Runoff Storage Potential of Drained Wetland Depressions in the Des Moines Lobe of Iowa

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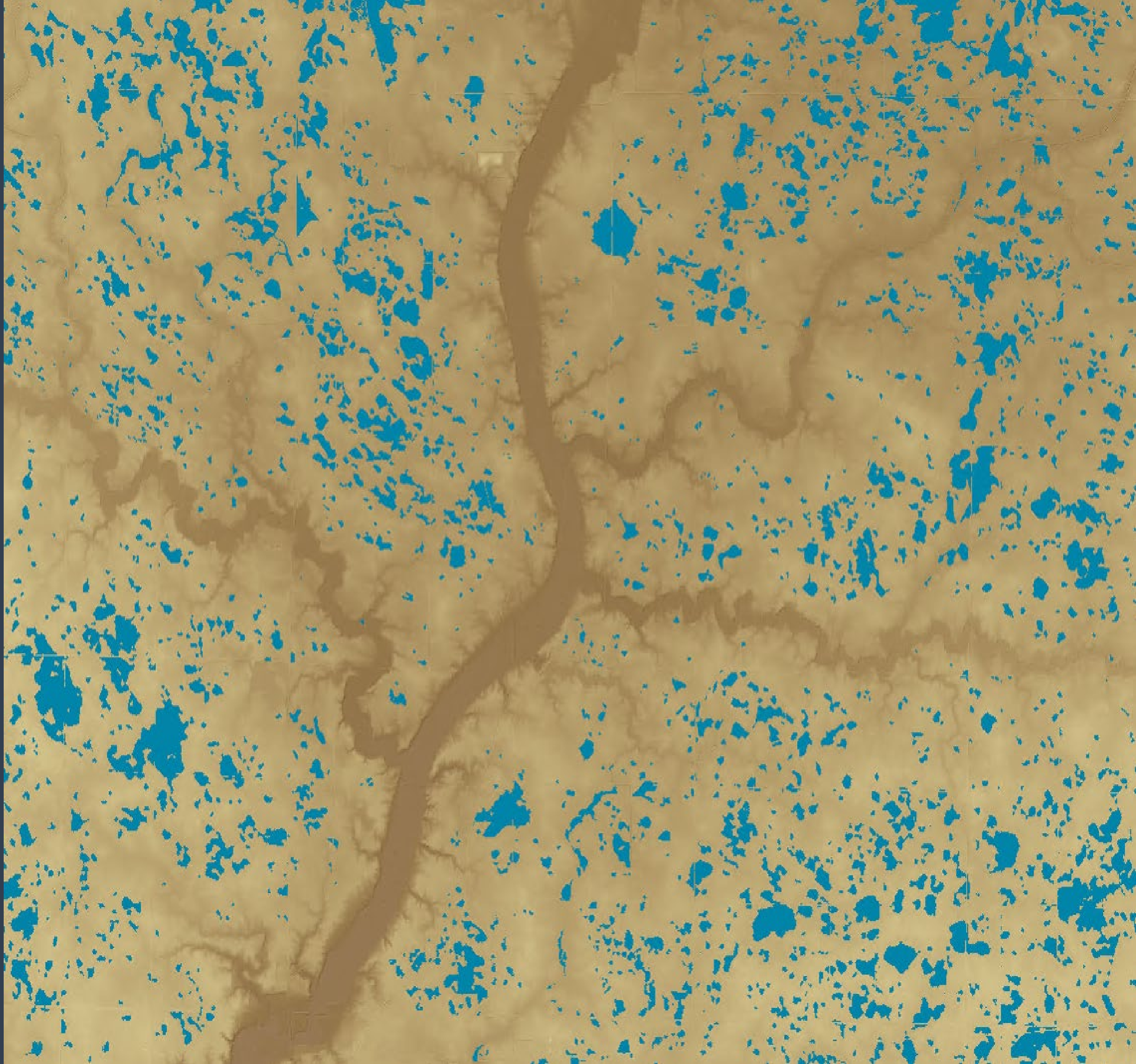

- Why do we care about depressions and runoff retention?
- Project focus
- Characterization of morphology for the Des Moines Lobe of Iowa
- Influence of depressions on surface runoff retention in the Des Moines Lobe of Iowa
- Connectivity of depressional networks and runoff characteristics

Prairie Pothole Region of North America

- Highly altered landscape
- Restoration of ecosystem functions
- Restoration of drained pothole wetlands
- Flood mitigation

Restoration of ecosystem functions (Galatowitch and van der Valk, 1996)

- Guide or inform restoration of altered wetlands
- Restoration of hydrological regimes
- Wetland hydrology and seeding/plant growth

Understanding the roles of depressions on watershed and regional hydrology

- Flood mitigation impacts
- Modeling of rainfall-runoff
- Hydrologic connectivity (SWANCC – WOTUS)

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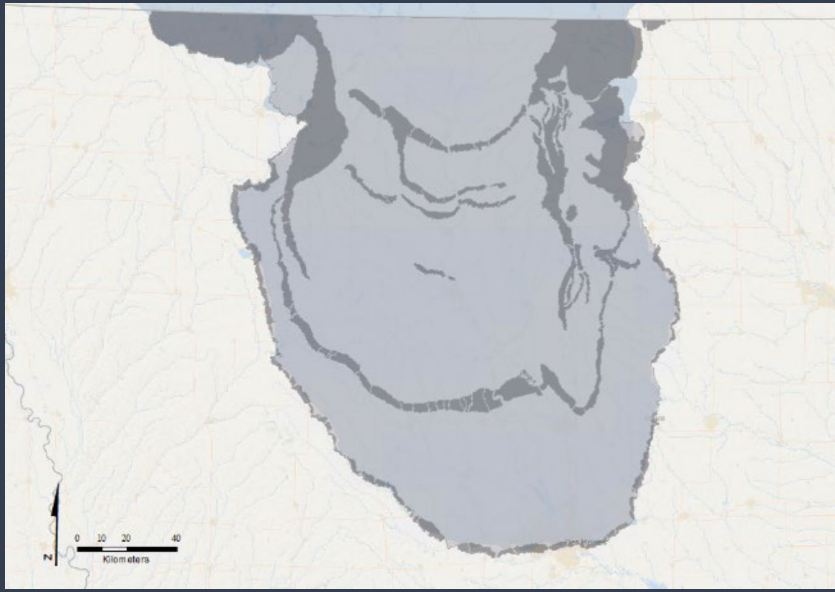
Des Moines Lobe of Iowa (DML-IA)

- ~21% of the state
- ~75% row crop agriculture
- Region-wide surface and sub-surface drainage



Pre-settlement

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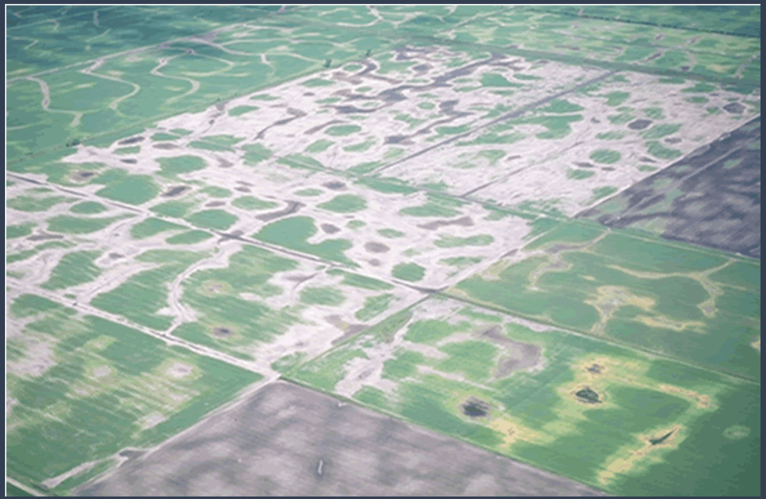
Post-settlement



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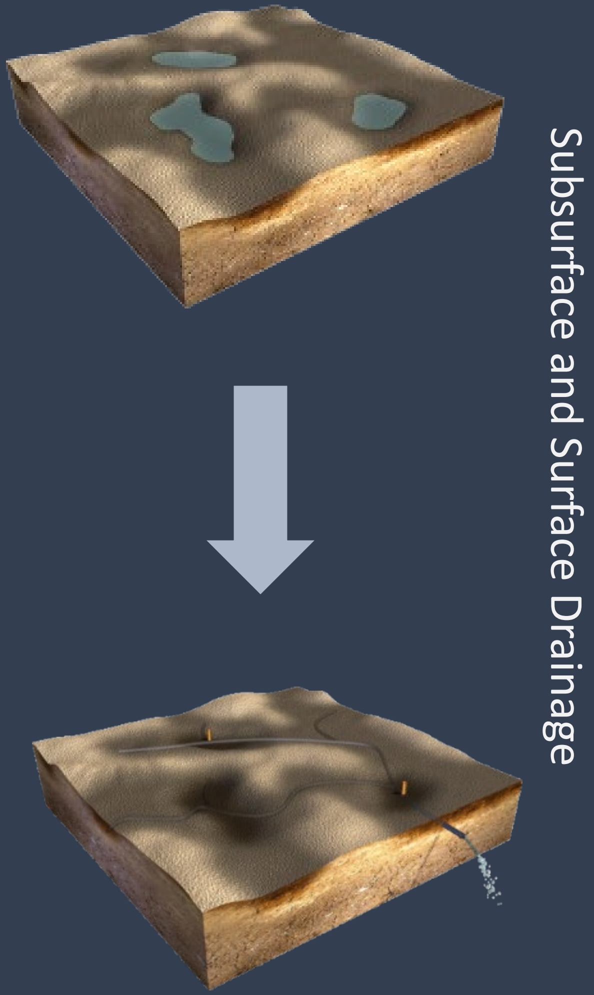


ISU Wetlands Research Lab

Nearly 95% of wetlands have been drained since the early 1900's

Nearly complete loss of wetland functions in this landscape

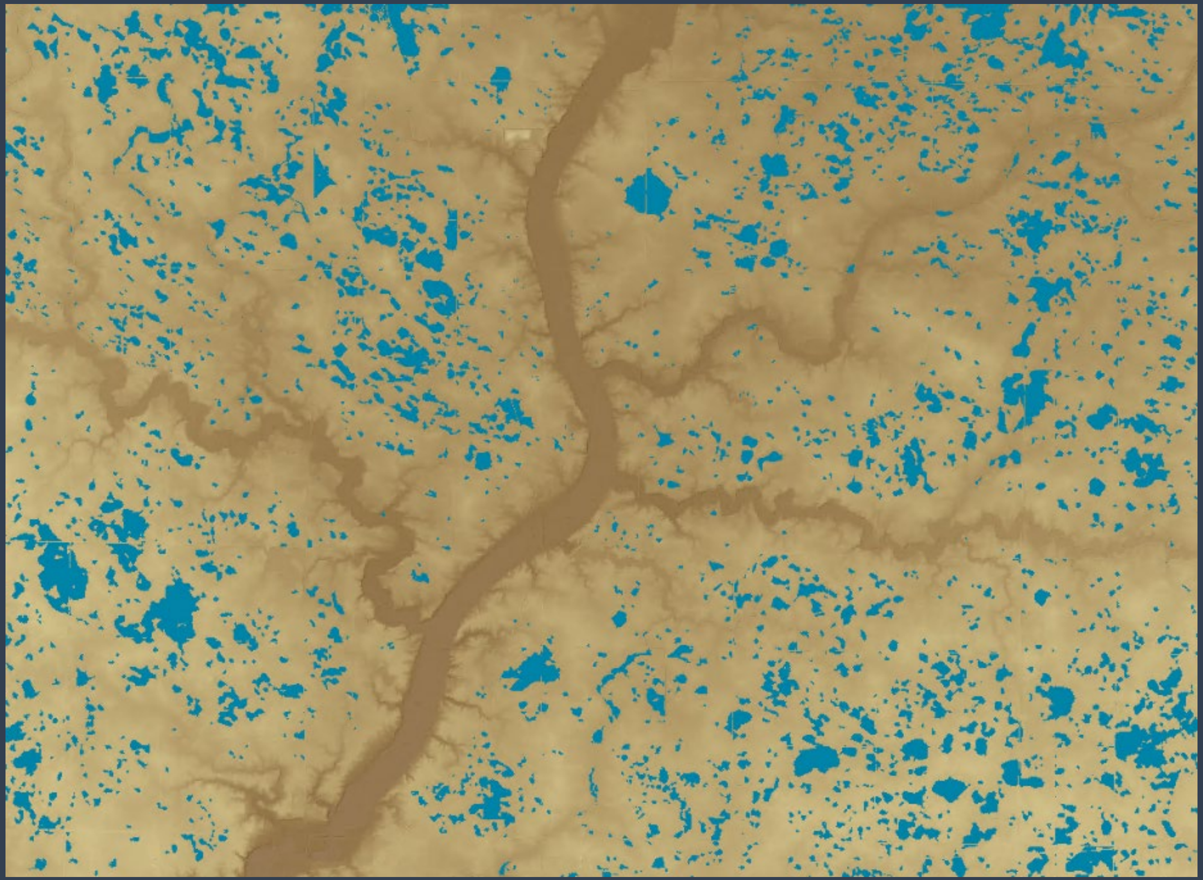
Many wetland depressions still morphologically intact

Wetland drainage has impacted runoff processes

EPA Region 7 WPDG (2015):

Statistically characterize bulk morphological properties across the DML-IA

Assess the roles of drained depressions on runoff processes in the DML-IA



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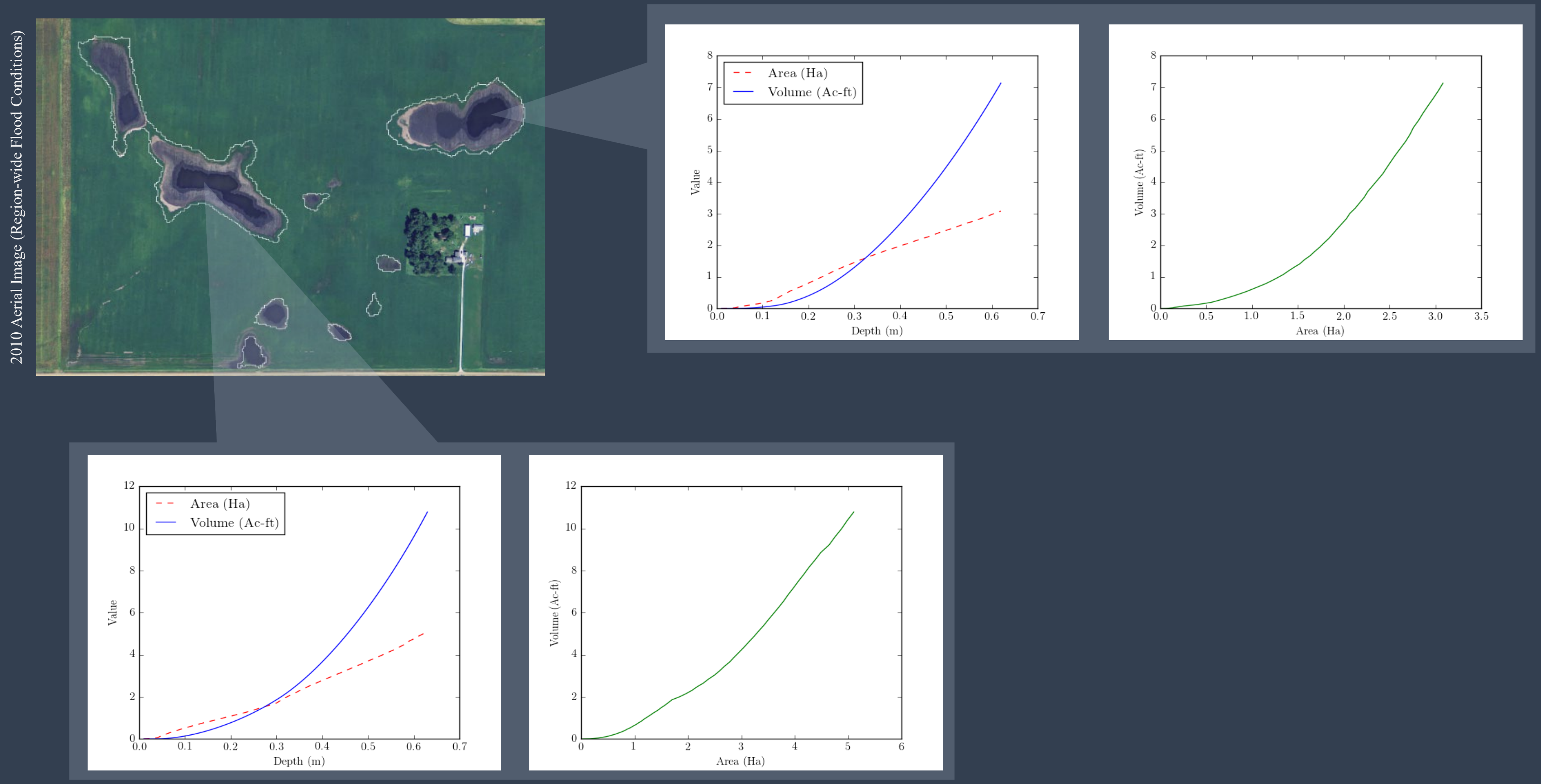
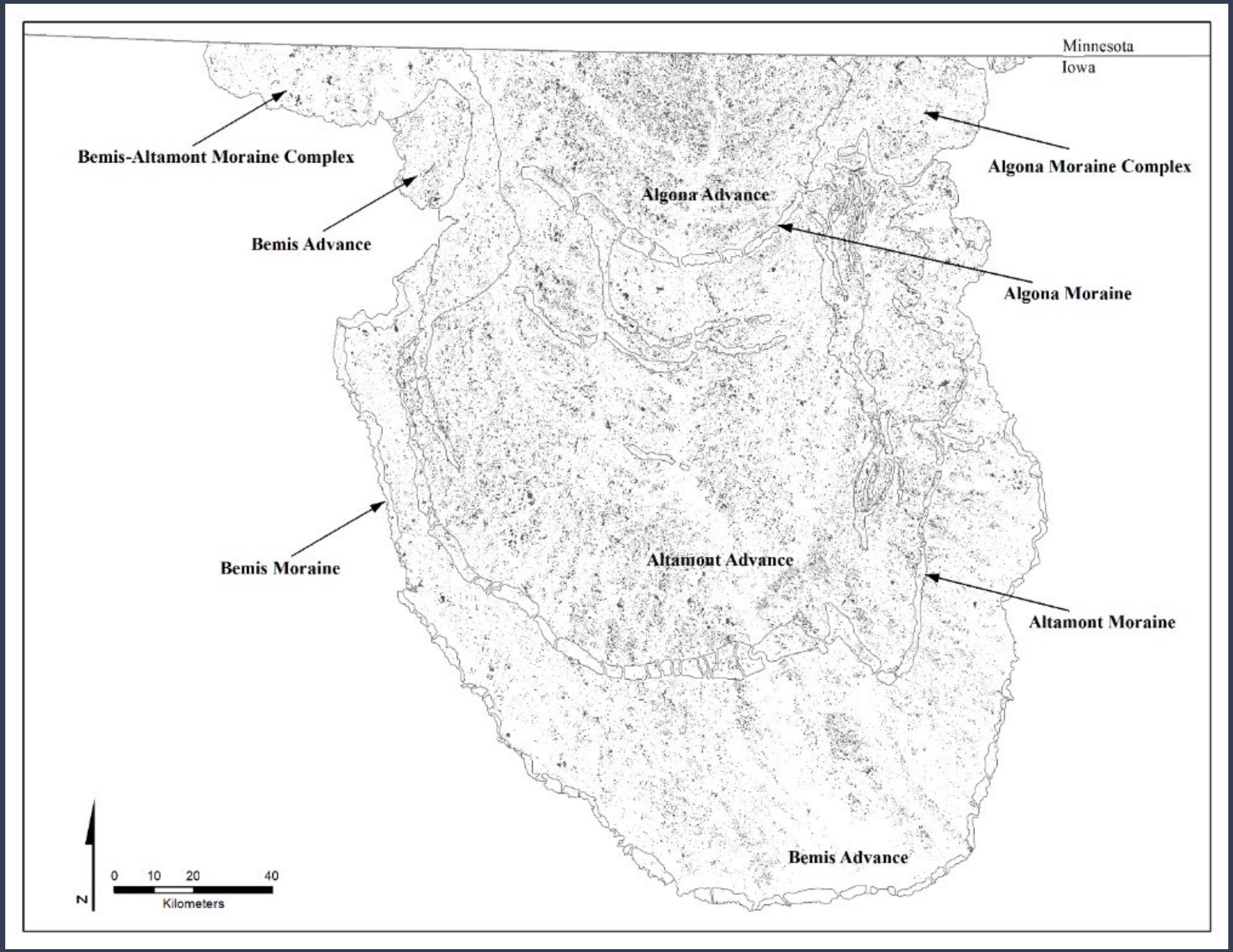
State-wide LiDAR flown in 2007 – 2010 + Hydrologically enforced (Gelder, 2013)

GIS tool to develop hypsographic curves over the entire DML (McDeid et al., 2018)

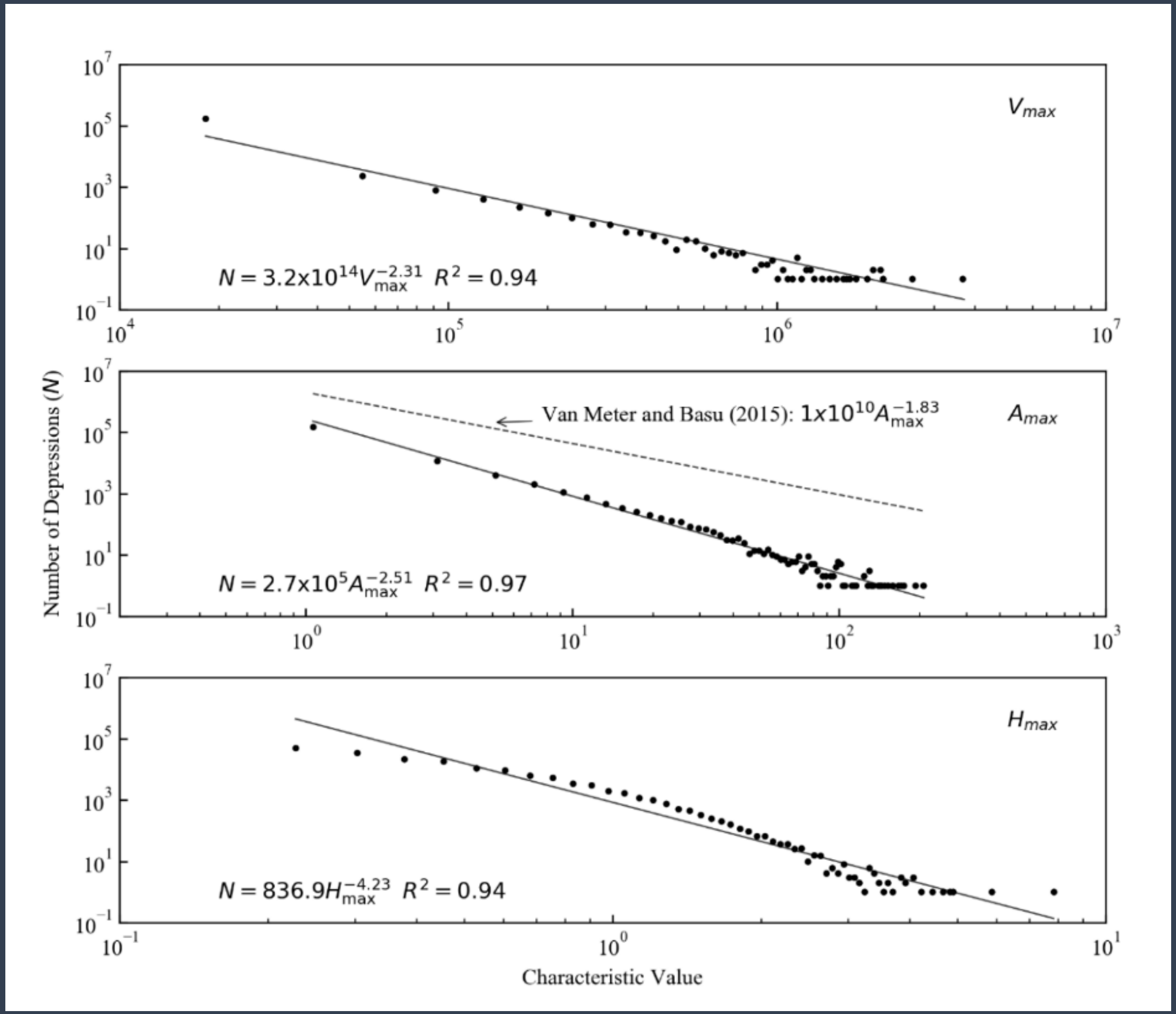




177,131 upland depressions identified

Not randomly distributed. Clustering in geomorphic regions

177,131 upland depressions identified



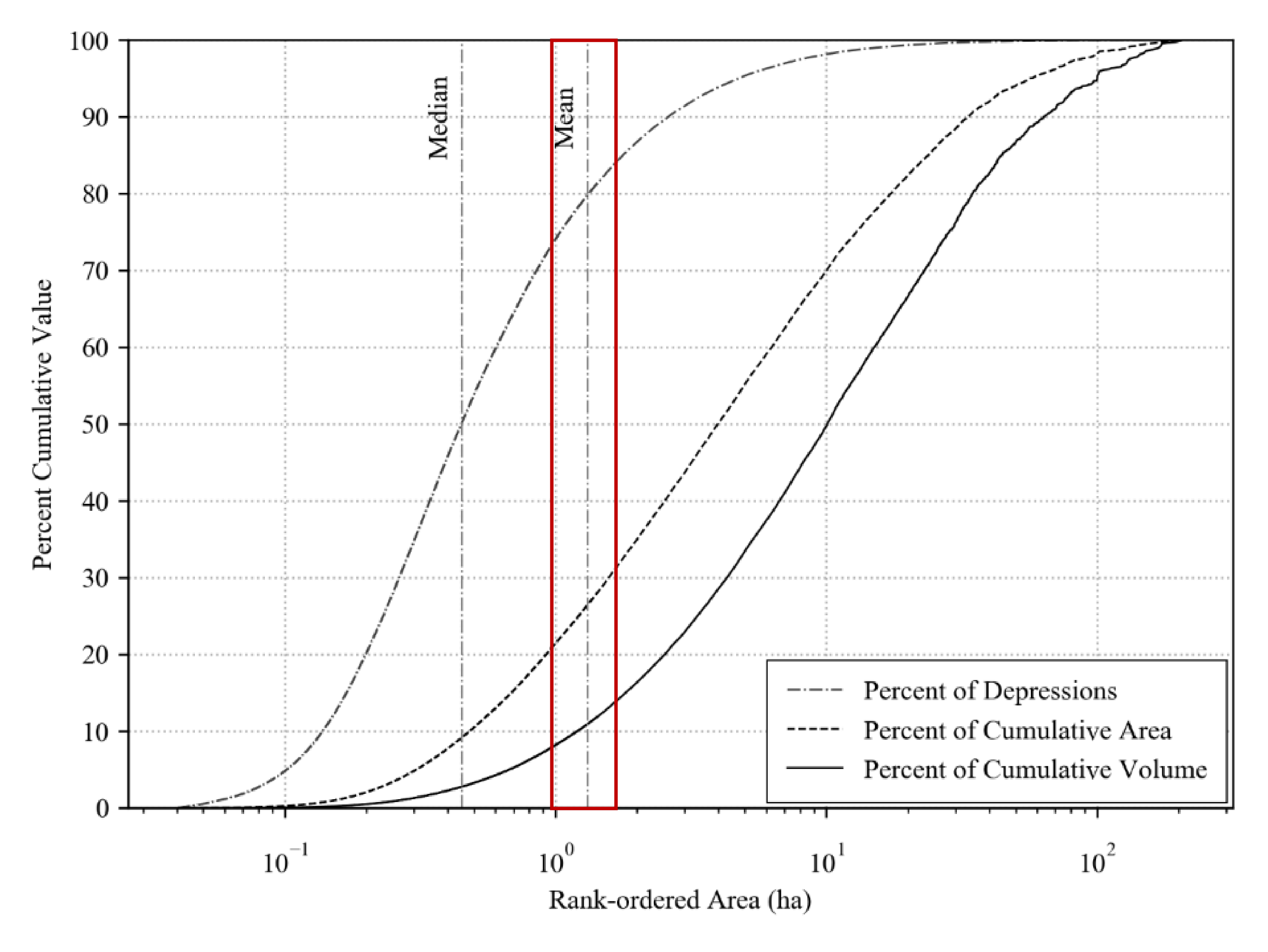
Storage volume (hectare-meters): Total - 90,348 (114% of Saylorville Reservoir Flood Storage). Average volume of 0.52. Max of 369.25

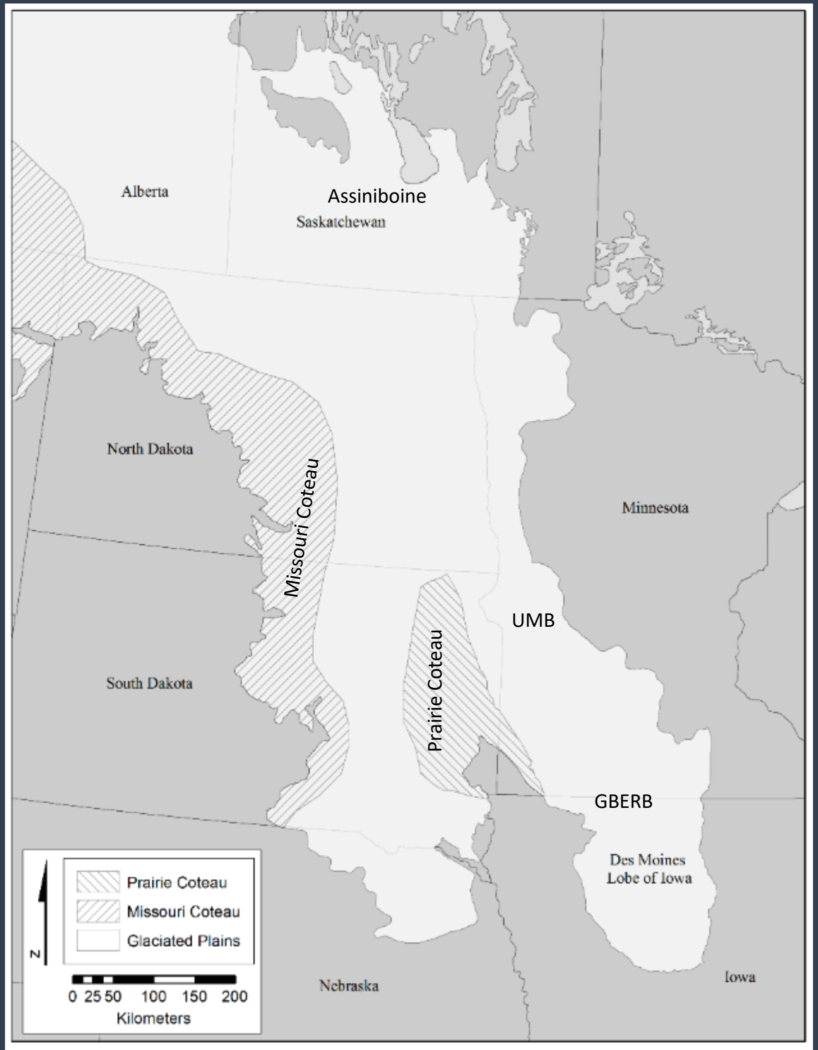
Area of inundation (hectares): Total - 226,848 Hectares (7.3% of the region). Average area of 1.31 hectares. Range 0.041 – 206.4 hectares

Maximum Depth (meters): 0.19 – 7.8. Average depth of 0.43

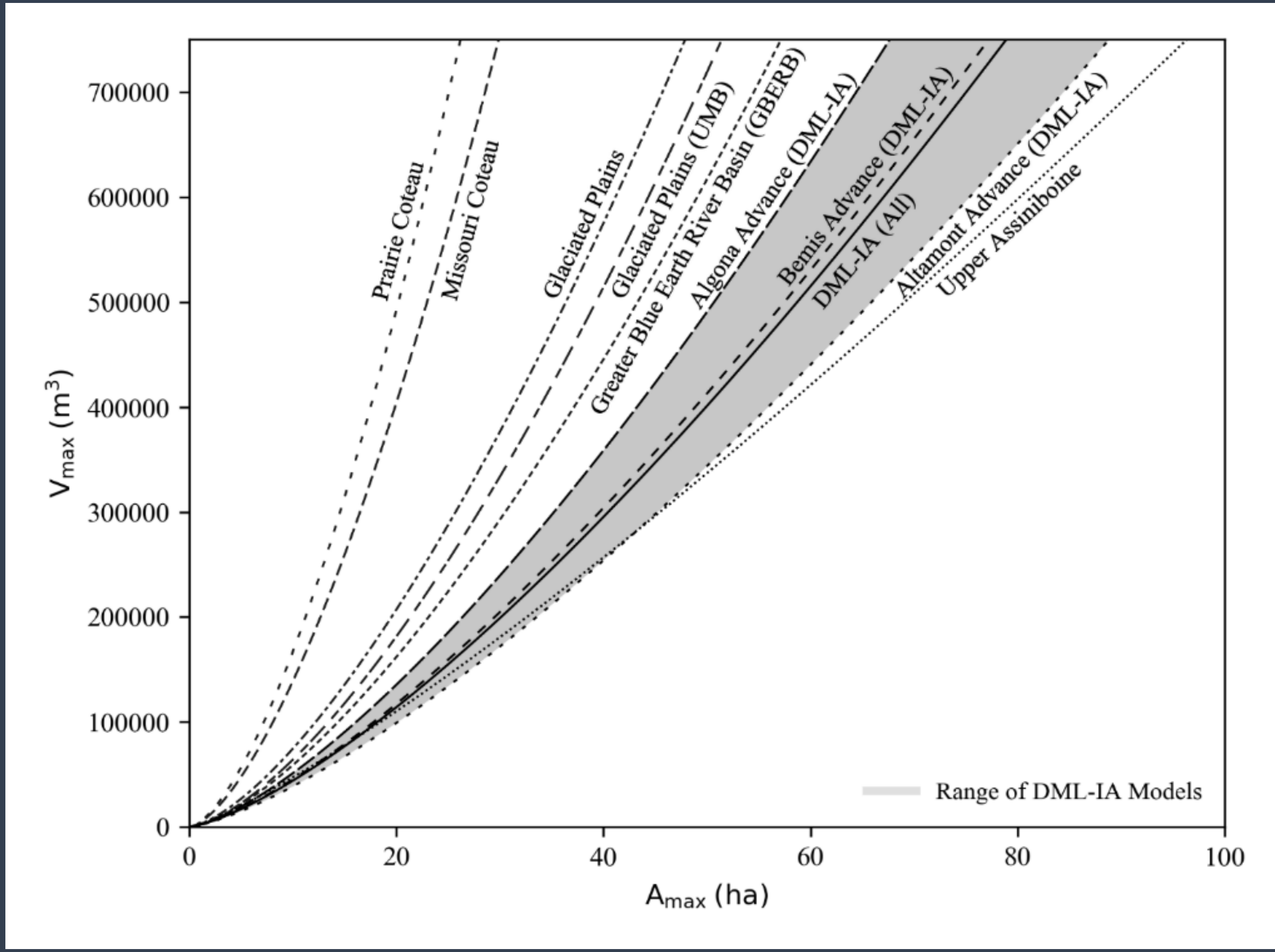
80% of depressions = 27% of depressional area = 12% of depressional storage

Potential depressional retention capacity of the region is concentrated in a few areas and a few large depressions





Care must be taken when applying an area-volume model developed for one region to another to estimate storage volumes



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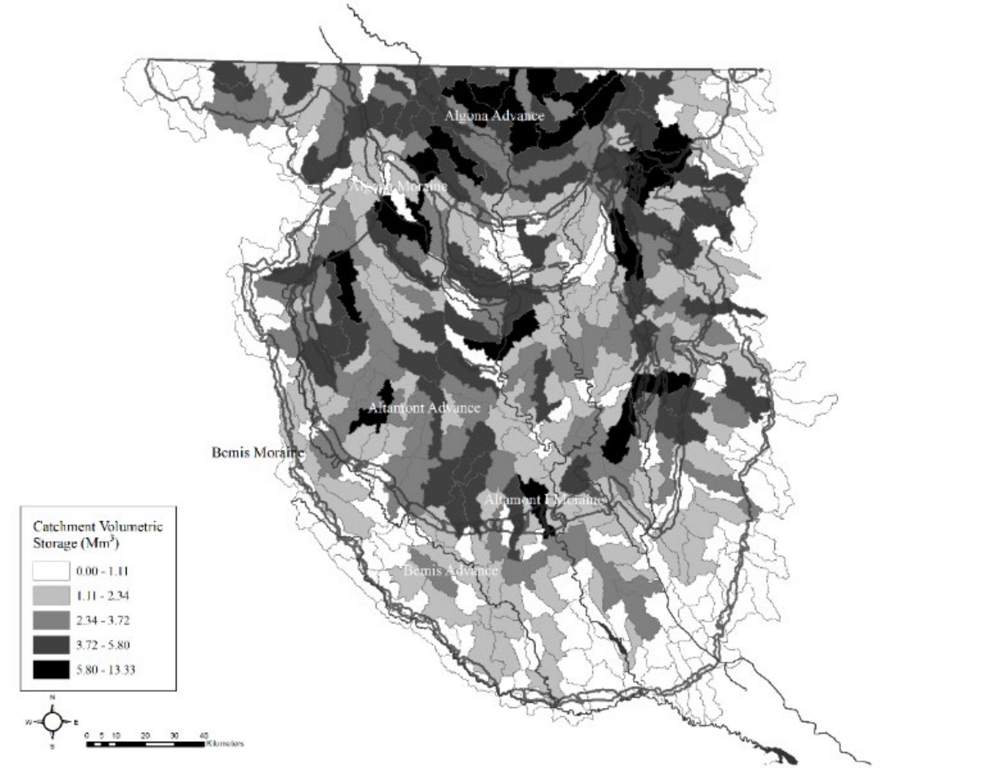
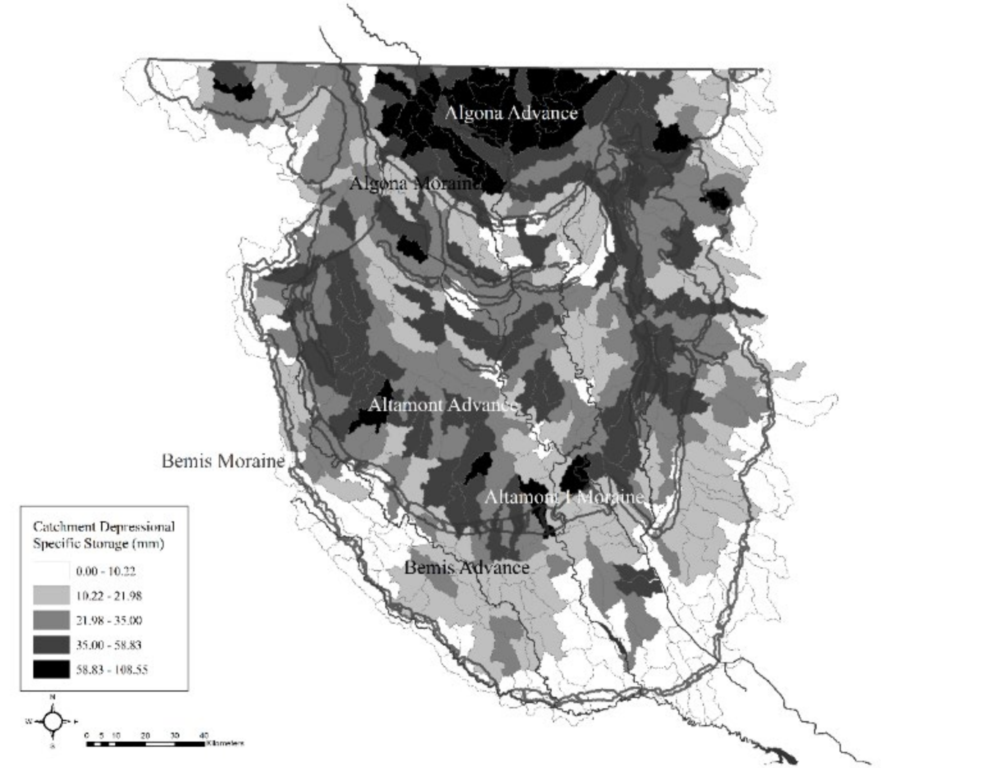
Total storage per HUC12 (Mm^3)

$$V_{t(i)} = \sum_{j=1}^{n} V_{\max(j)}$$



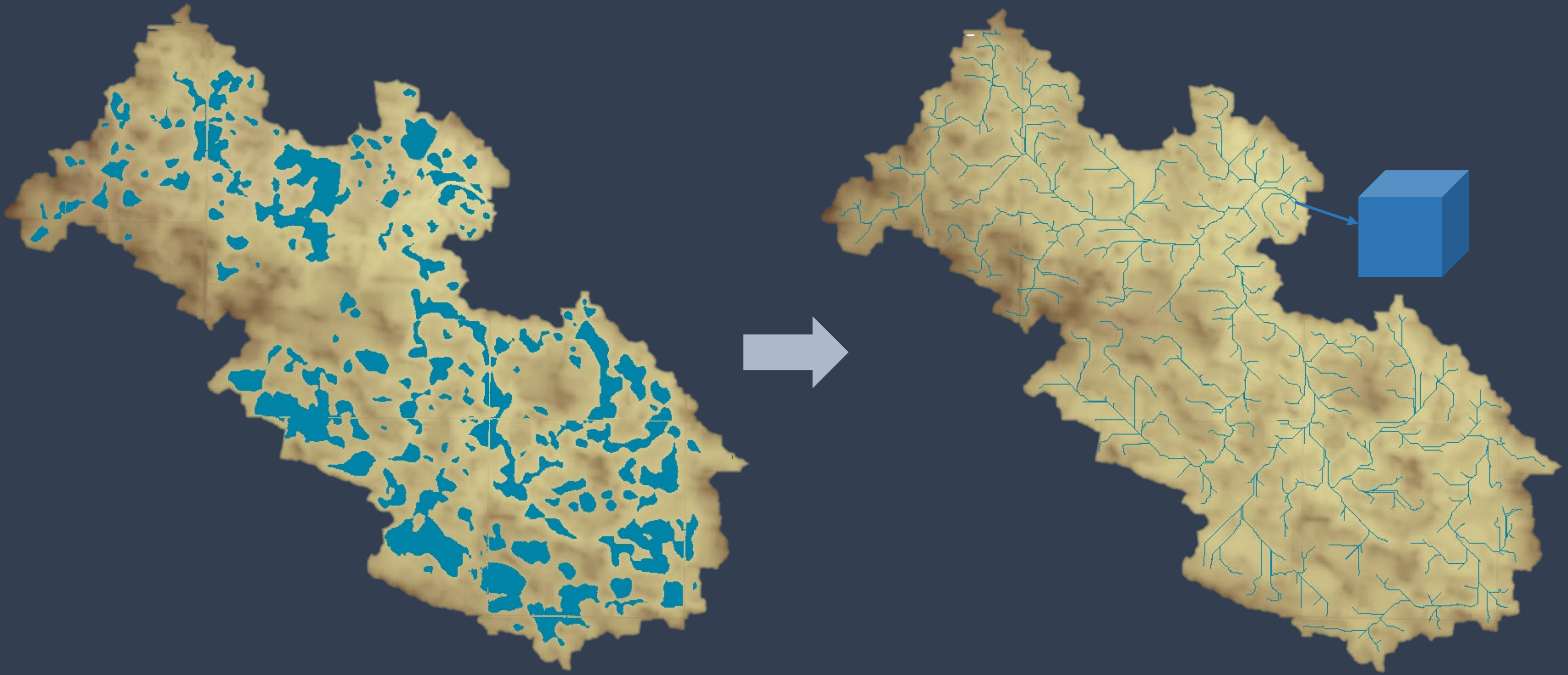
Catchment Depressional Specific Storage (mm)

$$S_{d(i)} = k \frac{V_{t(i)}}{A_{w(i)}}$$



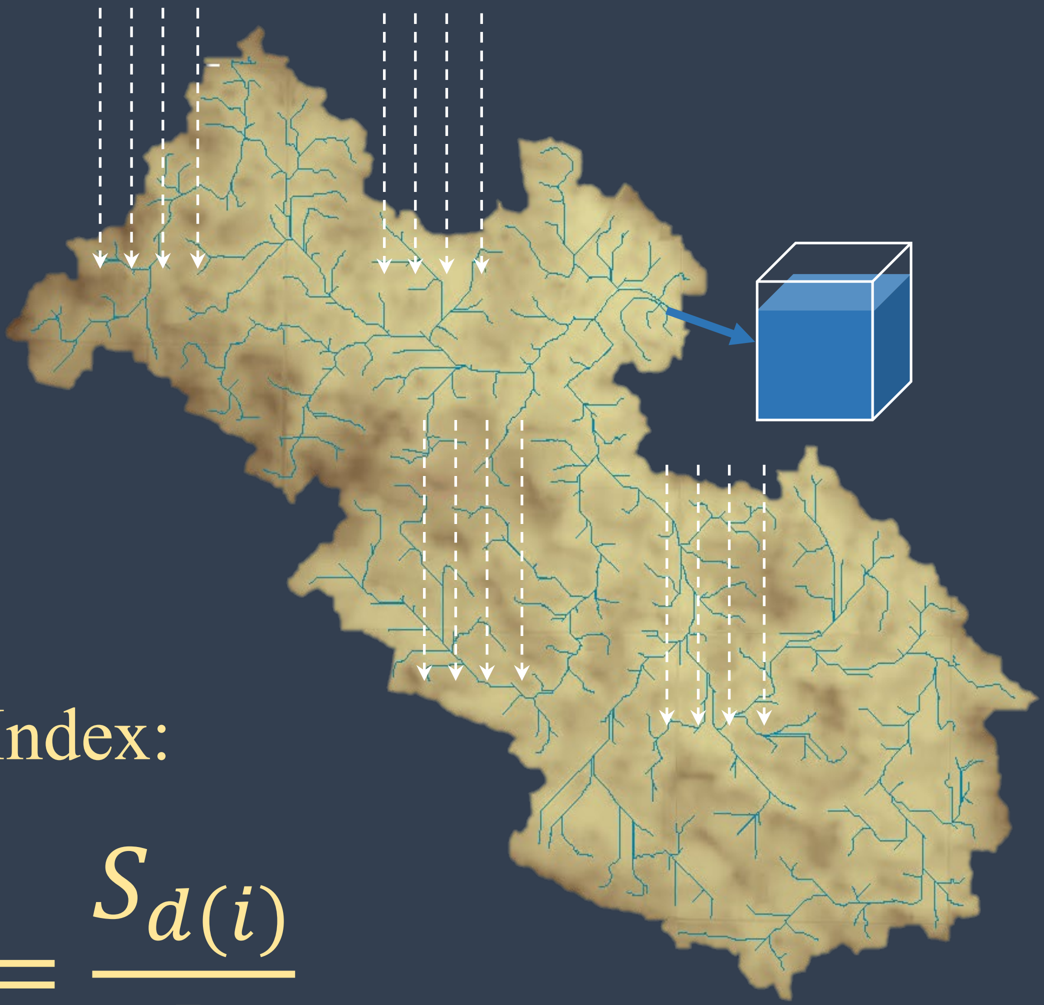
Green et al. (2019)

Catchment depressional specific storage gives an <u>upper limit </u>to depressional runoff retention



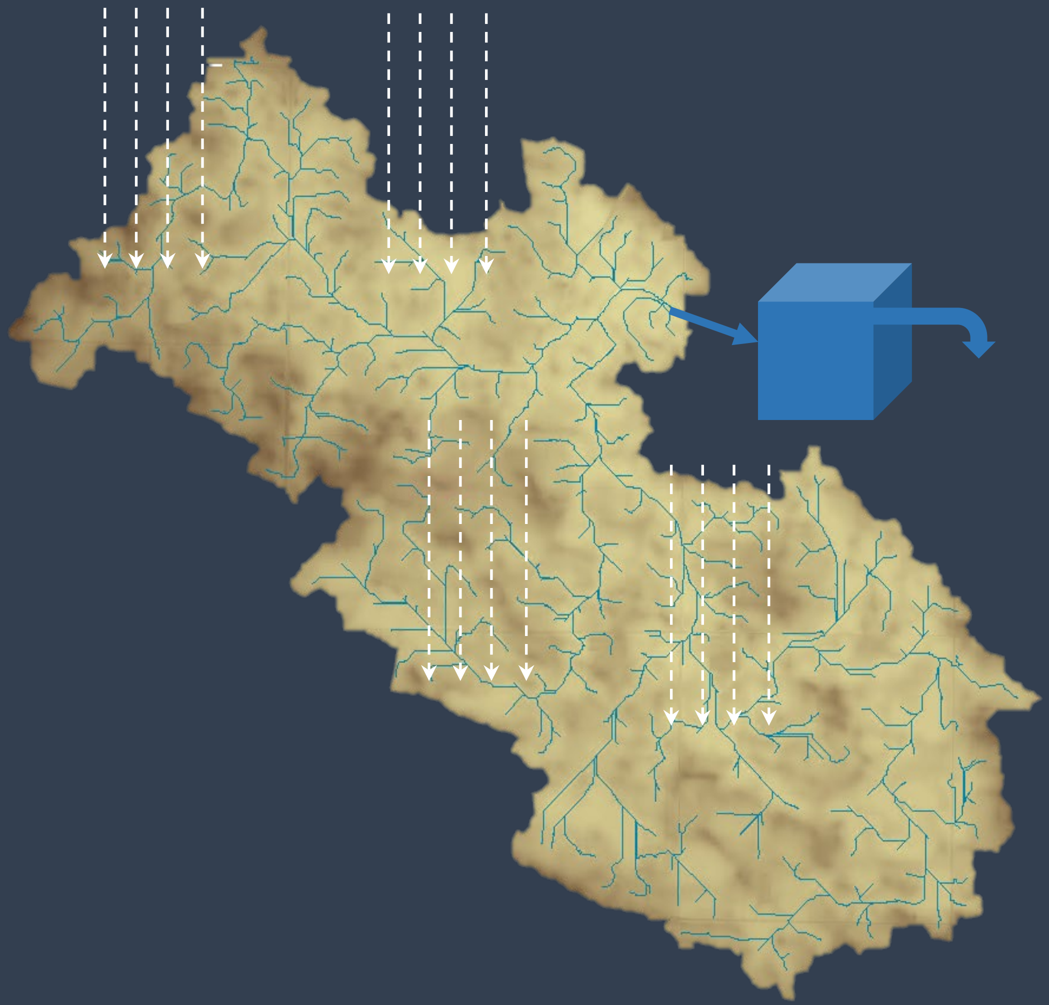
$R_{s(i)} \geq 1$:

Excess storage available



$R_{s(i)} < 1$:

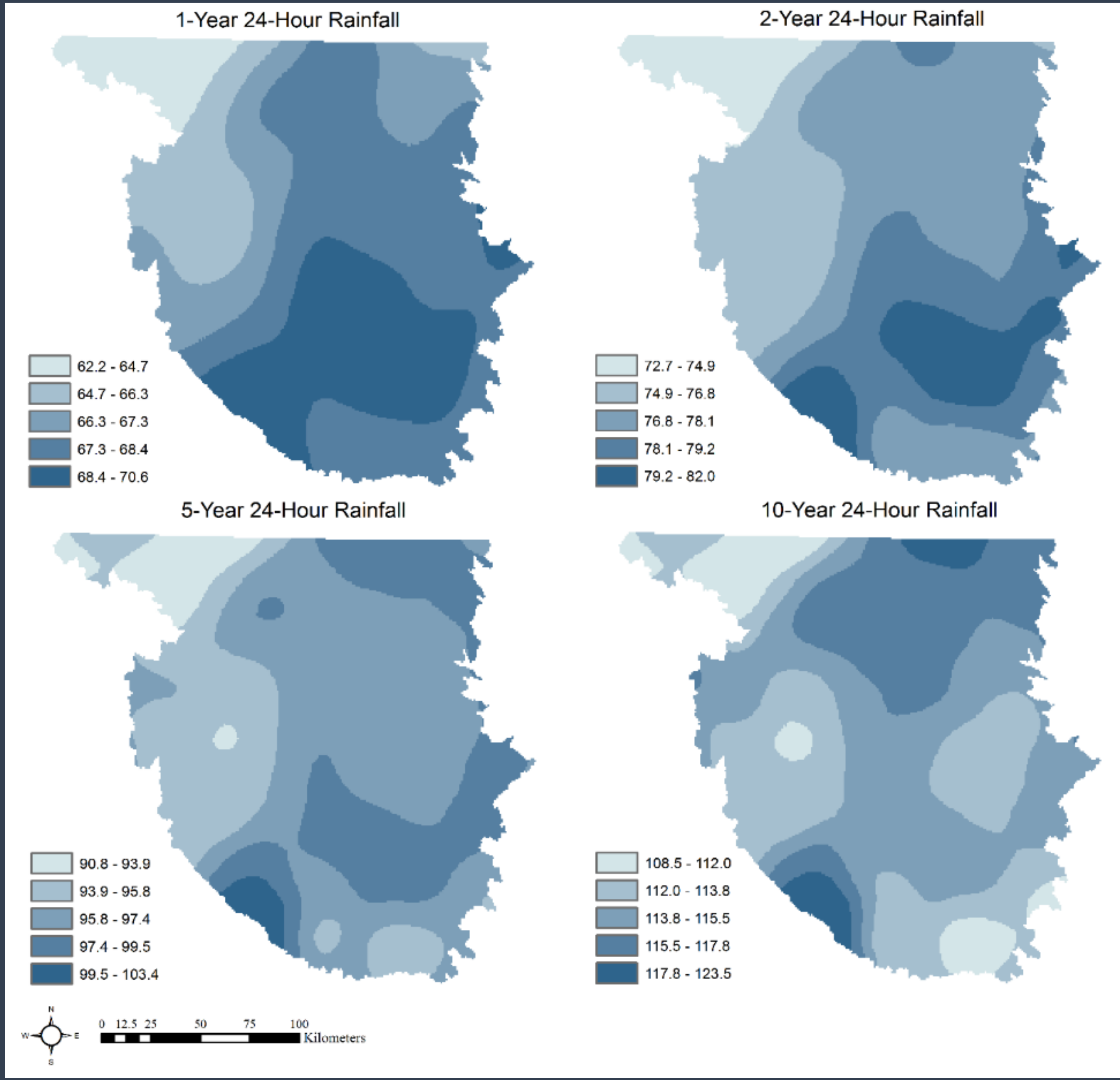
Storage exceeded

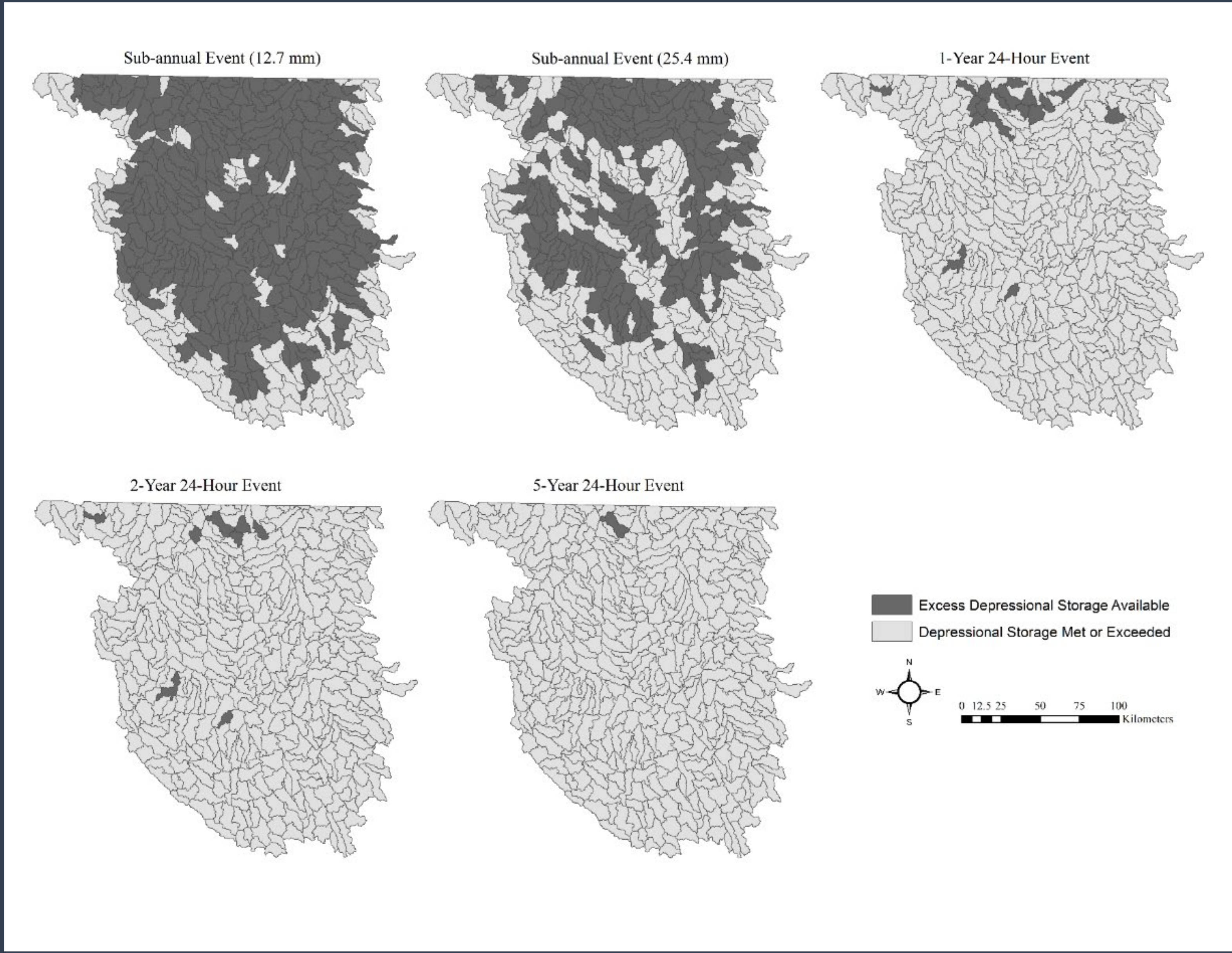


Runoff Index:

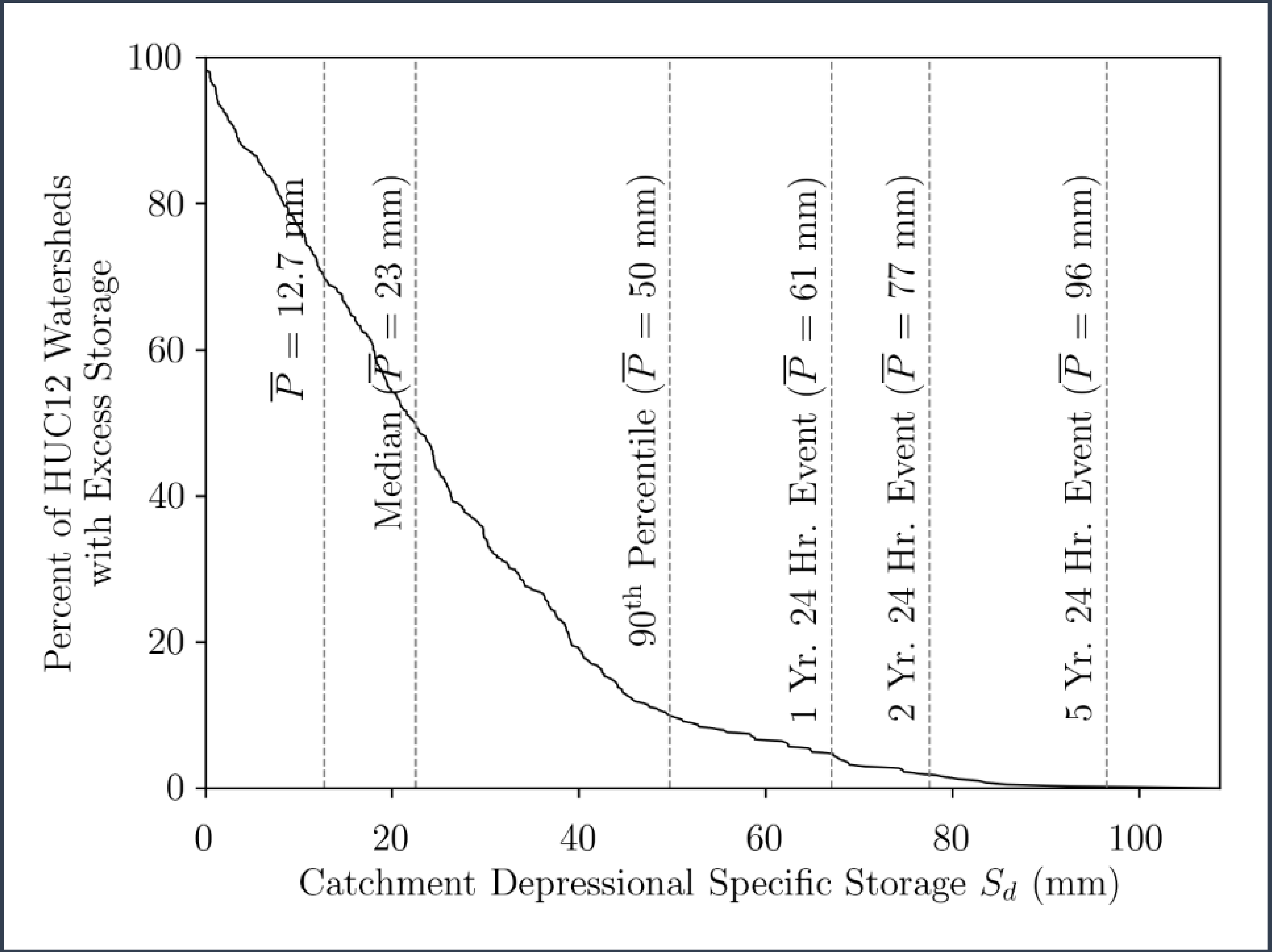
$$R_{s(i)} = \frac{S_{d(i)}}{P}$$

Sub-annual, 1, 2, 5, and 10 year 24-hr rainfall aggregated by HUC12 watershed using NOAA (2018) rainfall frequency estimates

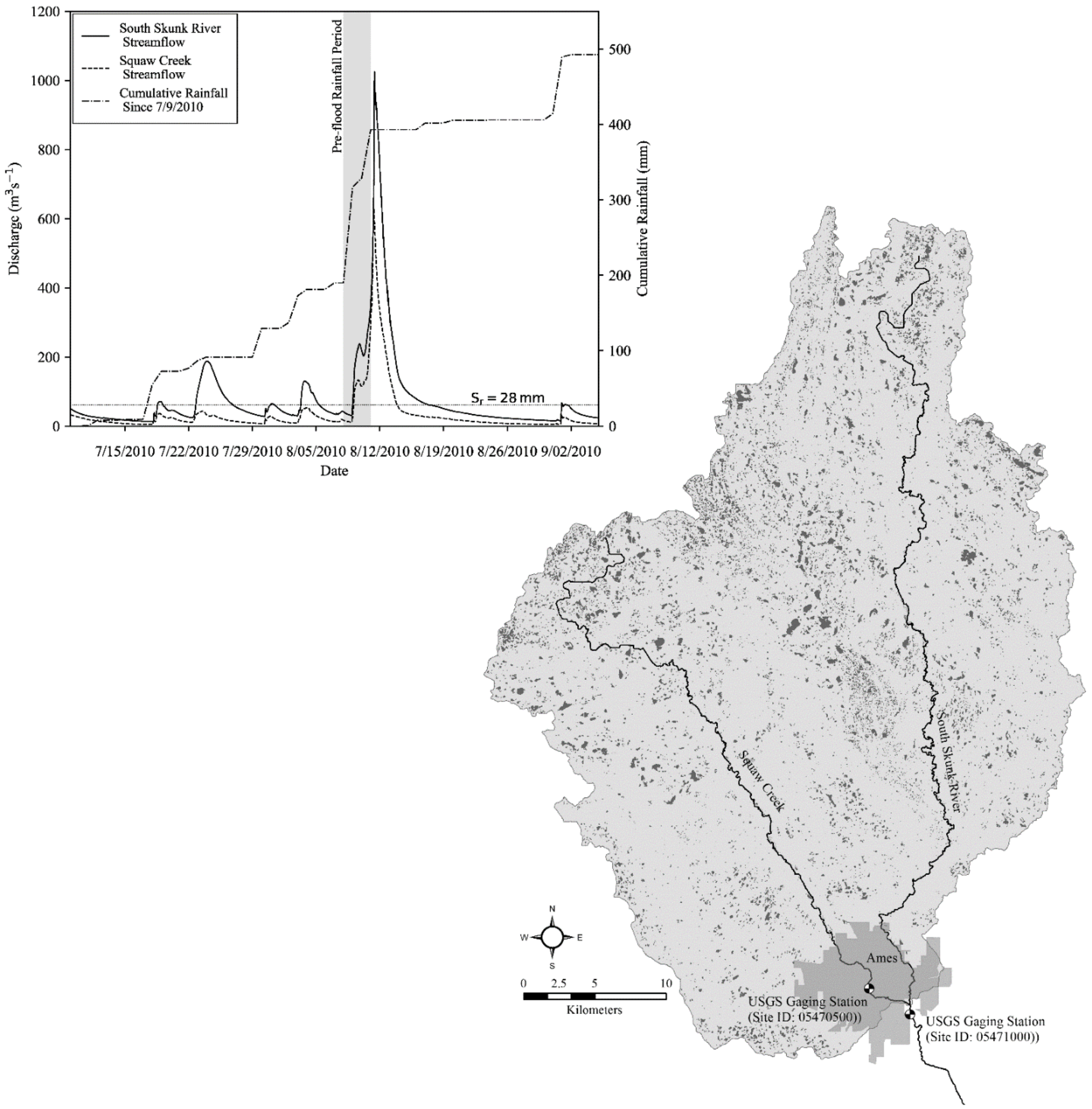




5% of watersheds can retain runoff from a 24-hour 1-year precipitation event (~ 2 in)



50% of HUC12 watersheds have enough depressional storage to retain up to 23 mm of rainfall.

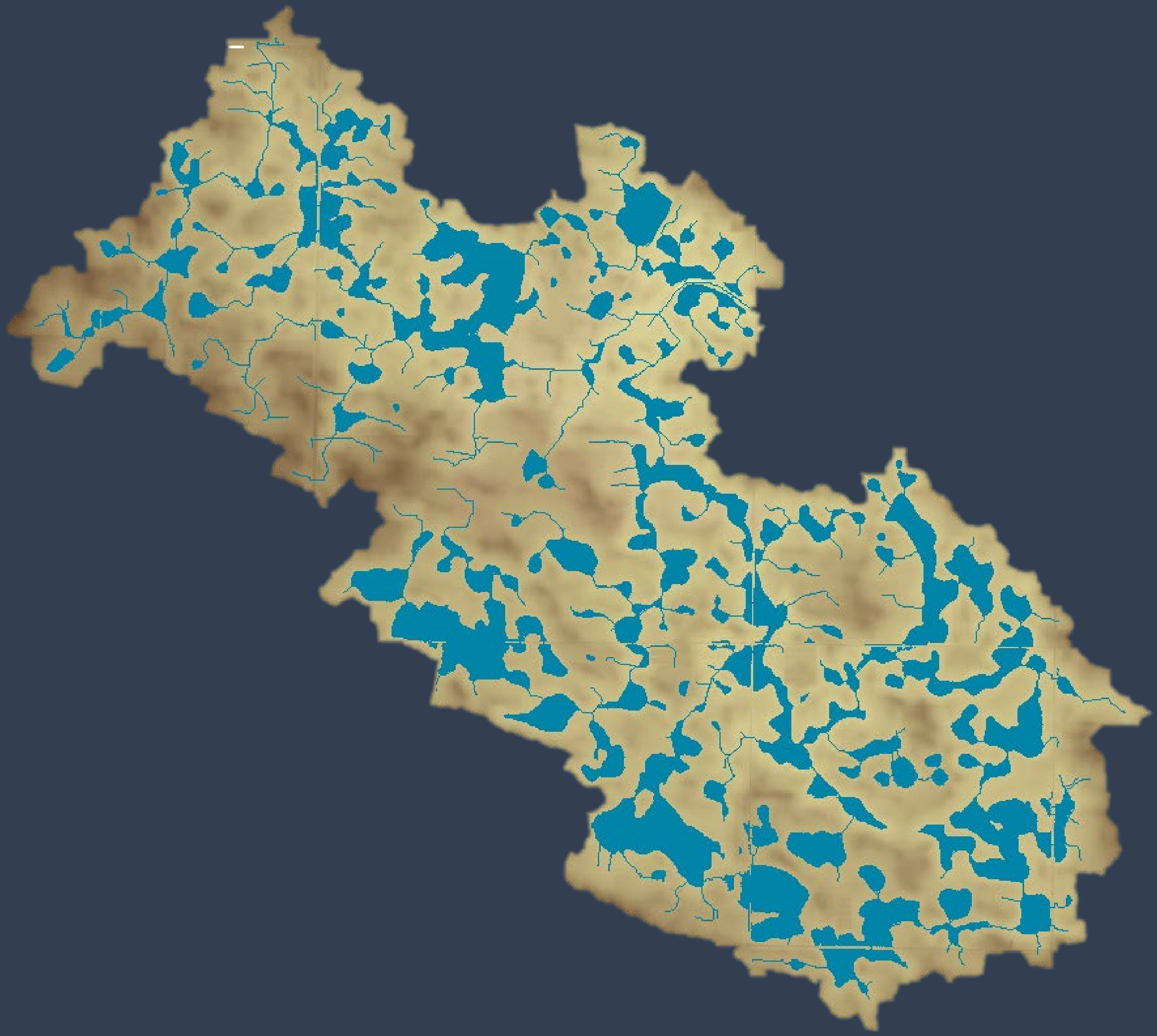


South Skunk River Streamflow
Squaw Creek Streamflow
Cumulative Rainfall Since 7/9/2010
Pre-flood Rainfall Period
S_r = 28 mm
Discharge (m^3s^{-1})
Cumulative Rainfall (mm)
Date
7/15/2010
7/22/2010
7/29/2010
8/05/2010
8/12/2010
8/19/2010
8/26/2010
9/02/2010
Squaw Creek
South Skunk River
Ames
USGS Gaging Station (Site ID: 05470500))
USGS Gaging Station (Site ID: 05471000))
N
S
E
W
0
2.5
5
10
Kilometers

Spatial arrangement of depressional network is critical

More sophisticated approaches are needed to evaluate connectivity and actual runoff dynamics:

- nD rainfall-runoff models
- Network cascade models



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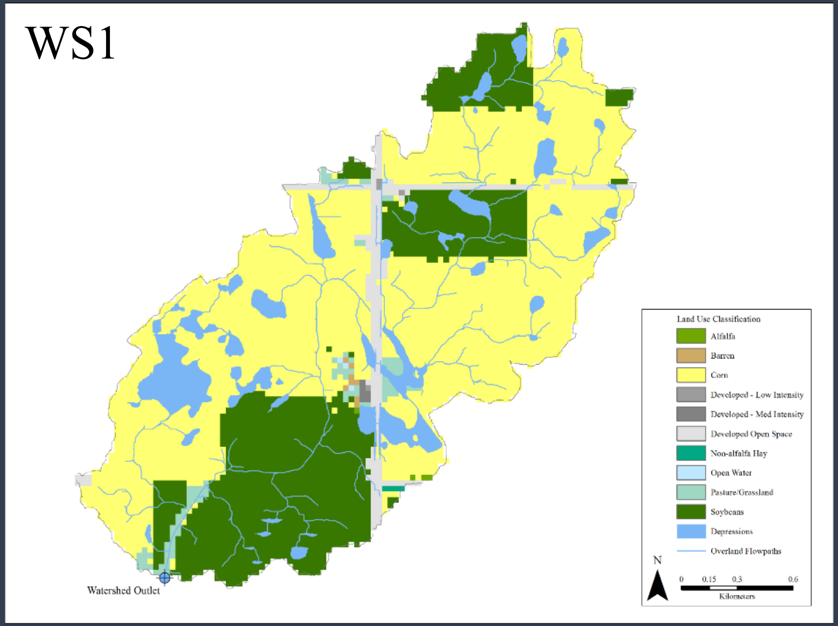
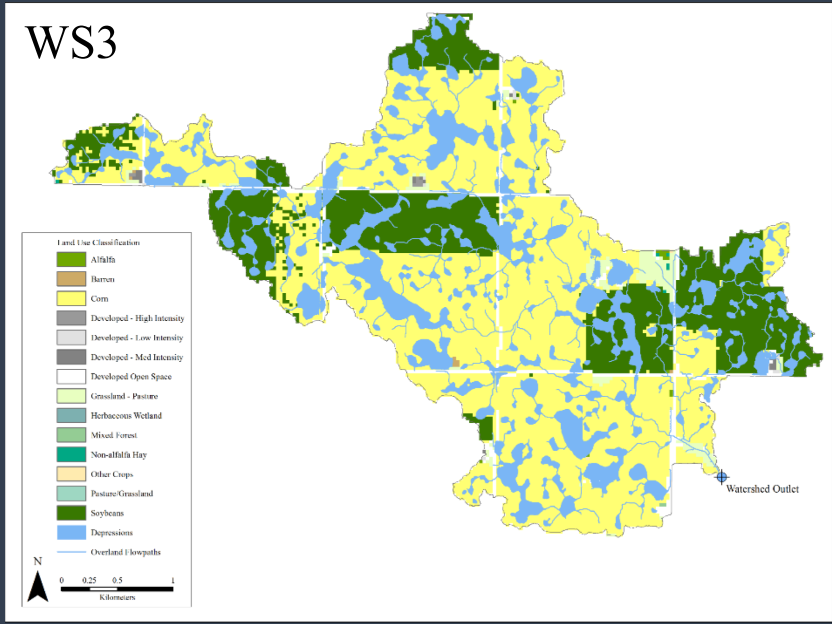
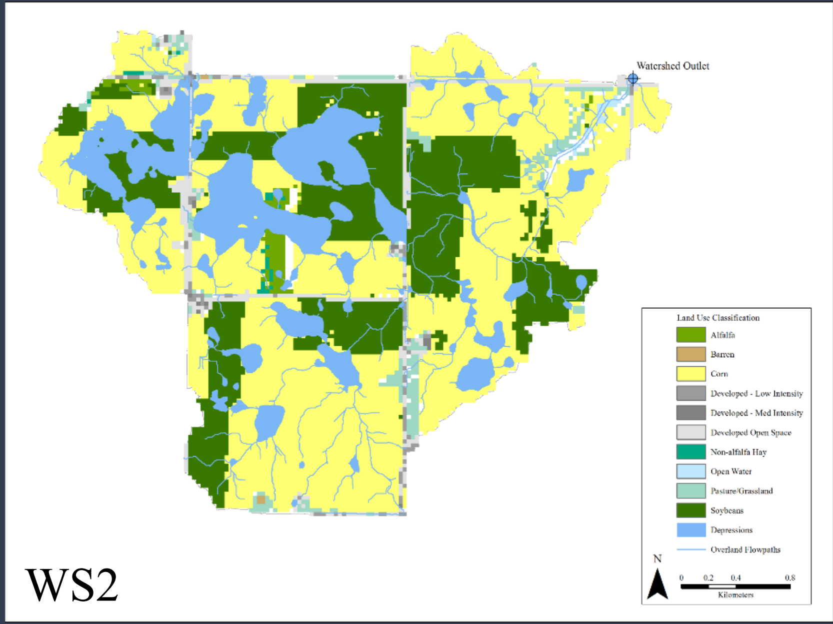
GSSHA Watershed Rainfall-Runoff Model (USACE)

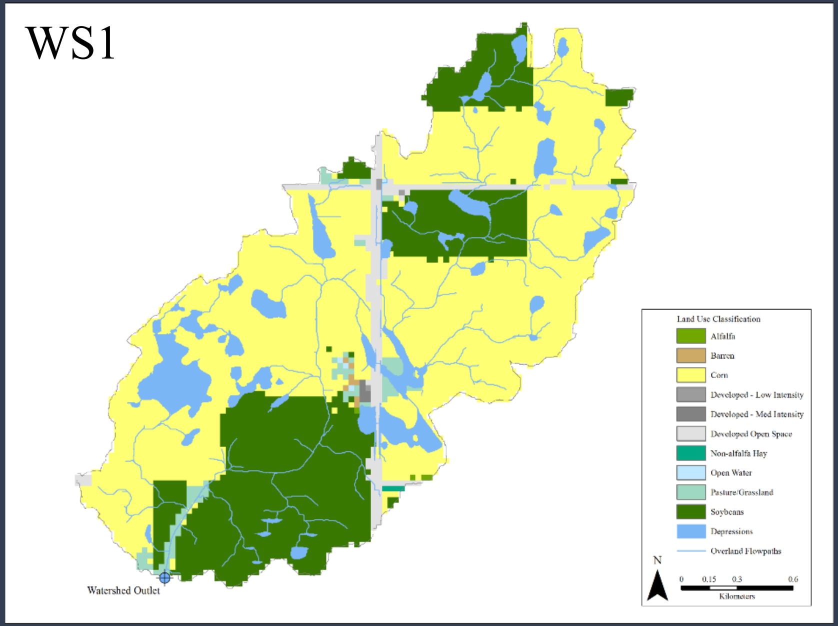
- 2-D diffusive wave equations for surface runoff
- 5-m horizontal resolution, 10 second time-step
- 24-hr Type-II precipitation for 25.4 to 165 mm events (sub-annual to 100-yr)
- Considered surface runoff only

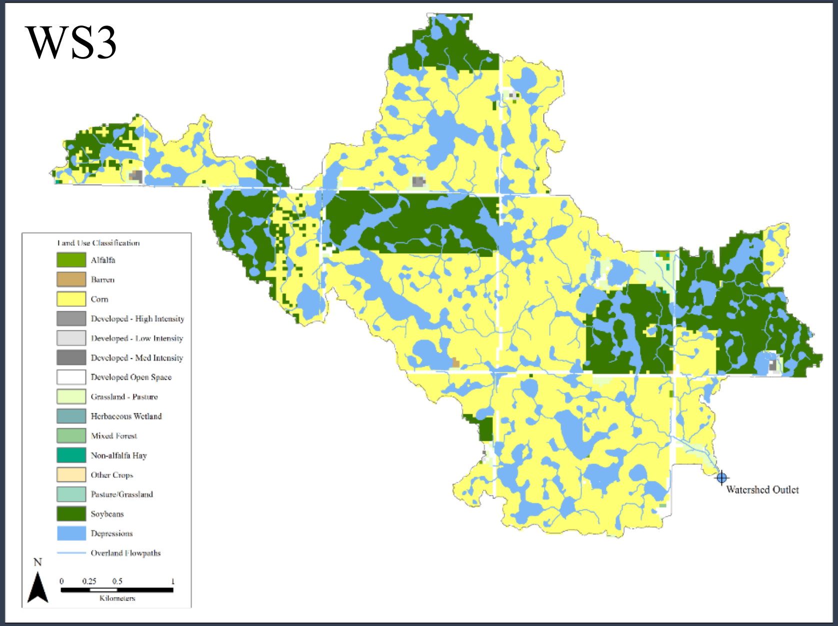


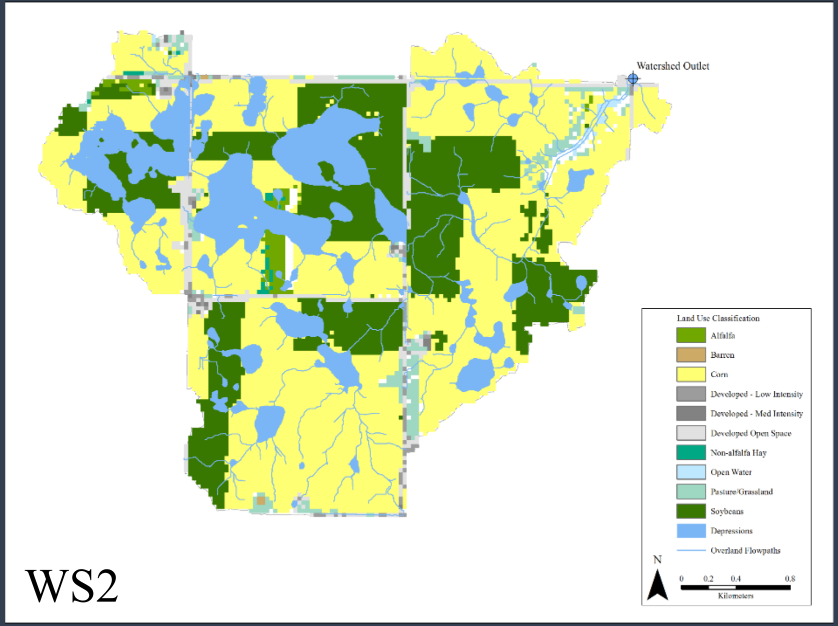


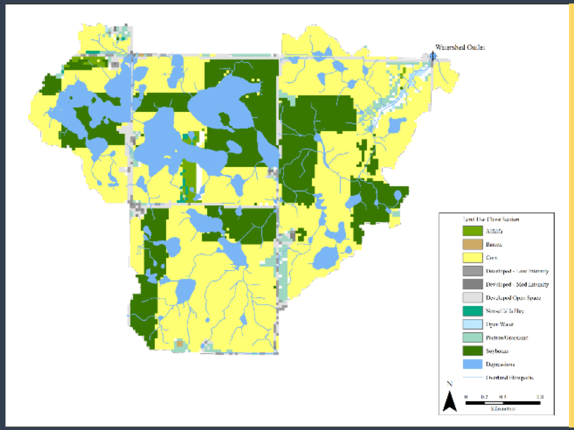


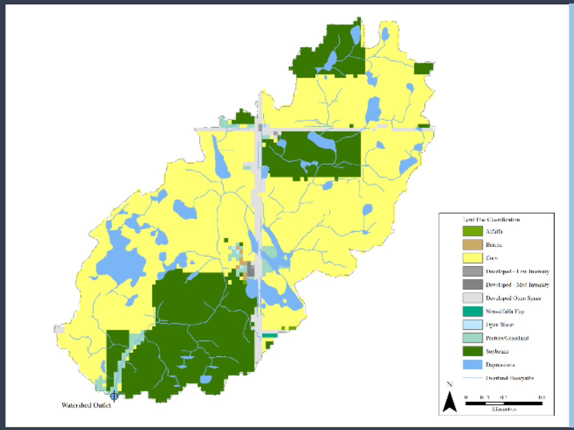
Watershed	Area (ha)	Cumulative Depressional Area (ha)	Number	Percent Depressional Area	Depressional Density (#/km^2)	Cumulative Depressional Storage Volume (Mm^3)
WS1	468	43.3	42	9.3	9.0	0.13
WS2	950	176.2	52	18.5	5.5	0.82
WS3	1263	274.8	221	21.7	17.7	0.92

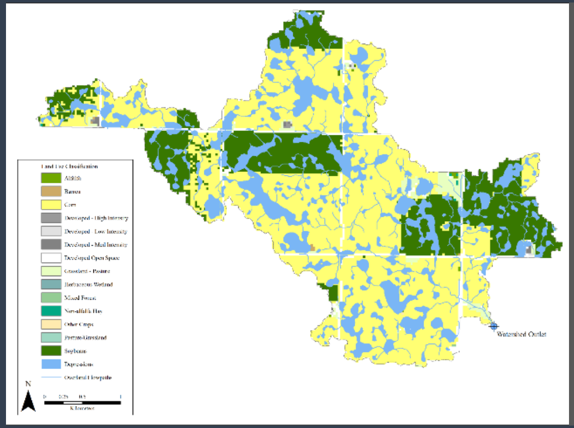




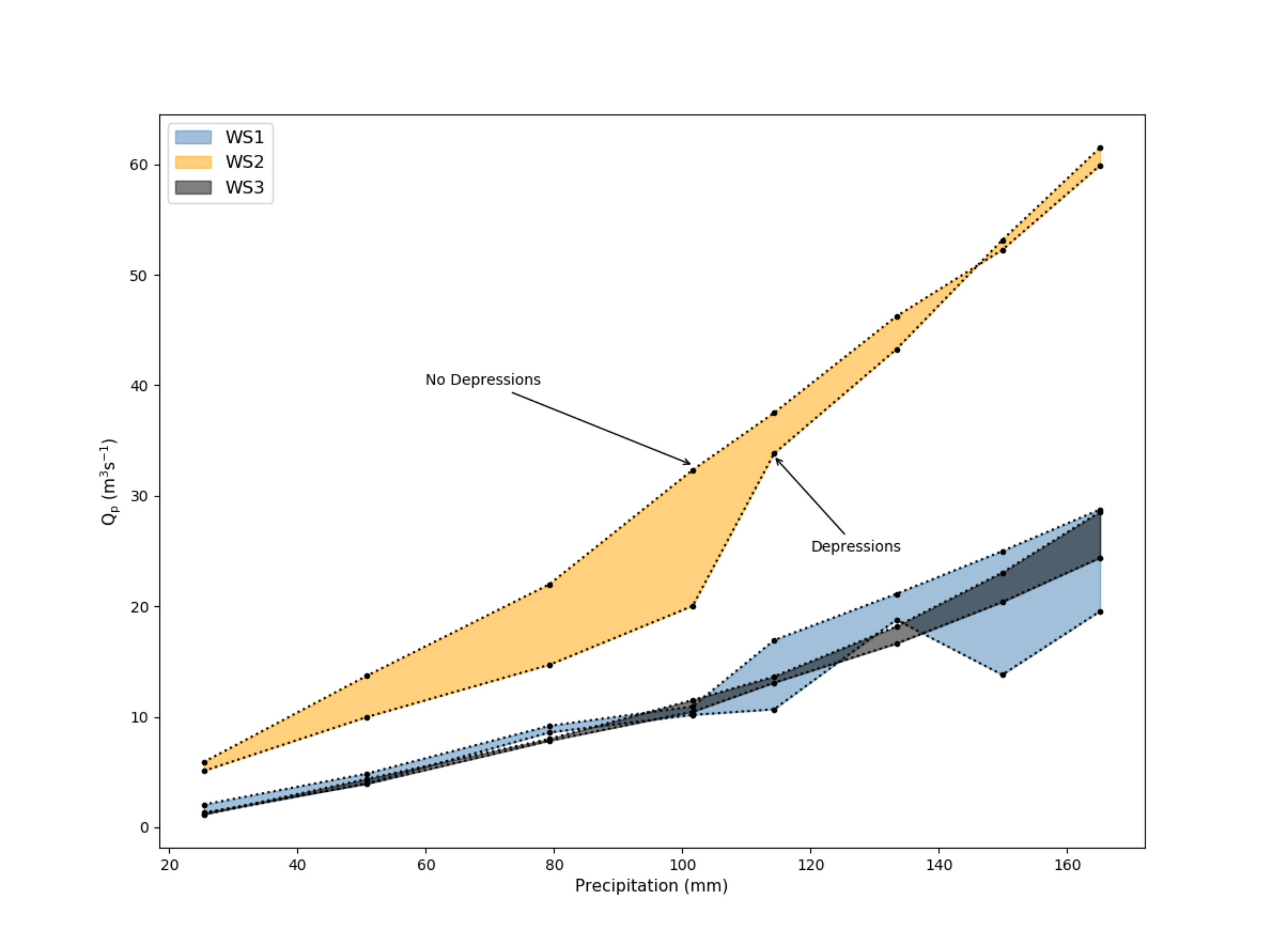




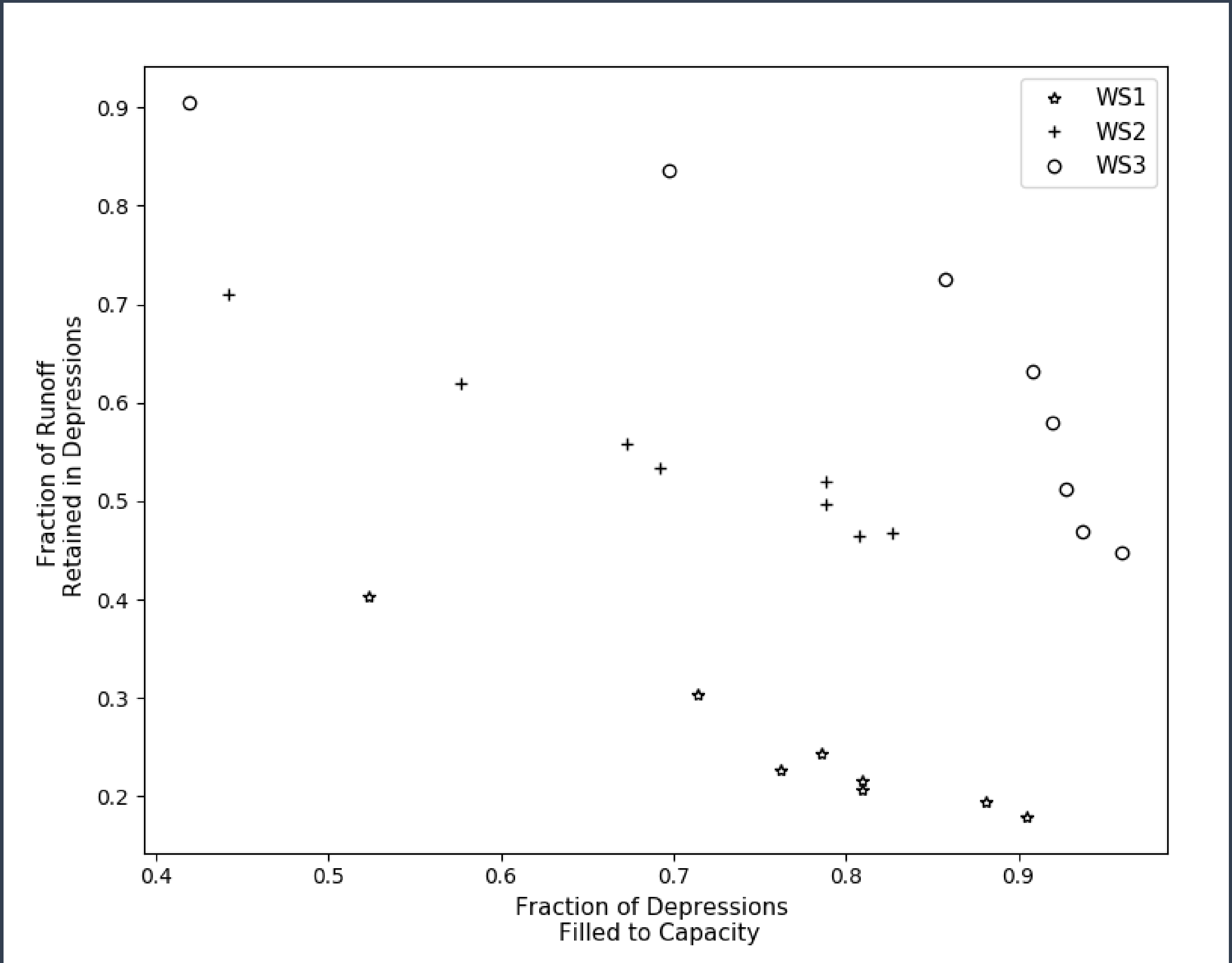




Peak Discharge

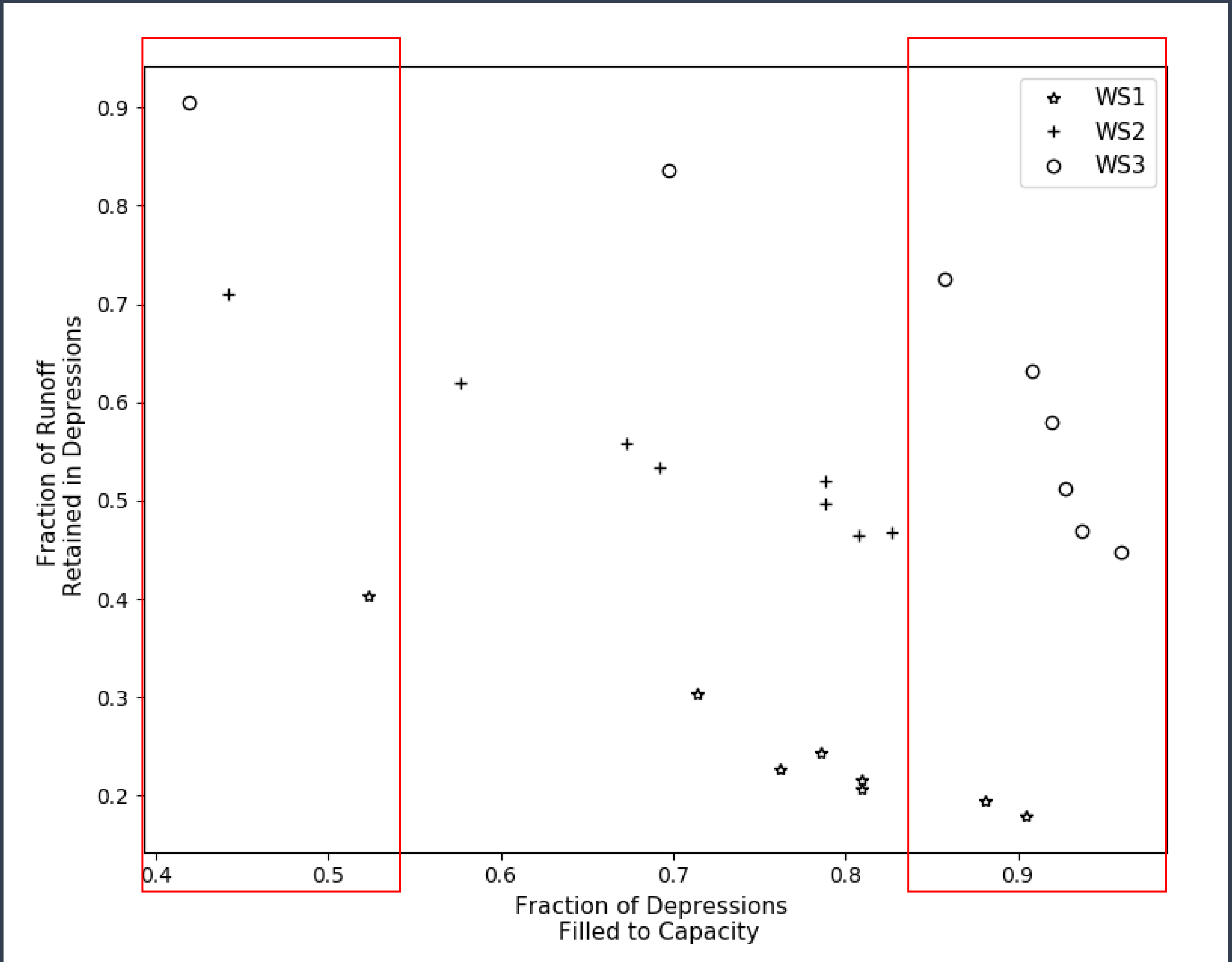


These results demonstrate that depressional fill-spill behavior is a complex non-linear process



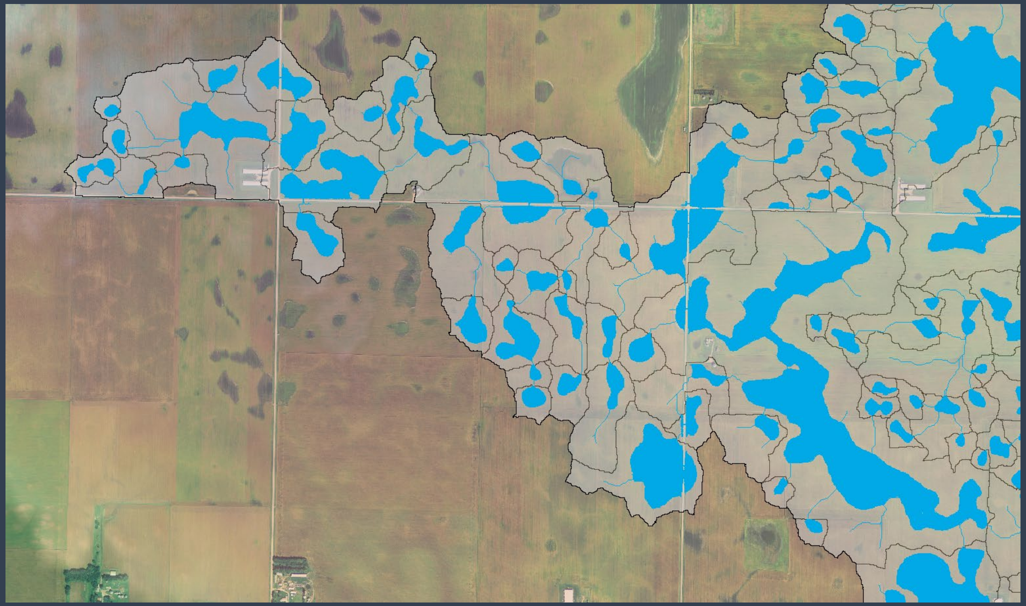
These results demonstrate that depressional fill-spill behavior is a complex non-linear process

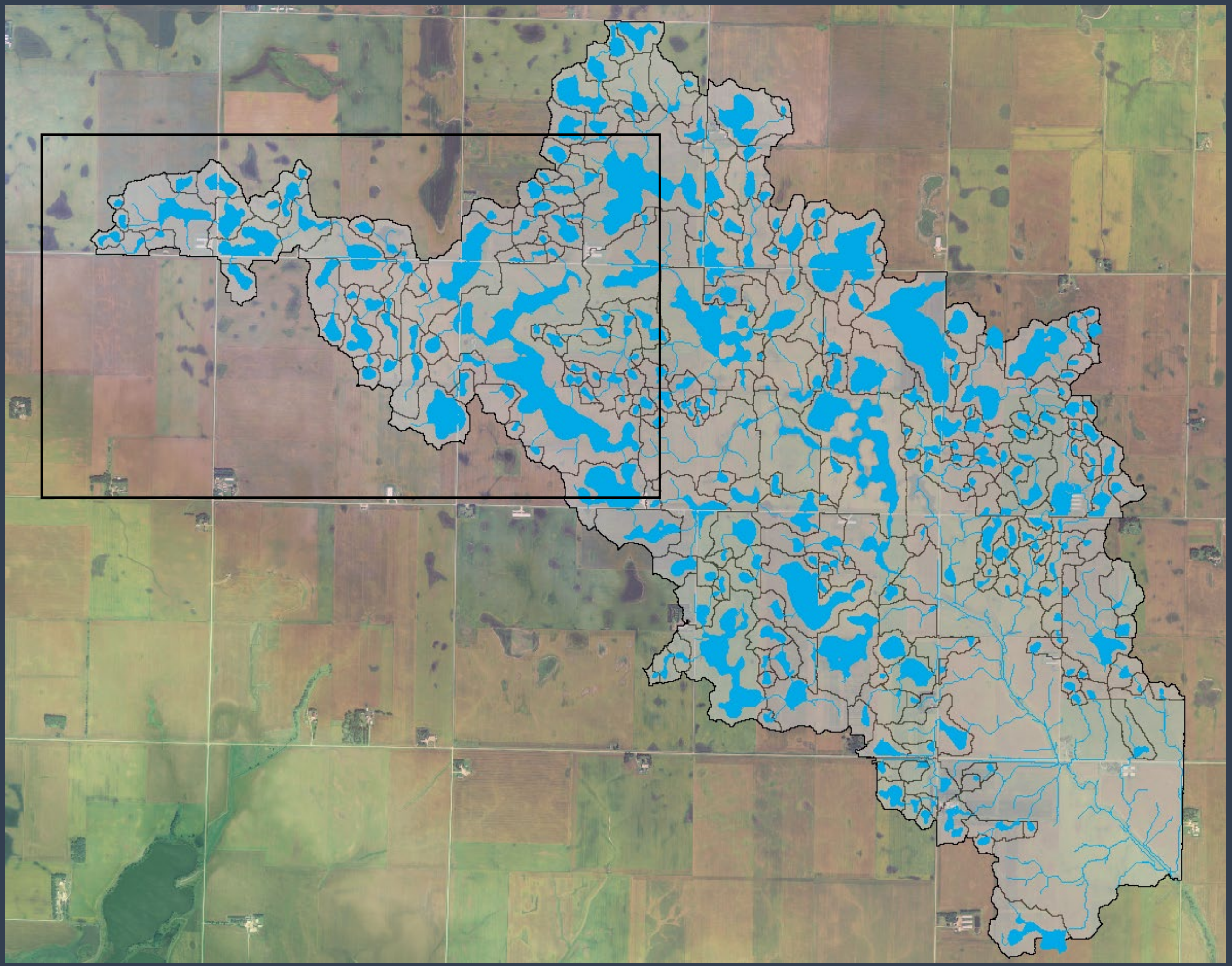
- For low rain events nearly all runoff is retained
- Simpler networks fill in succession linearly
- For large rain events nearly all depressions are filled
- For large rain events large depressions, which act as regulators, are filled, causing the sharp declines in runoff retention



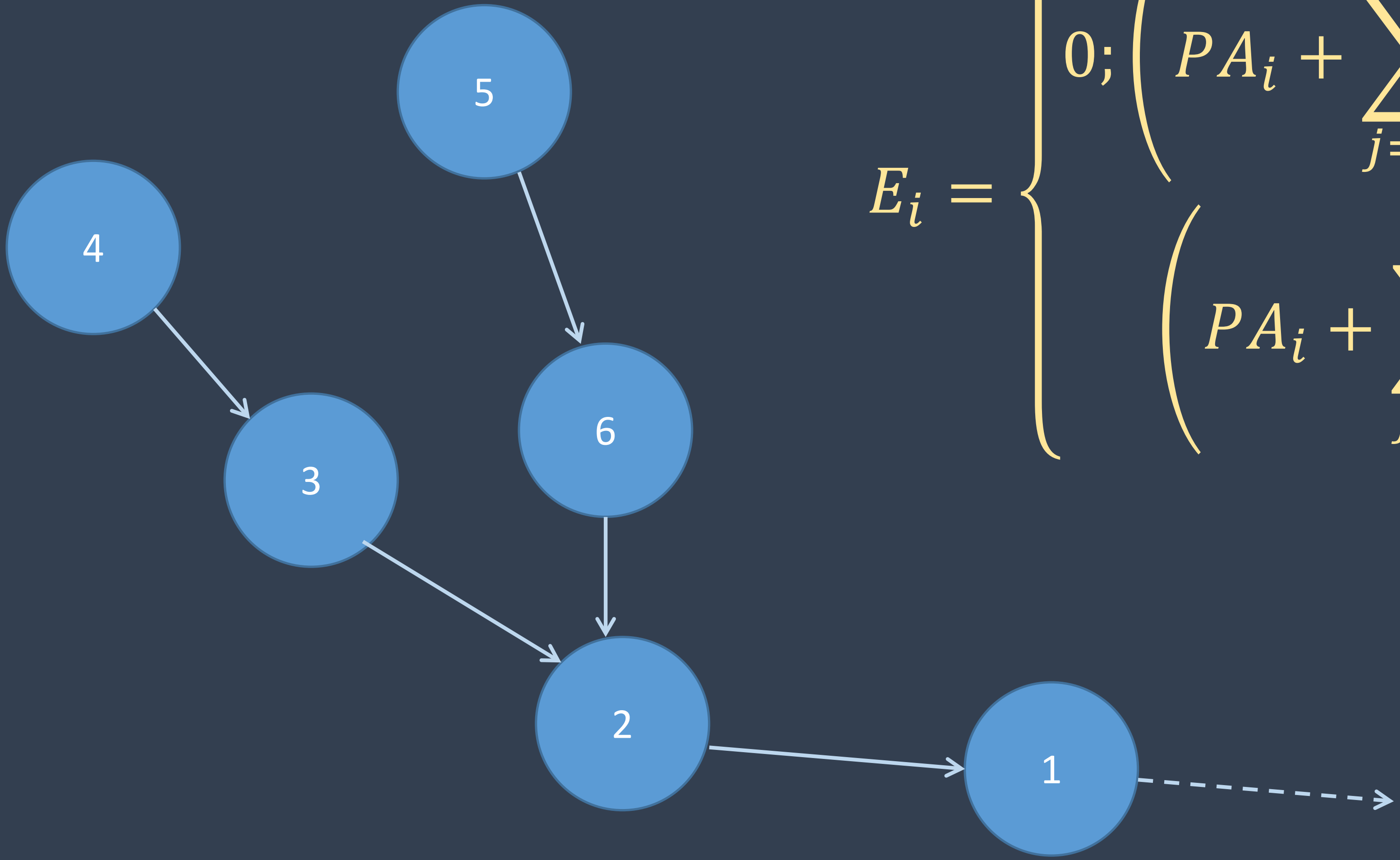
GSSHA is computationally intensive. Is there a more computationally efficient way to look at connectivity of the depressional network?

Depressional Network Cascade



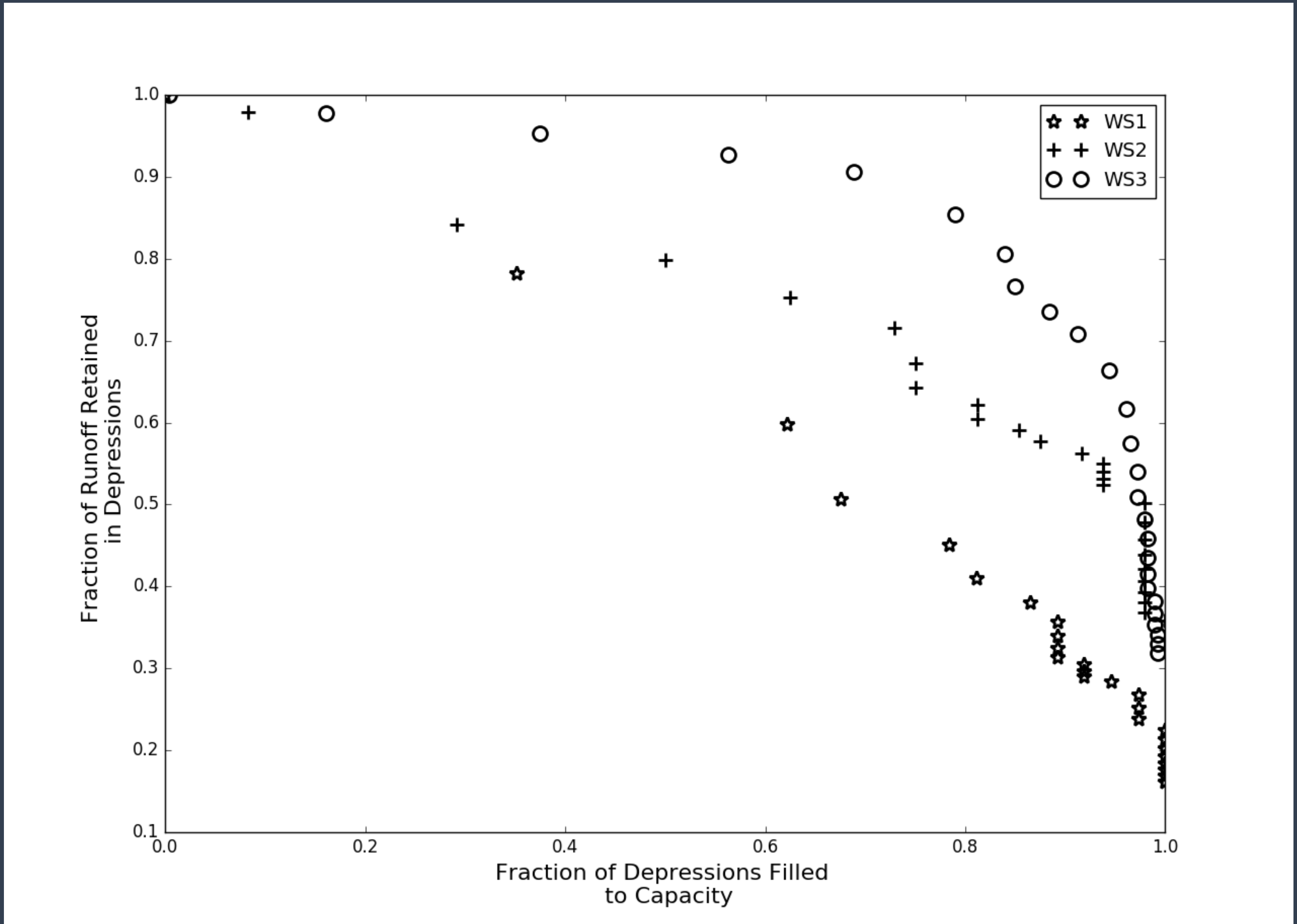


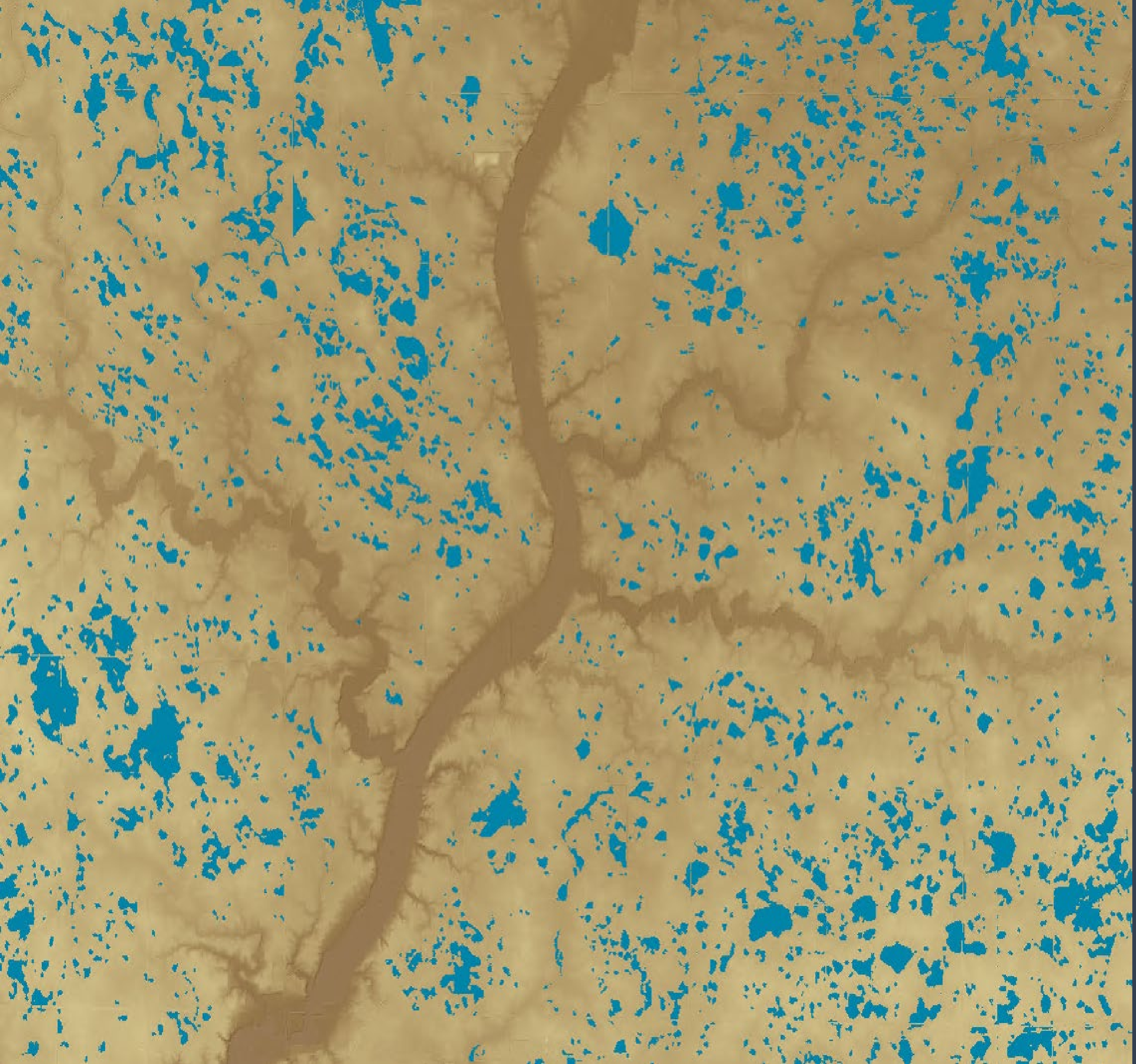
Mathematics of Depressional Network Cascade



$$E_i = \begin{cases} 0; \left(PA_i + \sum_{j=1}^{k} E_j \right) - V_i \leq 0 \\ \left(PA_i + \sum_{j=1}^{k} E_j \right) - V_i \end{cases}$$

Same patterns as observed with GSSHA model results, though some minor differences





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