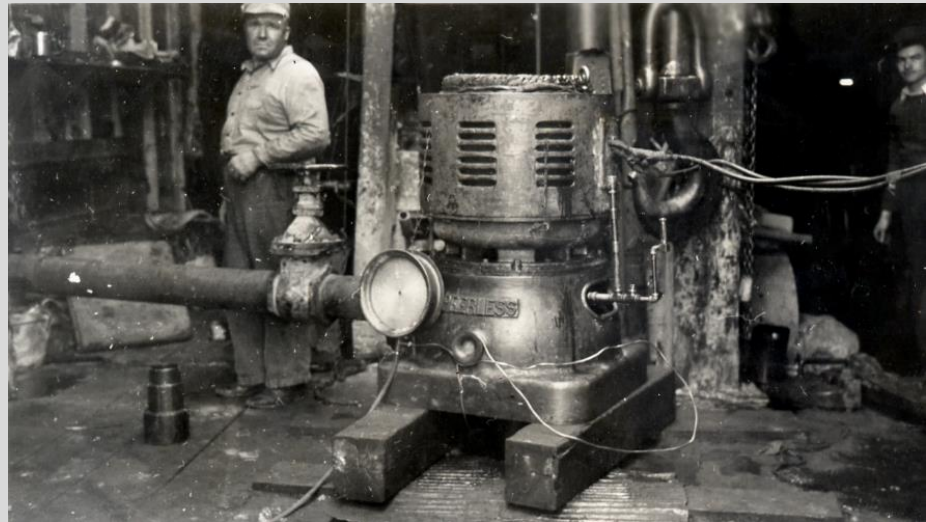


*Revisiting one of the largest aquifer tests in history: Implications for
fault zone hydrogeology and the declining groundwater supply in
Northeastern Illinois*



Well 2- April, 1941

Daniel R. Hadley, PG and Daniel B. Abrams, PhD

*Illinois State Water Survey,
University of Illinois*

GSA North-Central Meeting 2018

I ILLINOIS

Illinois State Water Survey

PRAIRIE RESEARCH INSTITUTE

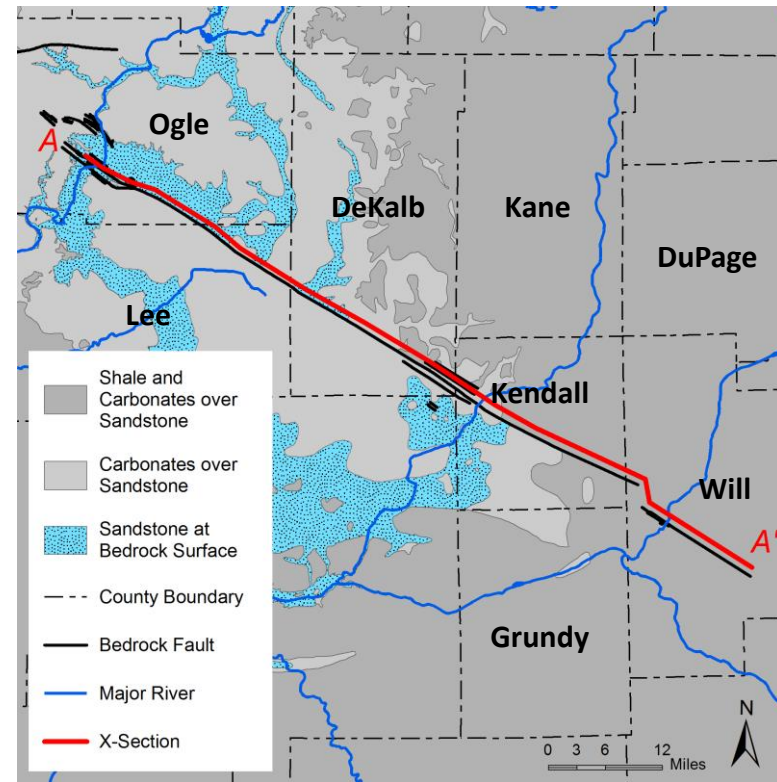
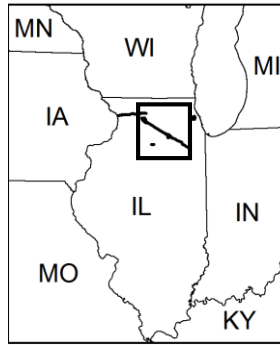


Hydrostratigraphy

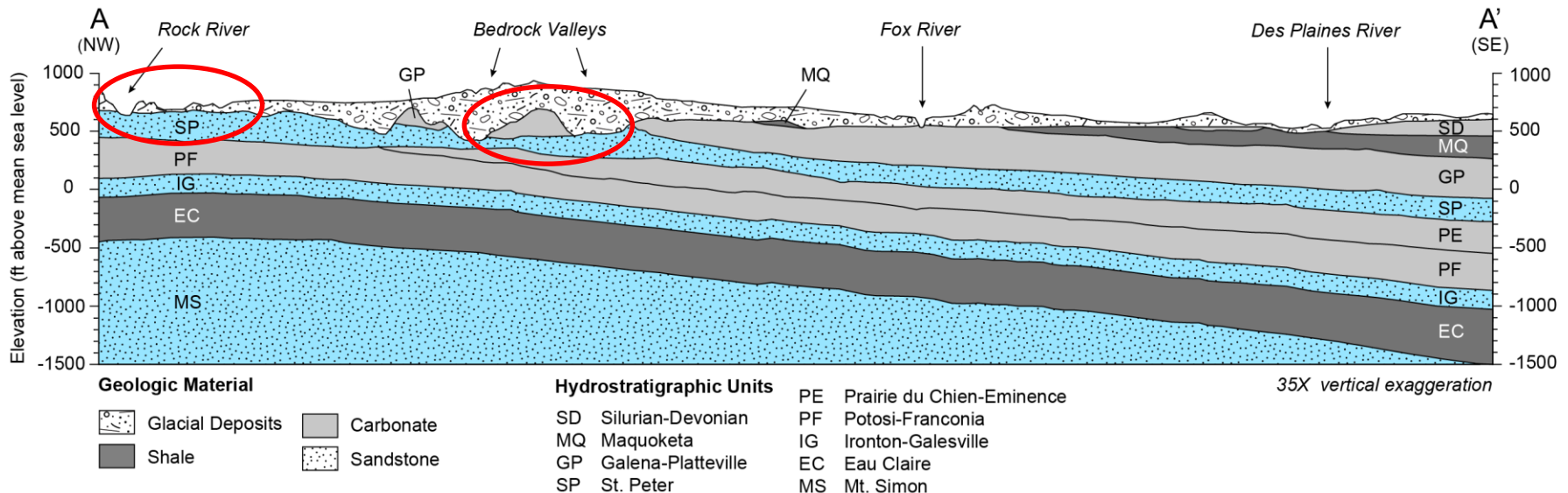
- St. Peter Sandstone
- Ironton-Galesville Sandstone

Sandwich Fault Zone

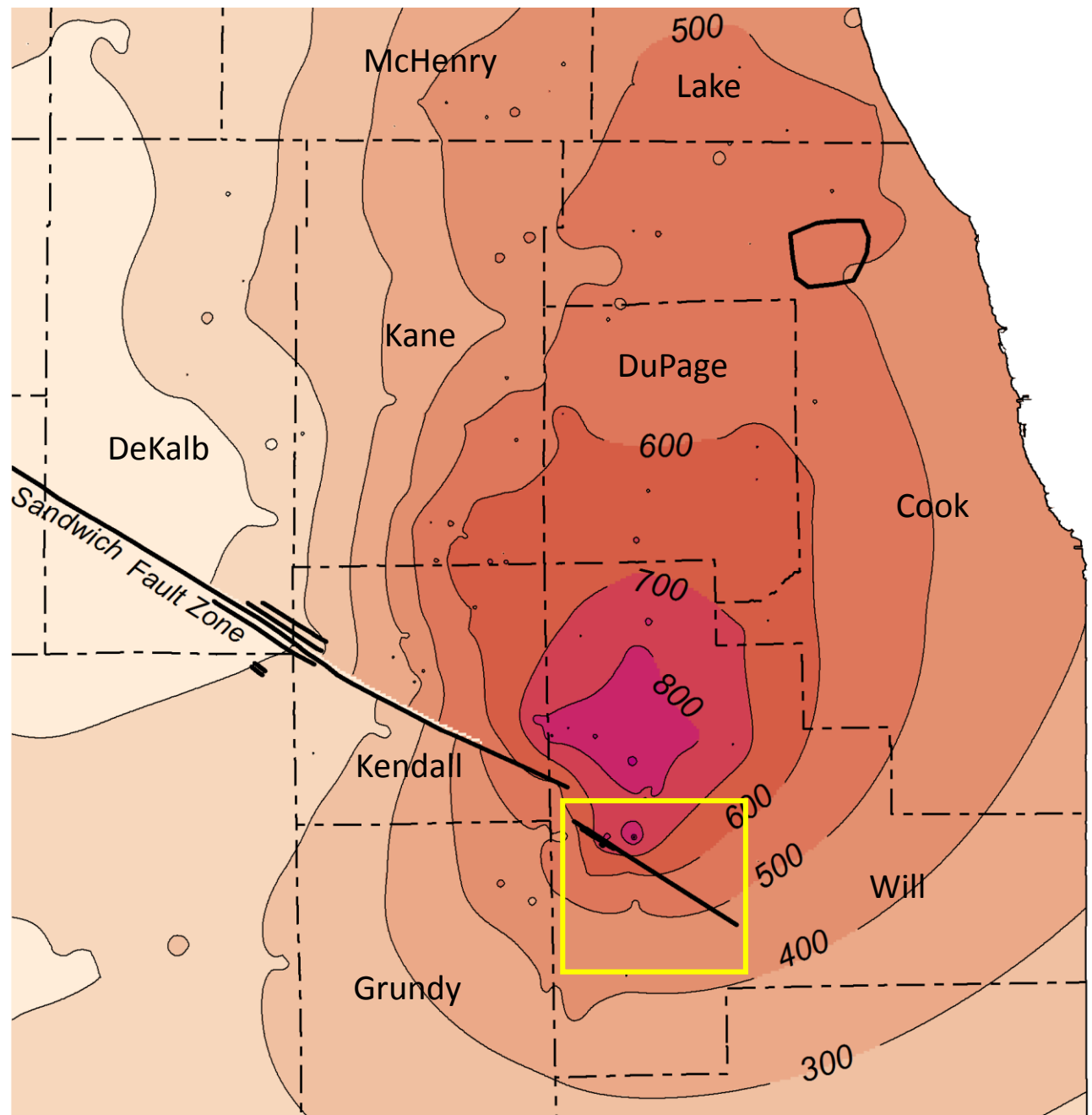
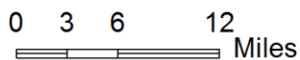
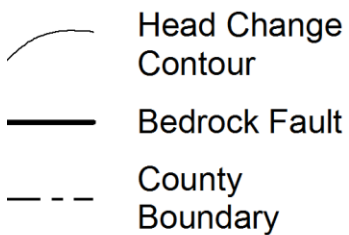
- High Angle Normal Fault
- 85 miles long, 1-2 miles wide
- Variable displacement, as much as 800 feet of offset



RECHARGE AREAS



Drawdown Since Predevelopment (ft)



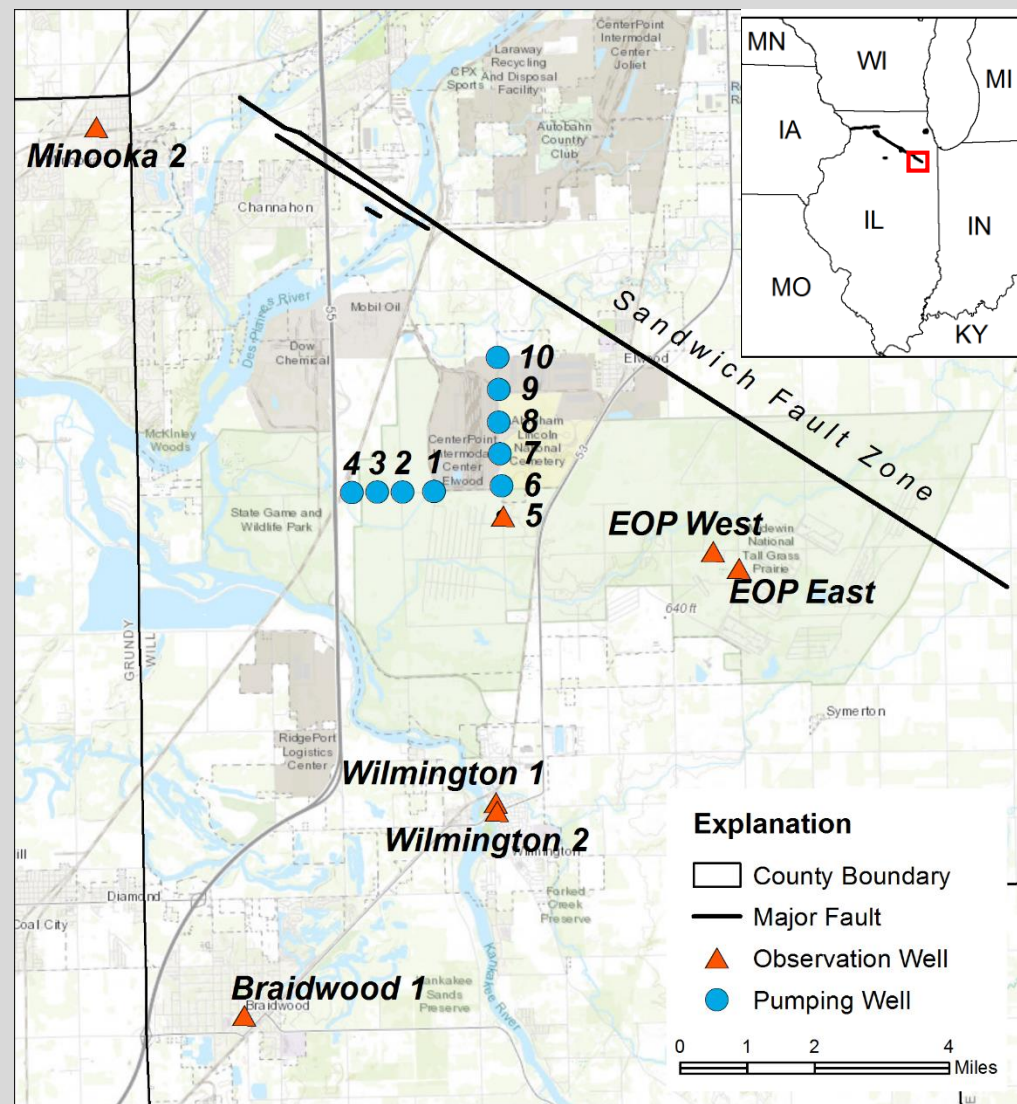
Fault zone modeled as a flow barrier with low hydraulic conductivity (K) zone (A HUGE UNKNOWN)

Arsenal Aquifer Test

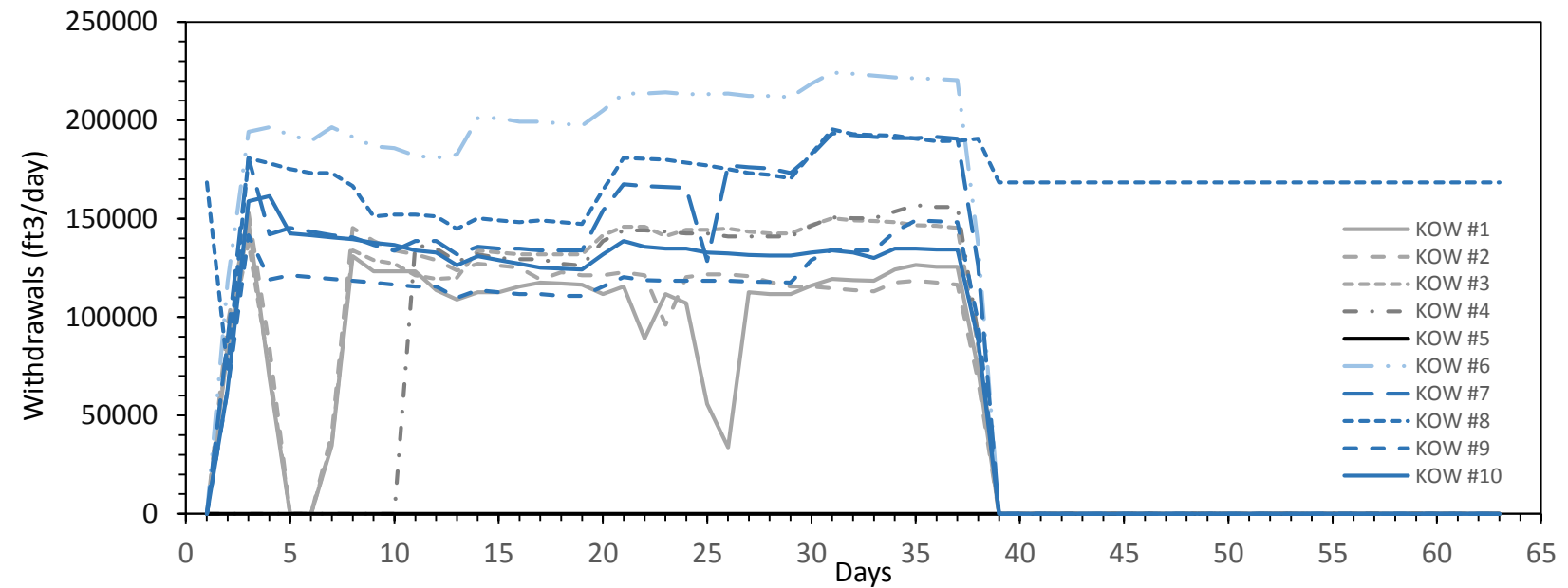
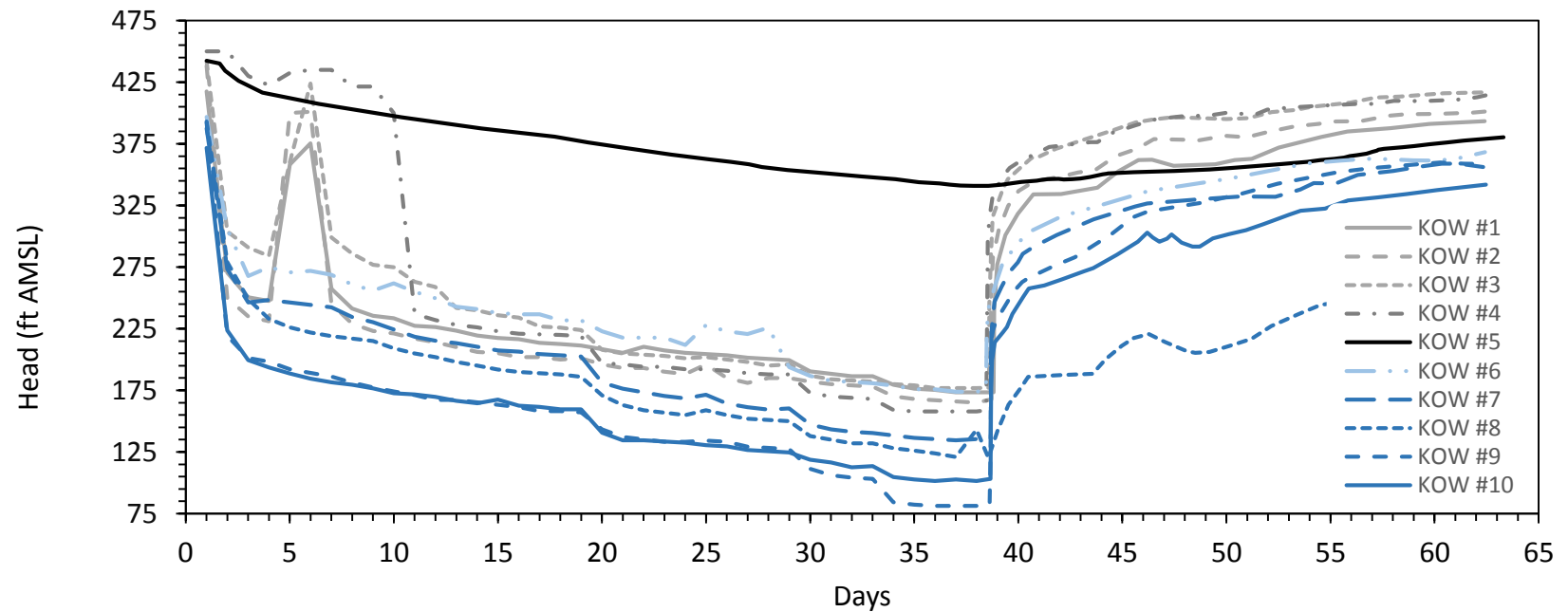
- WWII ammunition plant needed large water supply
- 10 Deep Sandstone Wells (evenly spaced)
- Open to both St. Peter and Ironton-Galesville Sandstones
- Conducted 37 day aquifer test in 1942
- 9 wells pumping over 9 MGD on average
- 1 St. Peter only observation well (5)
- Observations at adjacent plants and towns
- Daily withdrawal rates and water levels recorded
- 25 days of recovery observations
- Perhaps the largest aquifer test in North American history?

Questions

- *What can this aquifer test tell us about the fault?*
- *What can this aquifer test tell us about model parameters?*



Need for transient model

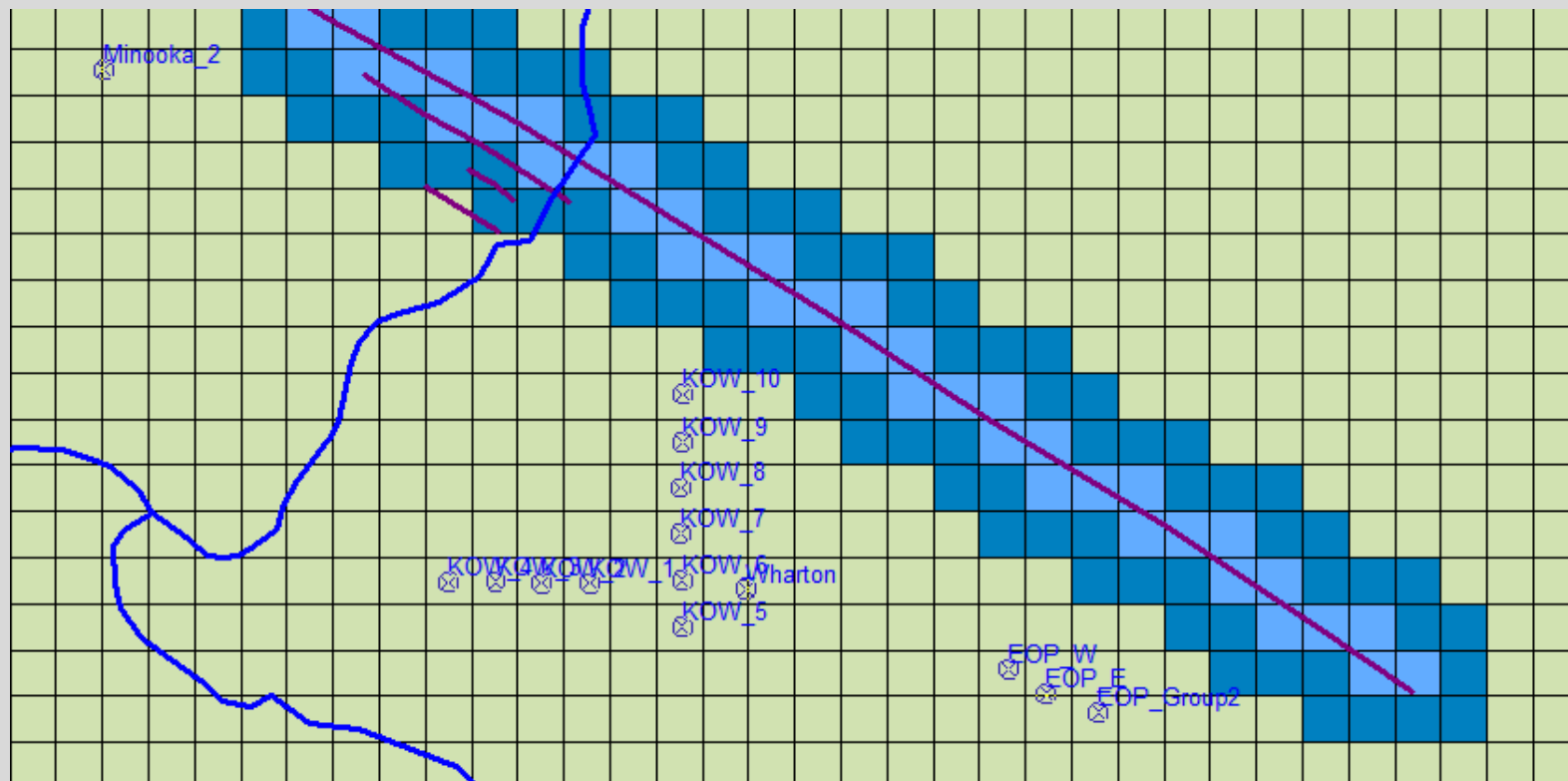


Model Setup

- Illinois Groundwater Model
- 21 layers (10 quaternary and 11 bedrock)
- 2500 ft² Grid
- 1863 to present (and future scenarios)
- Arsenal wells and observation wells simulated as CLN wells
- MODFLOW-USG

Fault Zone Conceptualization

- Inner Fault Core/Outer Damage Zone
- Varied sandstone hydraulic conductivity (K_h)
- Ranged from no change in comparison to host rock to 3 orders of magnitude decreases in K_h
- 23 different model runs so far

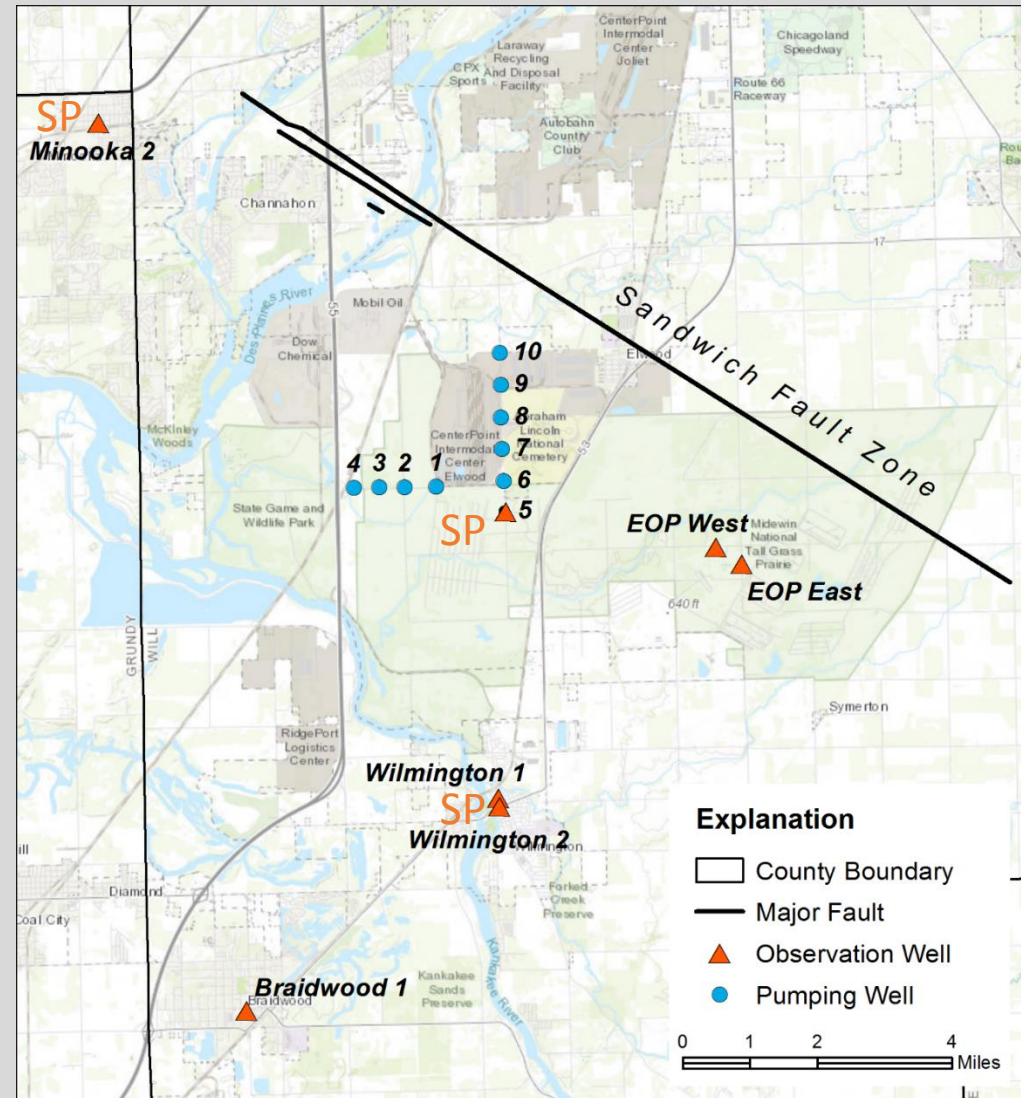


Initial Calibration

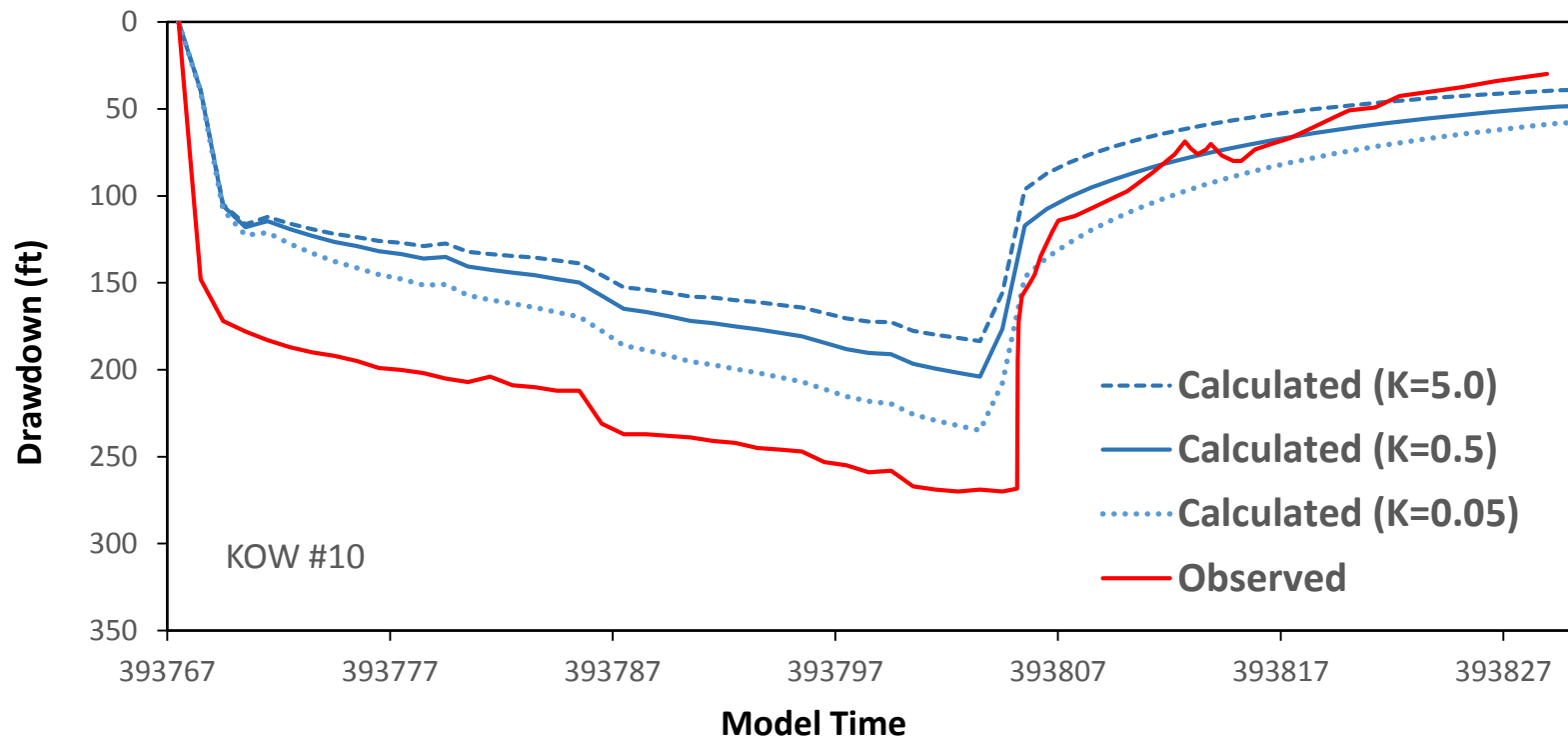
- Initial analytic analysis using Theis curve
- $K_h = 5 \text{ ft/day}$ for sandstones
- Specific Storage (S_s) = $5.5e^{-7} \text{ ft}^{-1}$

Calibration Targets

- 9 Pumping Wells
- 7 Observation Wells (3 St. Peter only wells and 4 multiaquifer wells)
- Overall Drawdown
- Slope of drawdown curves
- Regional historic calibration to heads, needs updated locally
- Confined conditions throughout the test

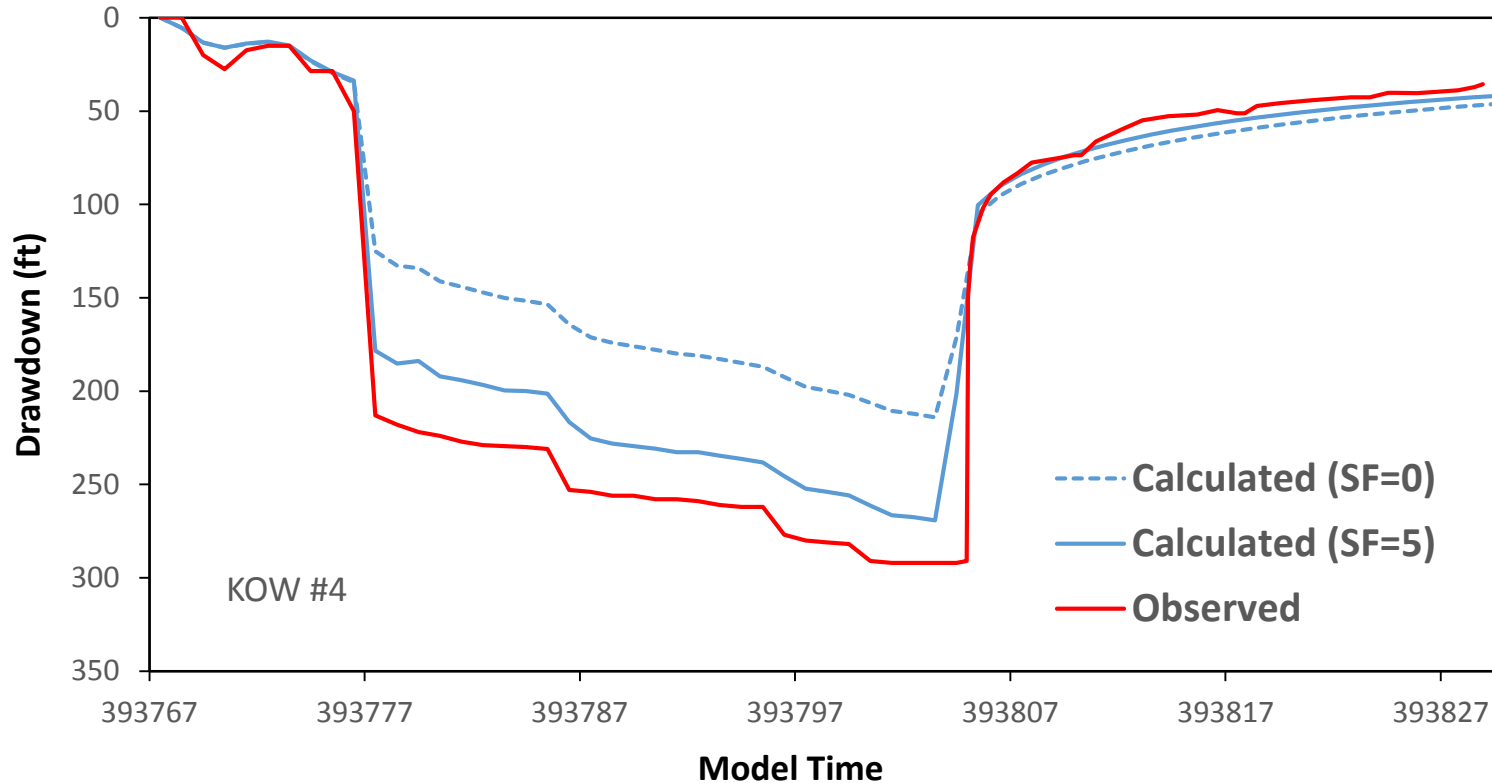


Calibration- K of Fault Zone

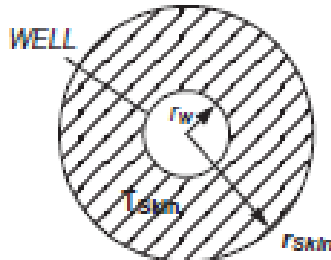


- Well 10 and 9 have low specific capacities and slowest recovery (closest to fault)
- Slope of drawdown curve affected by fault hydraulic conductivity
- Order of magnitude decrease ($K_h=0.5$ ft/day) seems *just right*
- Arsenal wells (and especially far observation wells) insensitive to fault flow resistance
- ***Fault Zone has large impact locally (within 1-3 miles), much less influence beyond that***

Calibration-Skin Factor

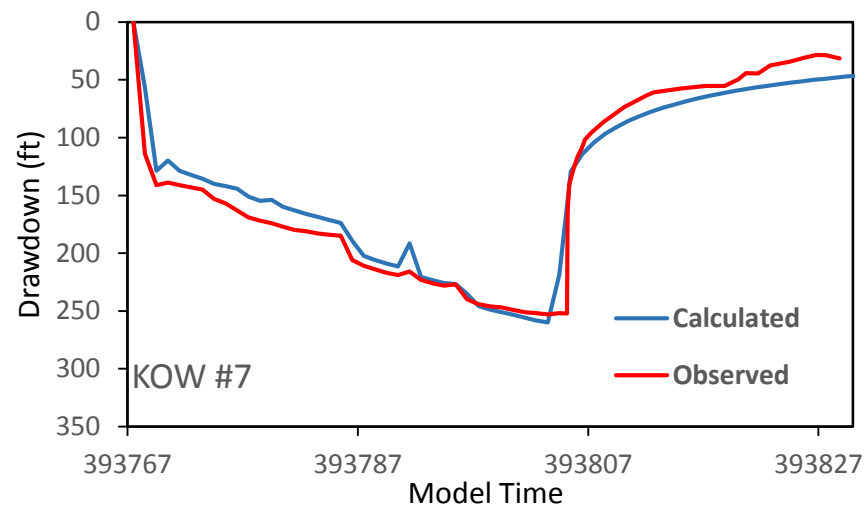


$$Skin = \left(\frac{T}{T_{Skin}} - 1 \right) \ln \left(\frac{r_{Skin}}{r_w} \right) \text{ where,}$$



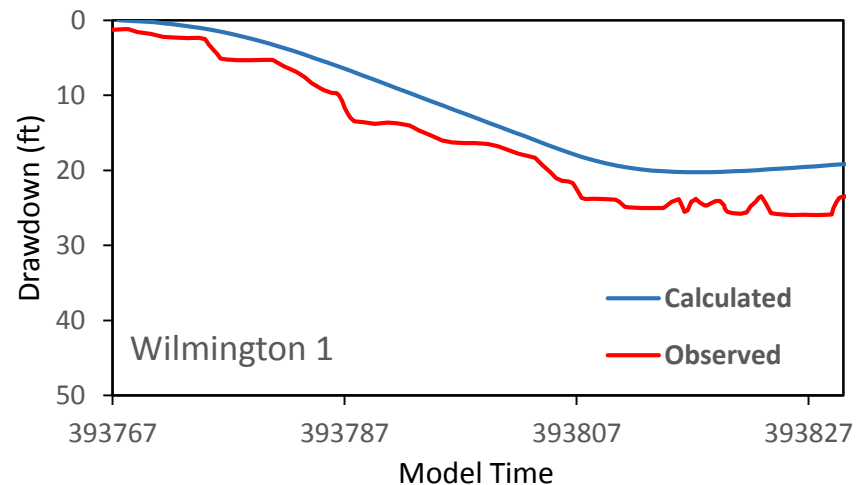
- Skin Factors simulate well inefficiency
- Needed to match observed drawdowns
- Particular to each well
- Positive skin factor- $K_{aquifer} > K_{skin}$
- ***Does not affect slope of drawdown***

Pumping Wells (Run #23)



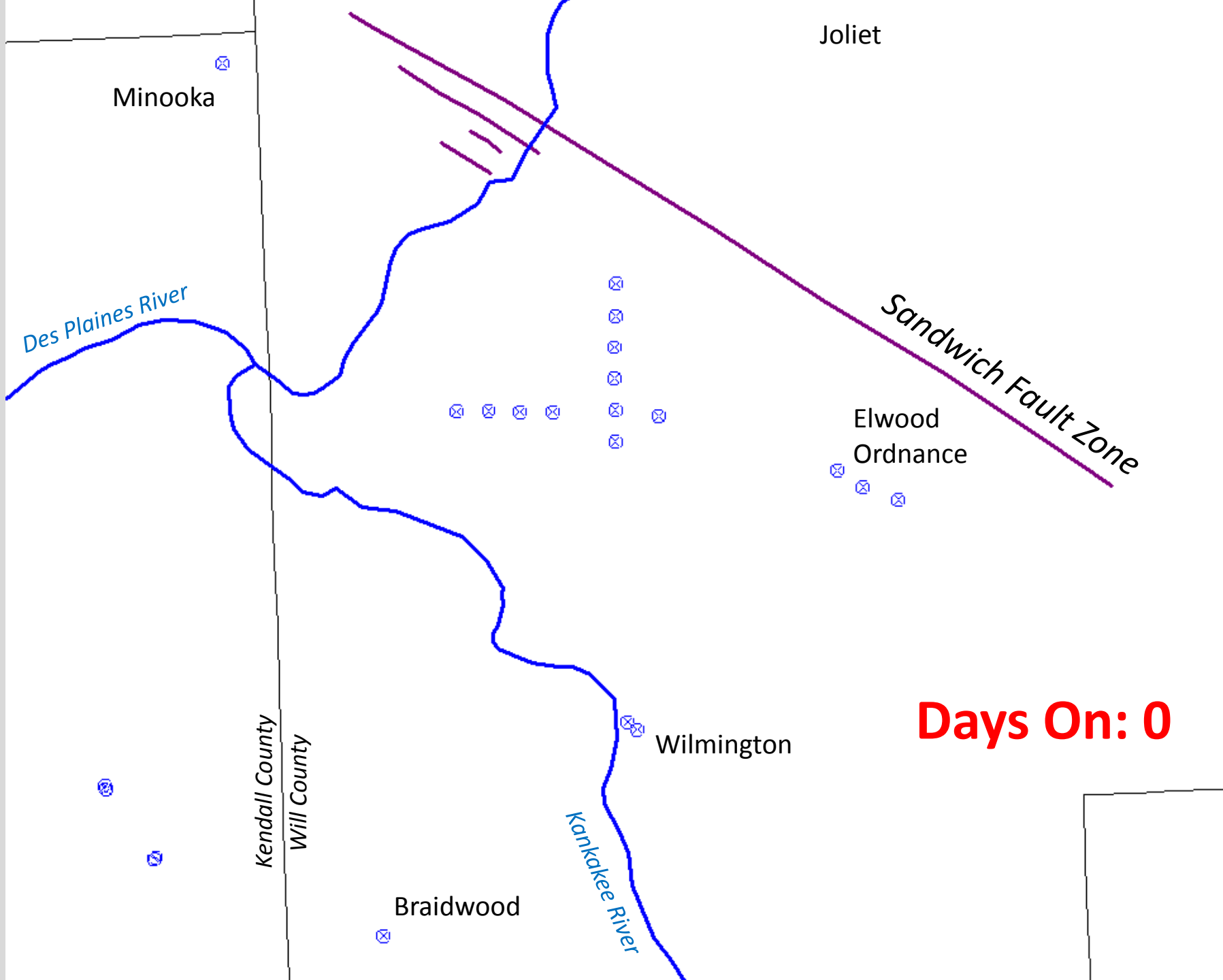
| | Calculated | Observed | Residual |
|--------|------------|----------|----------|
| KOW 1 | 259 | 244 | 15 |
| KOW 2 | 249 | 273 | -24 |
| KOW 3 | 271 | 265 | 6 |
| KOW 4 | 269 | 292 | -23 |
| KOW 6 | 268 | 223 | 45 |
| KOW 7 | 259 | 252 | 7 |
| KOW 8 | 249 | 250 | -1 |
| KOW 9 | 275 | 311 | -36 |
| KOW 10 | 252 | 270 | -18 |
| Mean | 261 | 264 | -3 |

Observation Wells (Run #23)



| | Calculated | Observed | Residual |
|-------|------------|----------|----------|
| KOW 5 | 119 | 101 | 18.0 |

| | Calculated | Observed | Residual |
|--------------|------------|----------|----------|
| Wilmington 1 | 16.5 | 22 | -5.5 |
| Wilmington 2 | 17.5 | 20 | -2.5 |
| Minooka 2 | 8.6 | 4 | 4.6 |
| Braidwood 1 | 3.3 | 2.5 | 0.8 |
| Mean | | | -2.6 |



Joliet

Minooka

Des Plaines River

Sandwich Fault Zone

Elwood
Ordinance

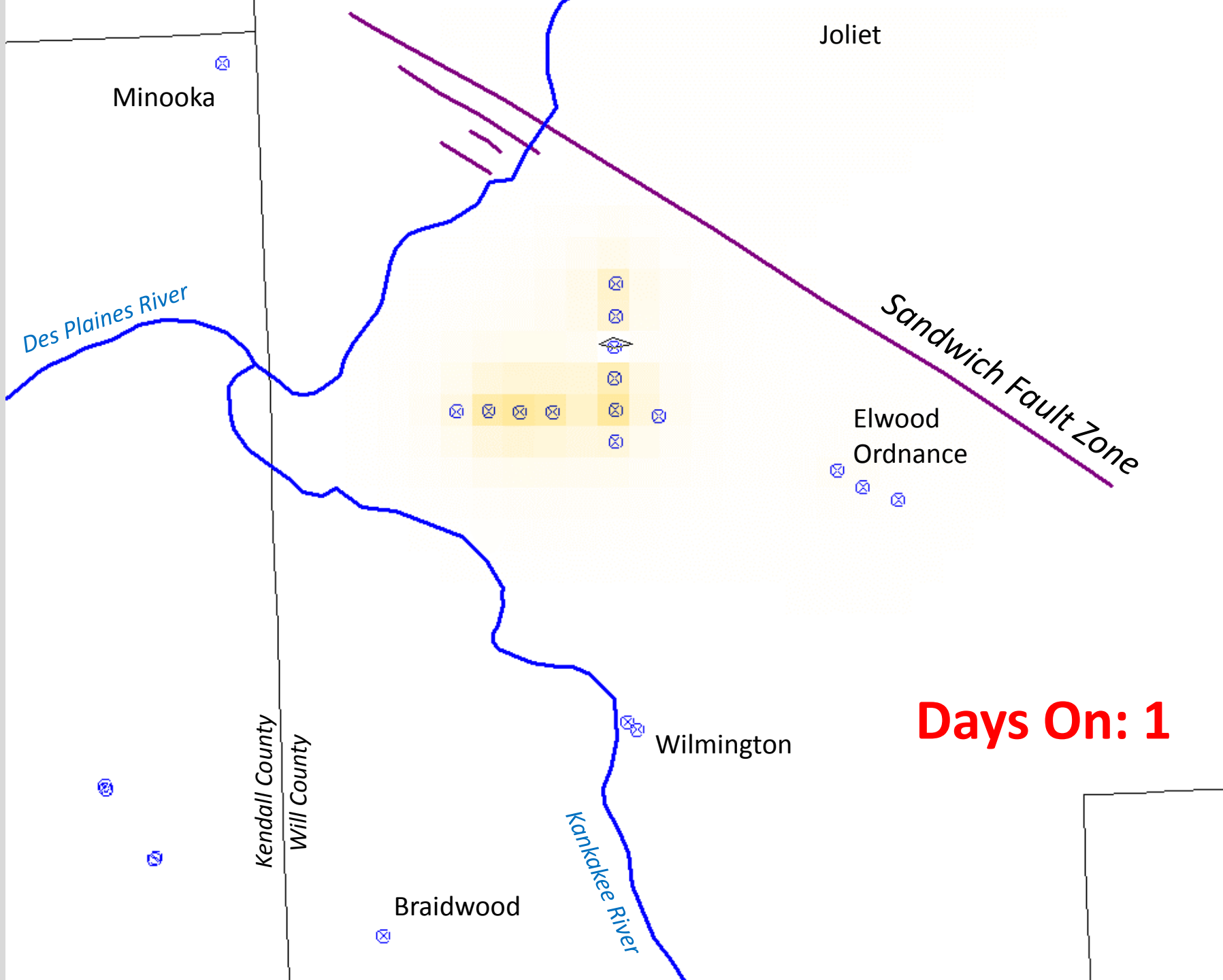
Wilmington

Braidwood

Kankakee River

Kendall County
Will County

Days On: 0



Minooka

Joliet

Des Plaines River

Sandwich Fault Zone

Elwood
Ordinance

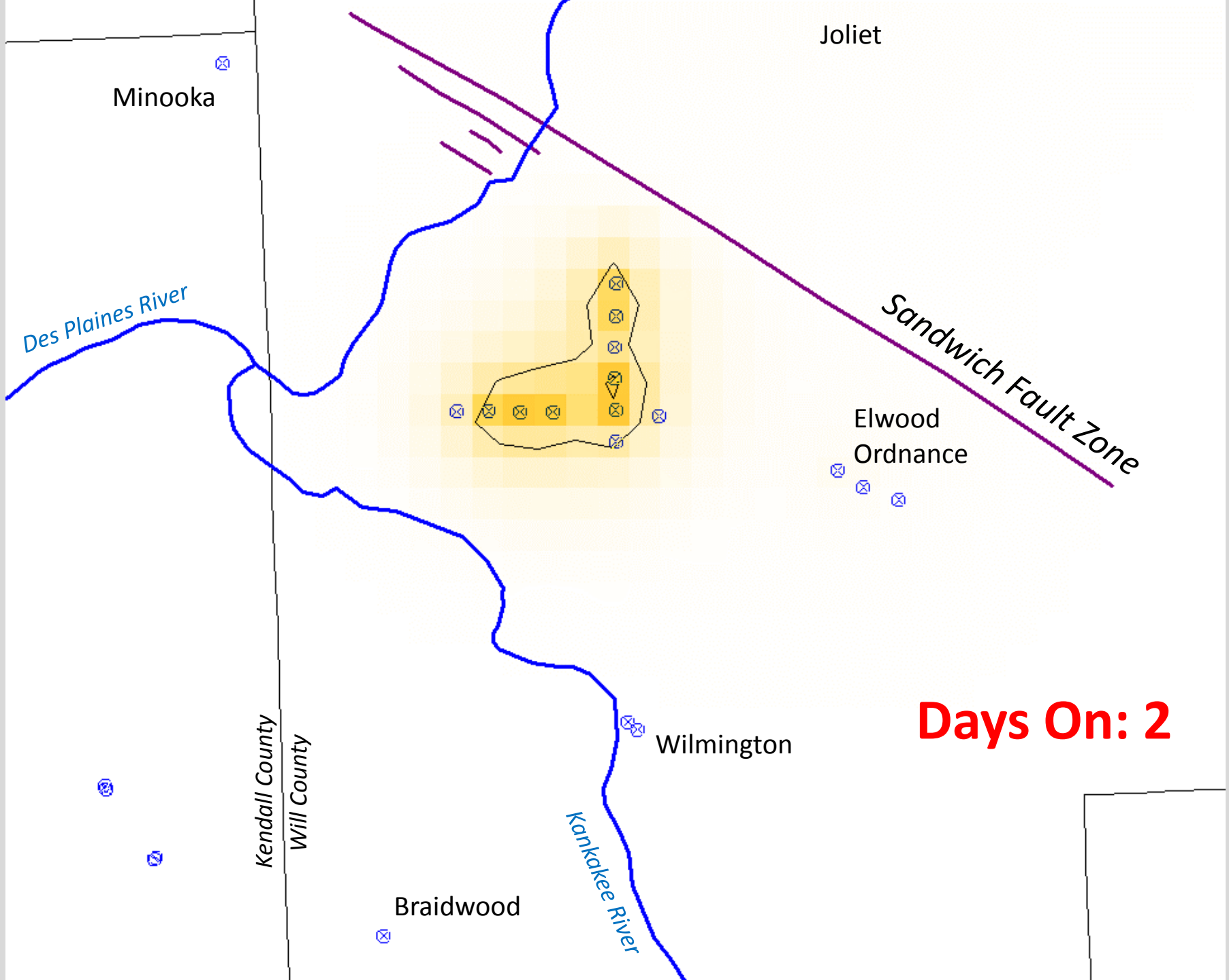
Wilmington

Braidwood

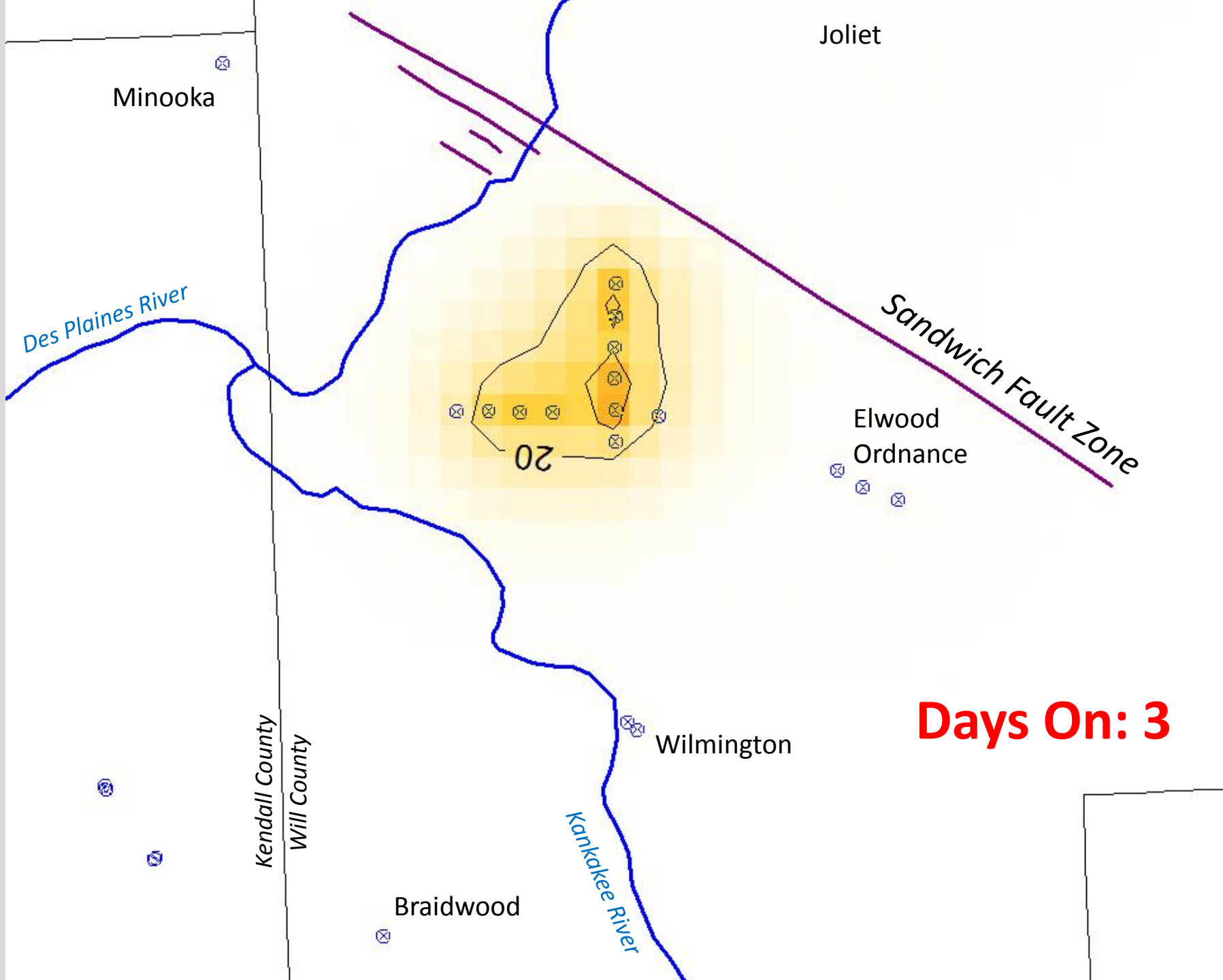
Kankakee River

Kendall County
Will County

Days On: 1



Days On: 2



Joliet

Minooka

Des Plaines River

Sandwich Fault Zone

Elwood
Ordinance

20

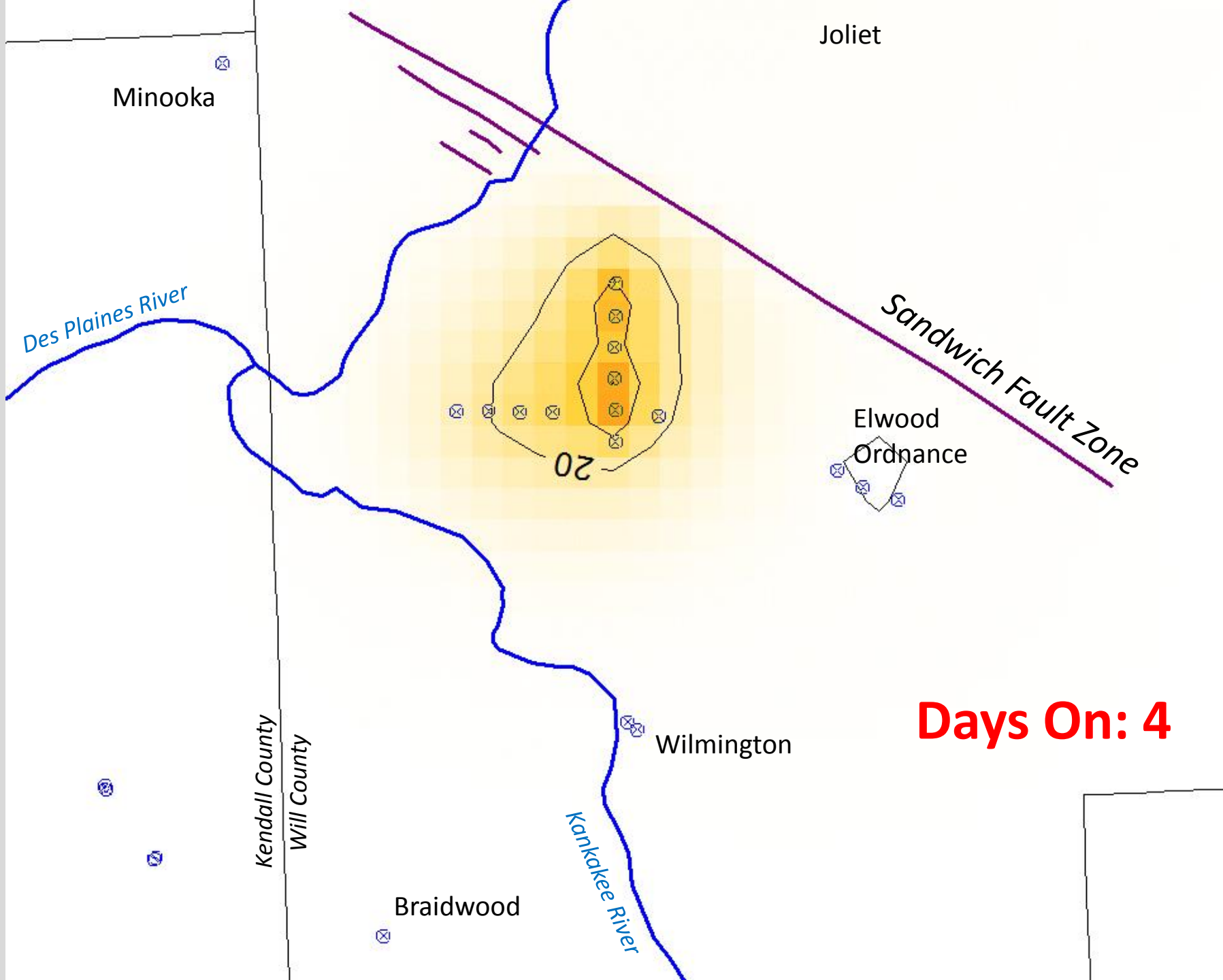
Kendall County
Will County

Wilmington

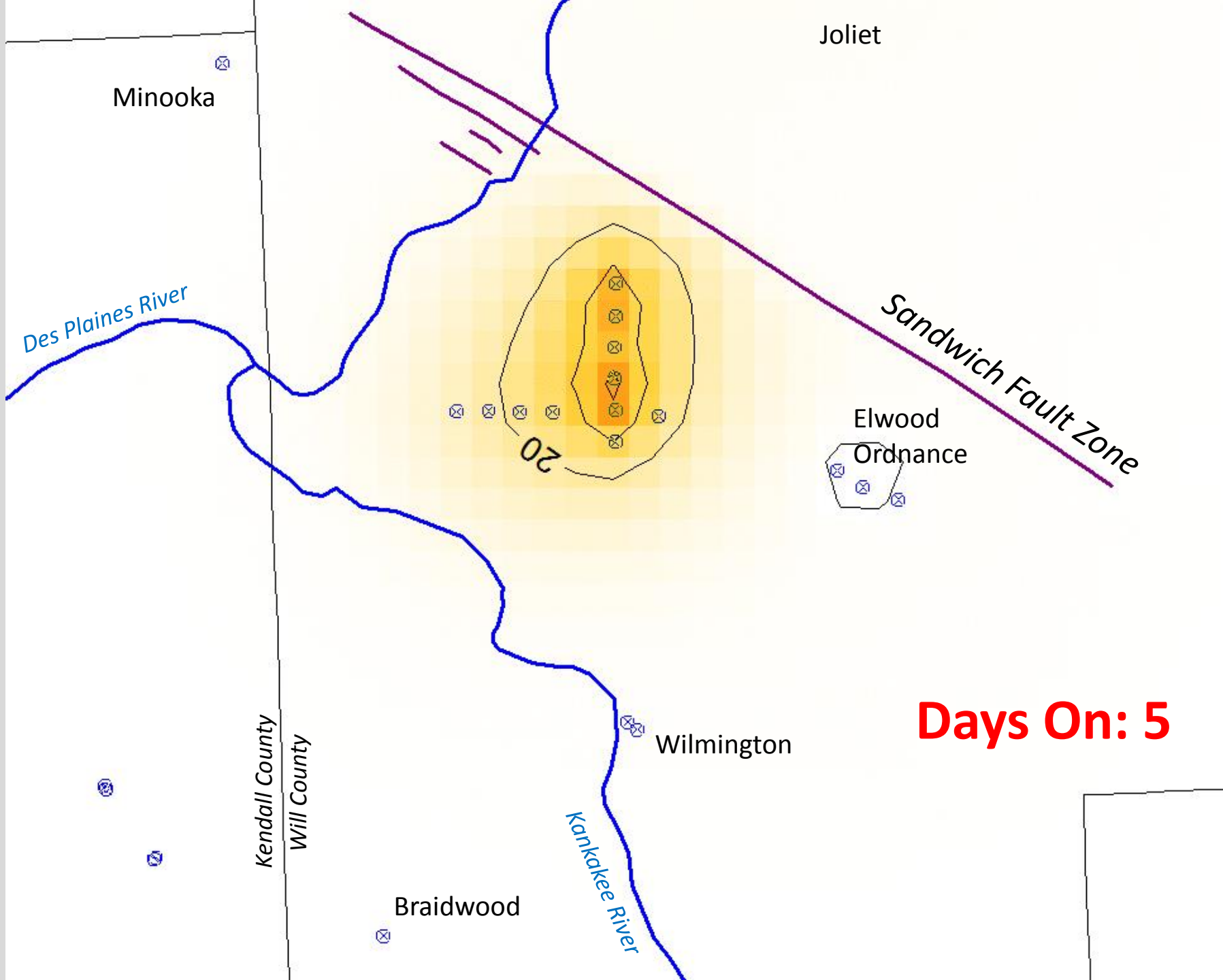
Braidwood

Kankakee River

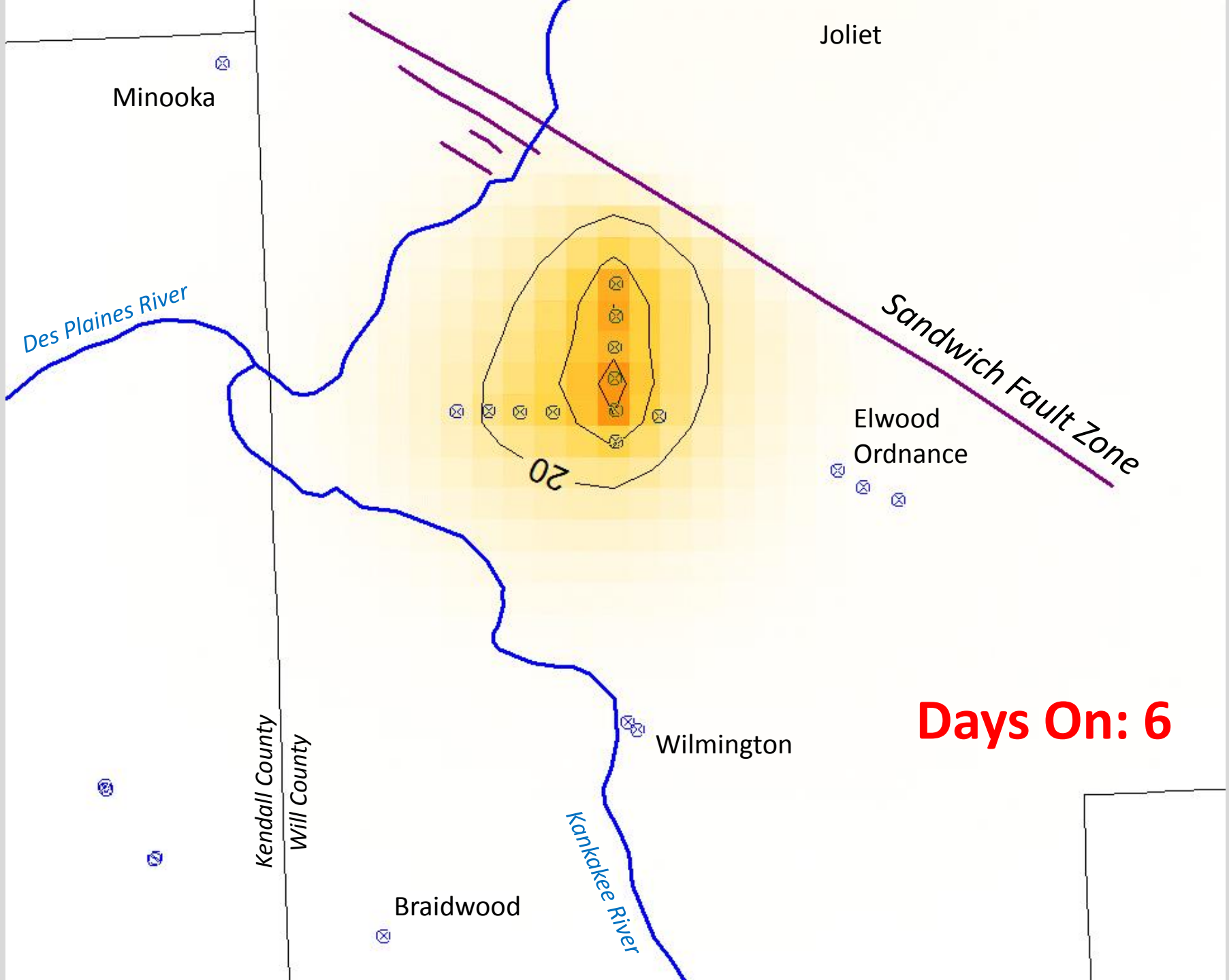
Days On: 3



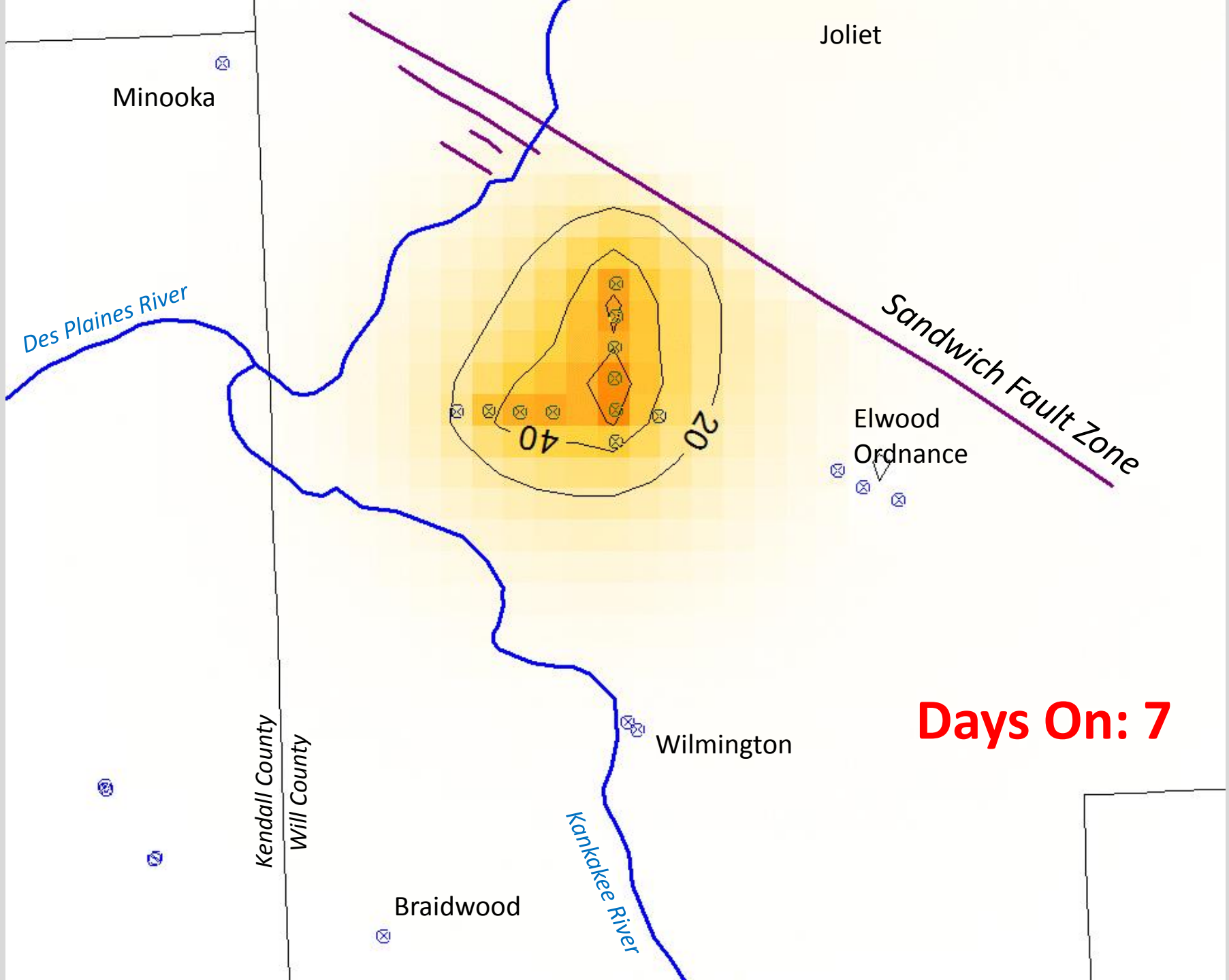
Days On: 4

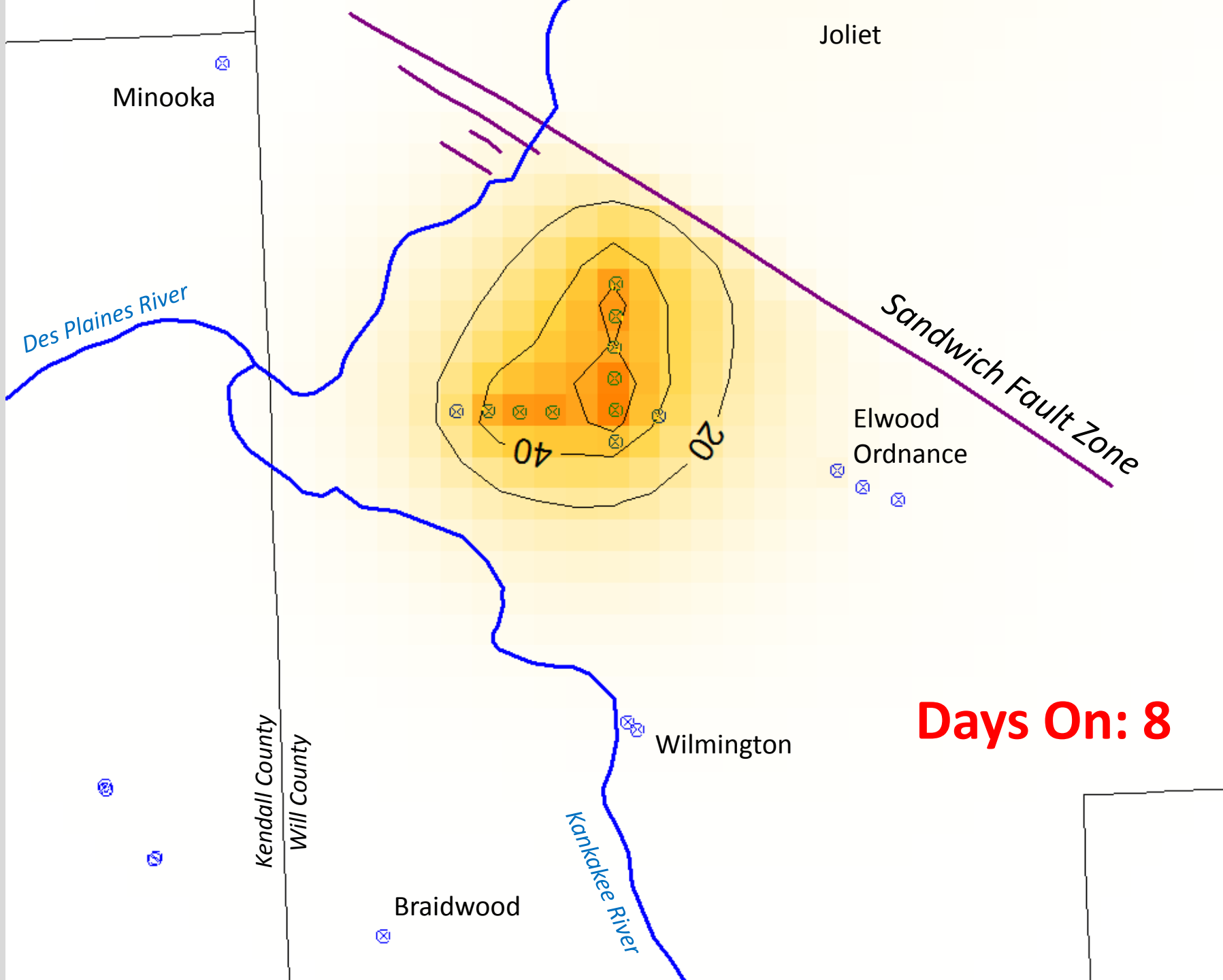


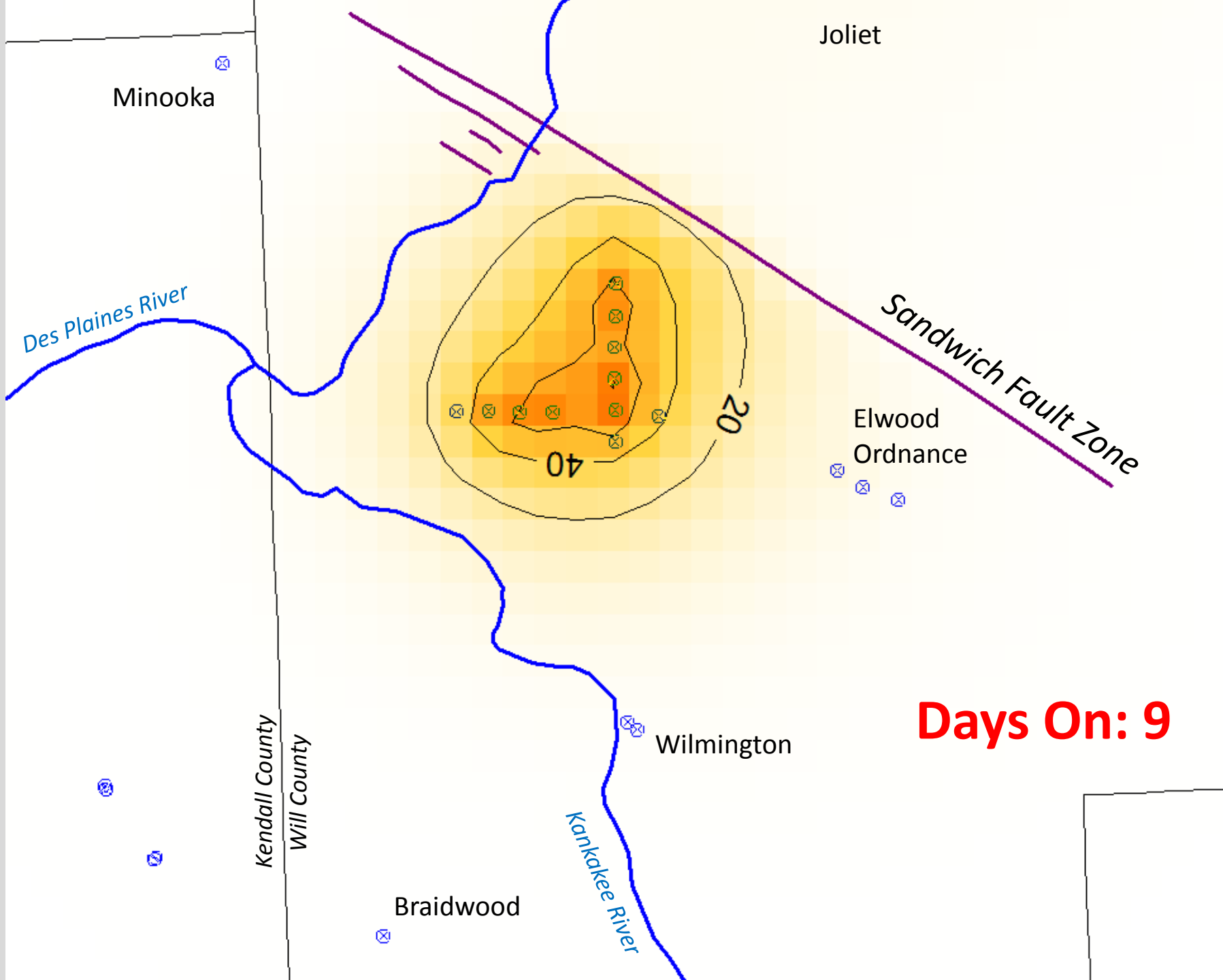
Days On: 5

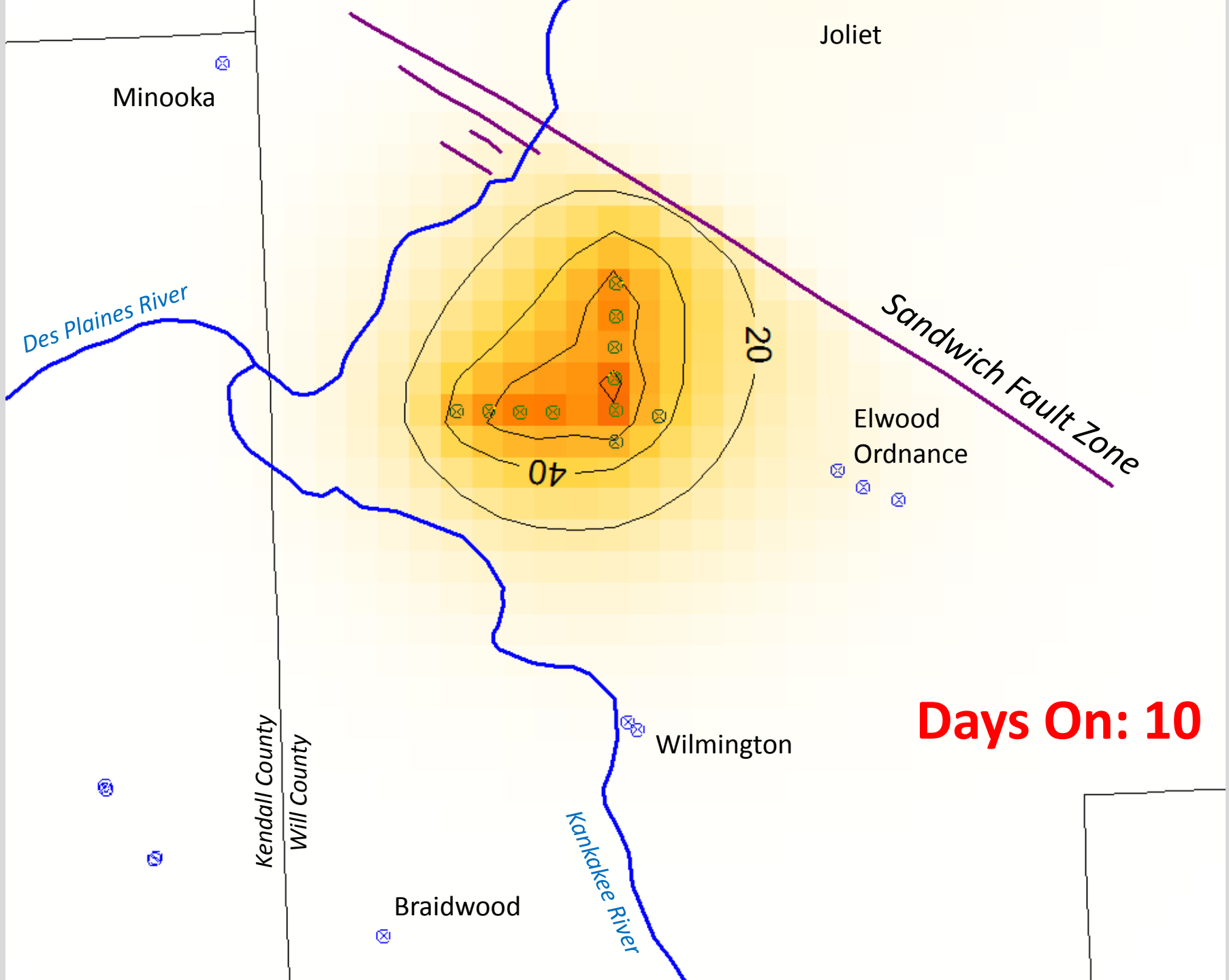


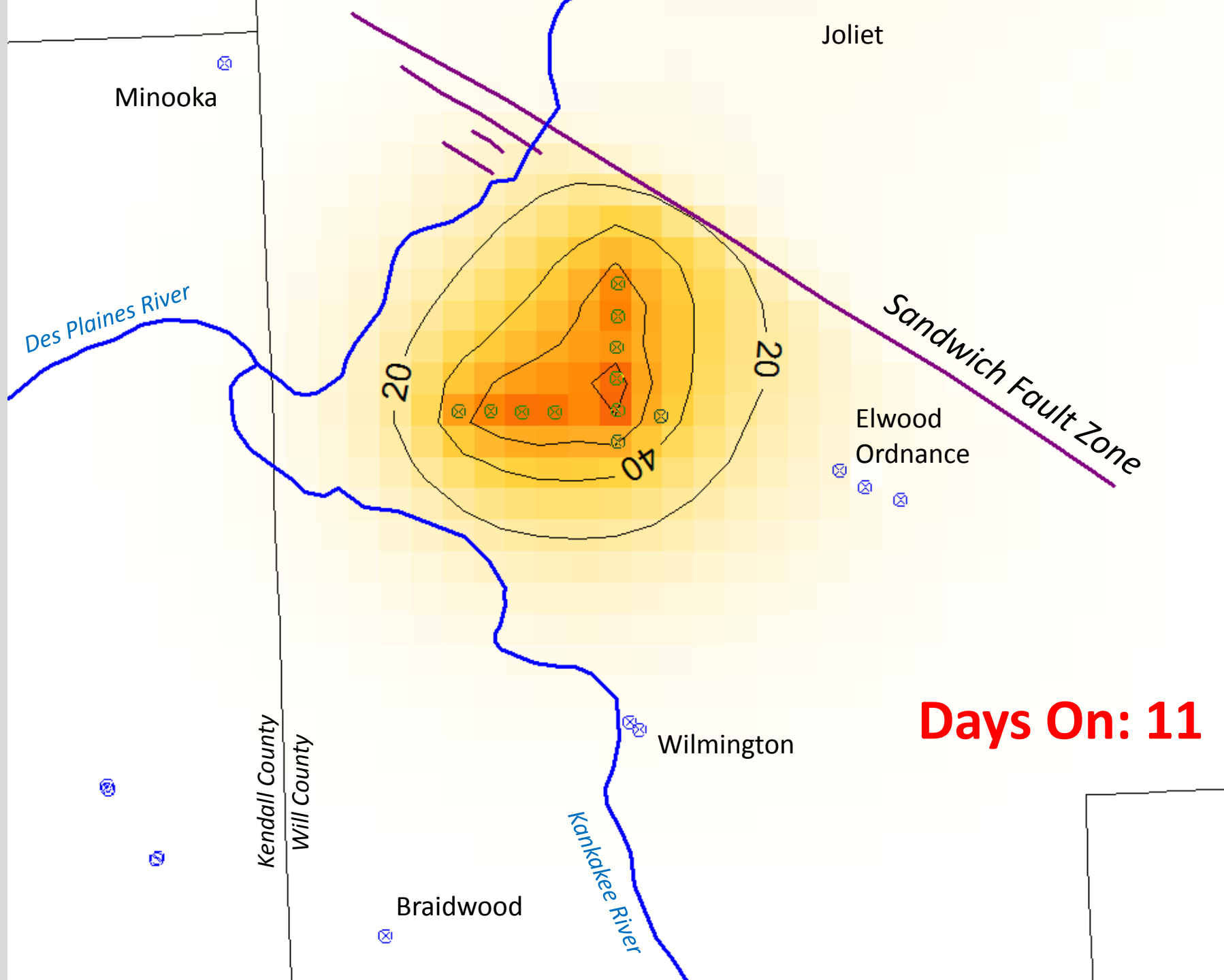
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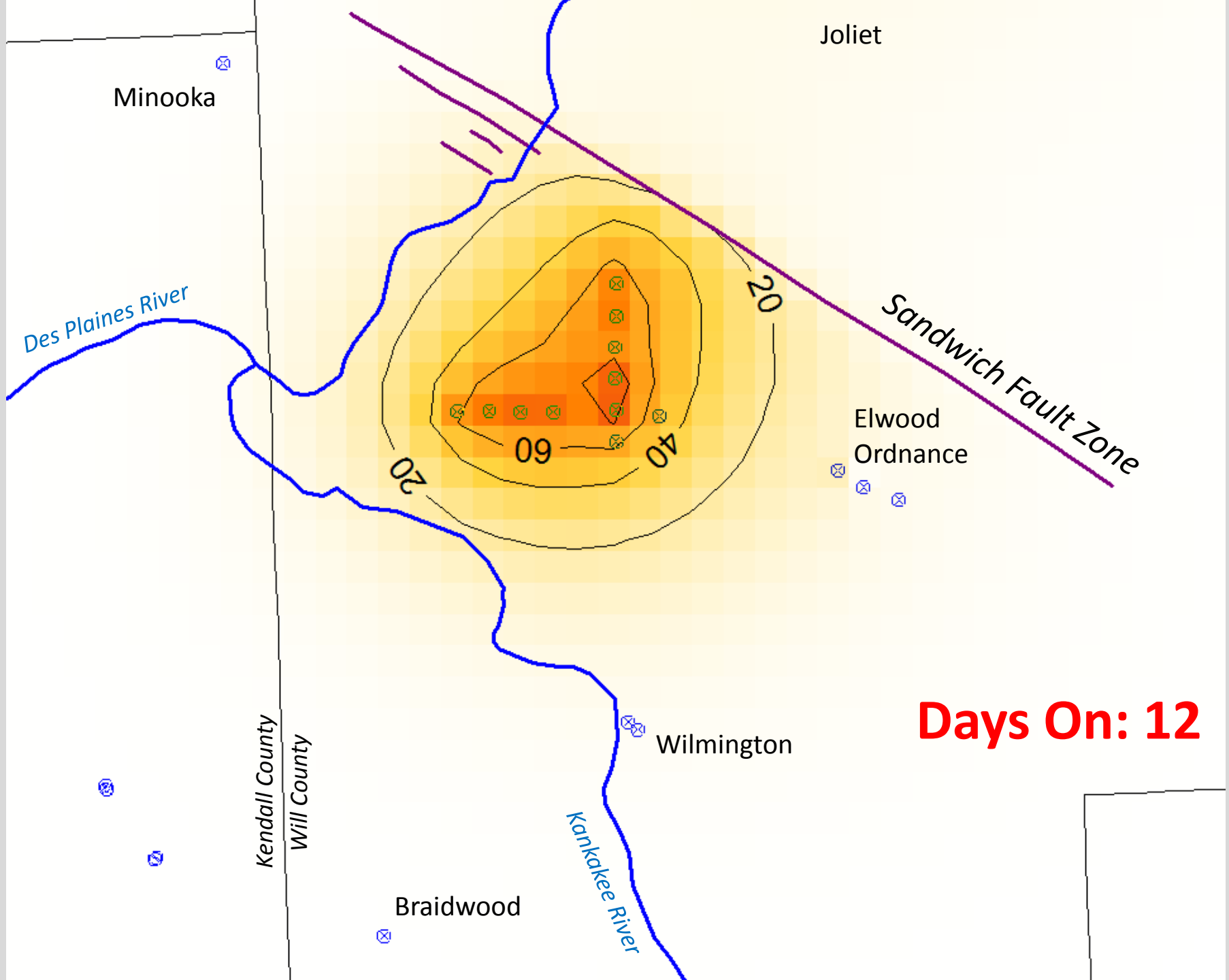


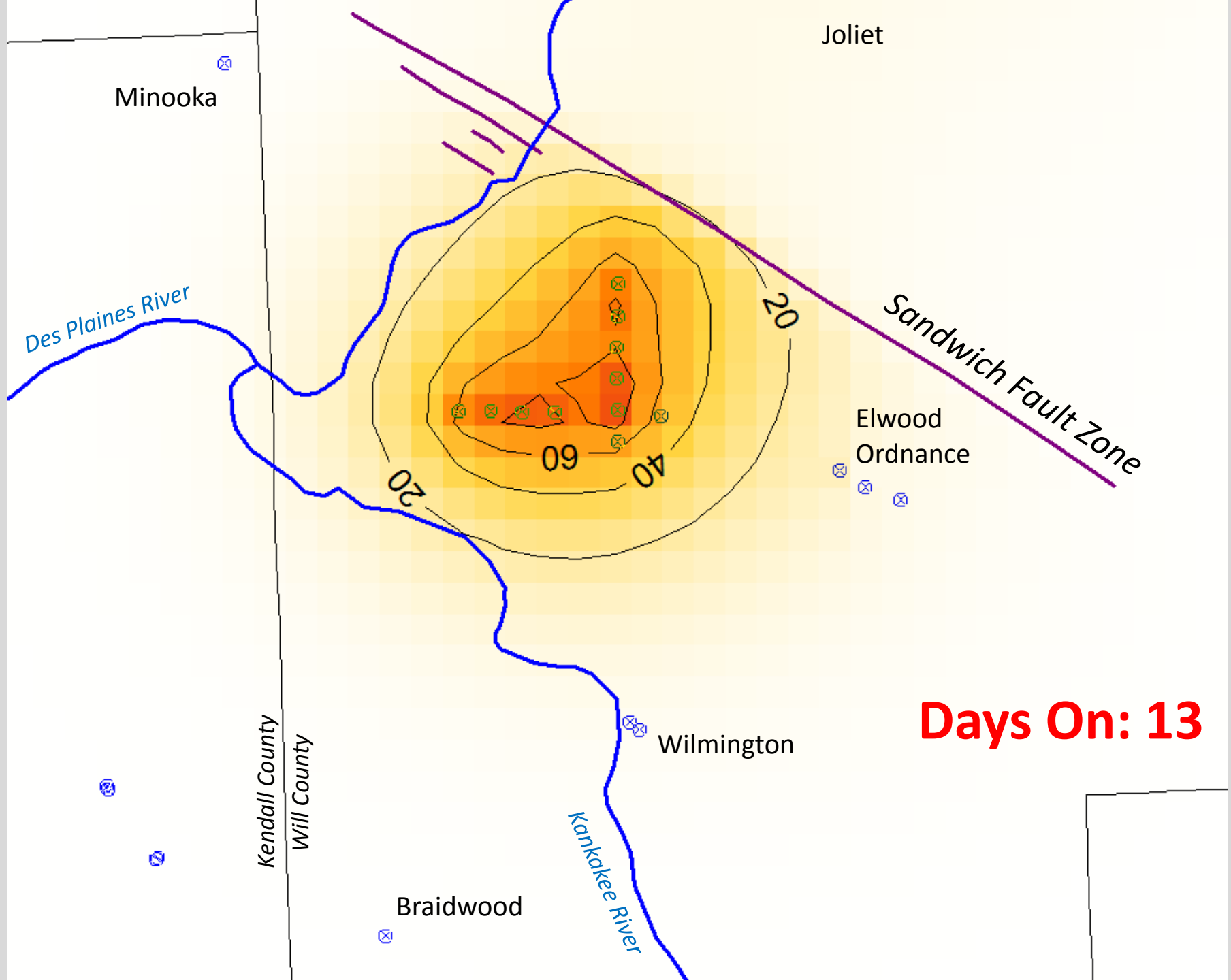


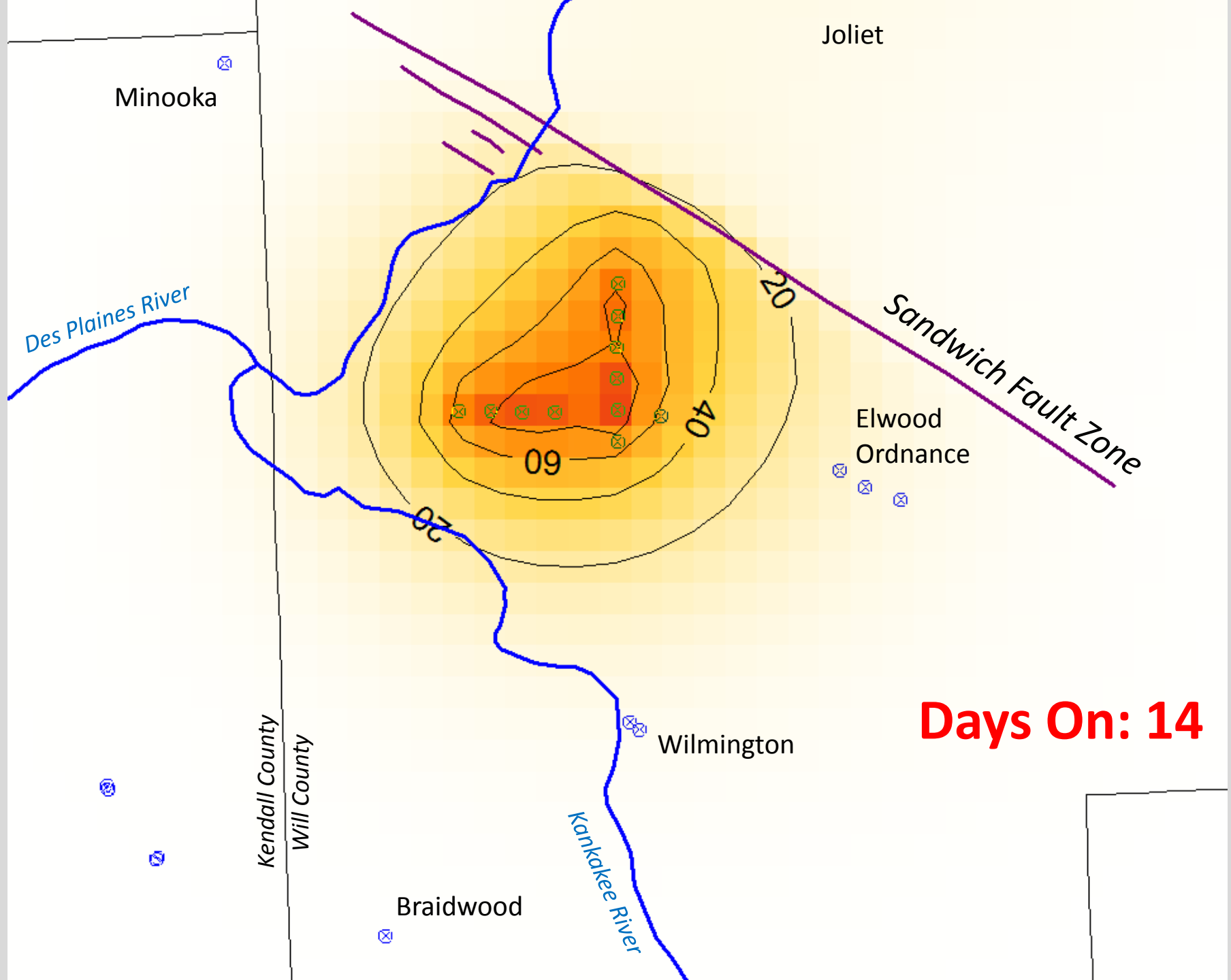




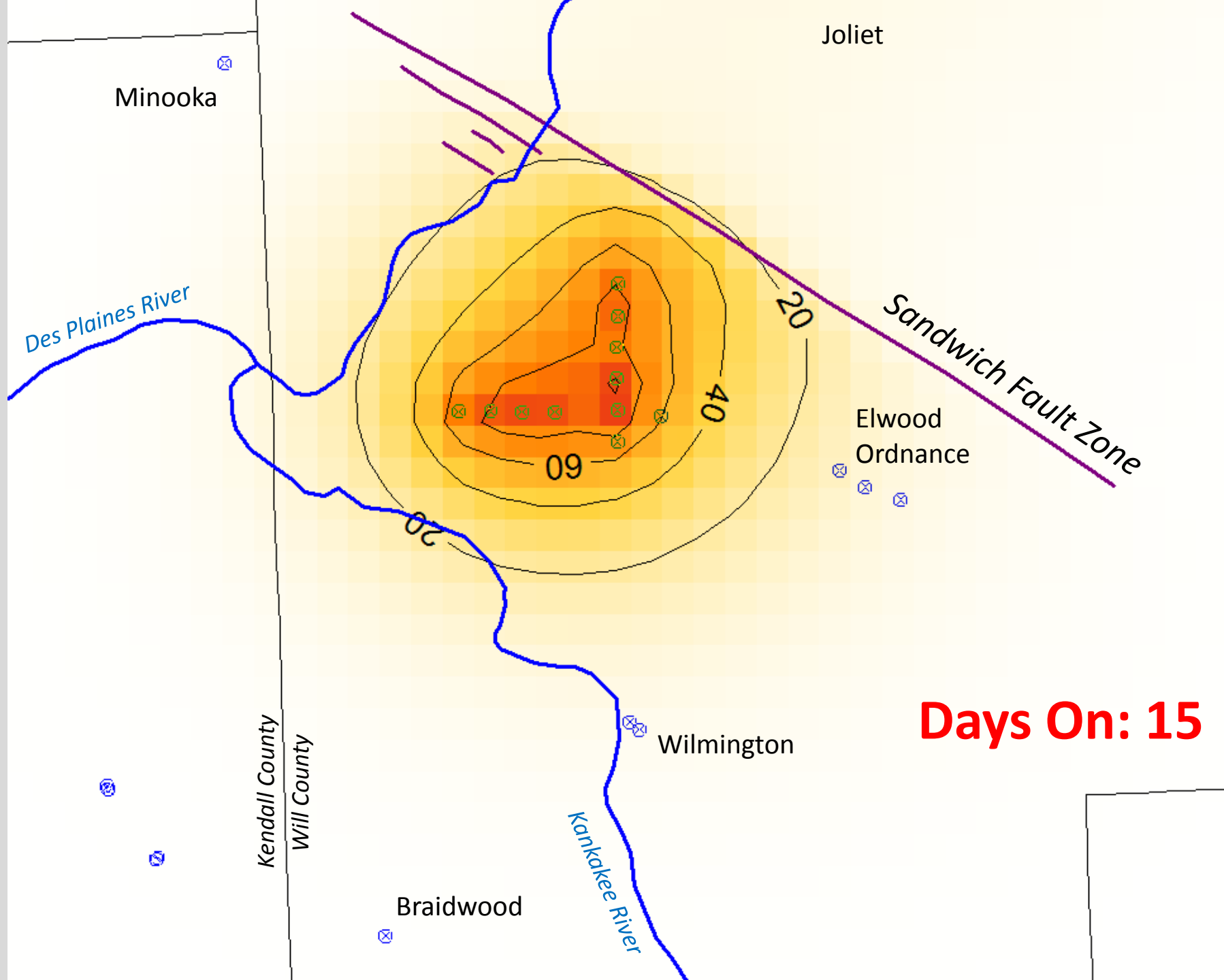




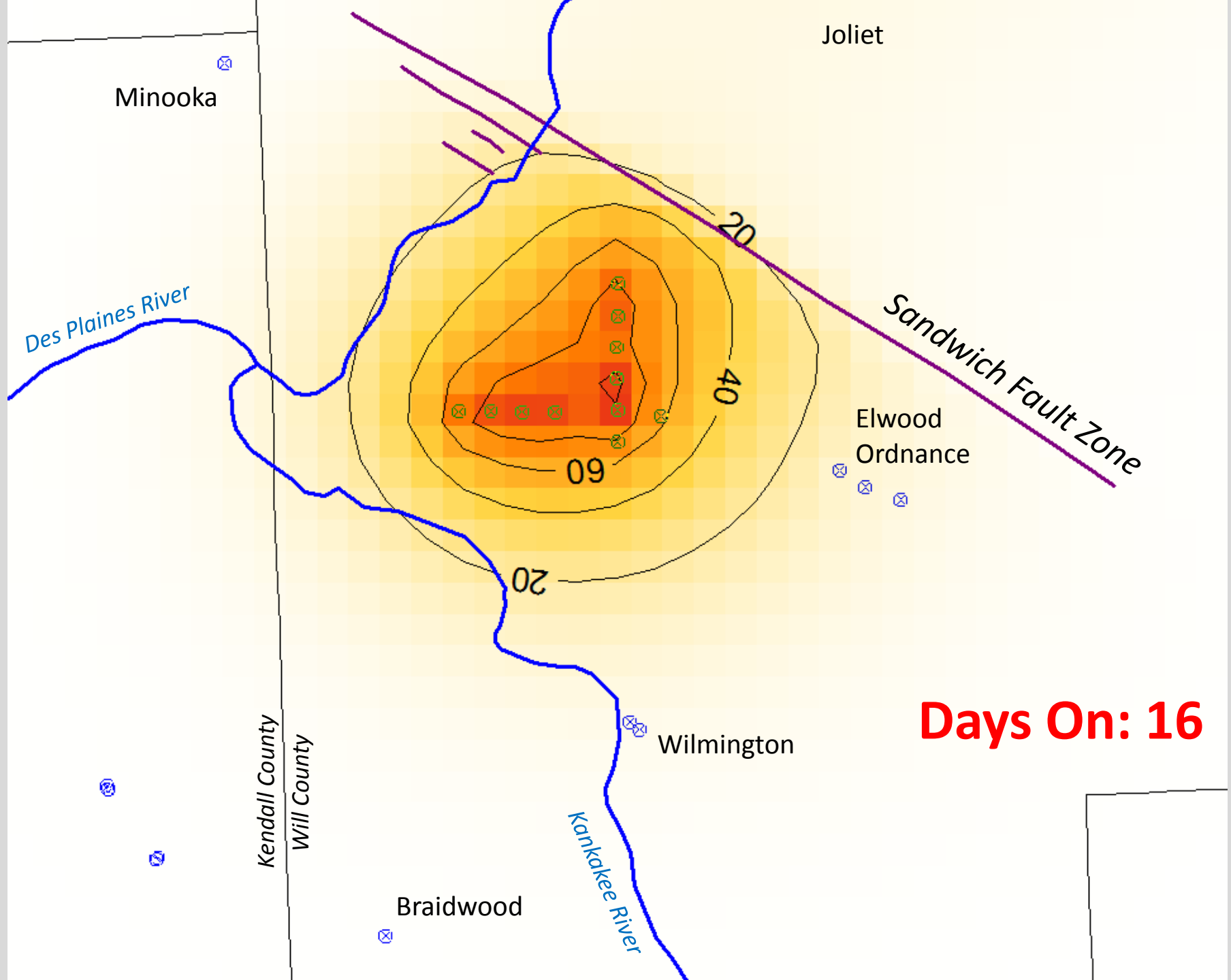


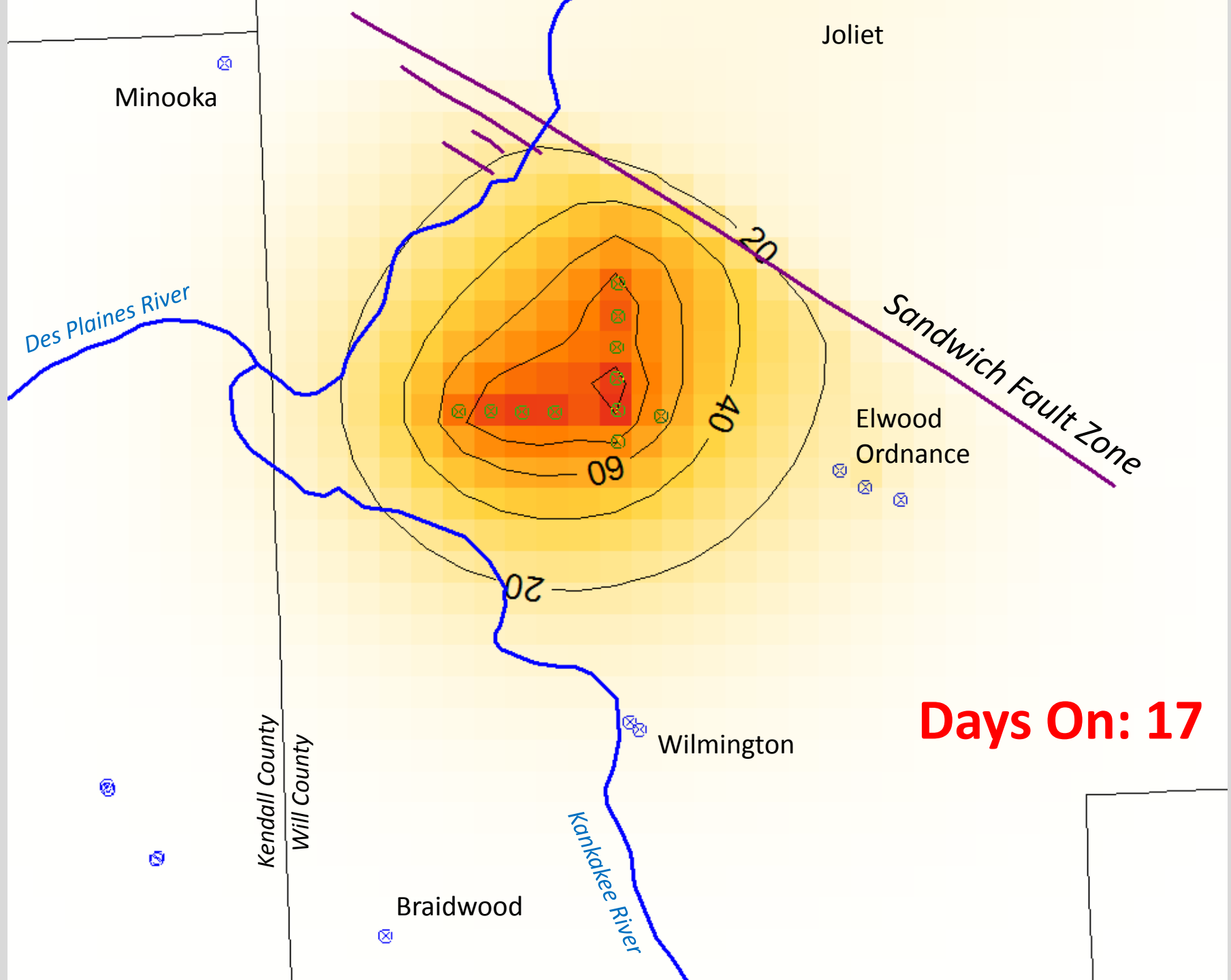


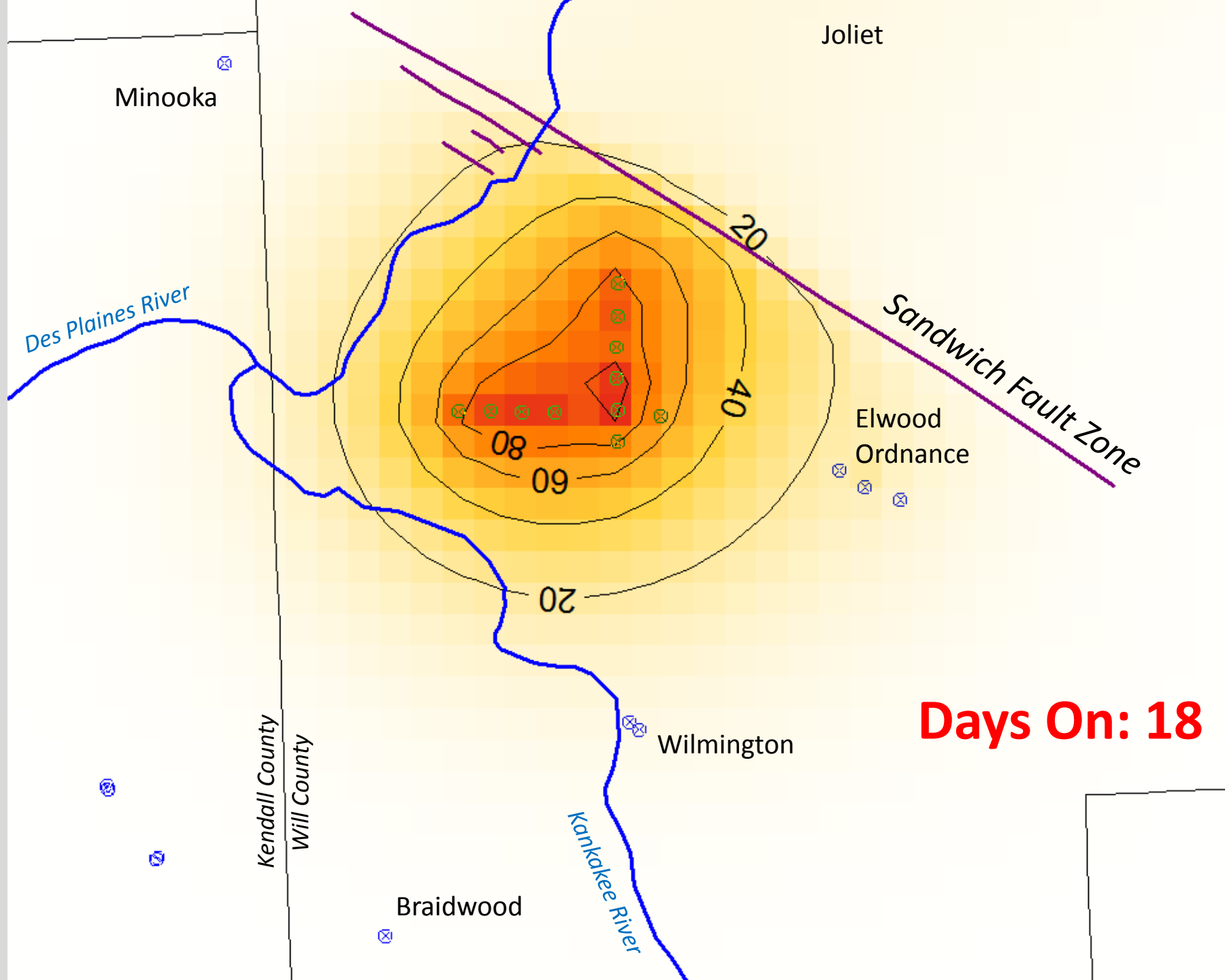
Days On: 14



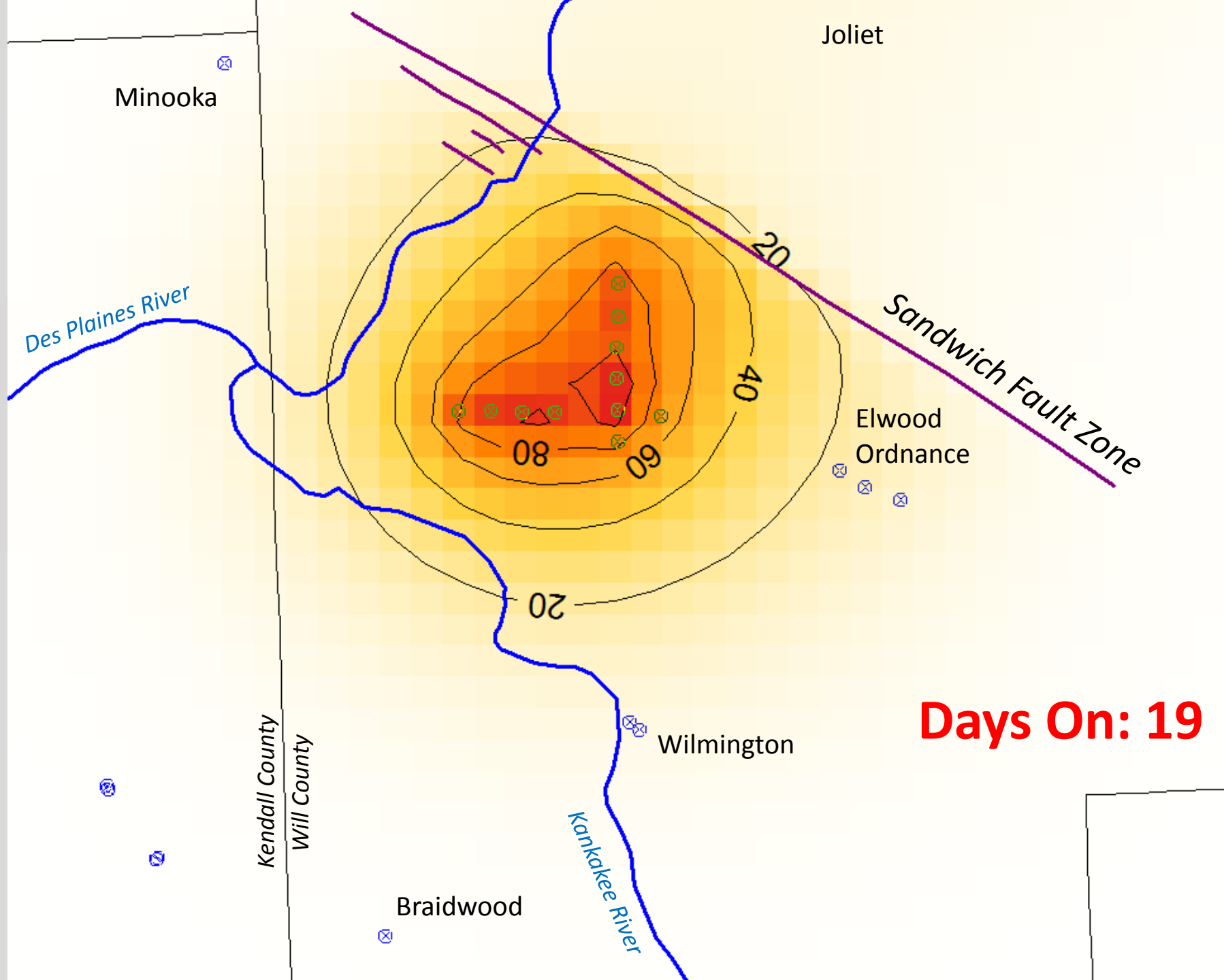
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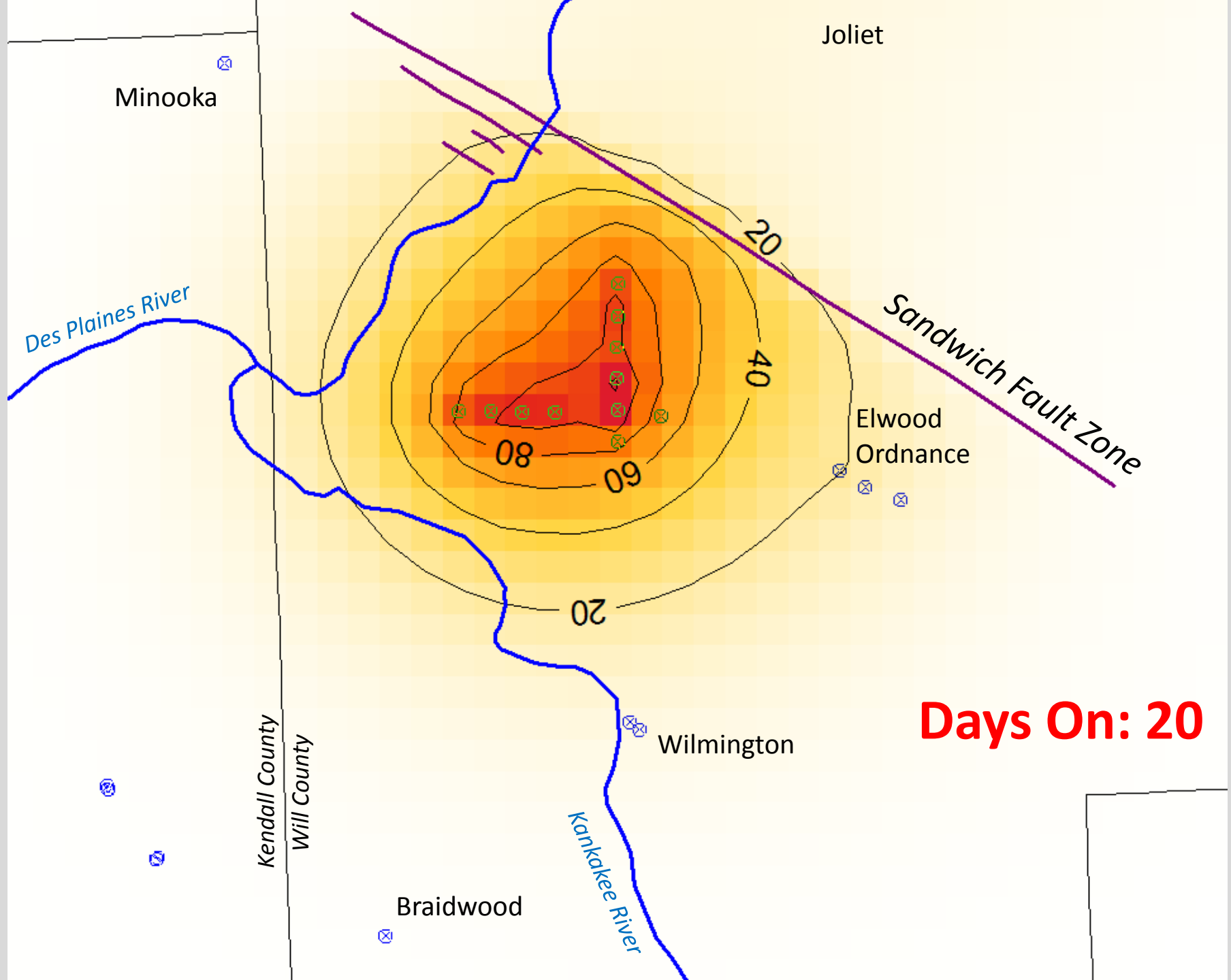


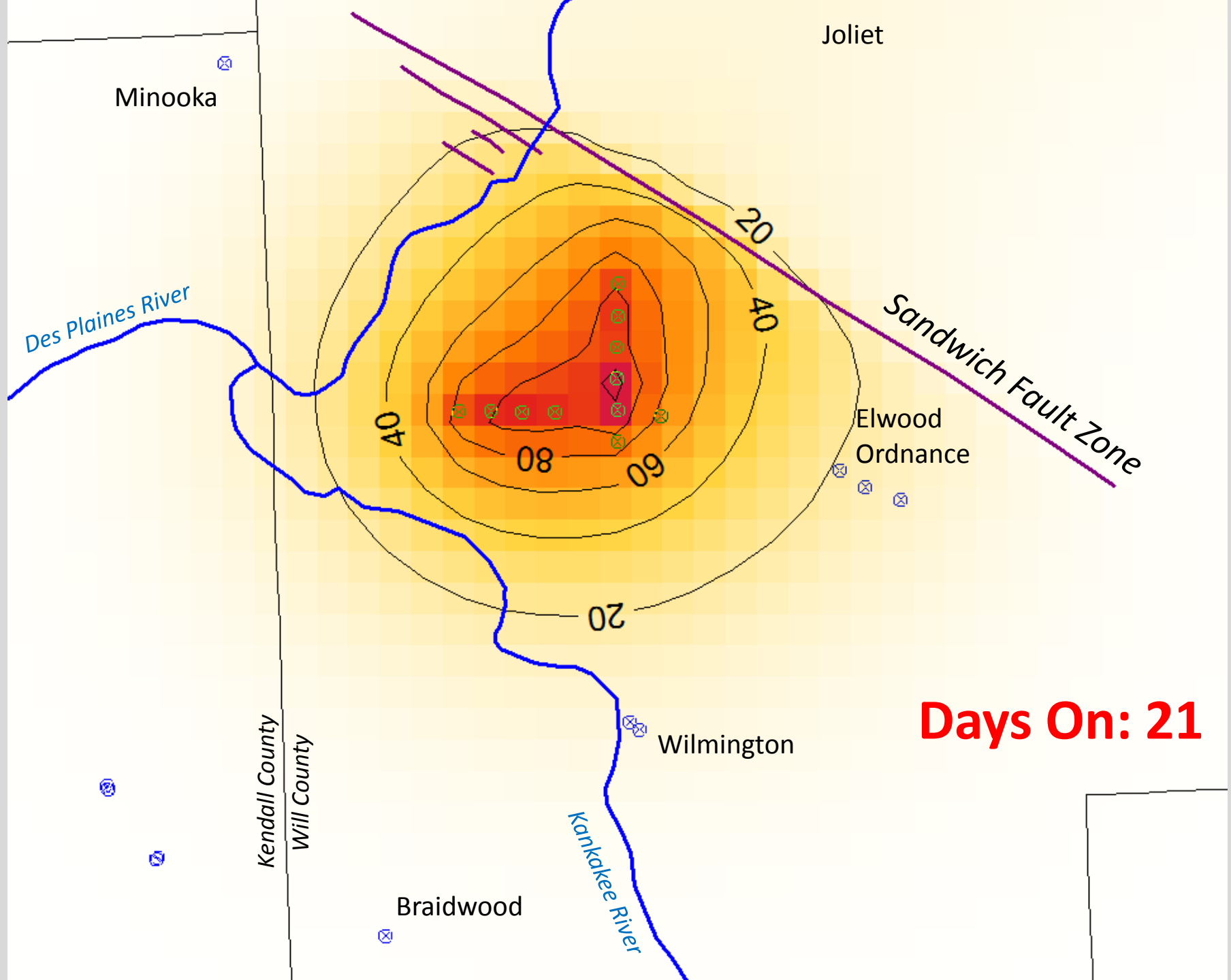


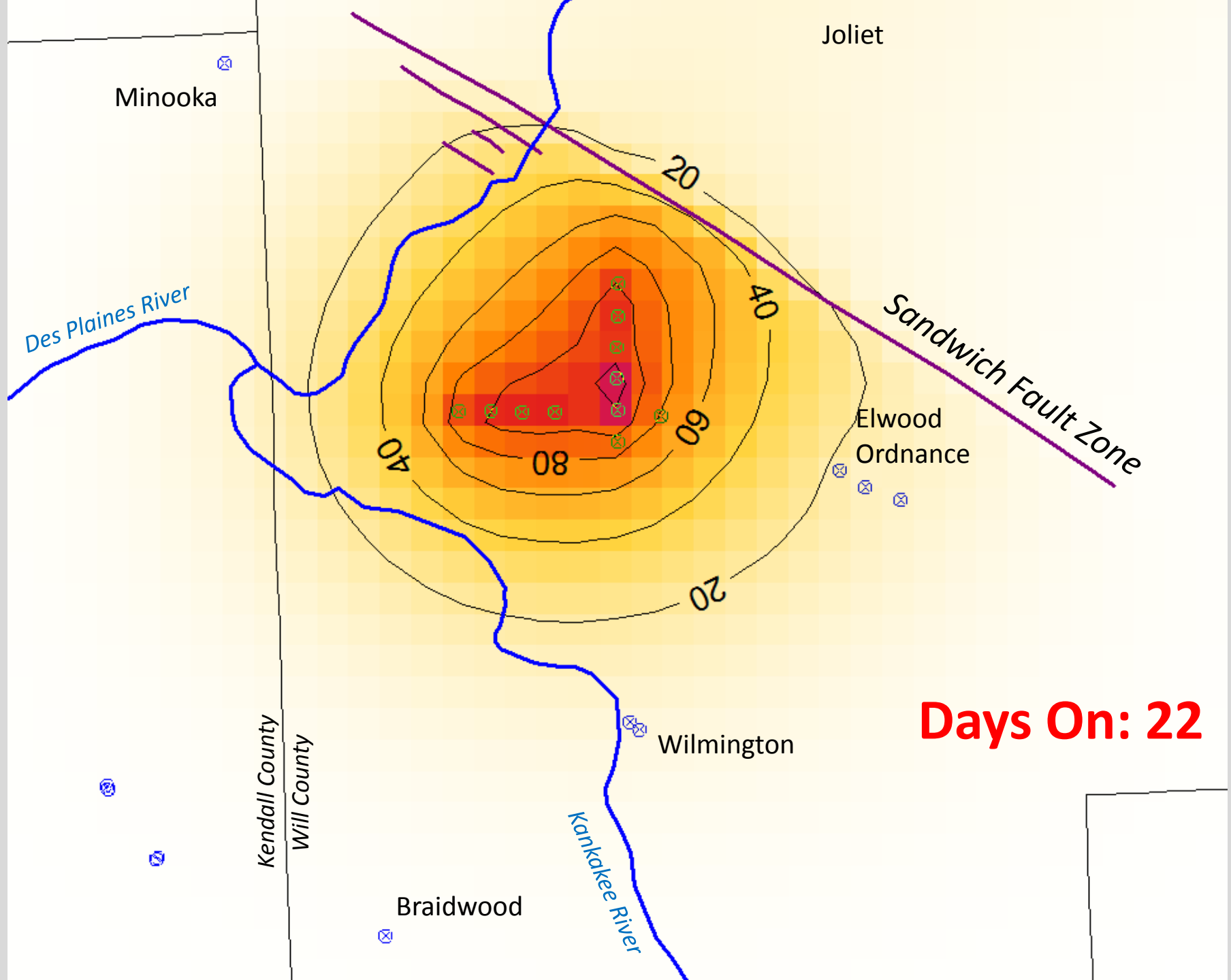


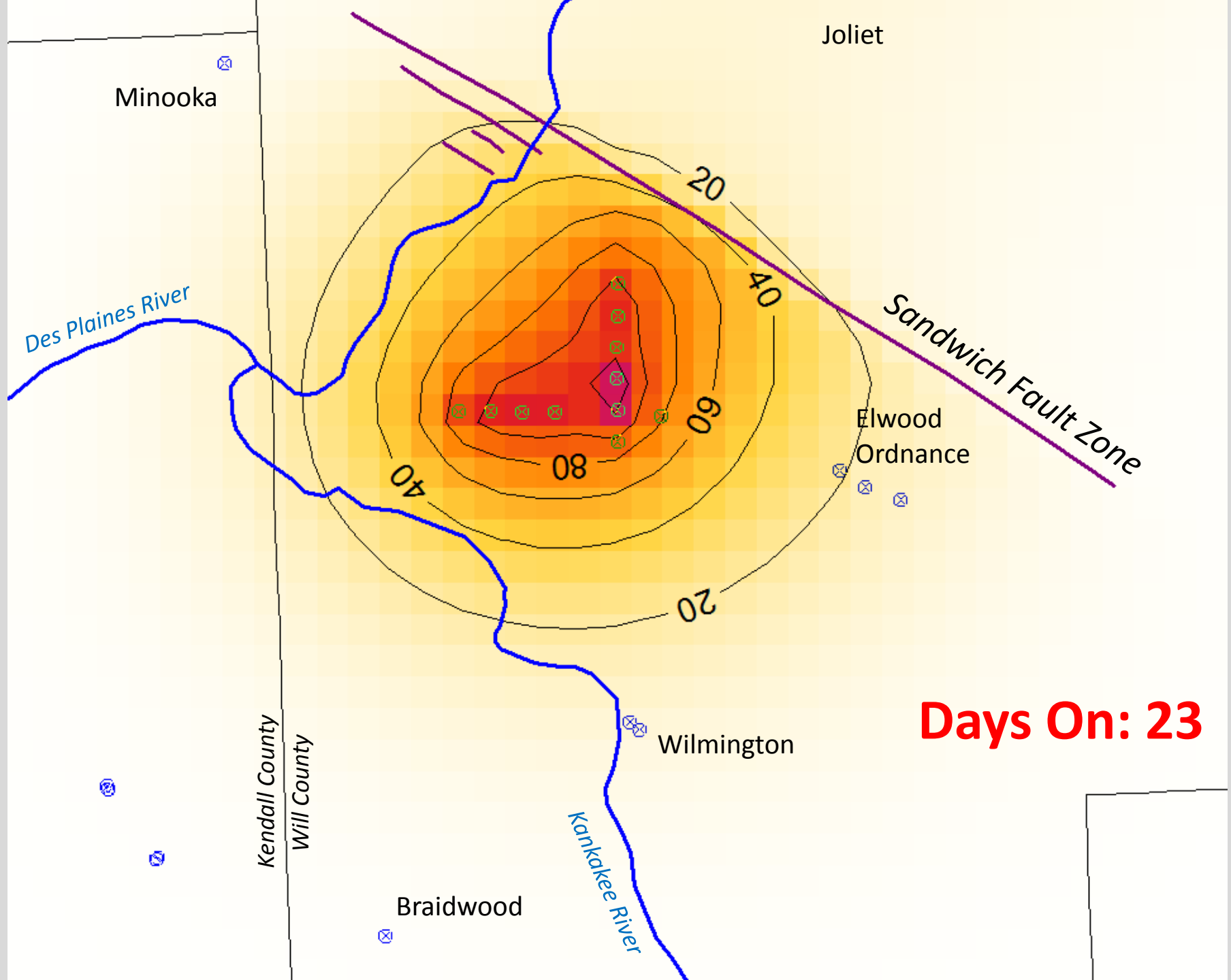
Days On: 18

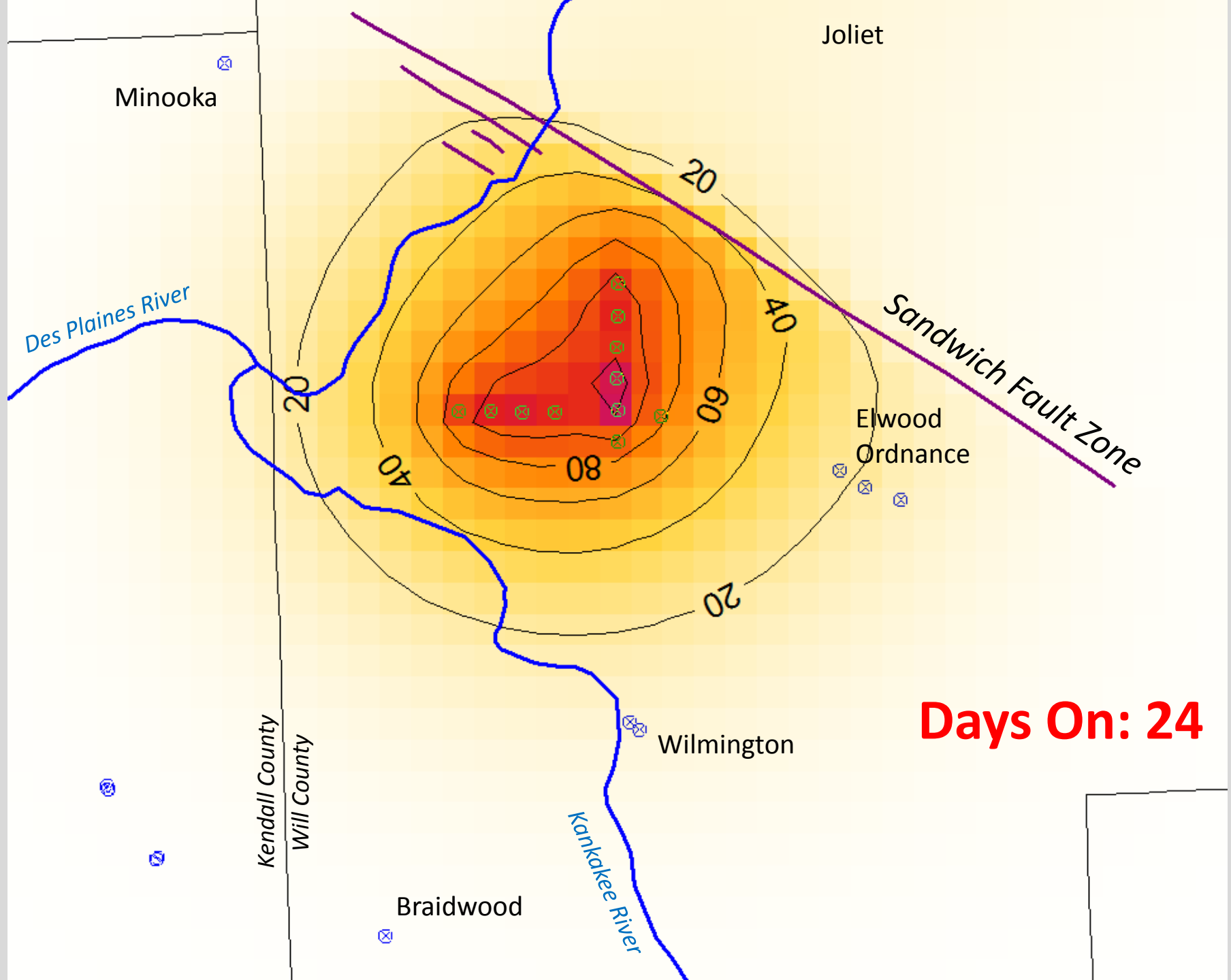


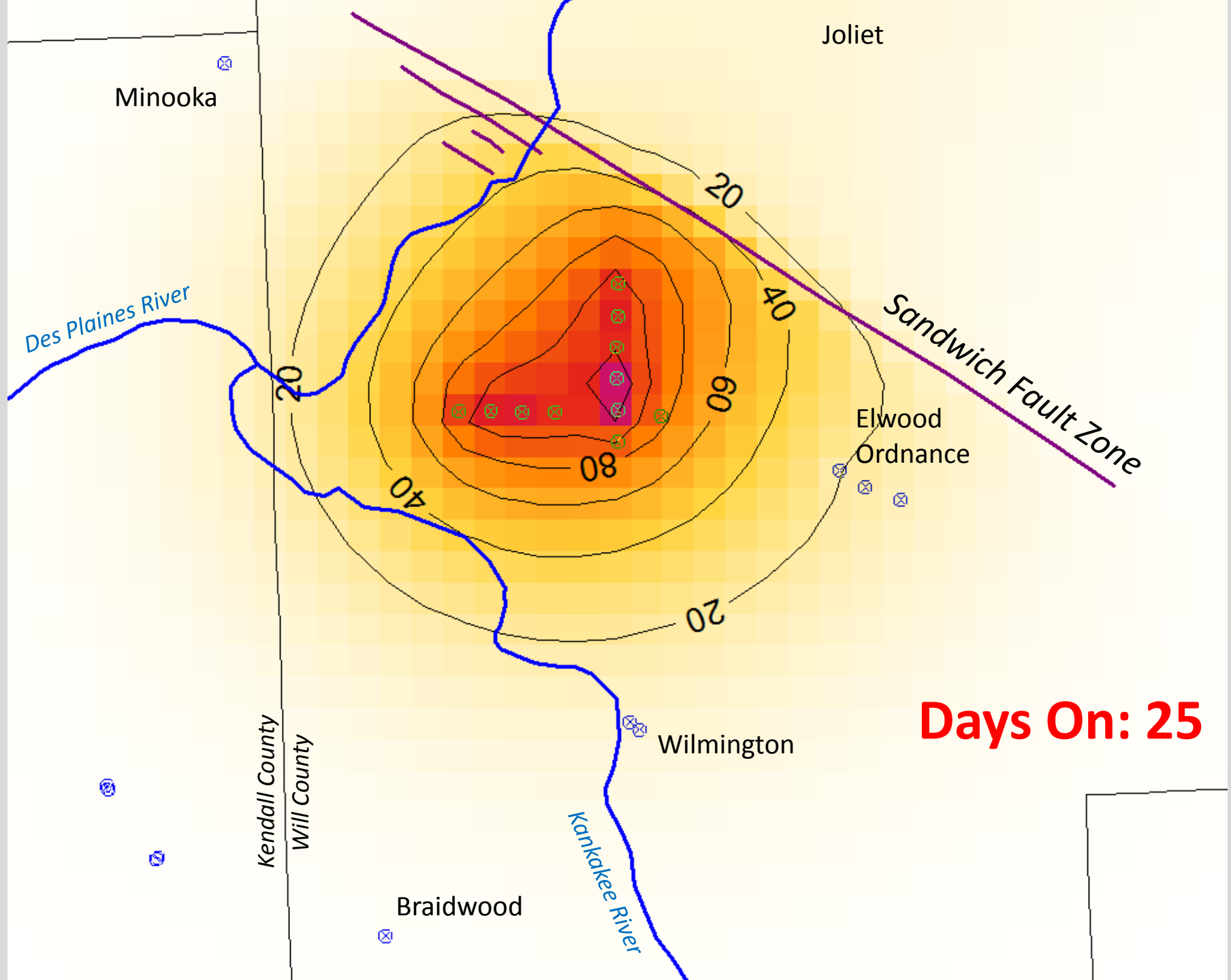


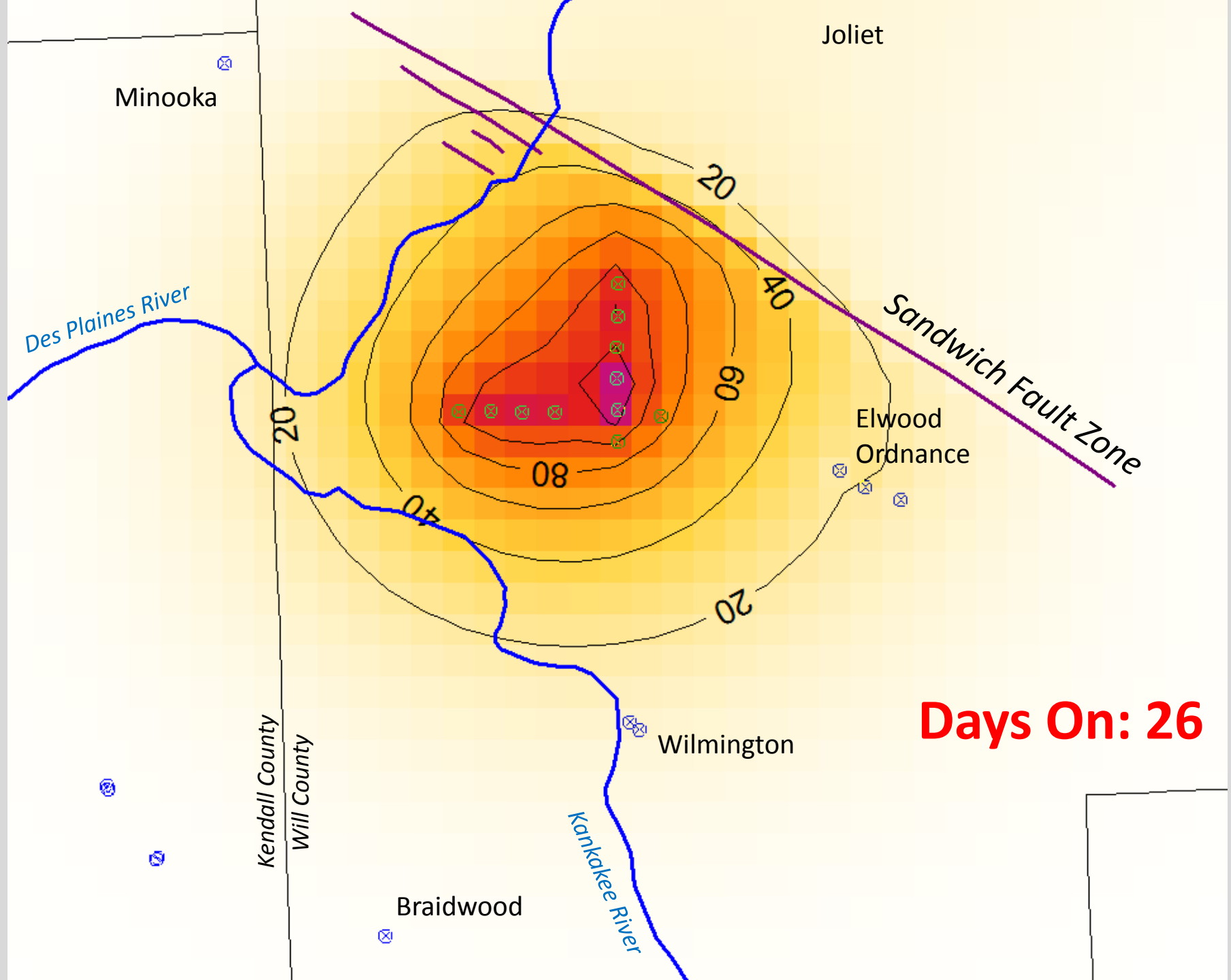


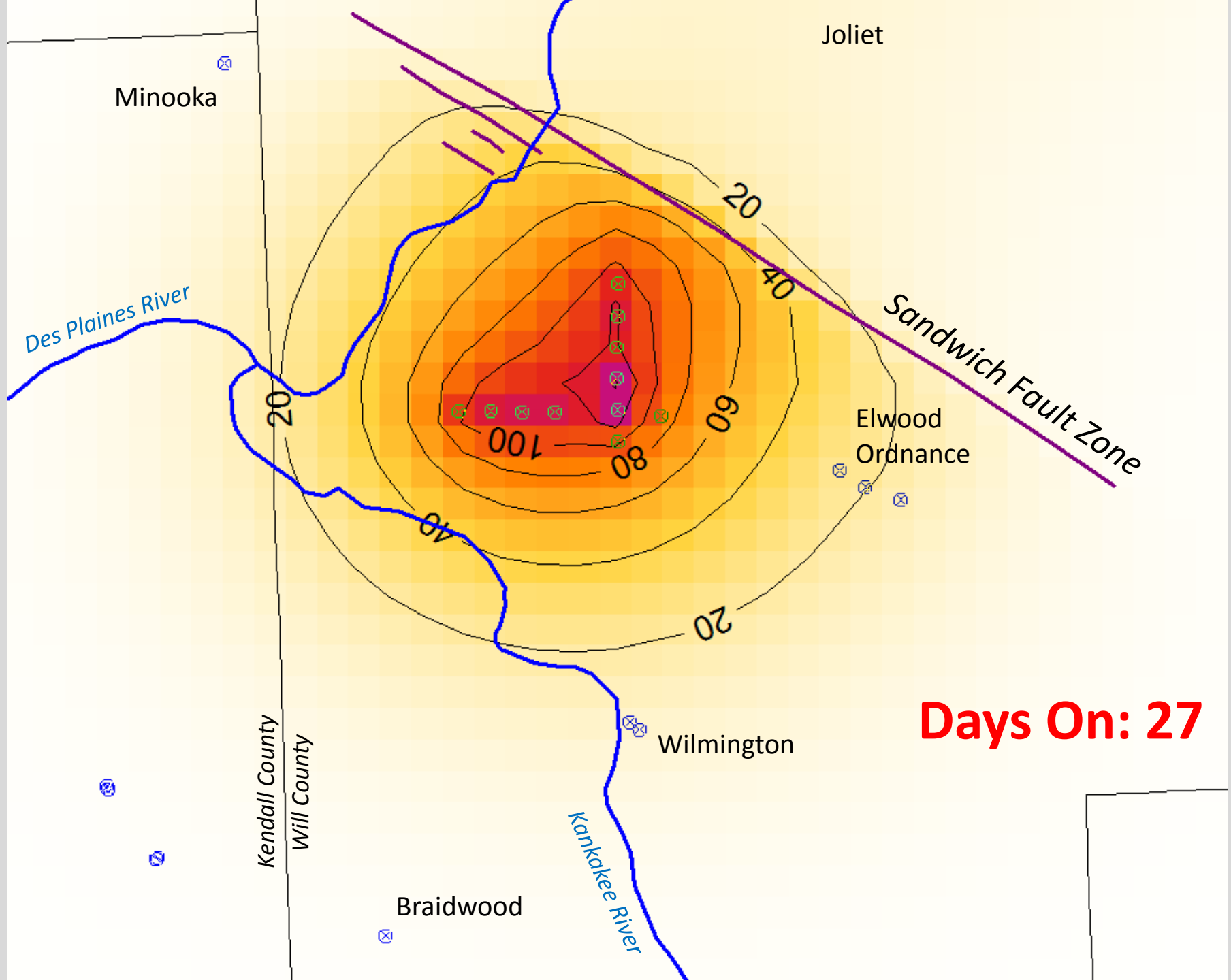


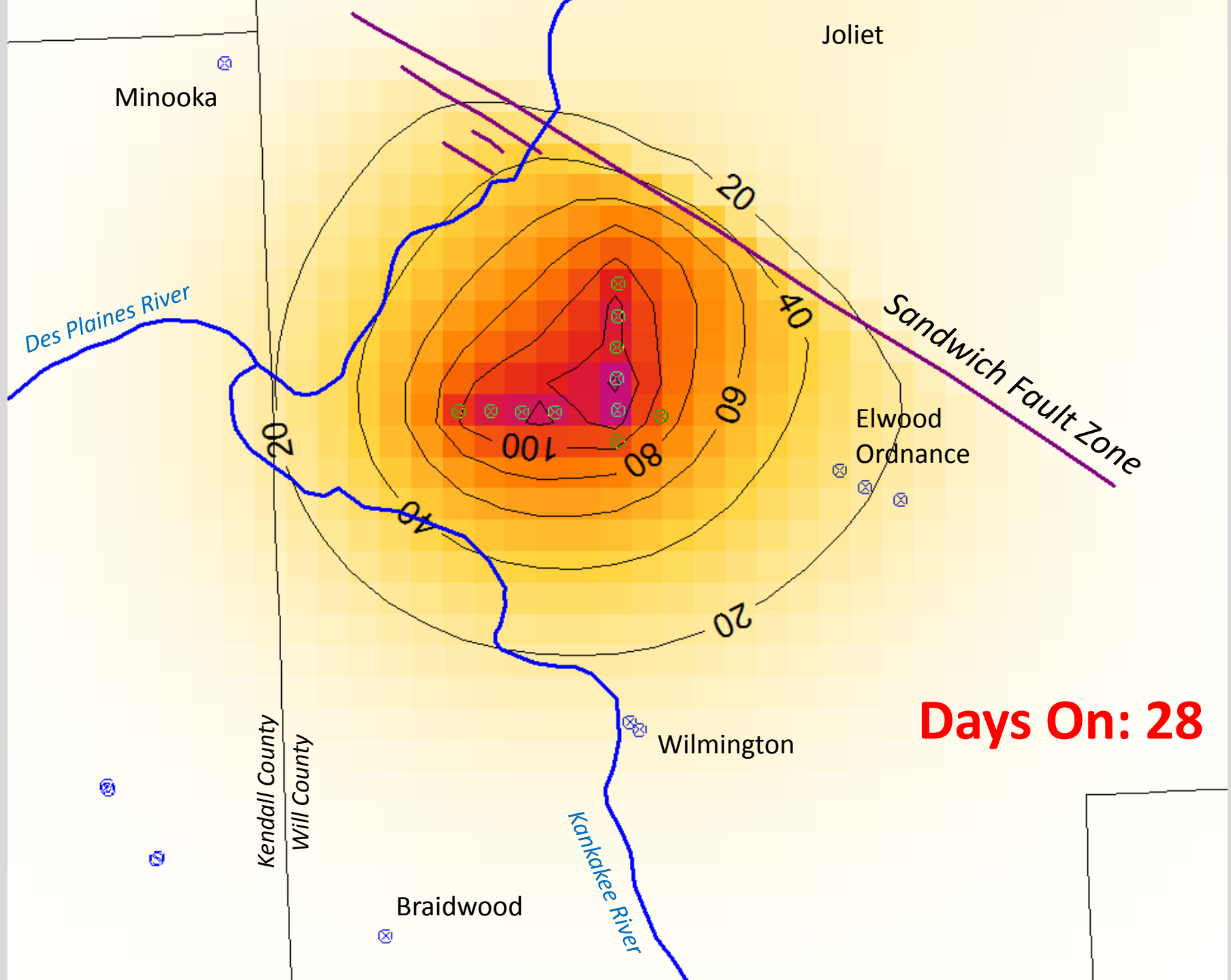


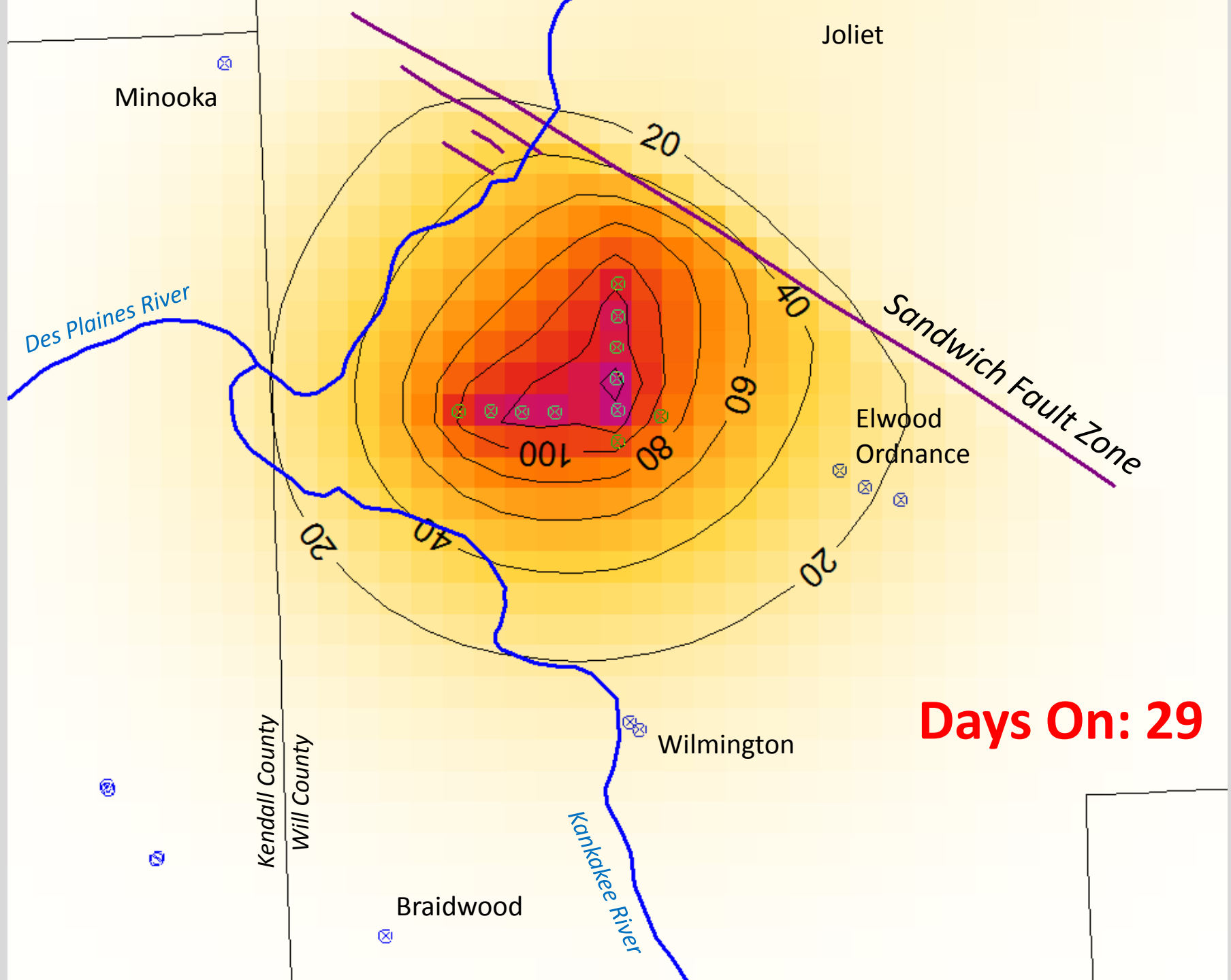


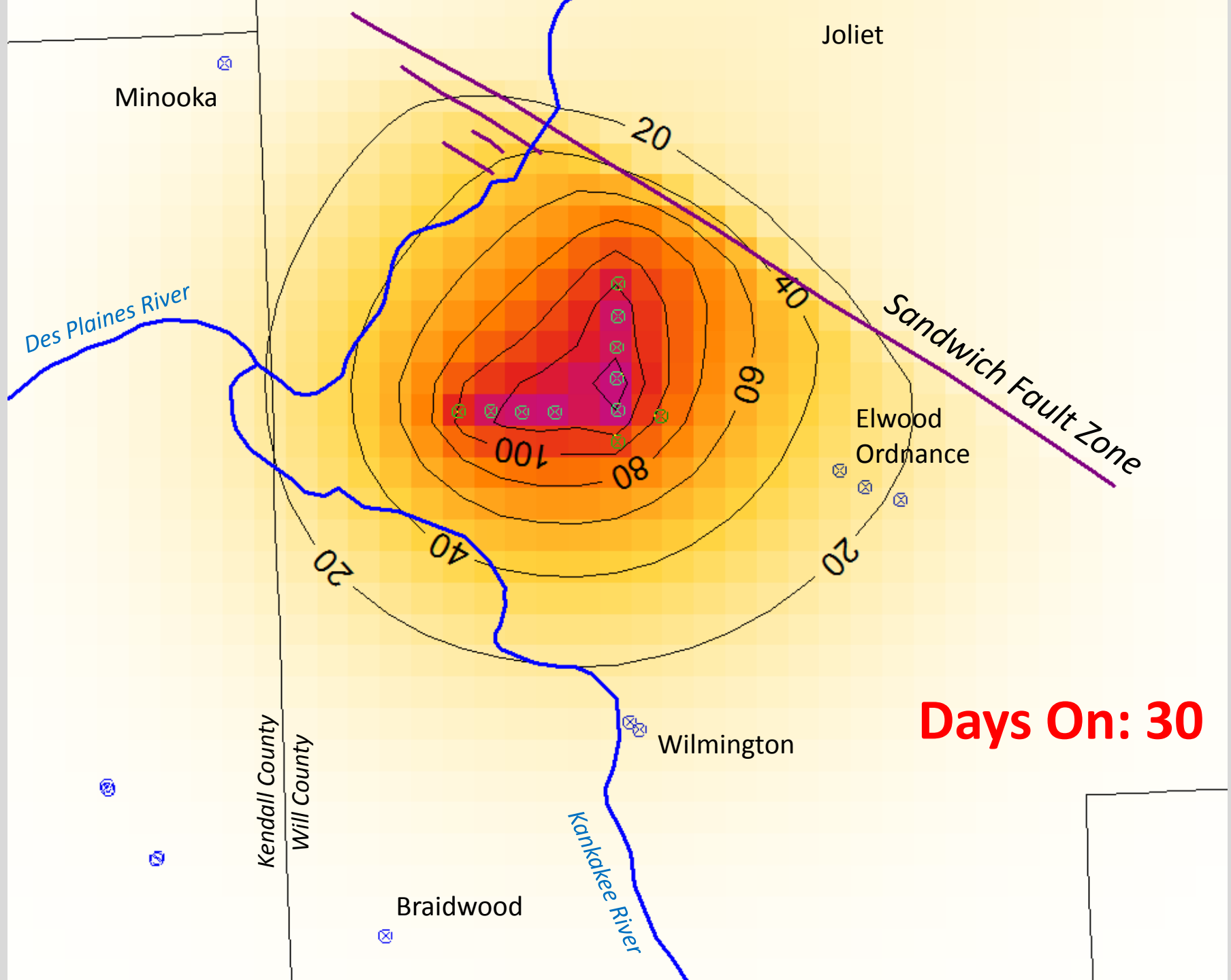


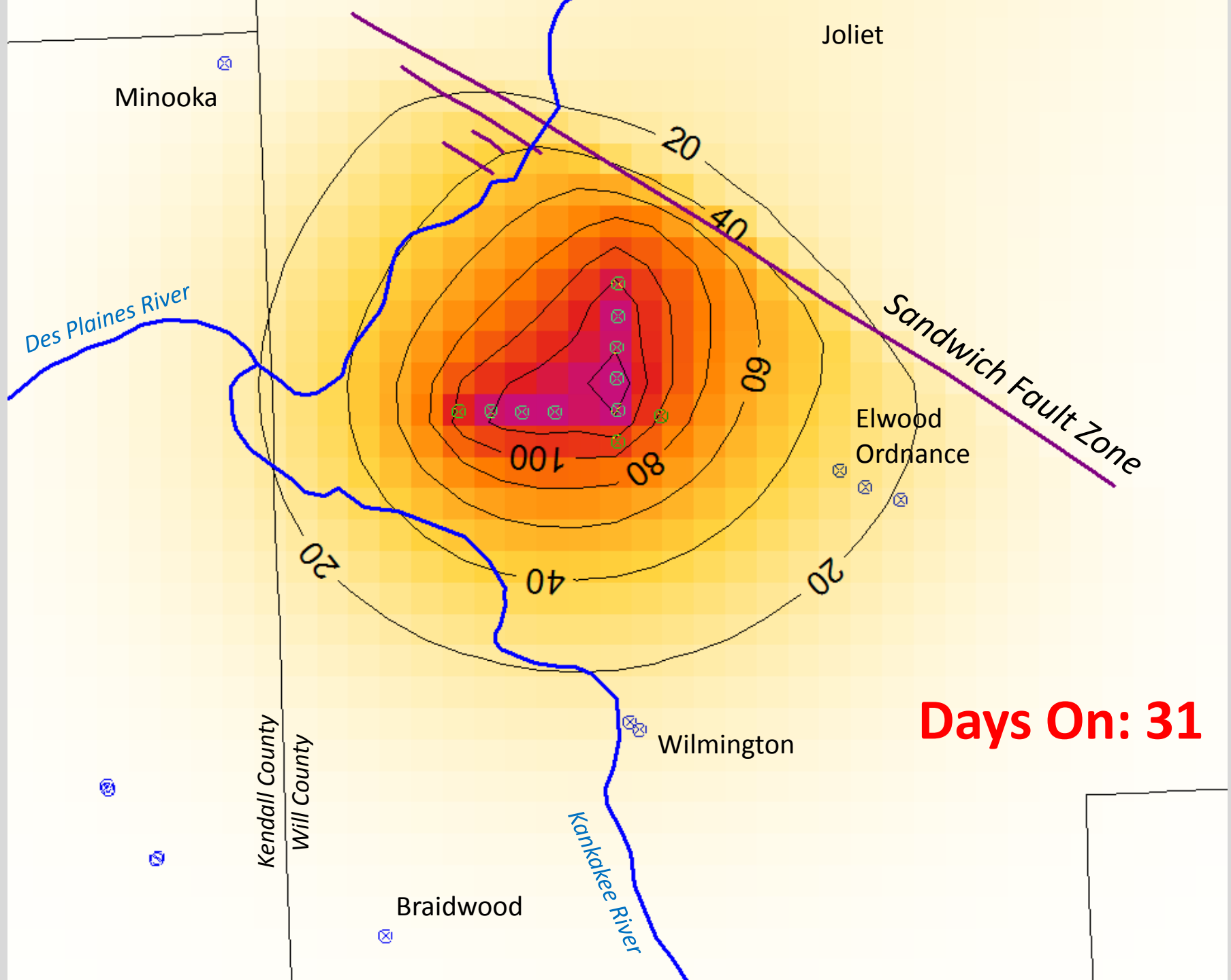


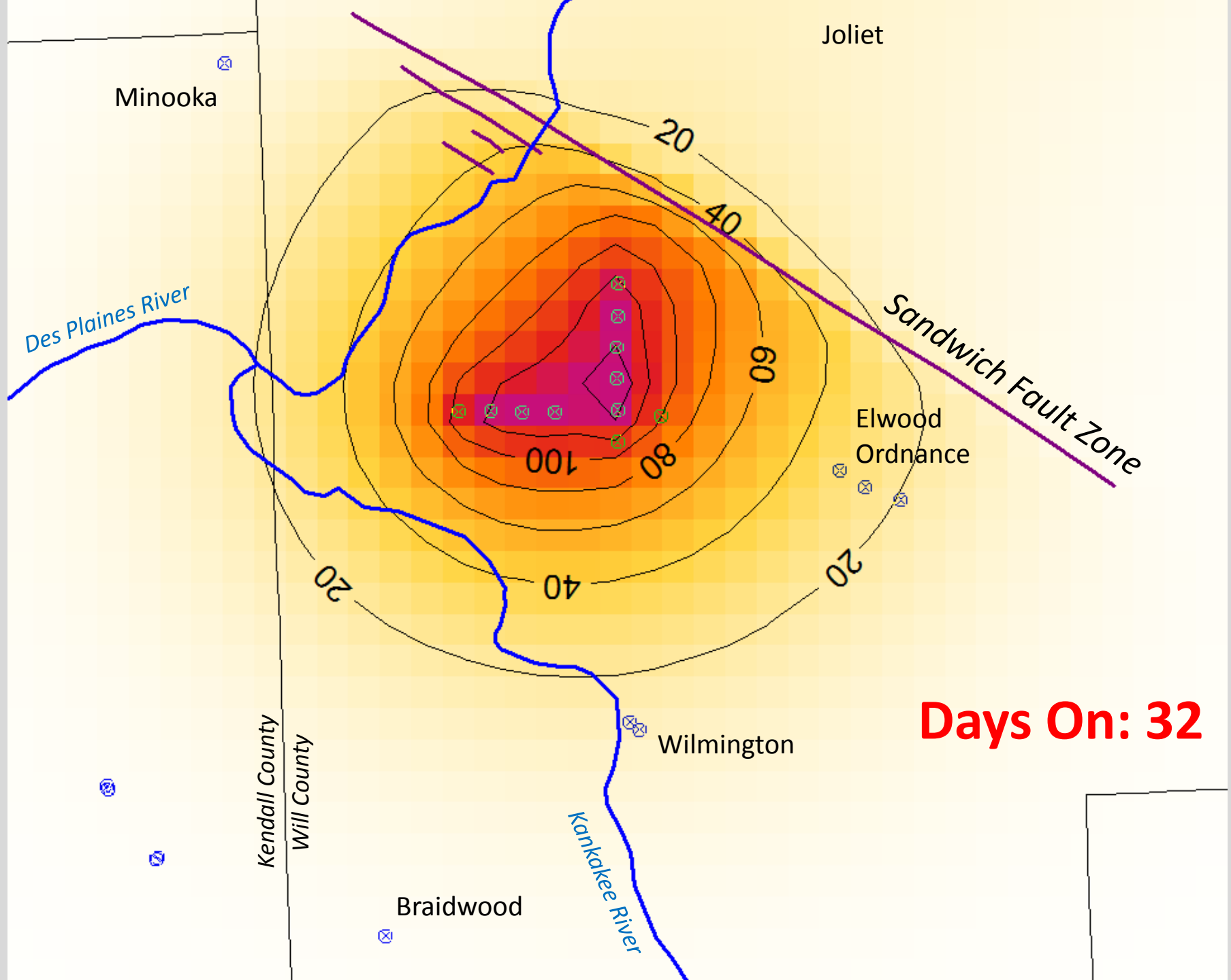


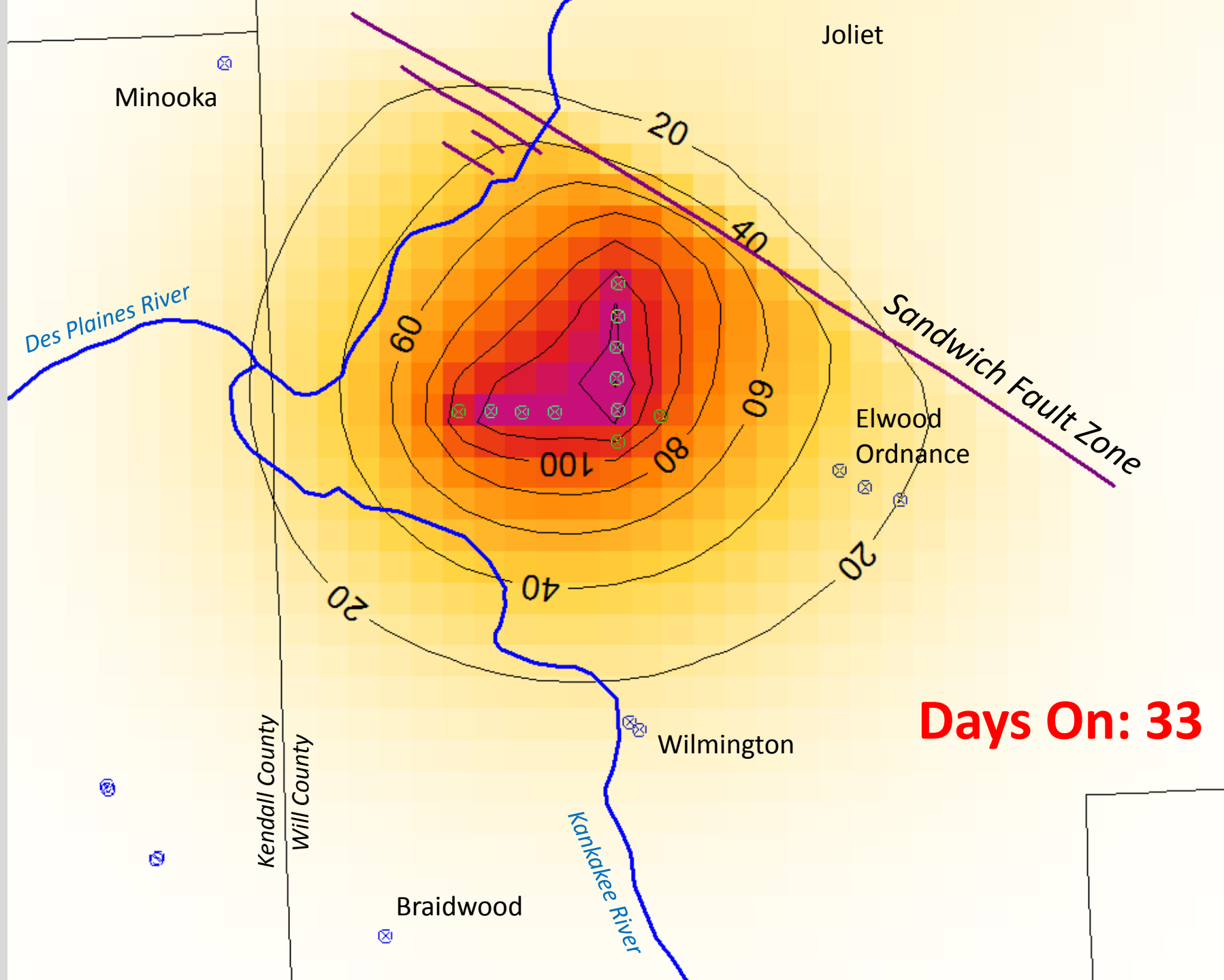


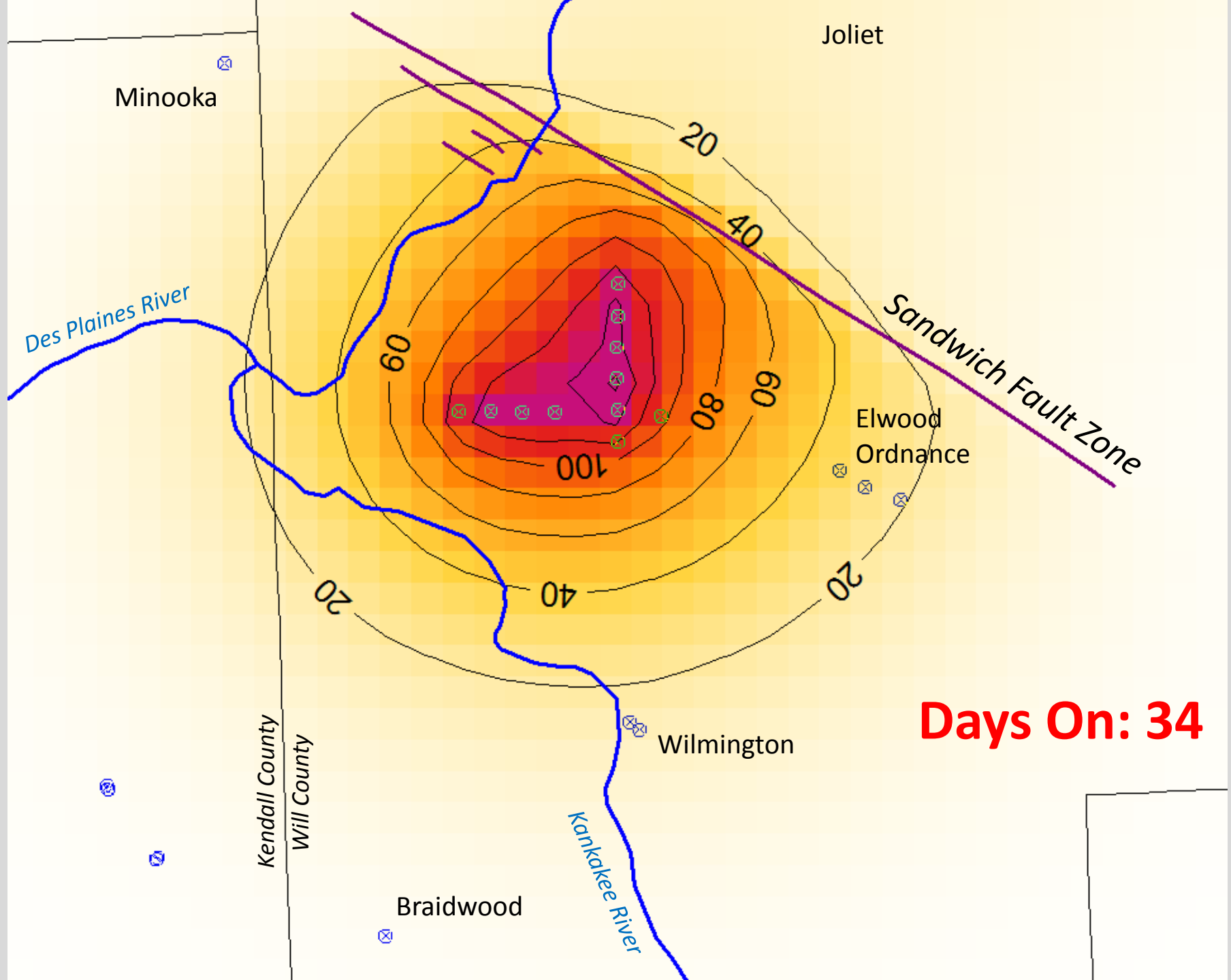


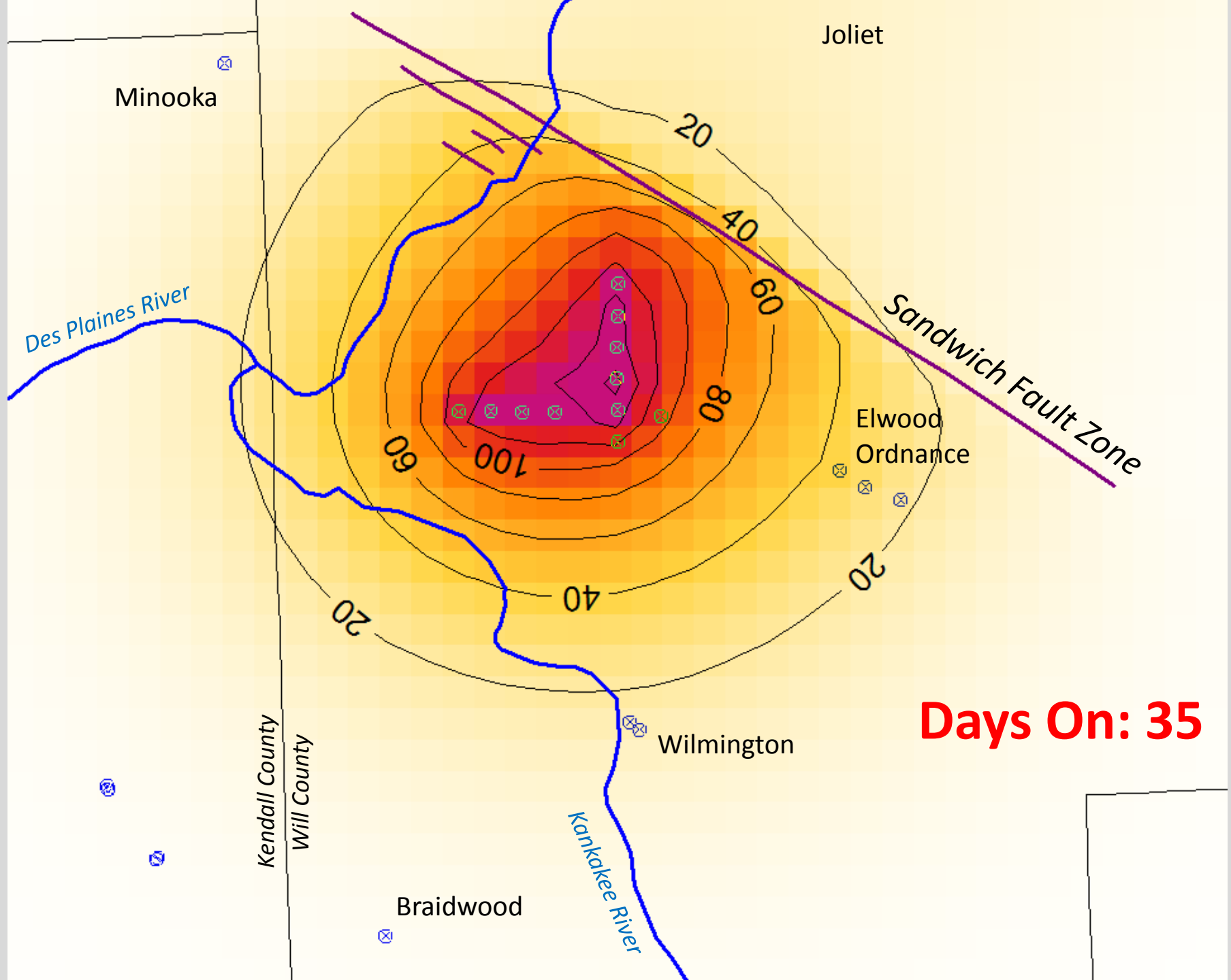


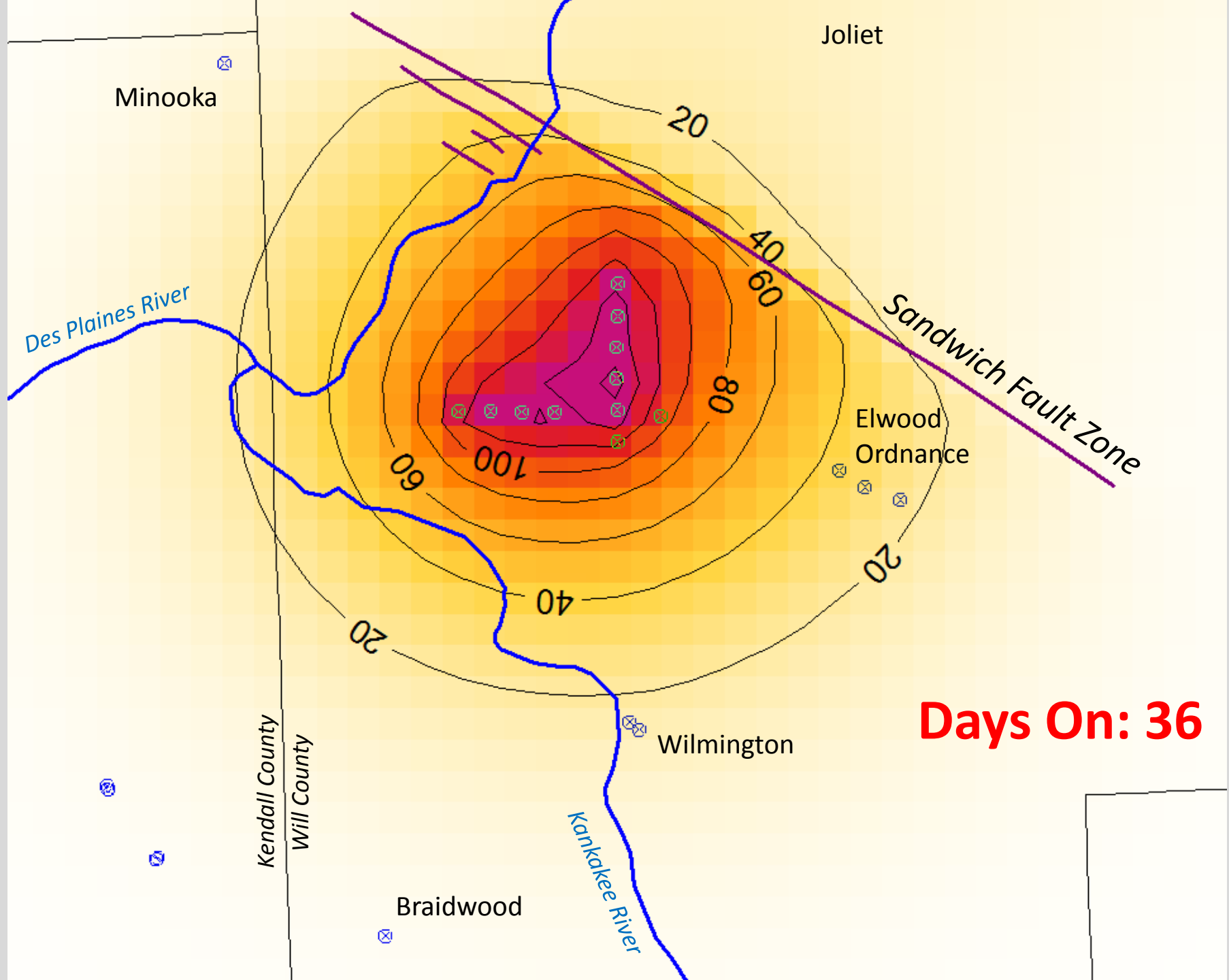


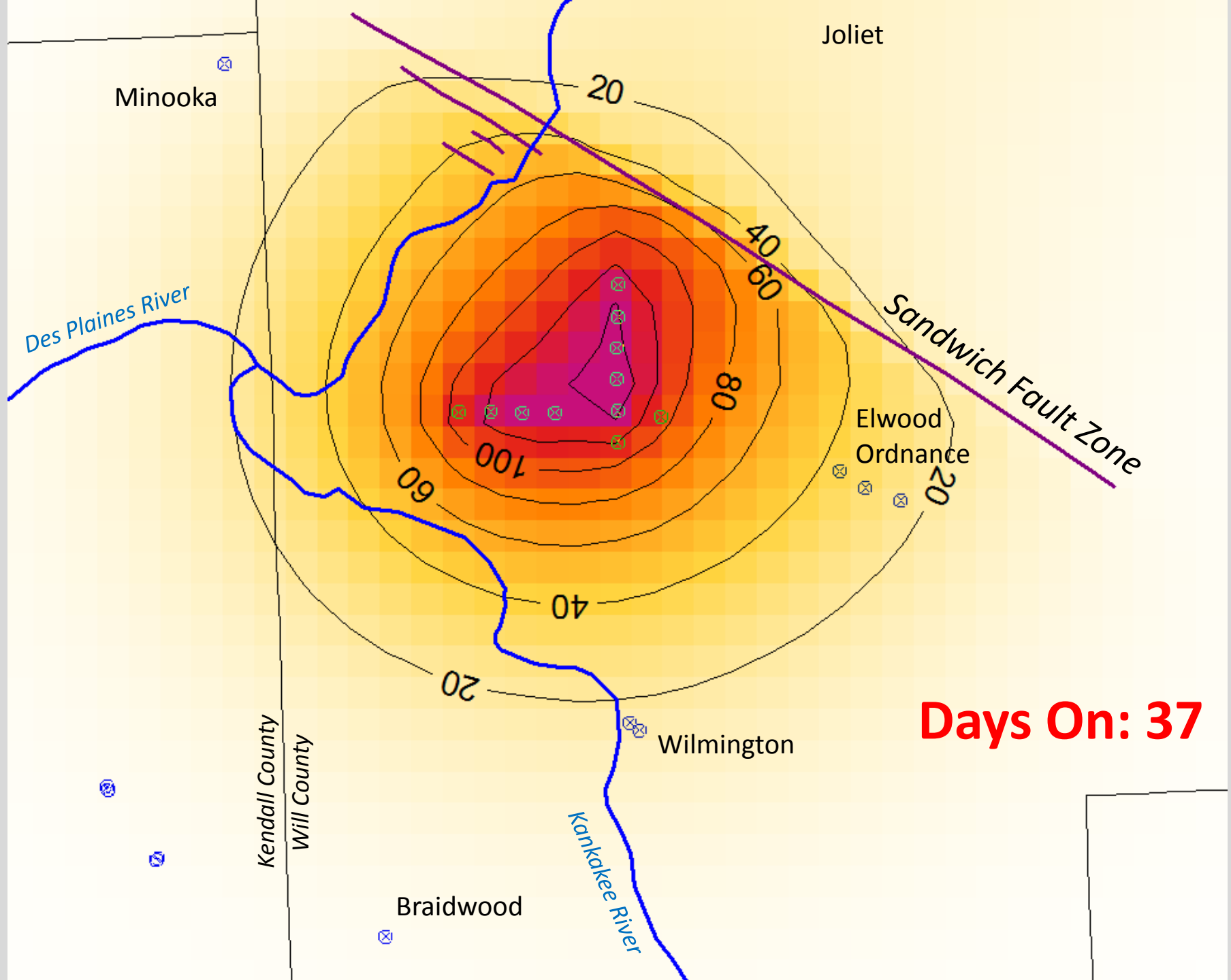


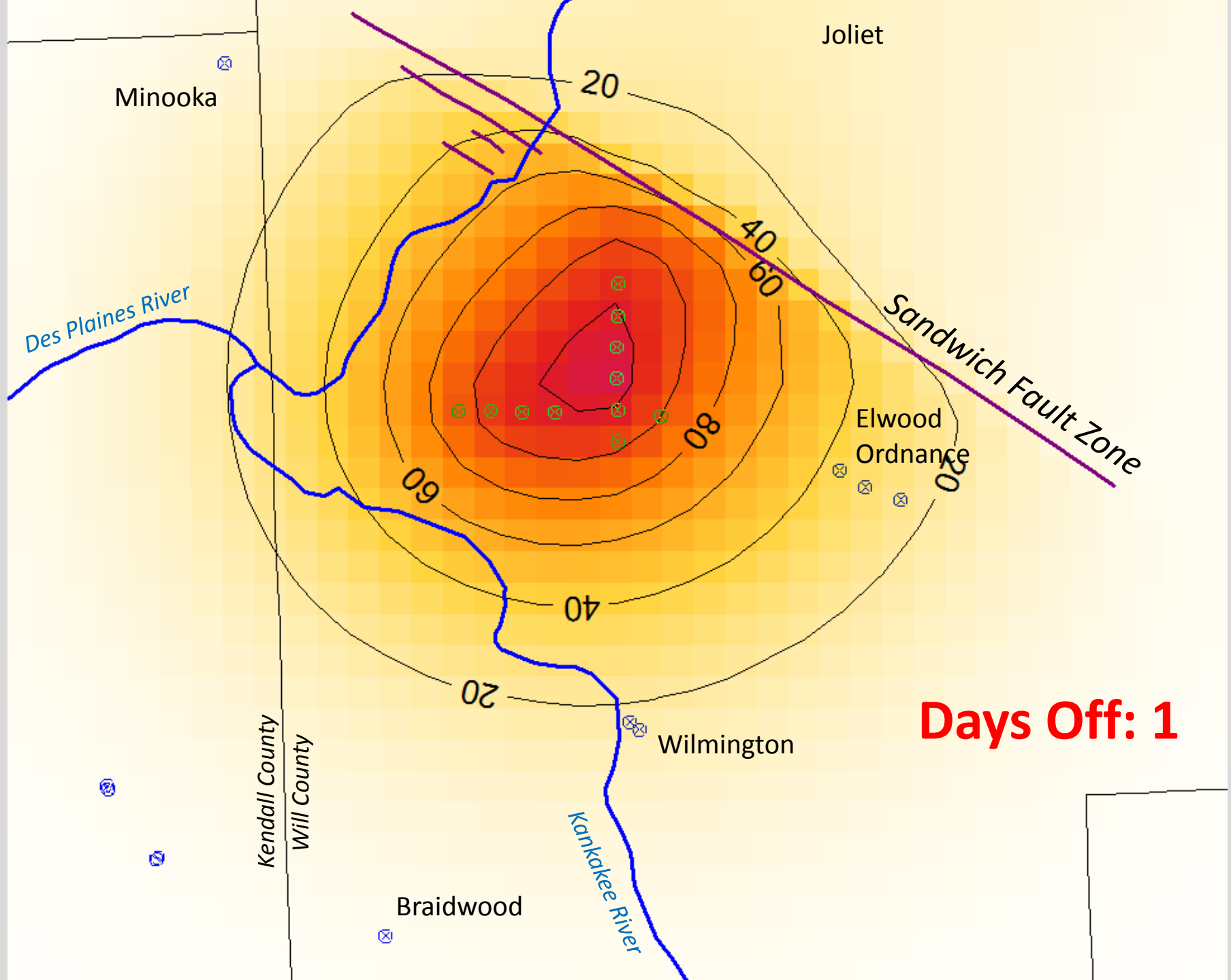


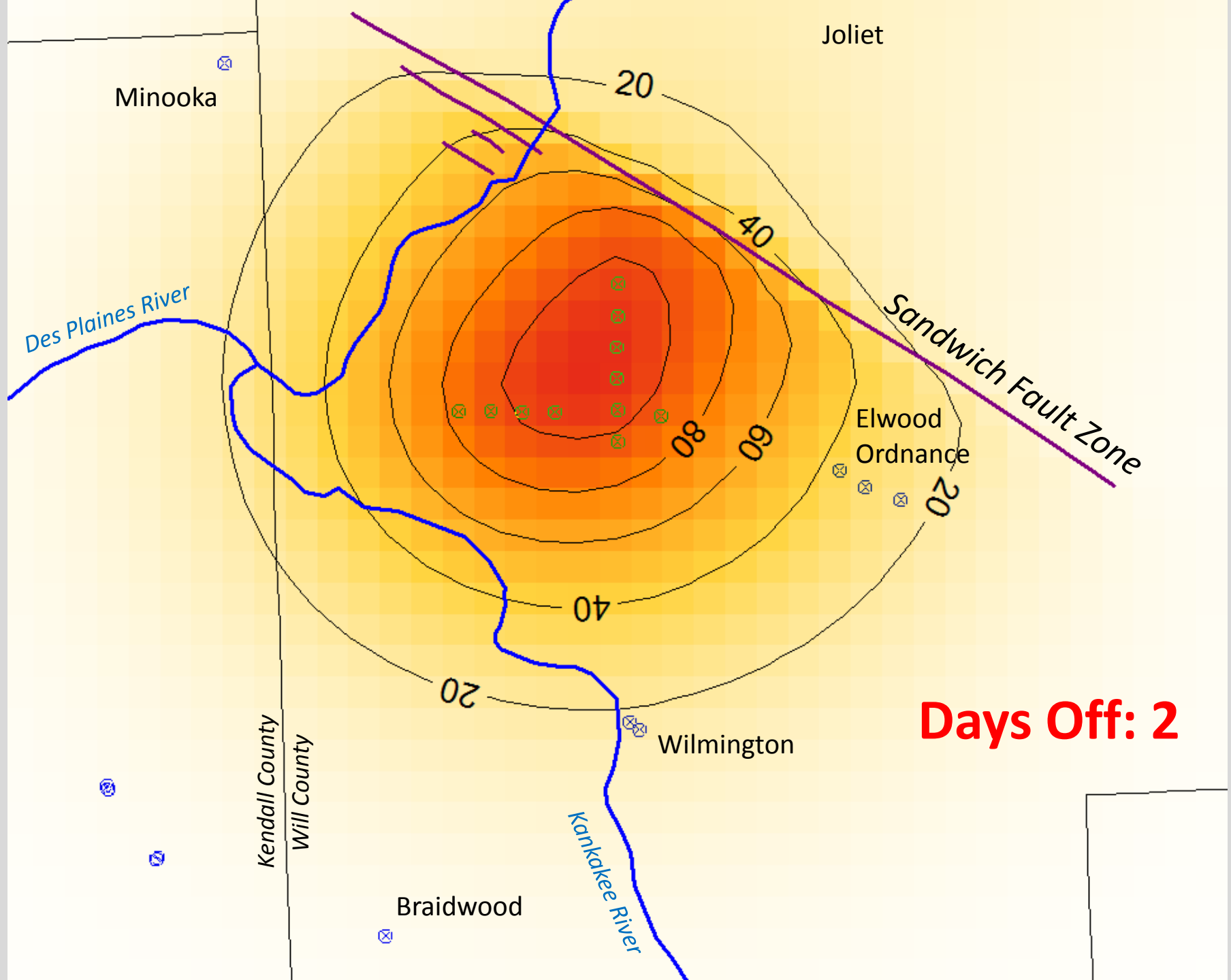


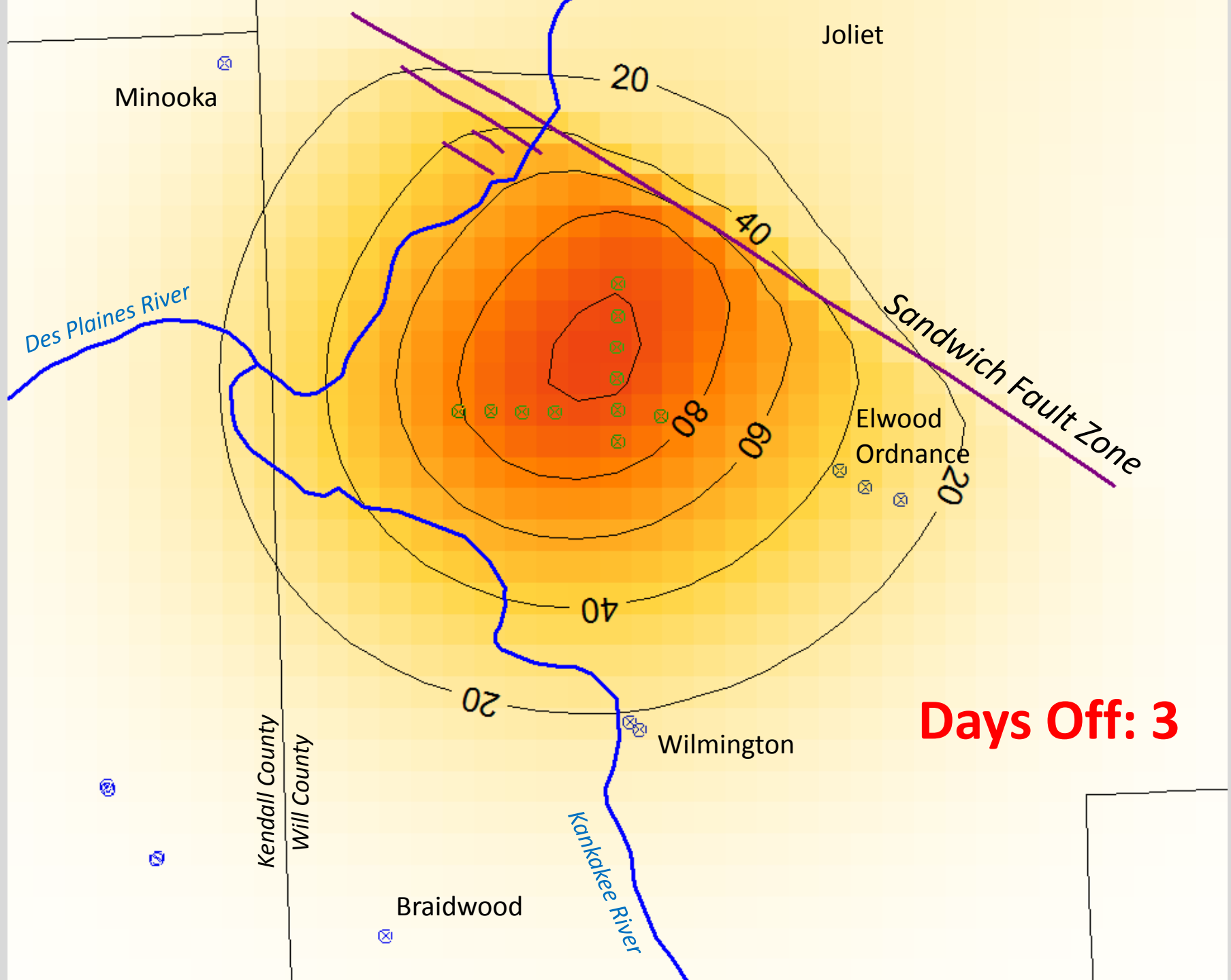




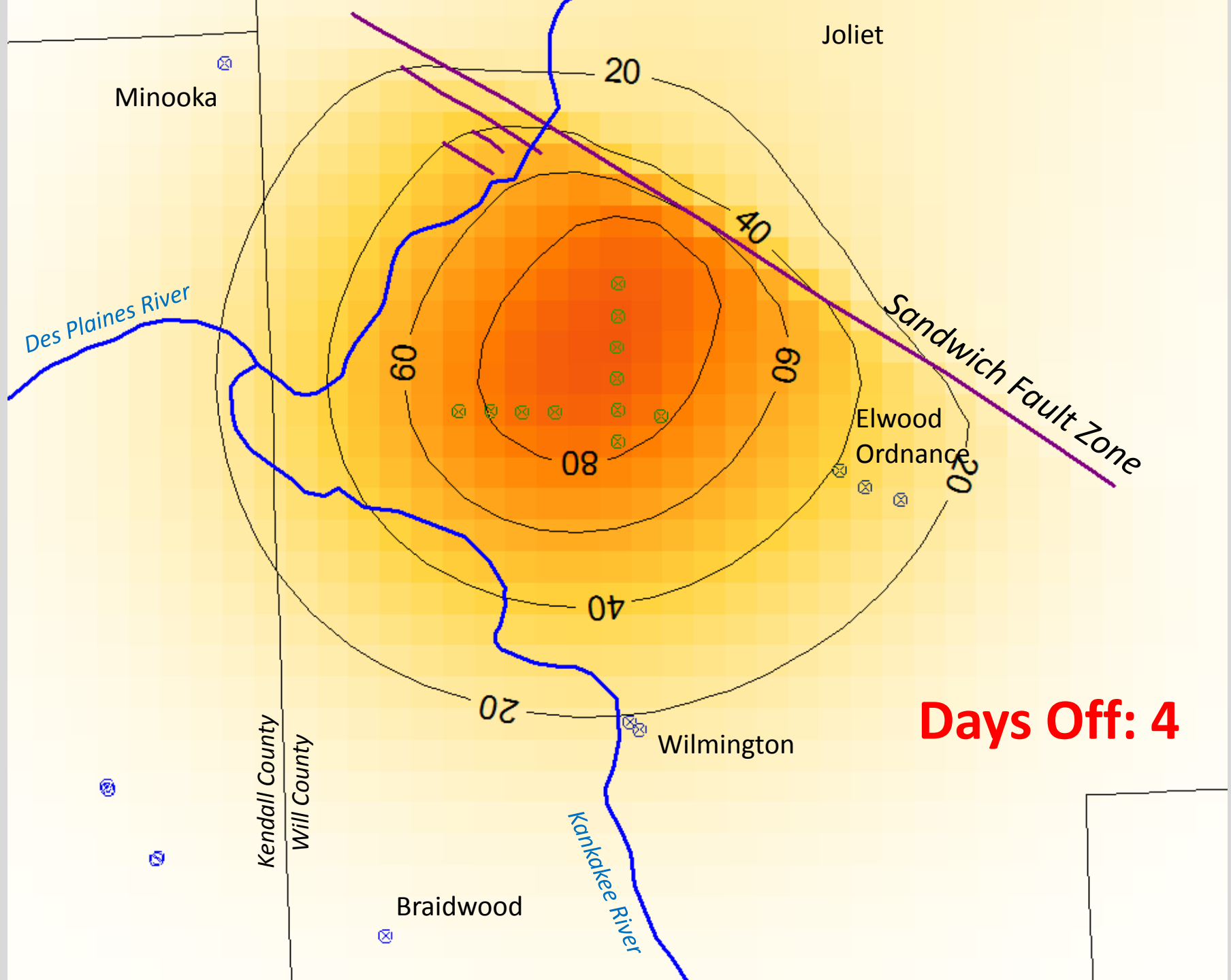


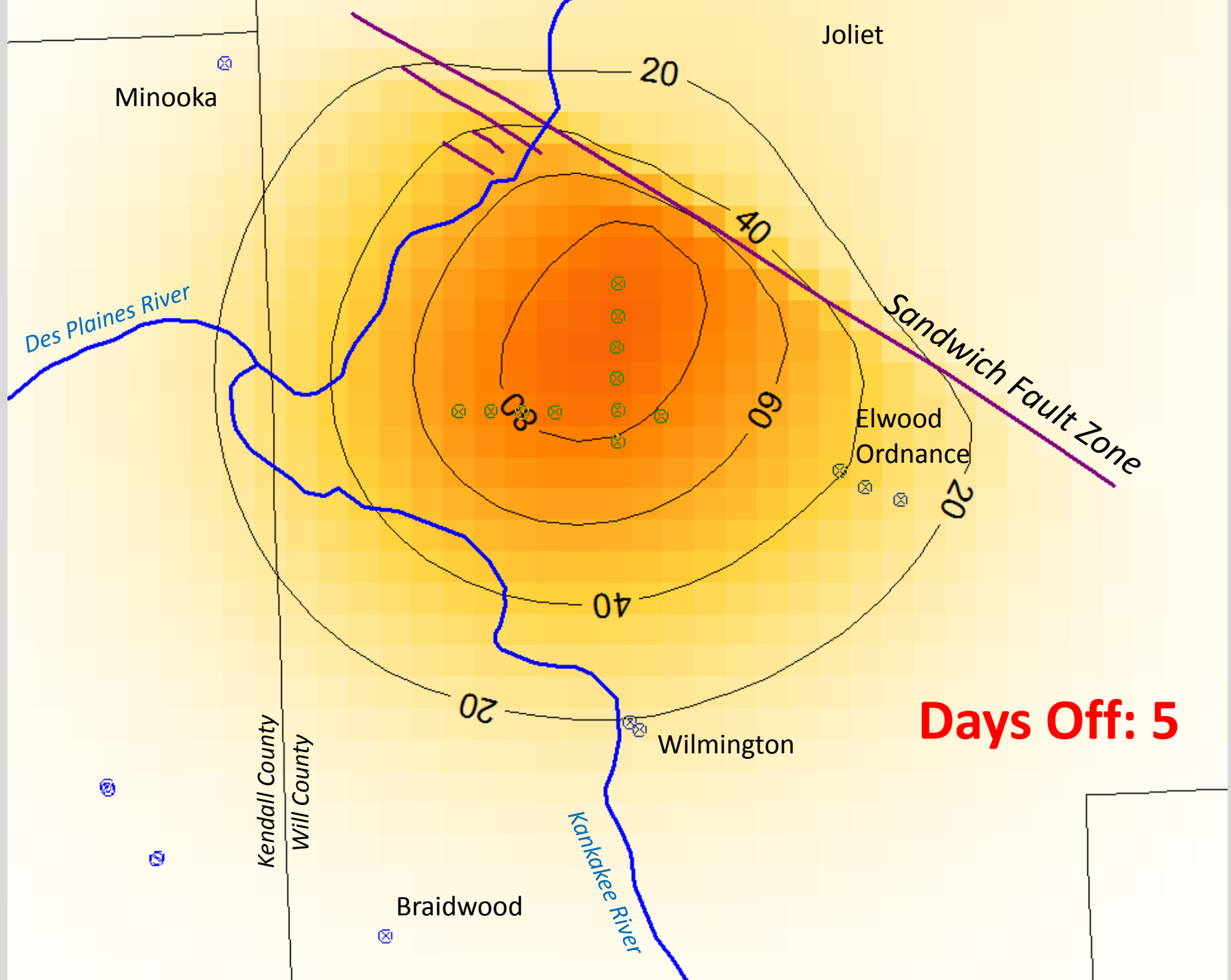


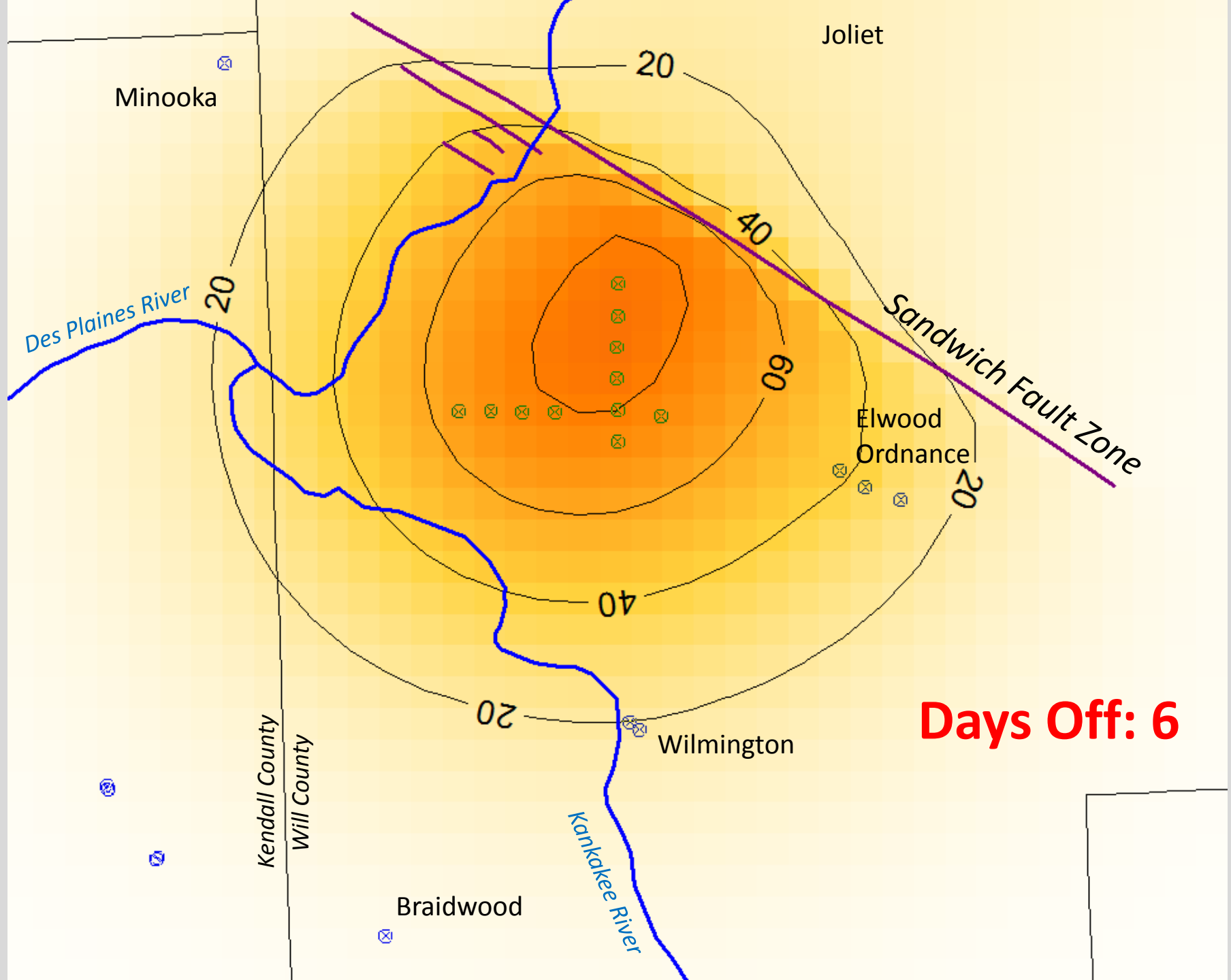


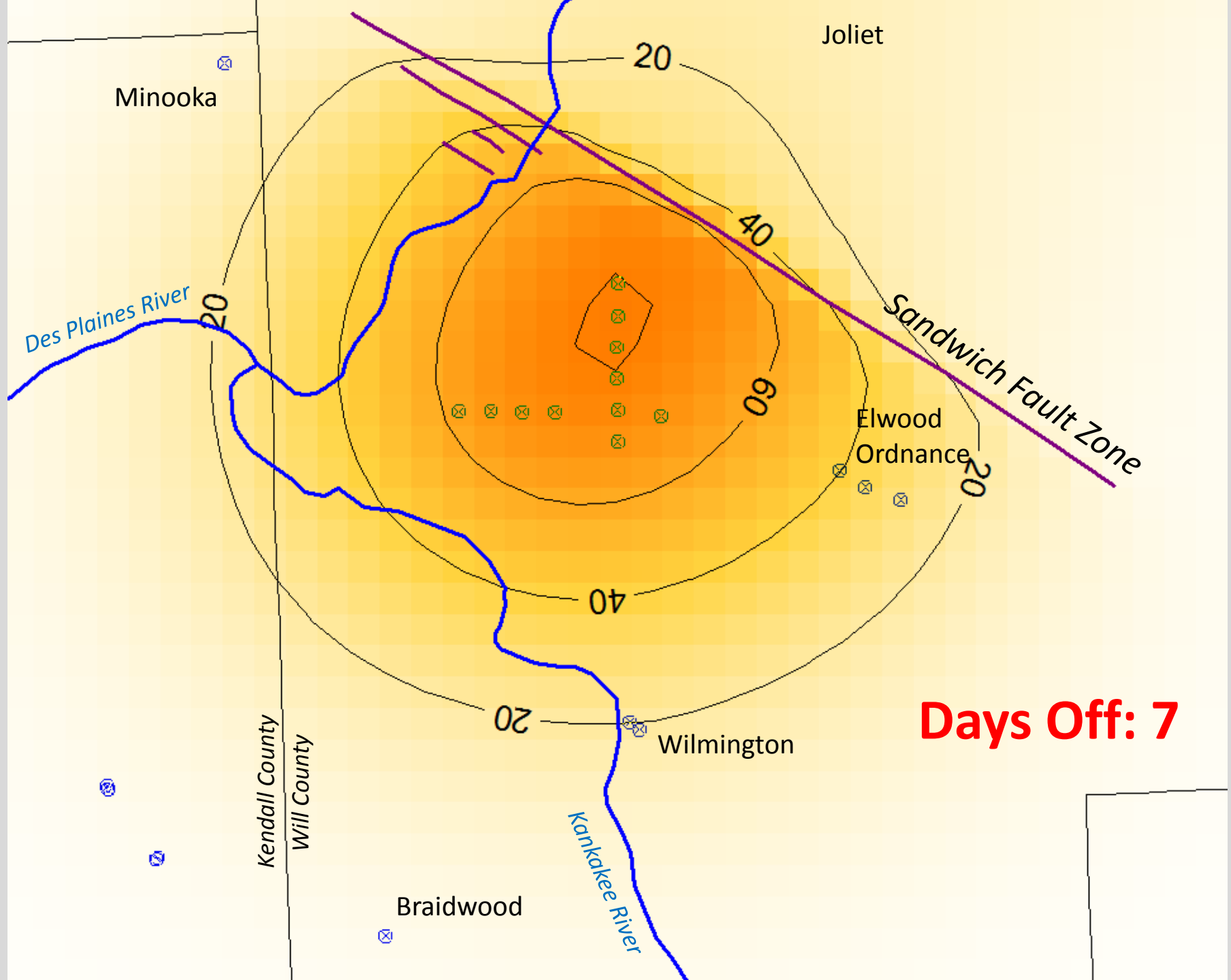


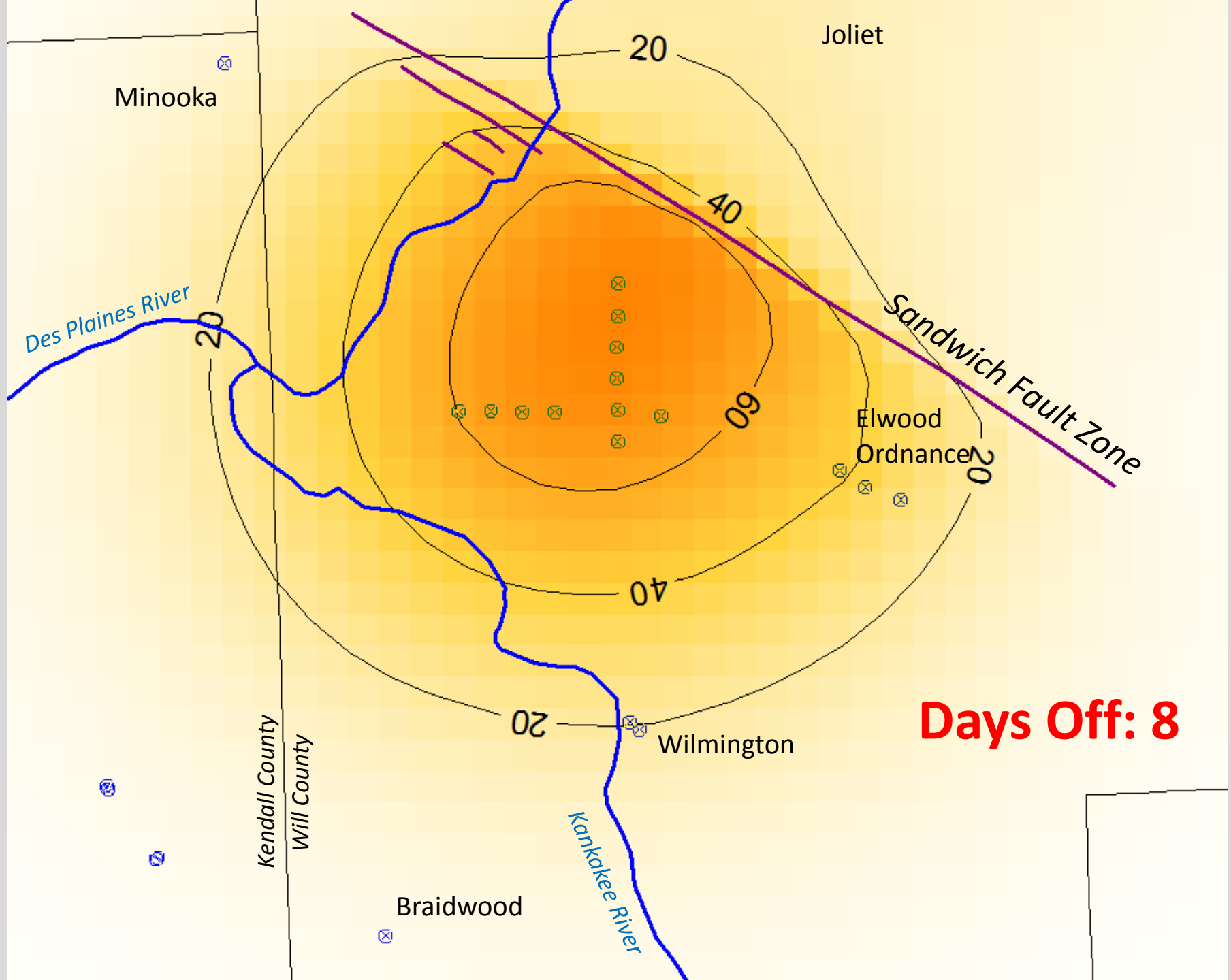
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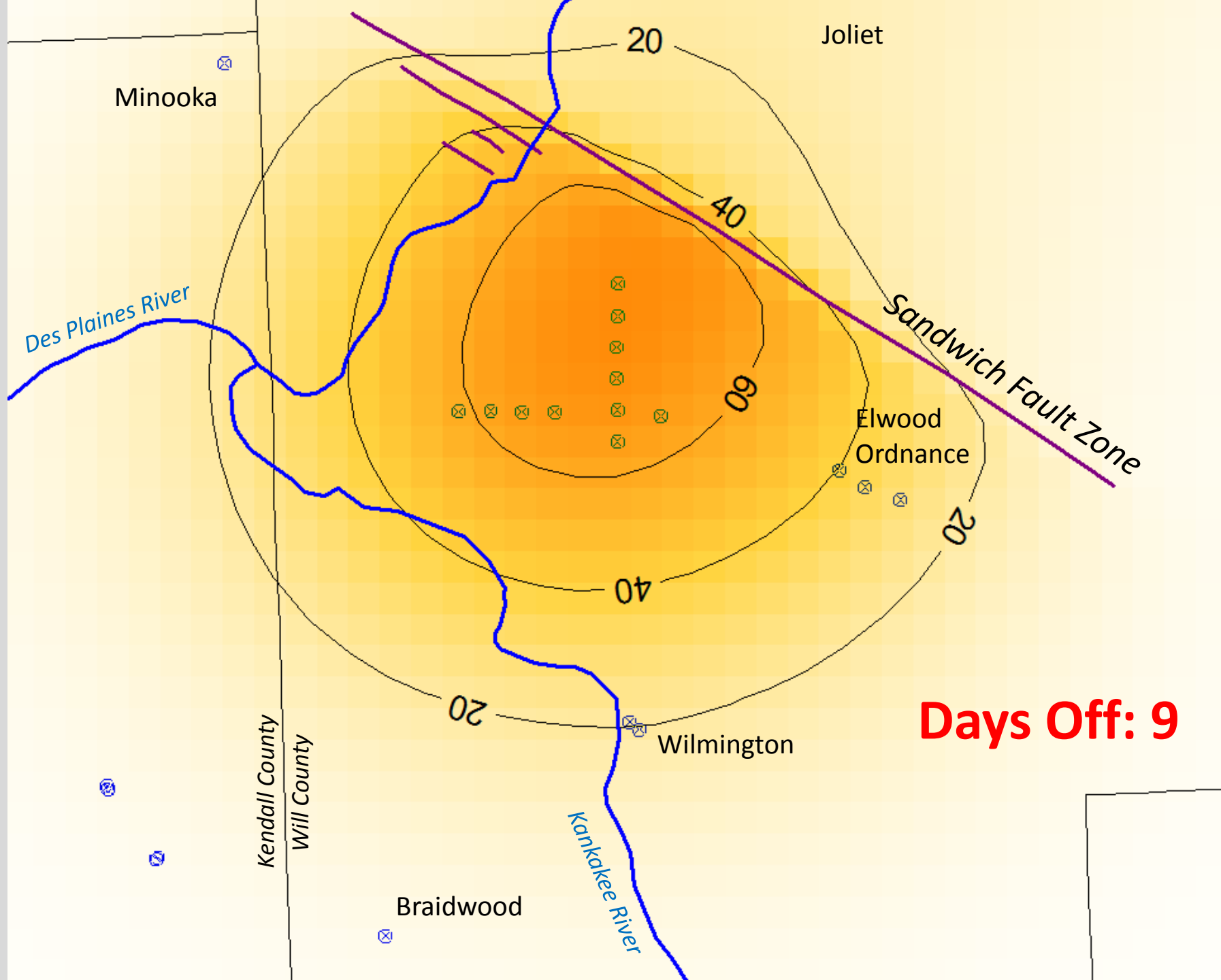




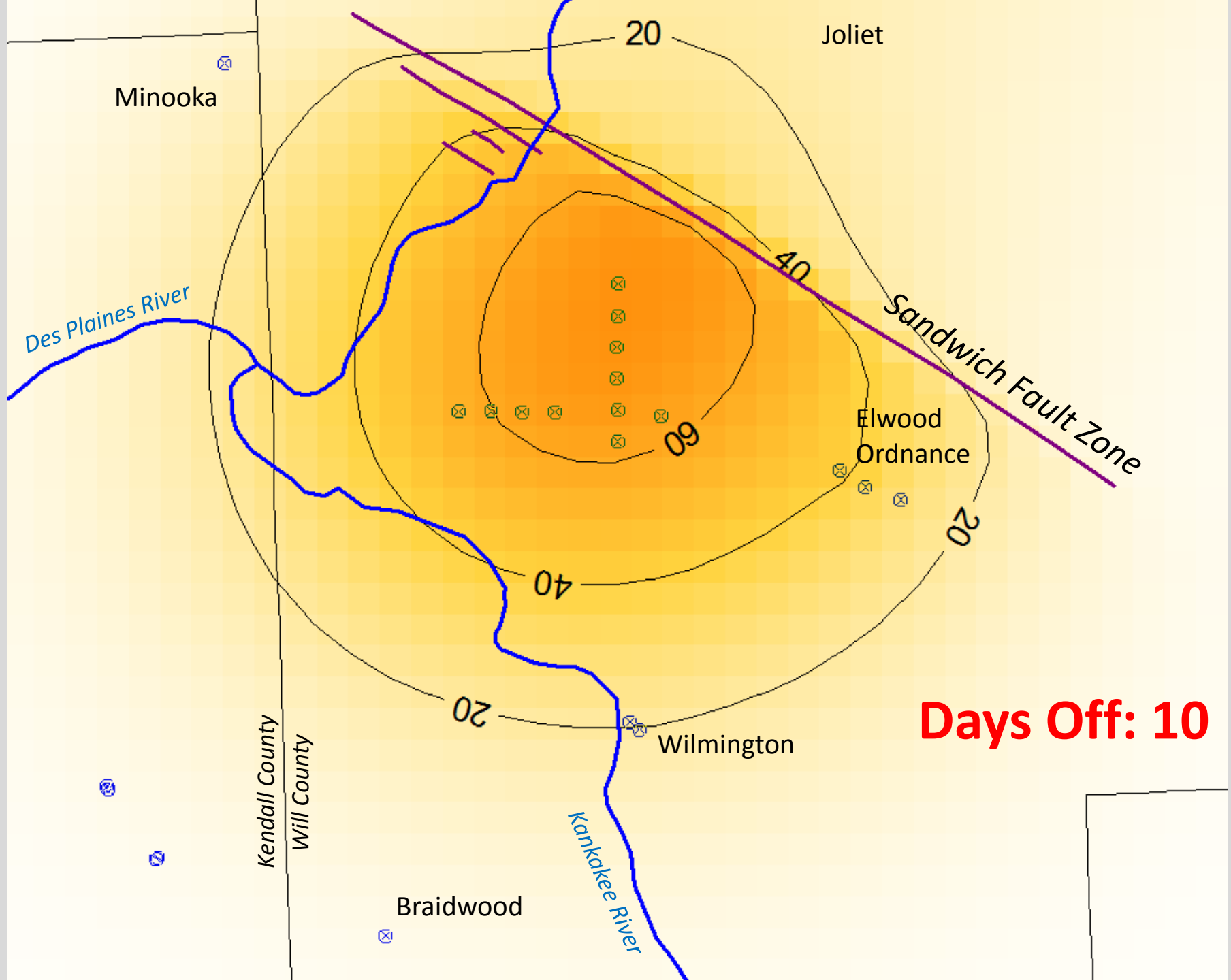


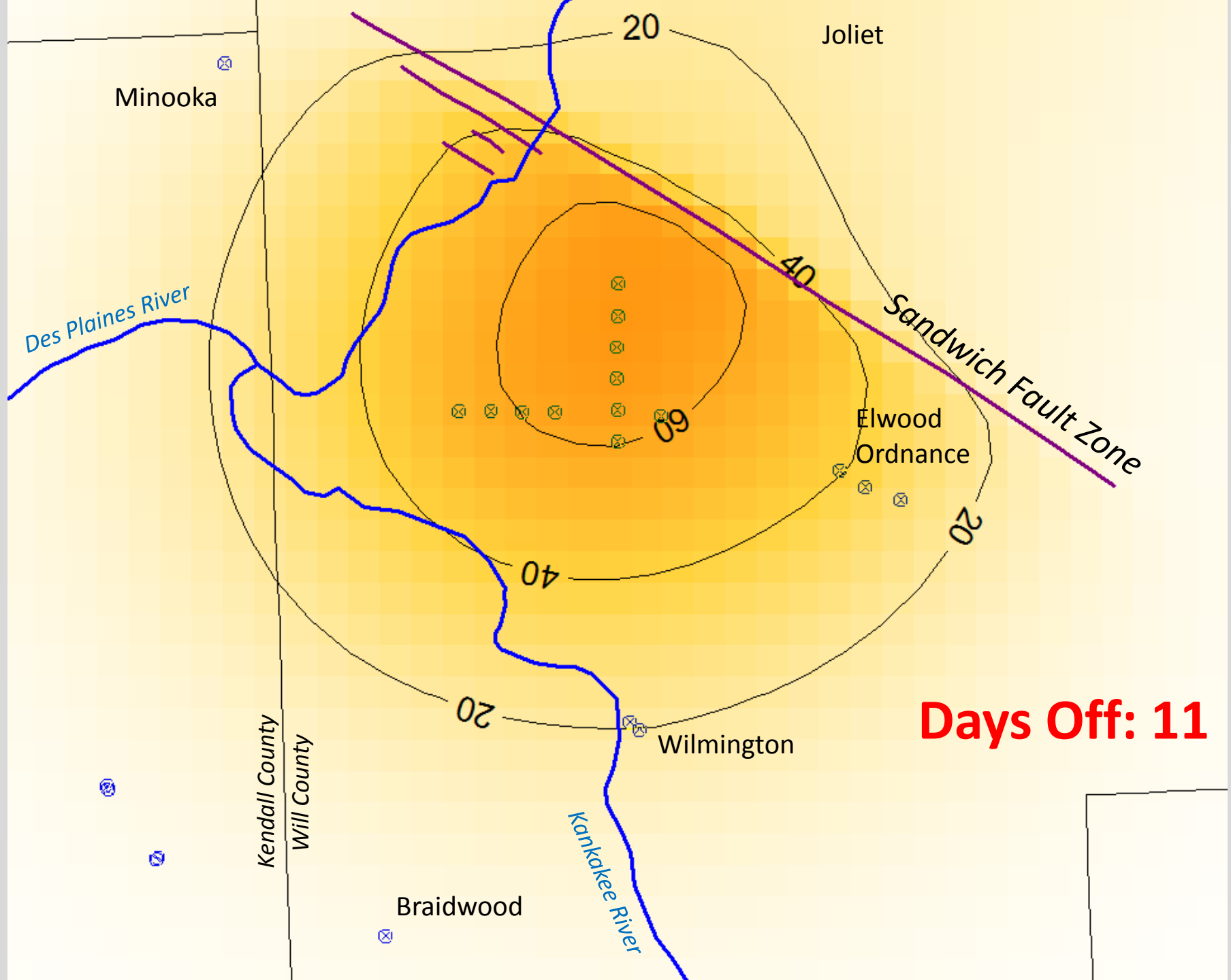


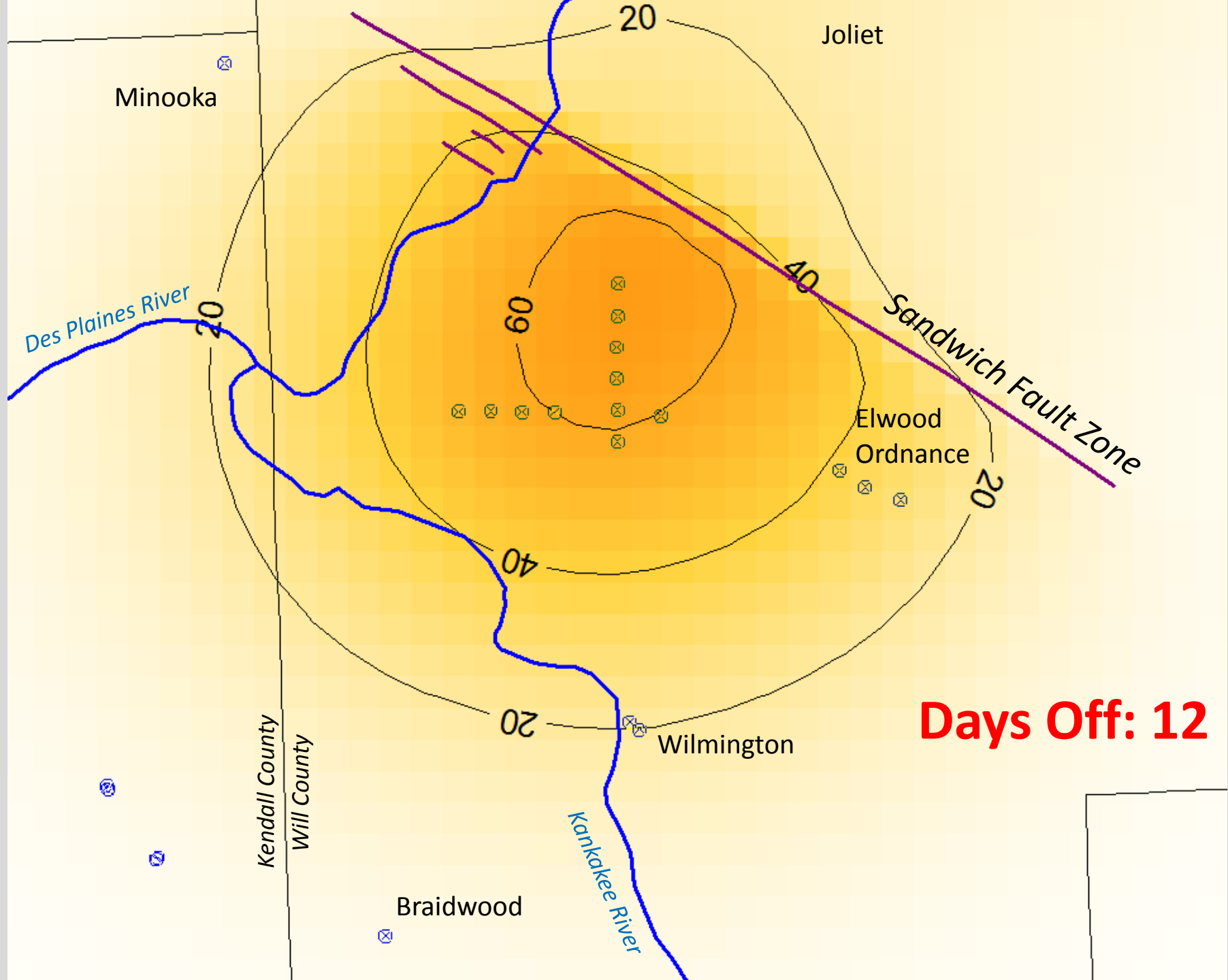


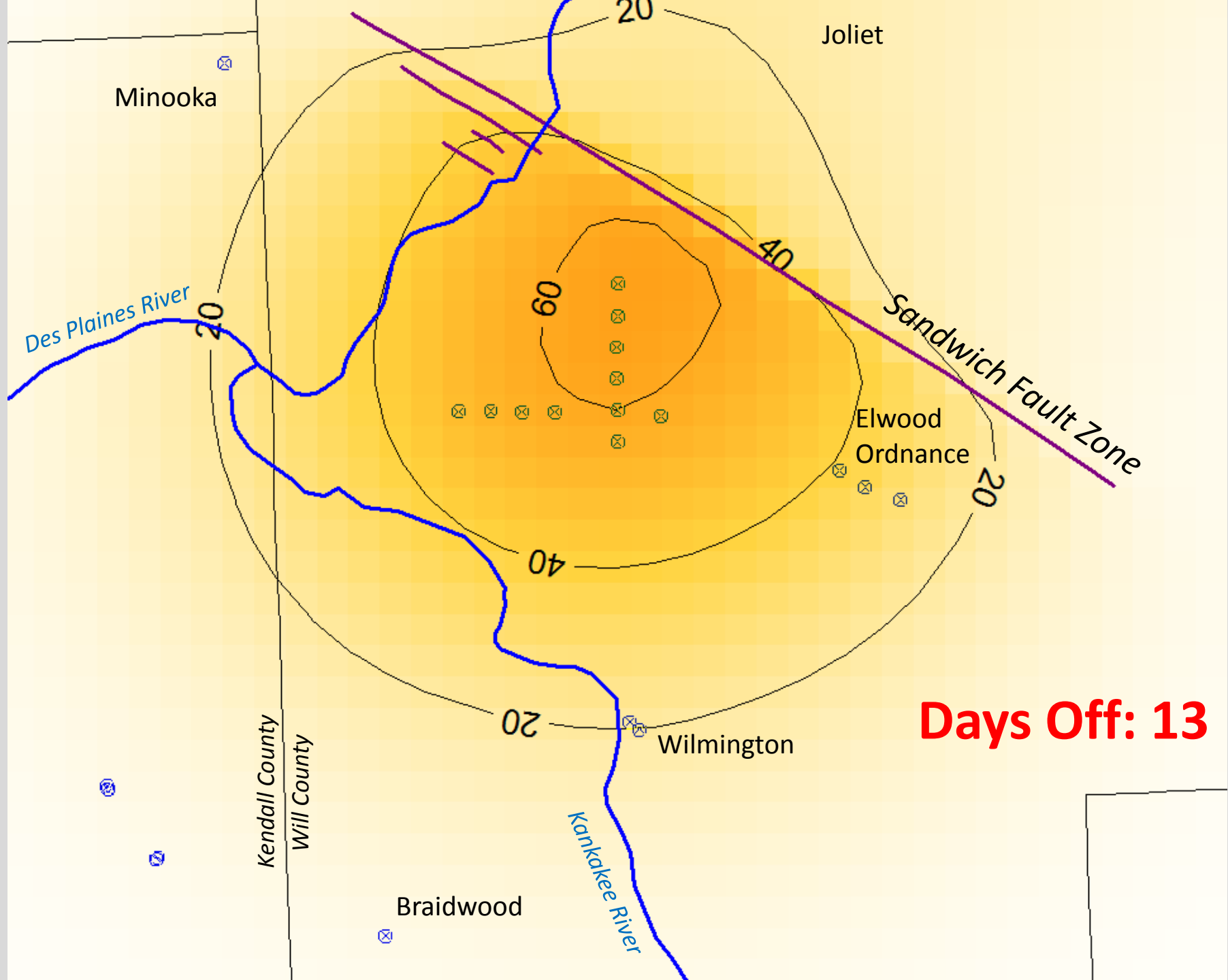


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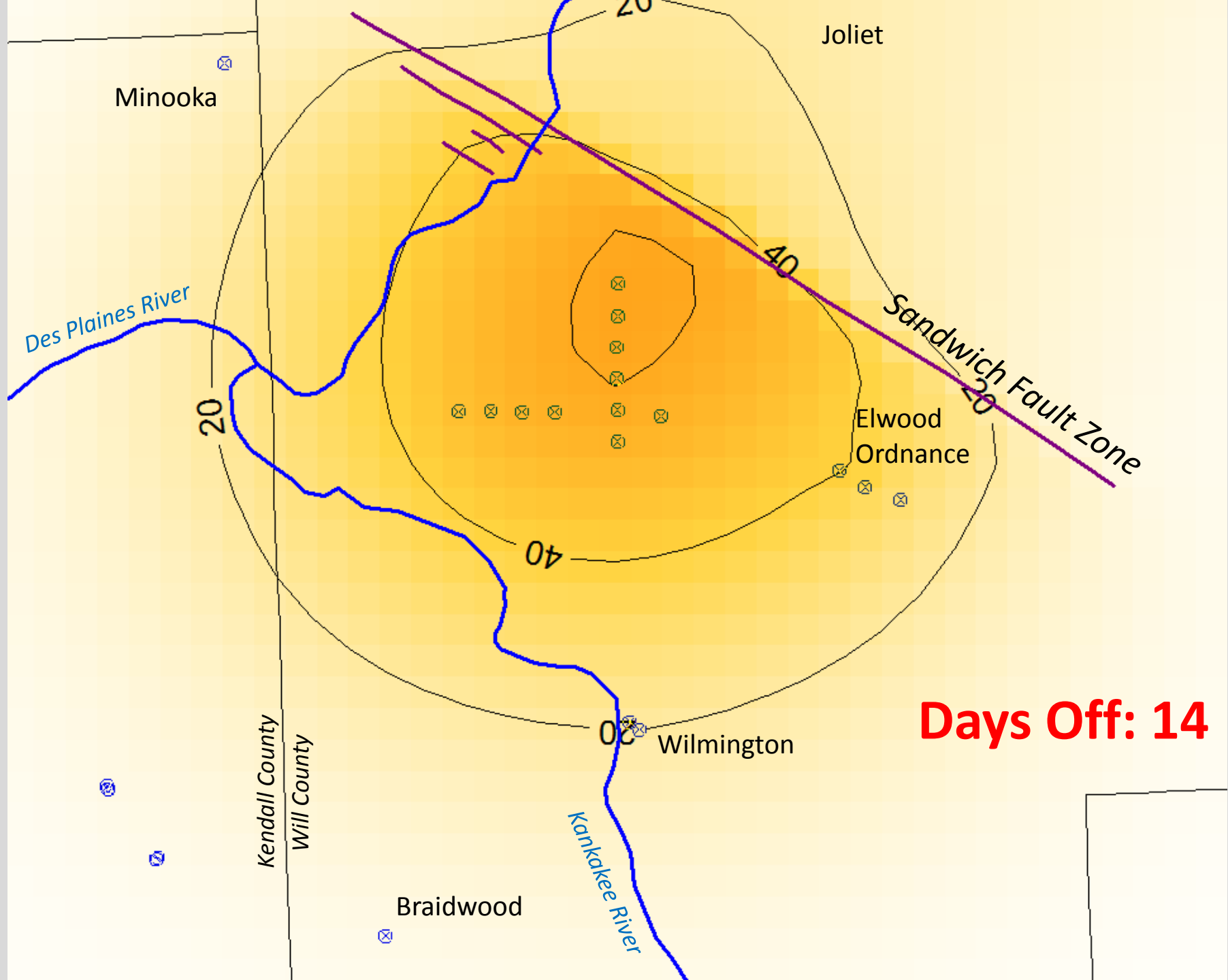


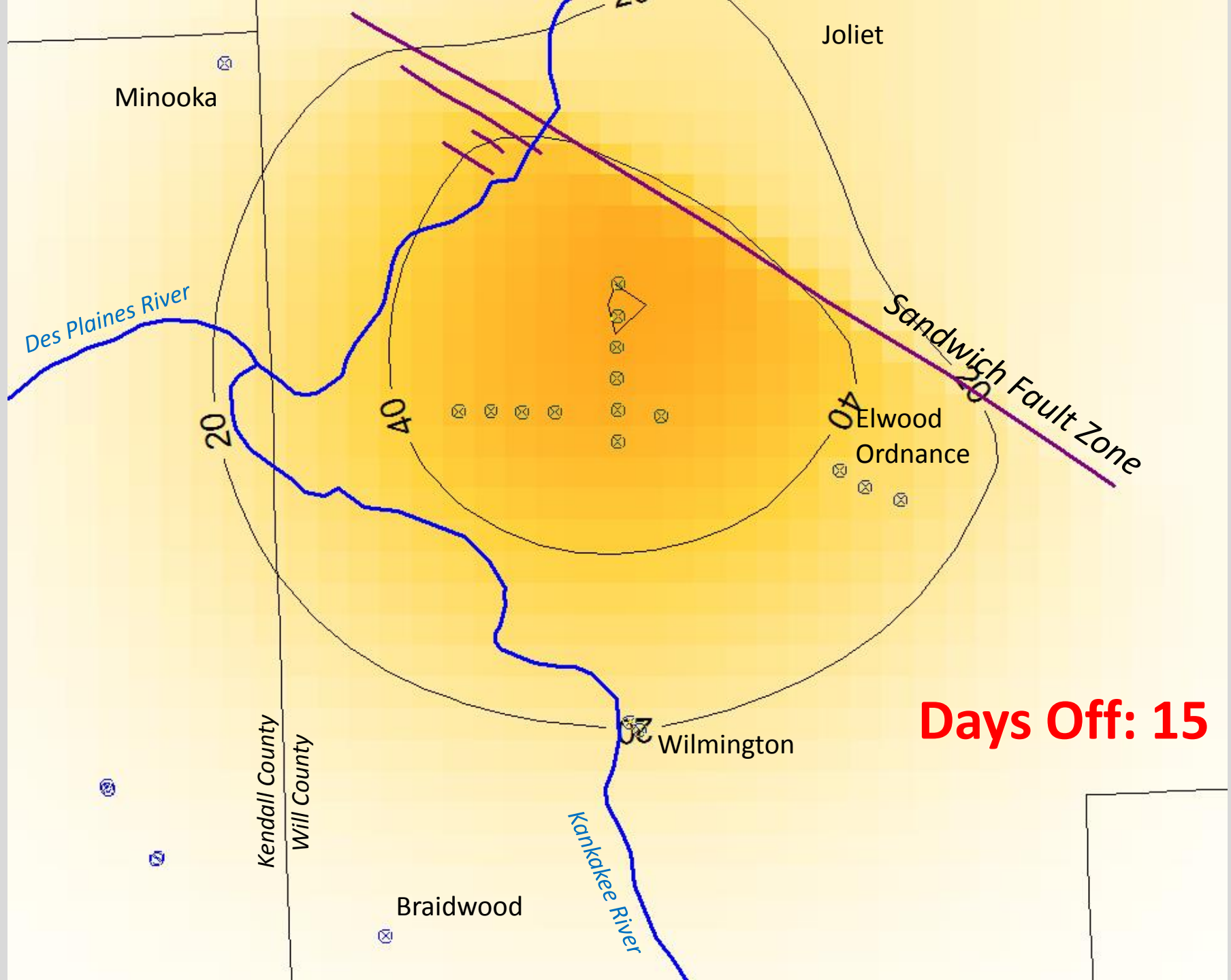


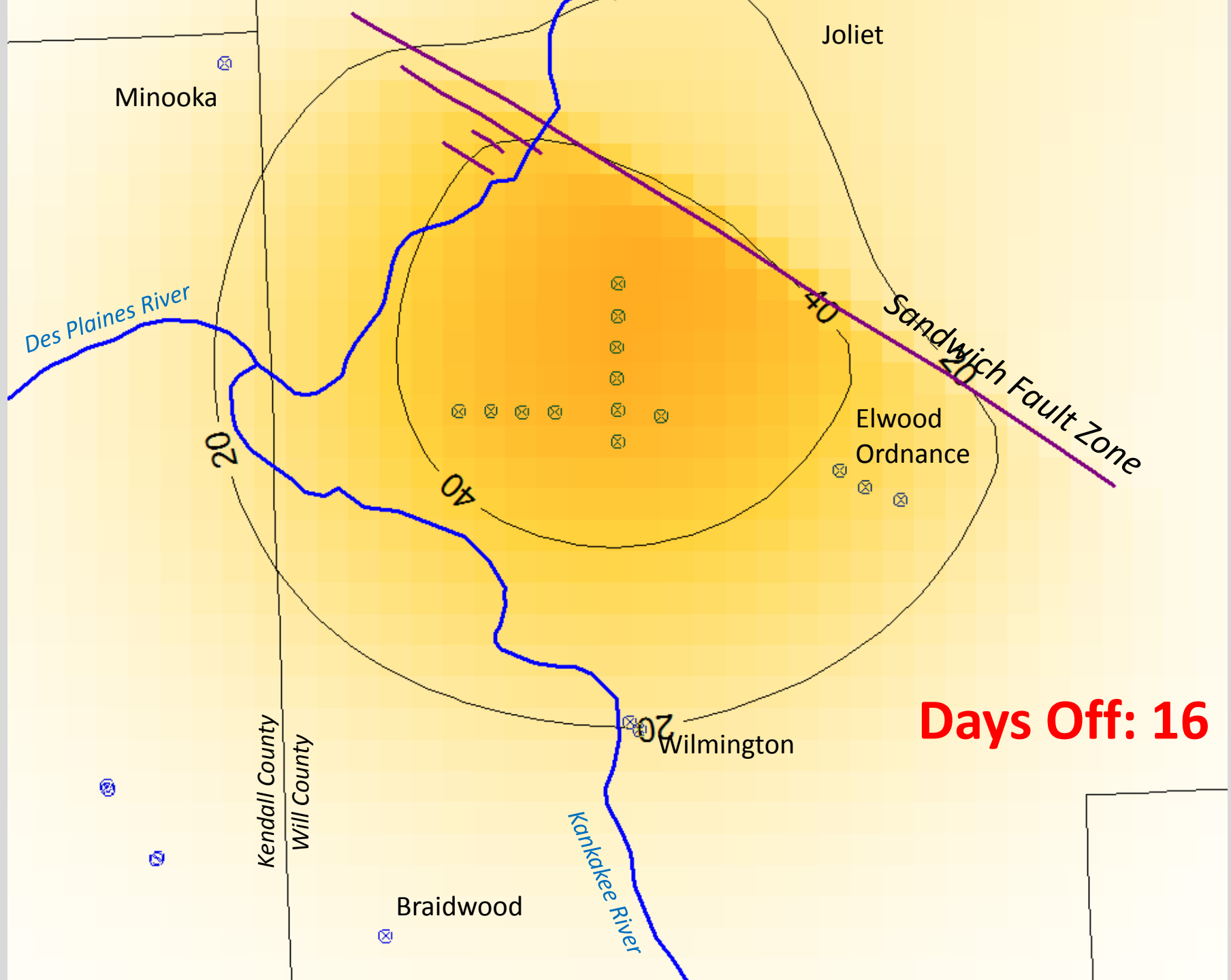


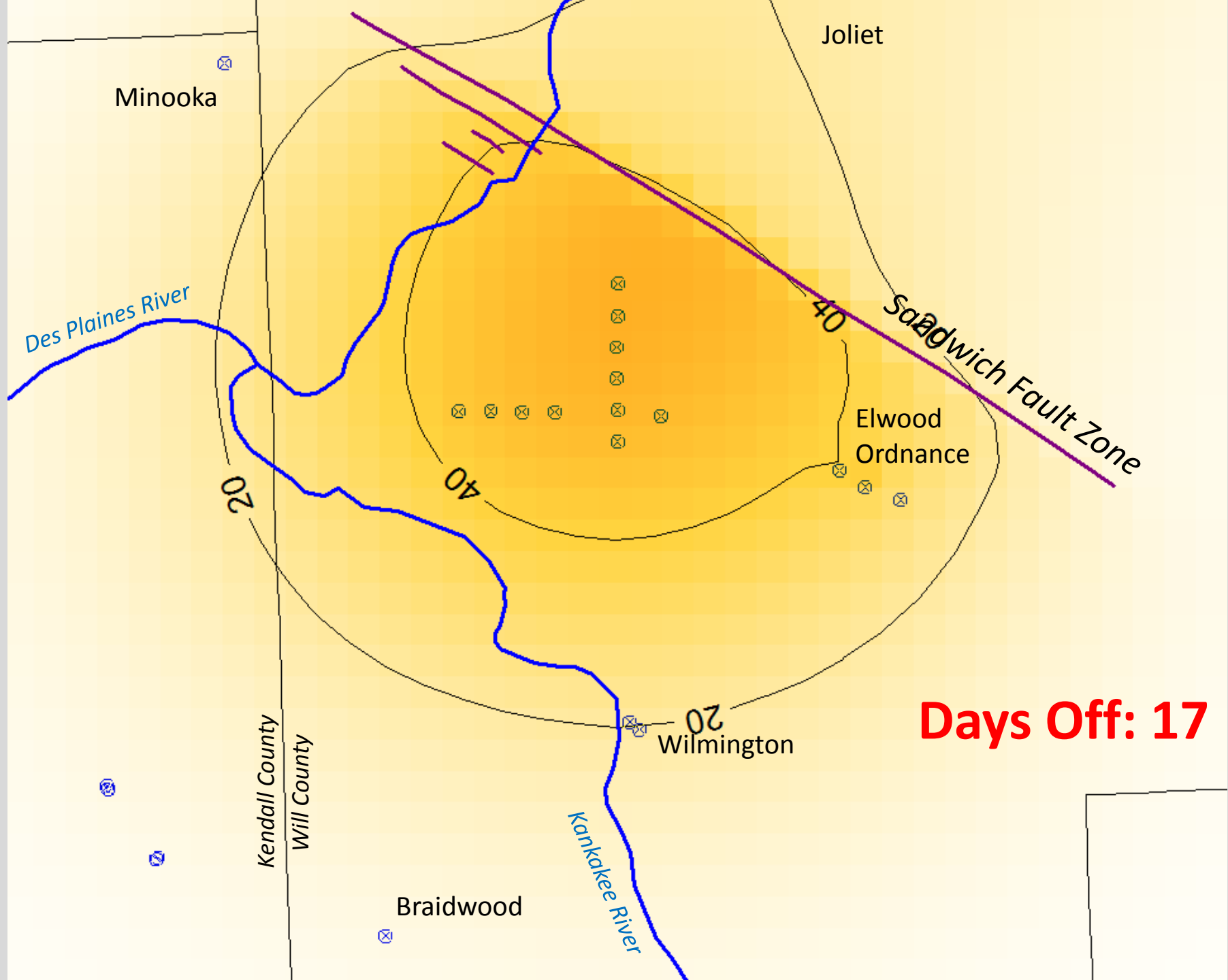


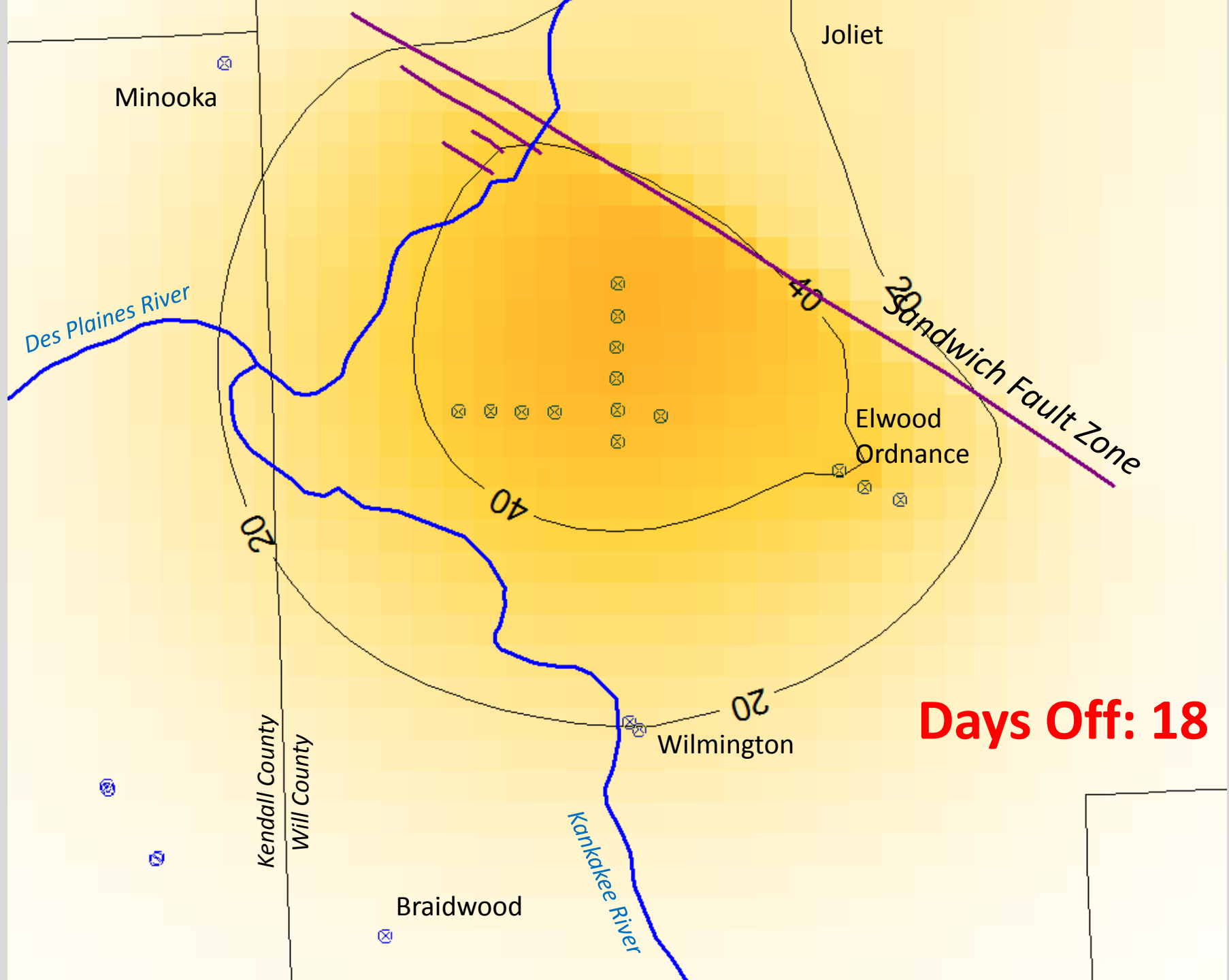
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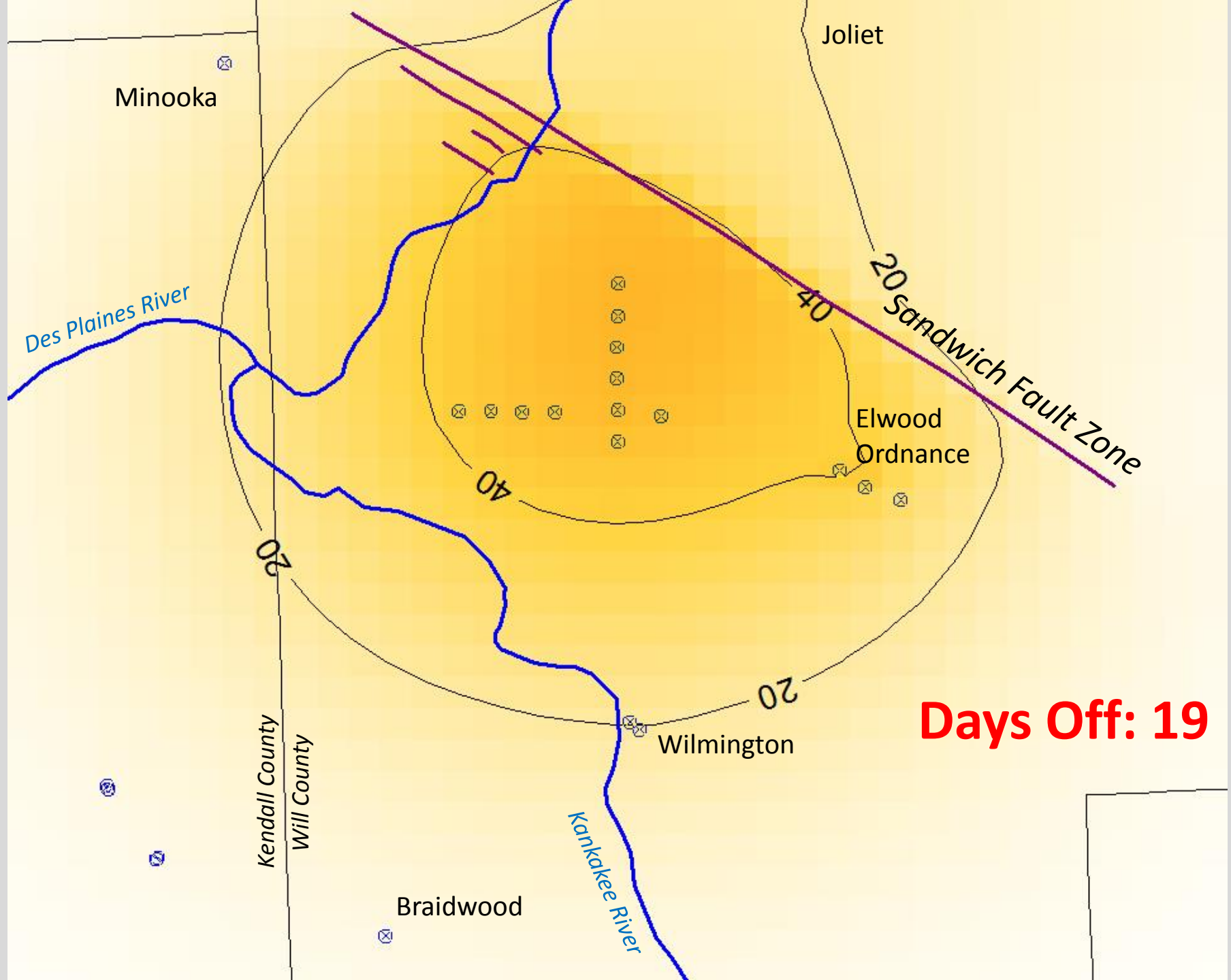


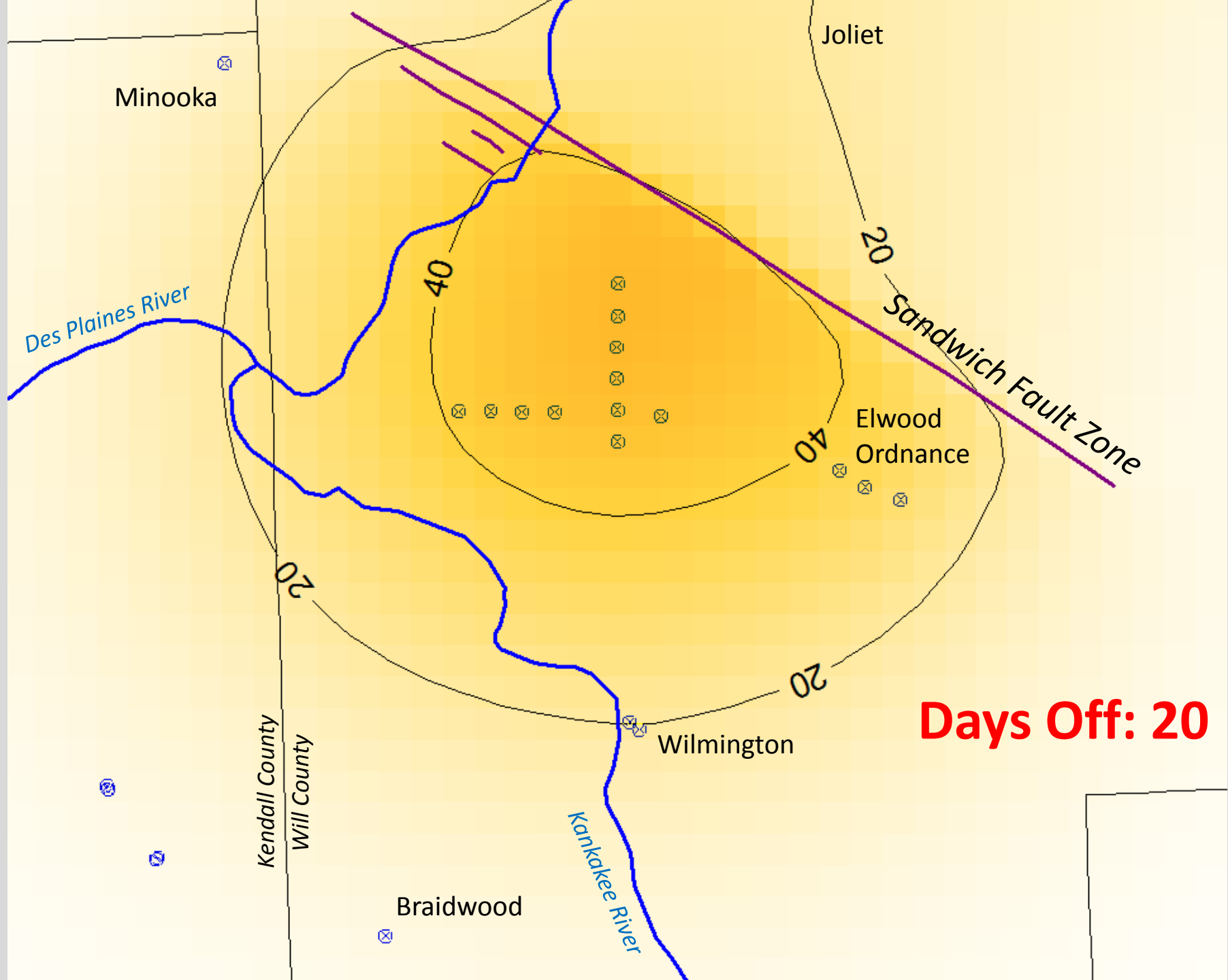


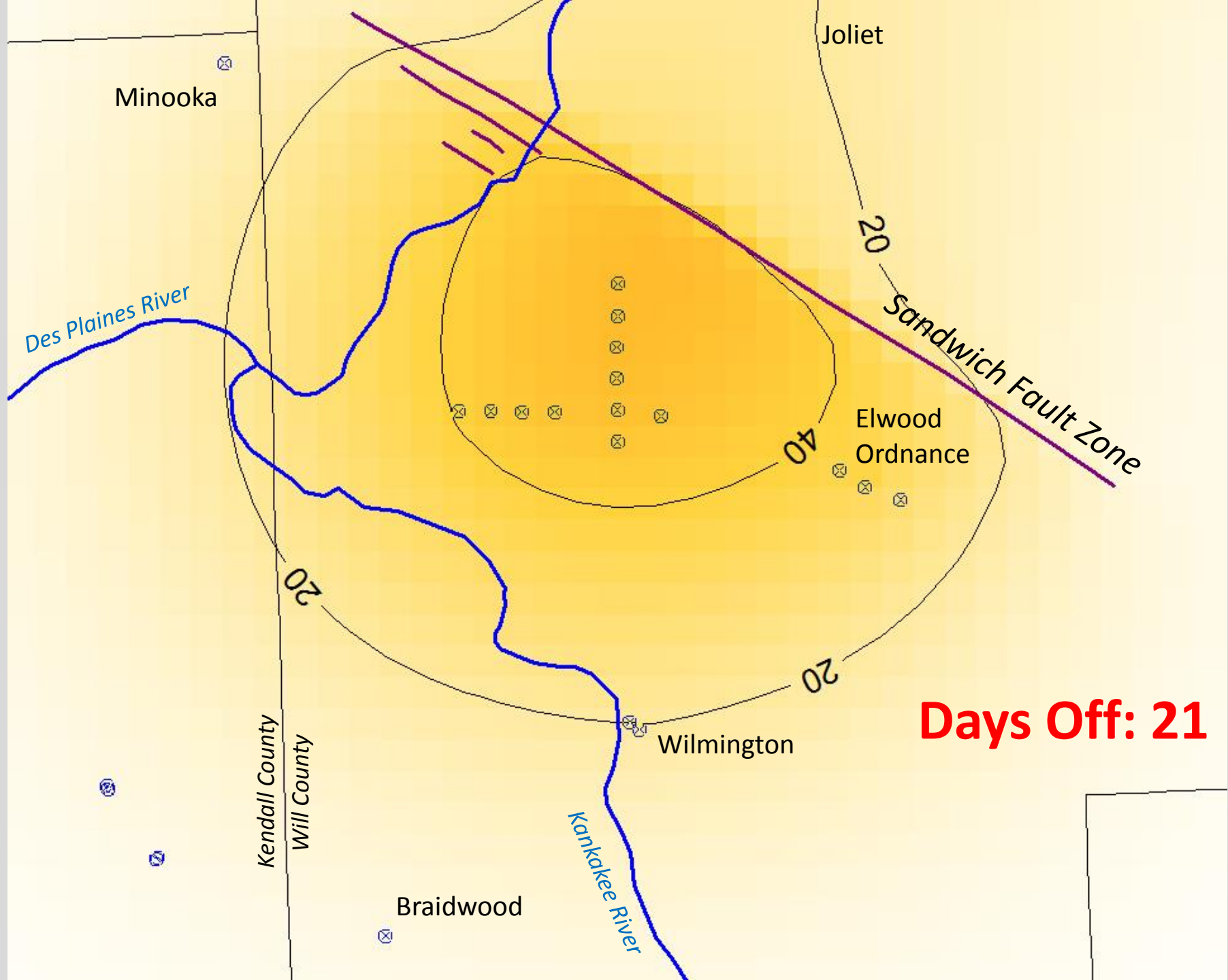


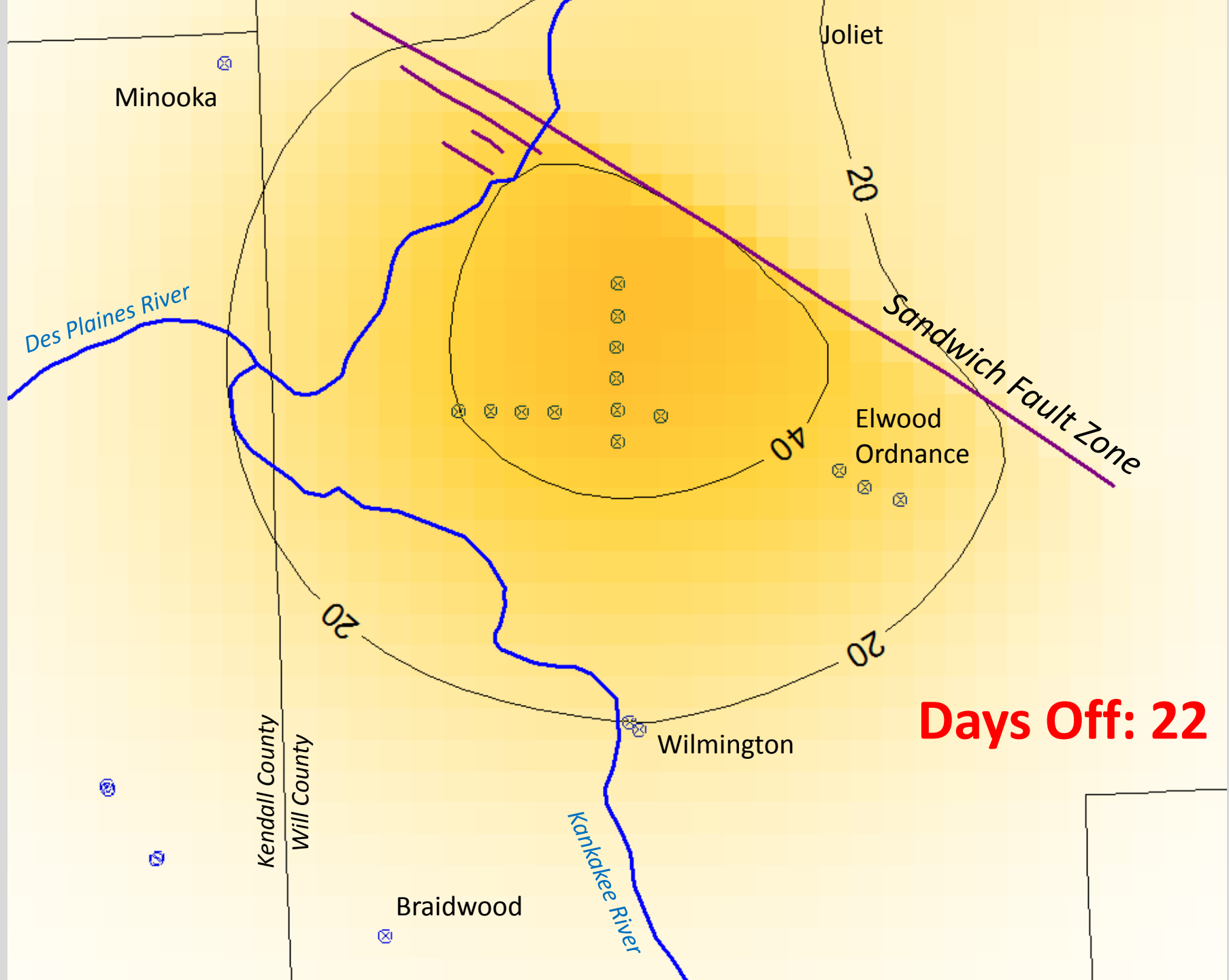


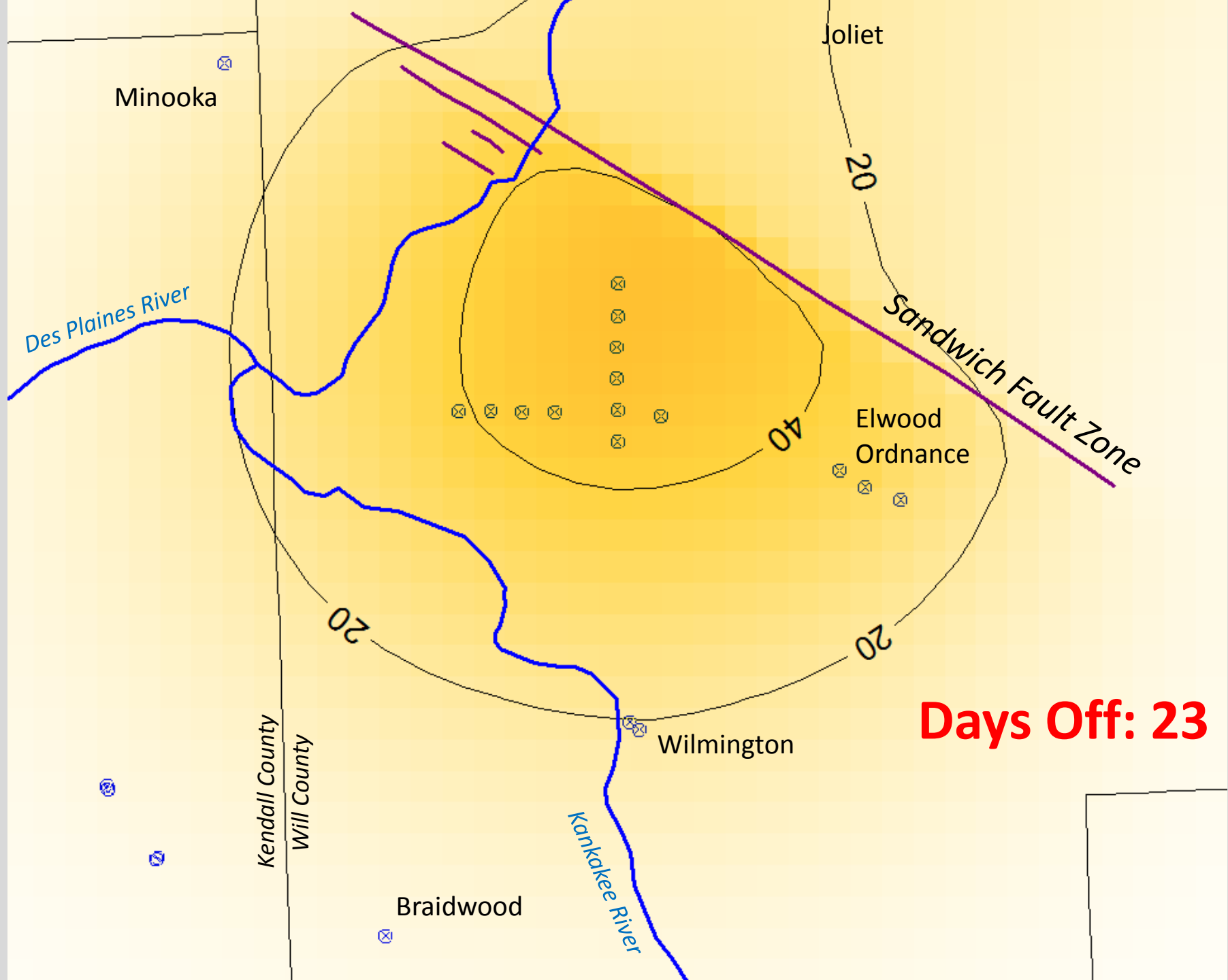


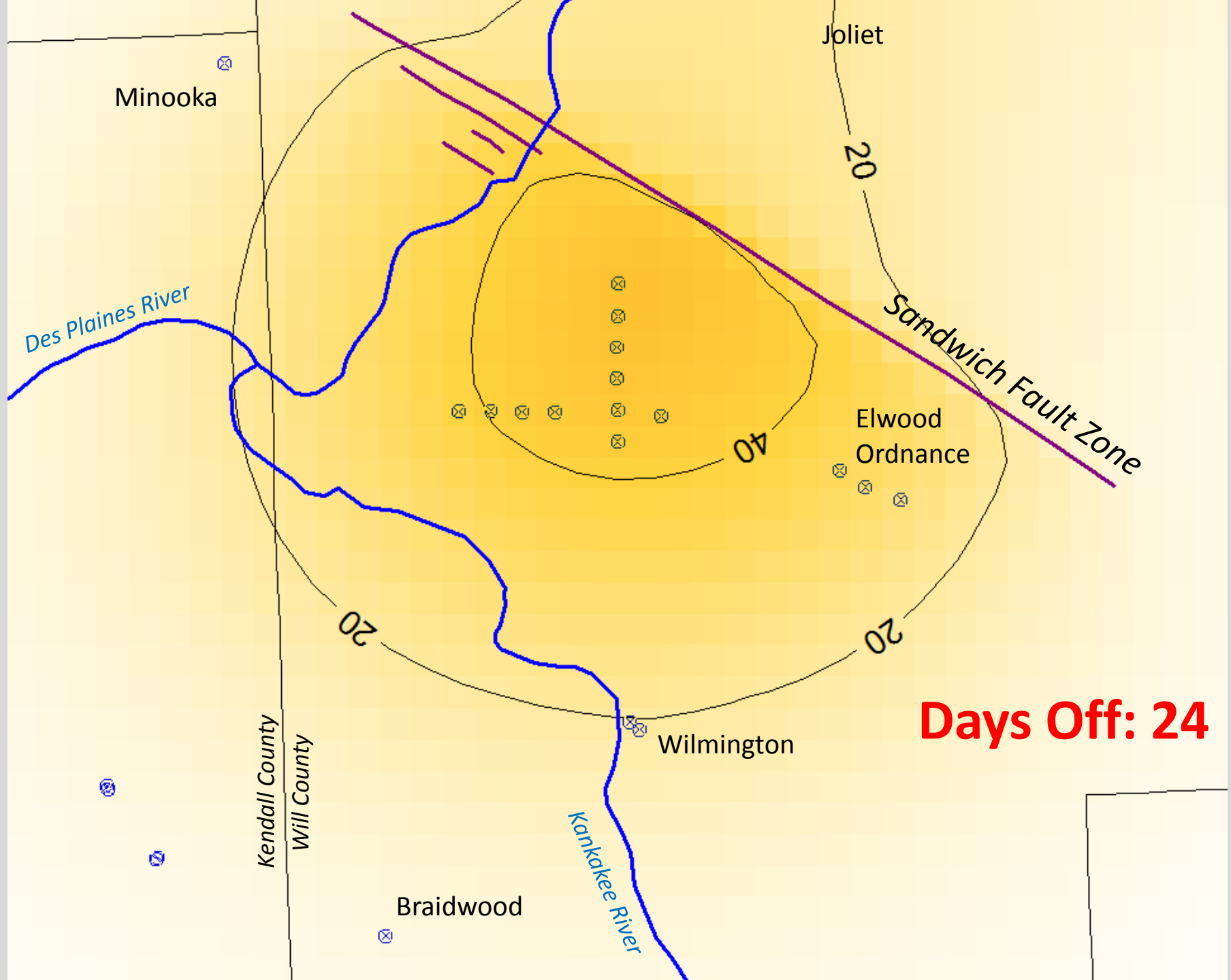


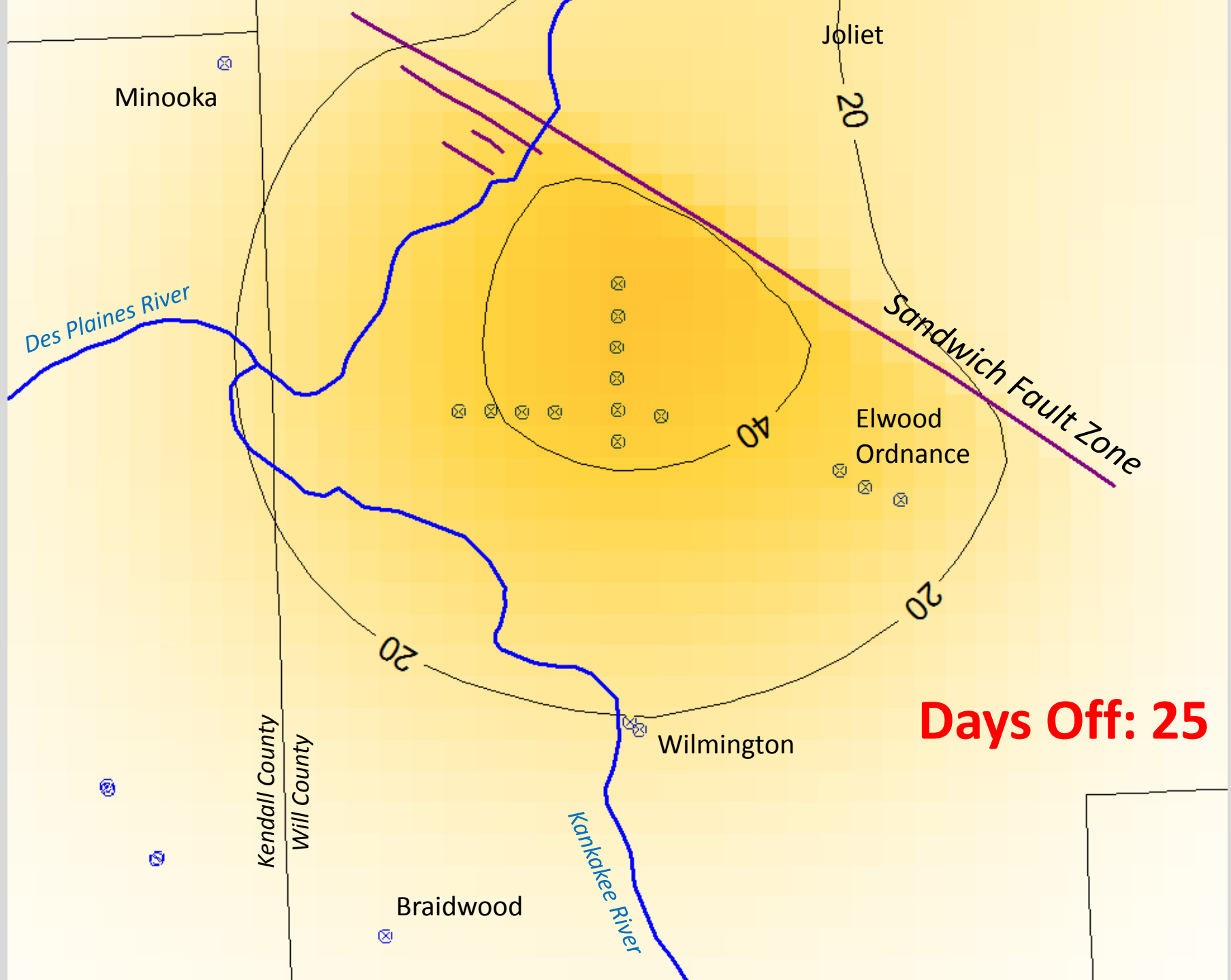






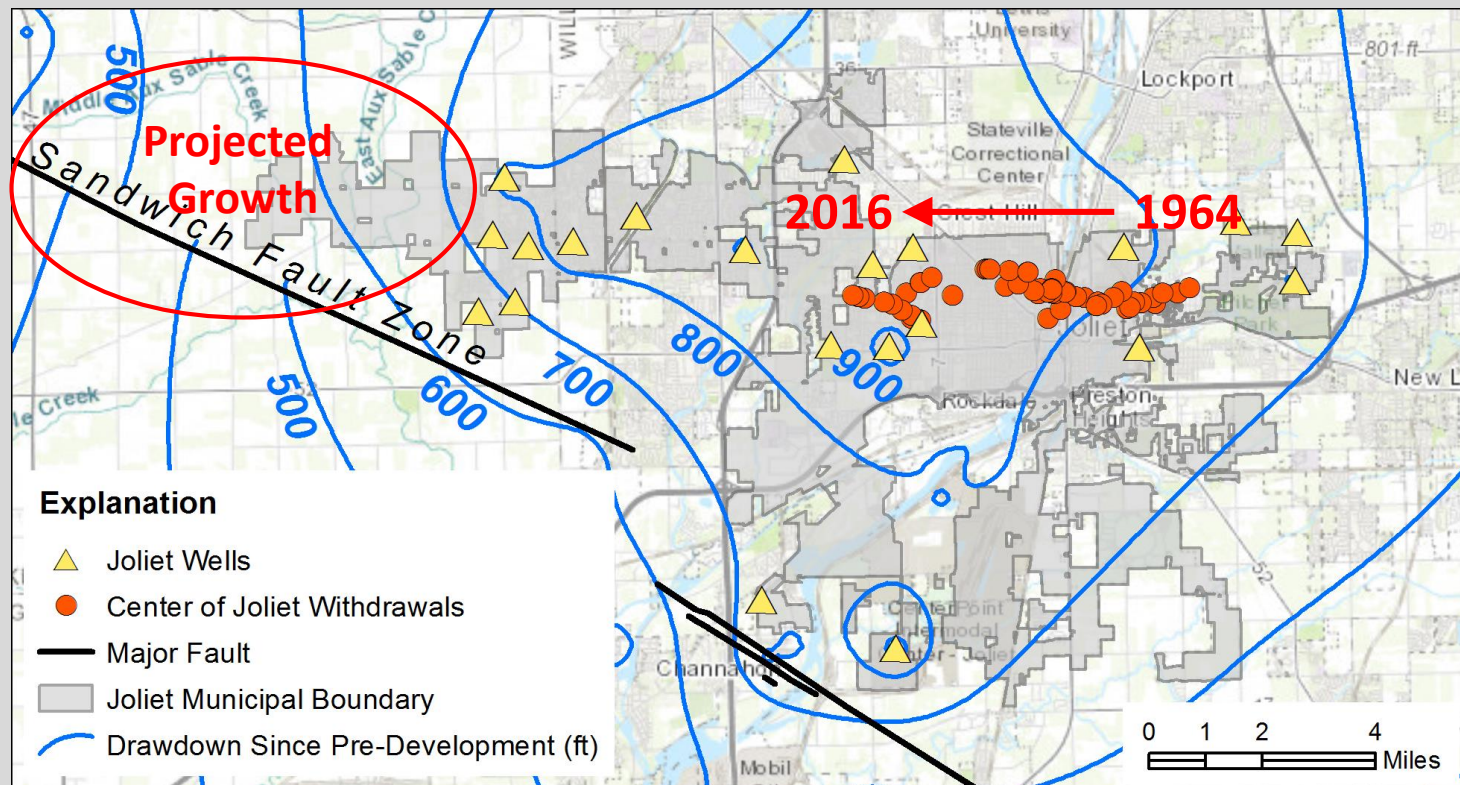






Implications for groundwater supply

- Joliet withdraws ~ 17 MGD from their 21 deep sandstone wells (as of 2015)
- Most population growth projected on western side of municipal boundary, likely place of new wells
- Extreme drawdown (1100-1200 feet of depth to water), ***pumps in danger of breaking suction!!***
- Crisis prompting communities to switch to alternative supplies



Conclusions/Future Work

- Unprecedented size and duration of the Arsenal Test allows regional insight into hydrogeology of vertical fault zone
- Used slope of drawdown curves as calibration targets for wells near fault
- **Skin factors** needed at CLN wells to match observed data, but **do not change slope of drawdown curves**
- **Order of magnitude decrease in K_h of sandstones within core of fault zone** (K_h around 0.5 ft/day)
- Far targets insensitive to influence of fault zone
- Joliet **center of pumping moving closer to fault zone**, decreasing specific capacities and less recharge to wells
- Quadtree refinement around fault zone, updating model geology

Questions?

drhadley@illinois.edu

217-300-0402

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