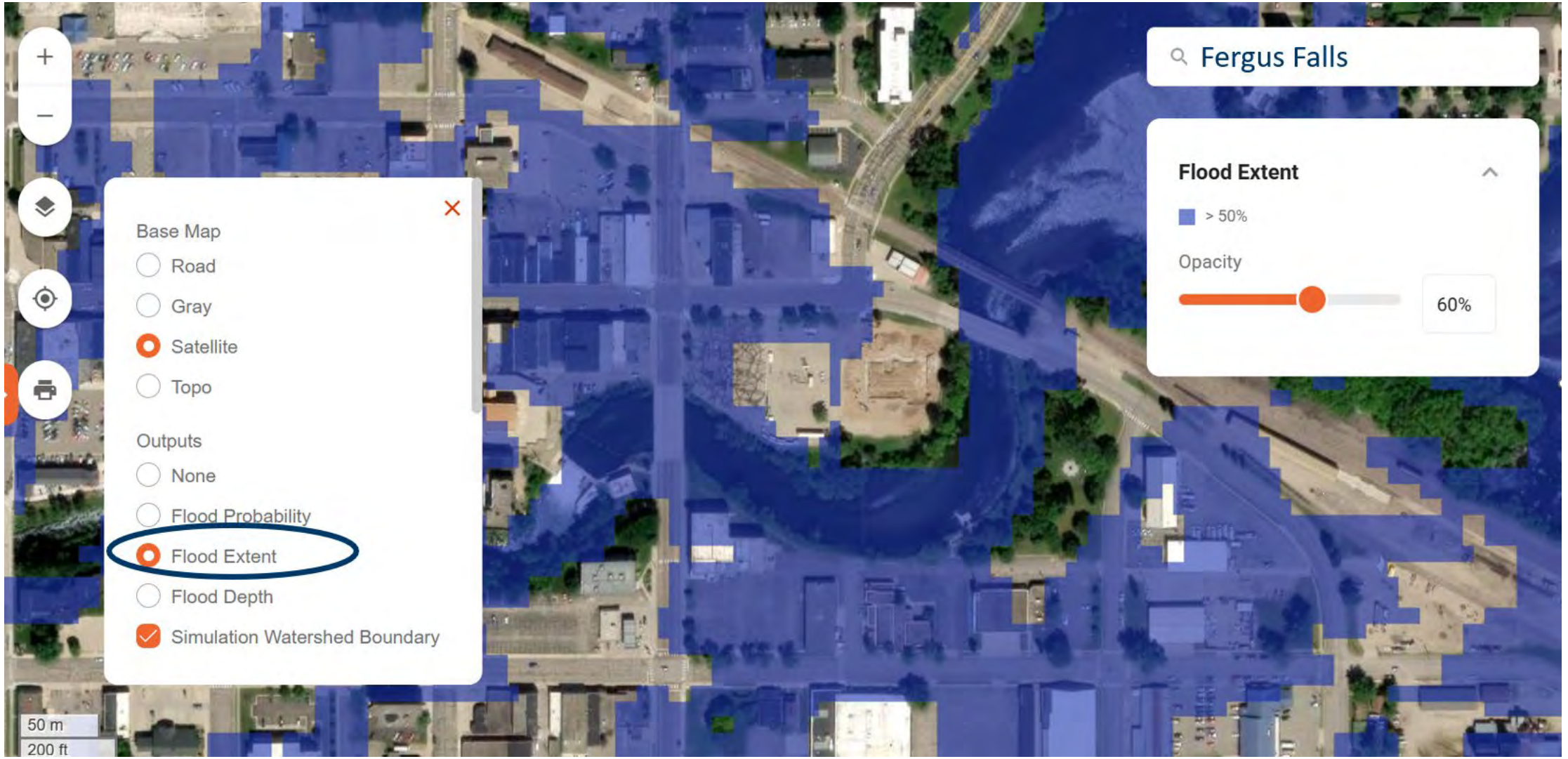
Cell size = about 0.02 acres or 1,000 square feet

1% Annual Chance Flood Probability

1% Annual Chance Flood Extent

Prediction (Extents) – The Flood Prediction or Flood Extent is the predicted extent of inundation for all areas with 50% or greater confidence level of flooding for that given simulation.

1% Annual Chance Flood Extent

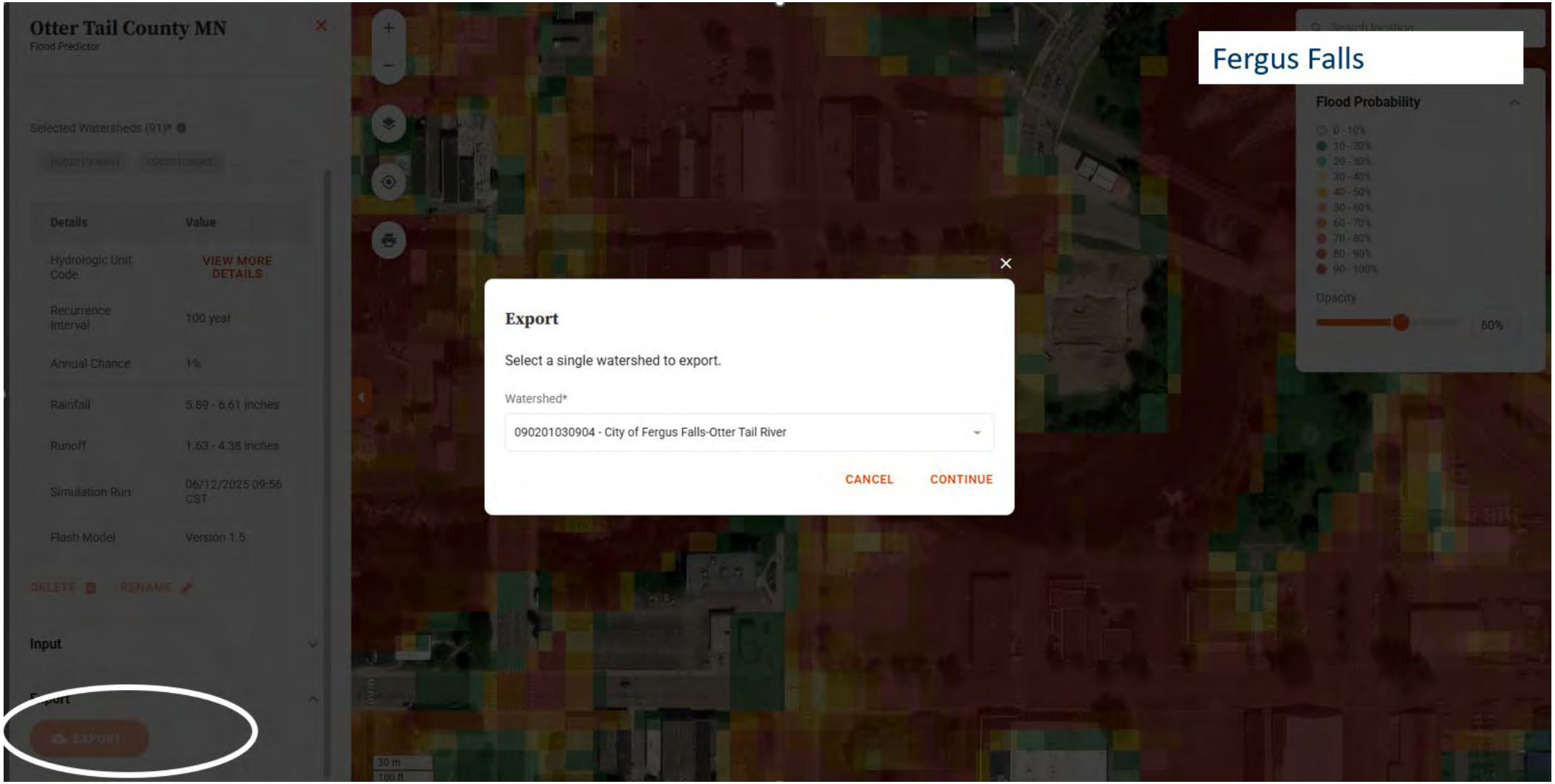


1% Annual Chance Flood Depth

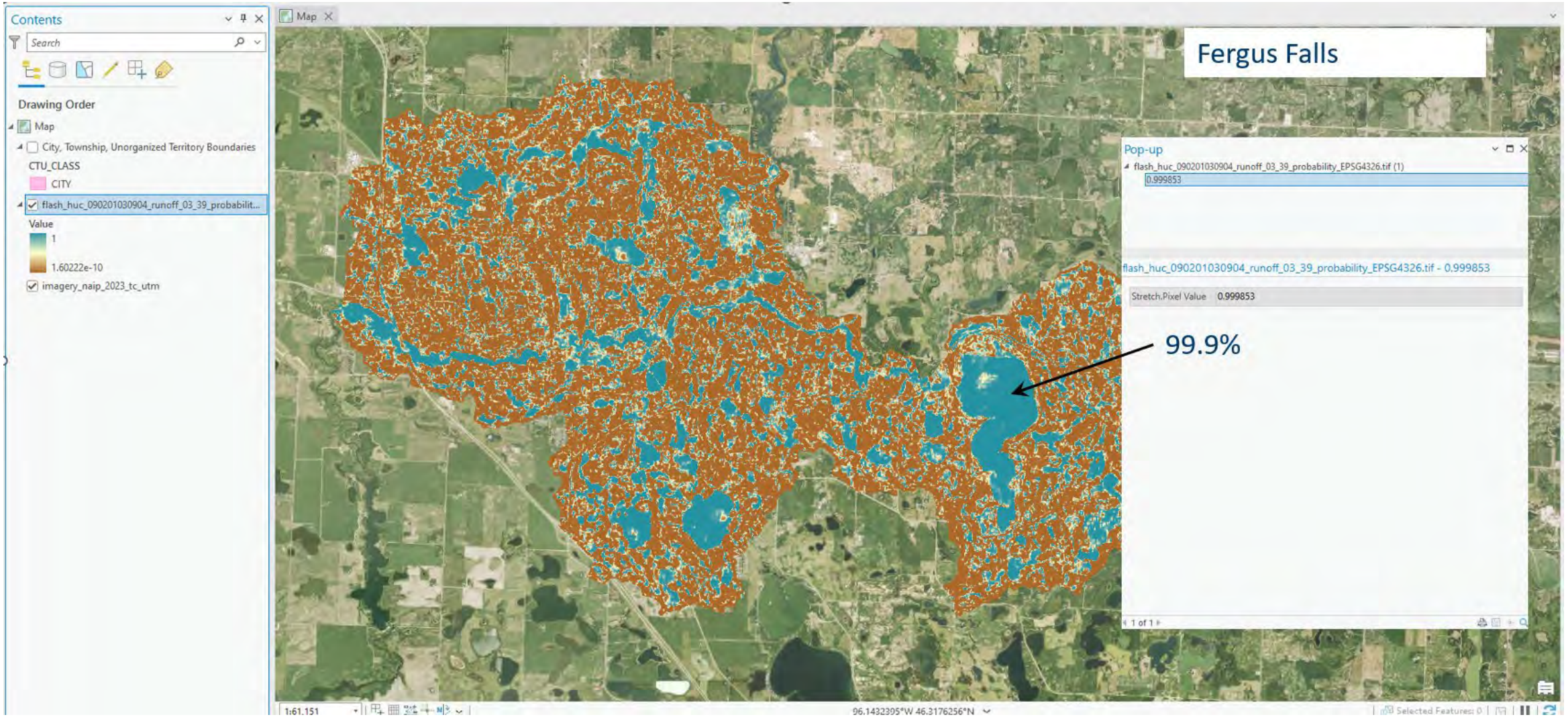
Depth – The Depth is the predicted depth of flood water based on the predicted flood extents and simulation scenario. The depth is shown as gradations from 0 to greater than 5 feet within the predicted extent of flooding and can be queried by cell on the map.

1% Annual Chance Flood Depth

Exporting Data



Flood Probability Raster File Export



Virtual Demonstration (if time)

Garry Bennett, CFM

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