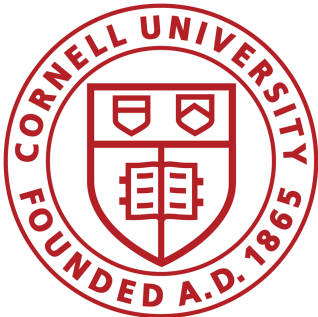


Geothermal Play Fairway Analysis of the Appalachian Basin: Lessons Learned in Reservoir Mapping and Characterization

Erin Camp, Teresa Jordan, Jefferson Tester, Jery Stedinger, Franklin Horowitz, Jared Smith, Calvin Whealton, Maria Richards, Cathy Chickering Pace, Matthew Hornbach, Beatrice Magnani, Zachary Frone, Brian Anderson, Xiaoning He, Zachary Frone, Kelydra Welcker



SMU®



GSA 2015, Baltimore, Maryland

Department of Energy

Acknowledgement and Disclaimer

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1. MOTIVATION

2. FAIRWAY RESULTS

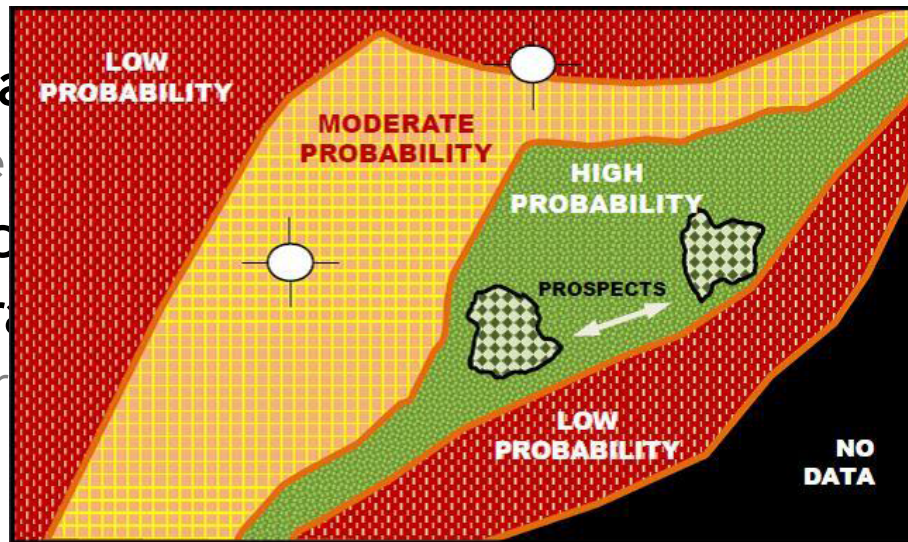
3. RESERVOIRS

“Combination of geologic factors that leads to the concentration of a desired resource”

Play Fairway Analysis

“Conducted during the **early** phases of resource **exploration** in order to **highlight** areas where more detailed exploration would be productive.”

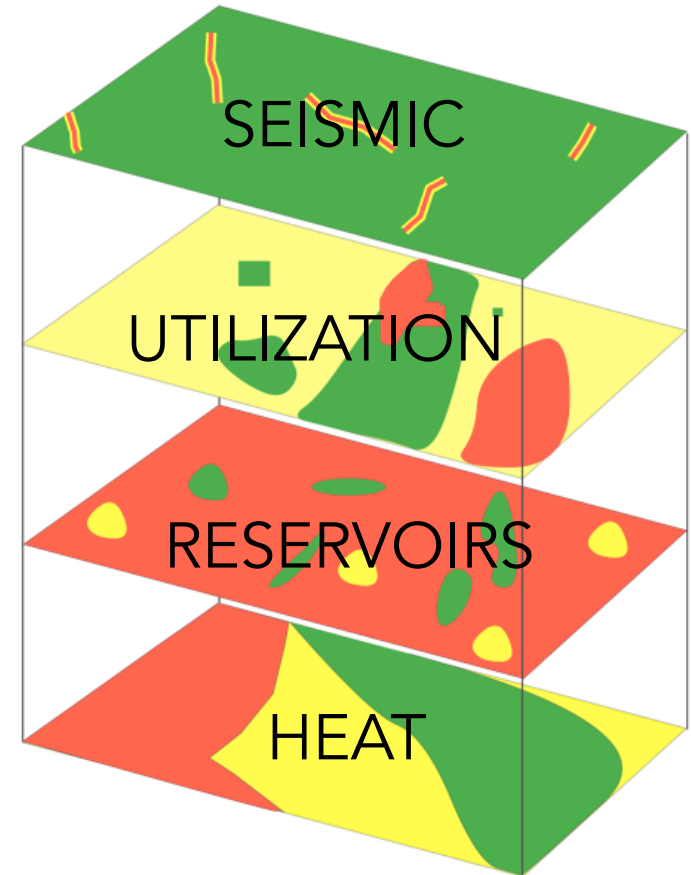
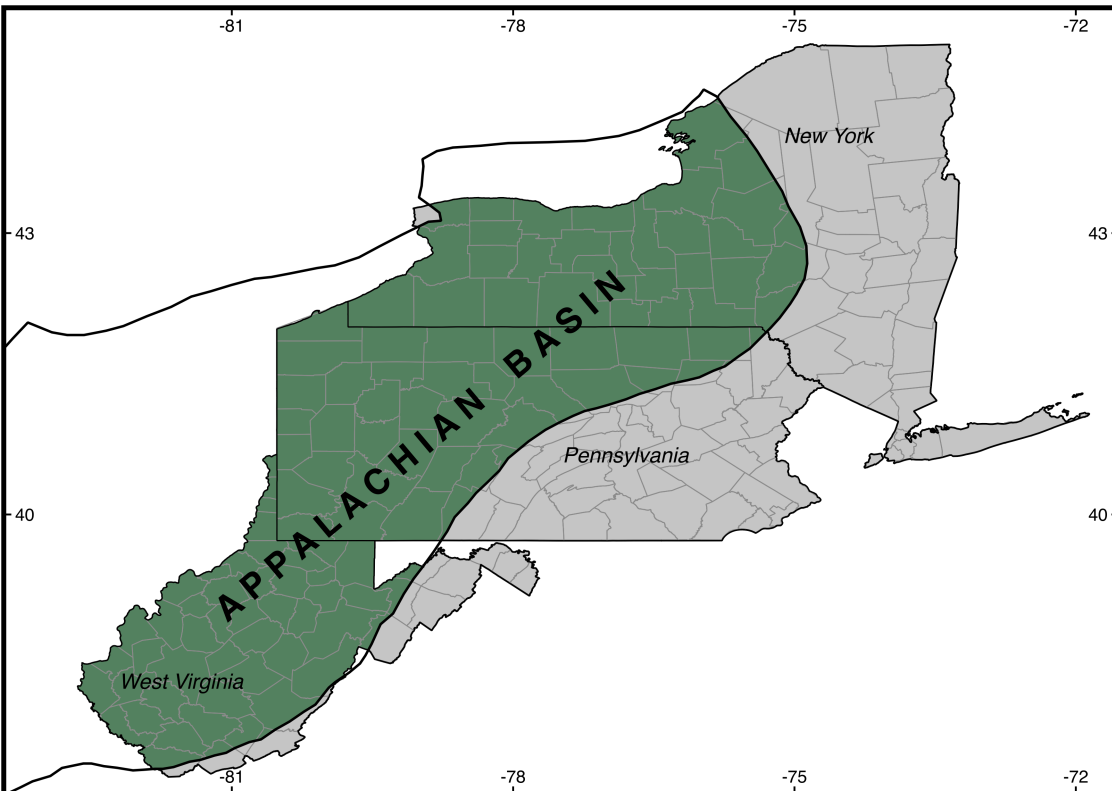
“The area in a basin that is favorable for an individual type of resource to occur and/or are predicted to have geologic characteristics favorable for resource occurrence”



Source:
U.S. Department of Energy
EERE Geothermal Play Fairway
Analysis Webinar Feb. 6, 2014

Geothermal Play Fairway Analysis

Sedimentary Basin
Hydrocarbon Reservoir
Low-temperature
Direct Use



PROJECT RESULTS

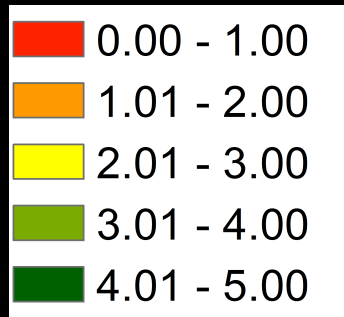
Thermal Resource

Natural Reservoirs

Seismic Risk

Utilization (Demand)

Combined



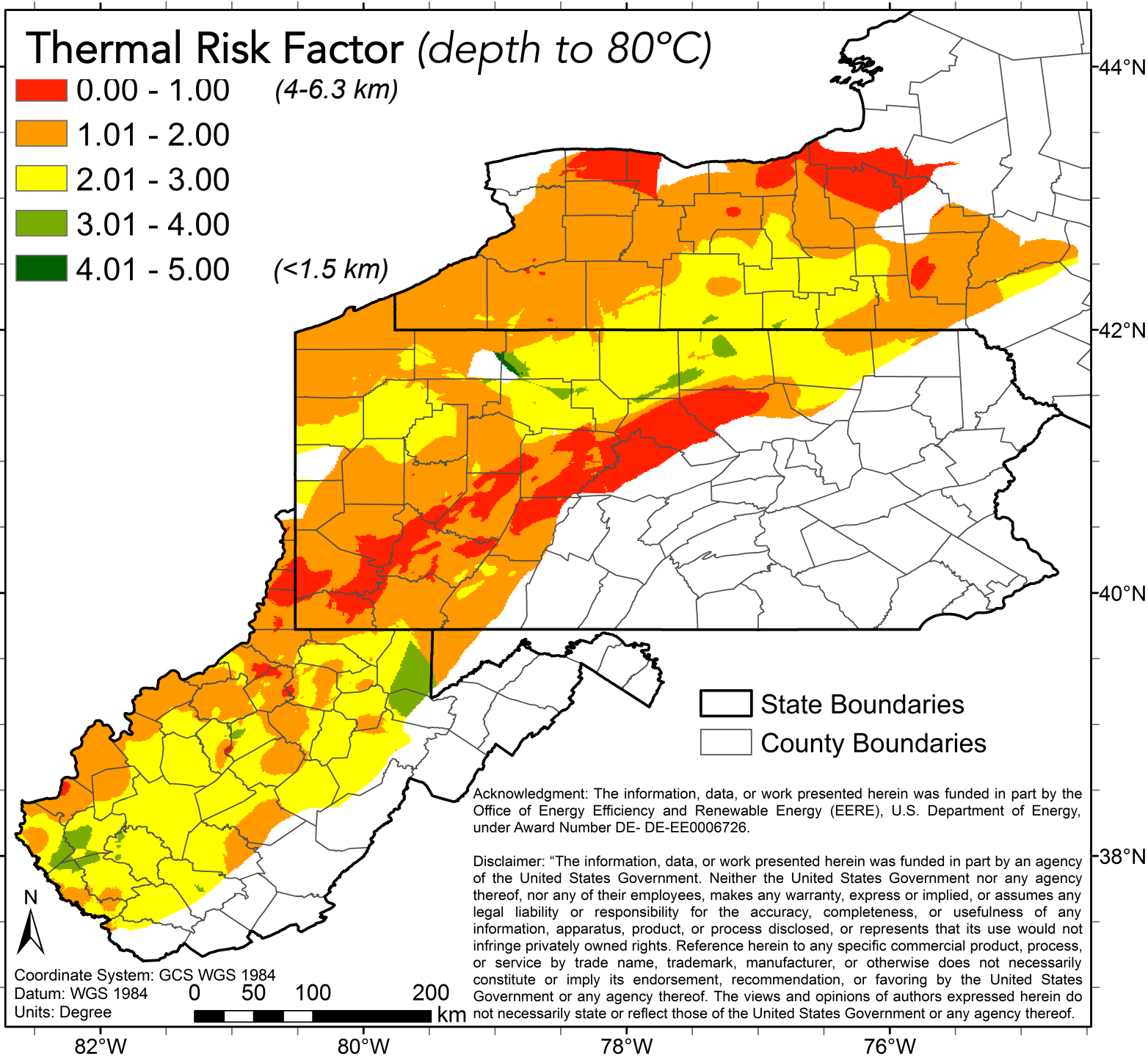
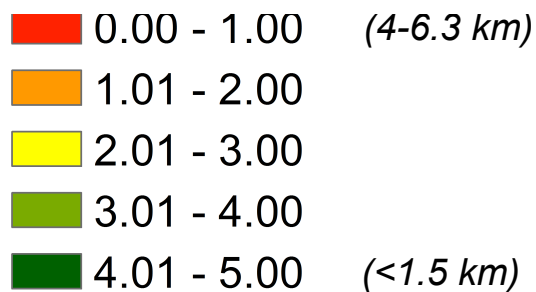
THERMAL

RESERVOIRS

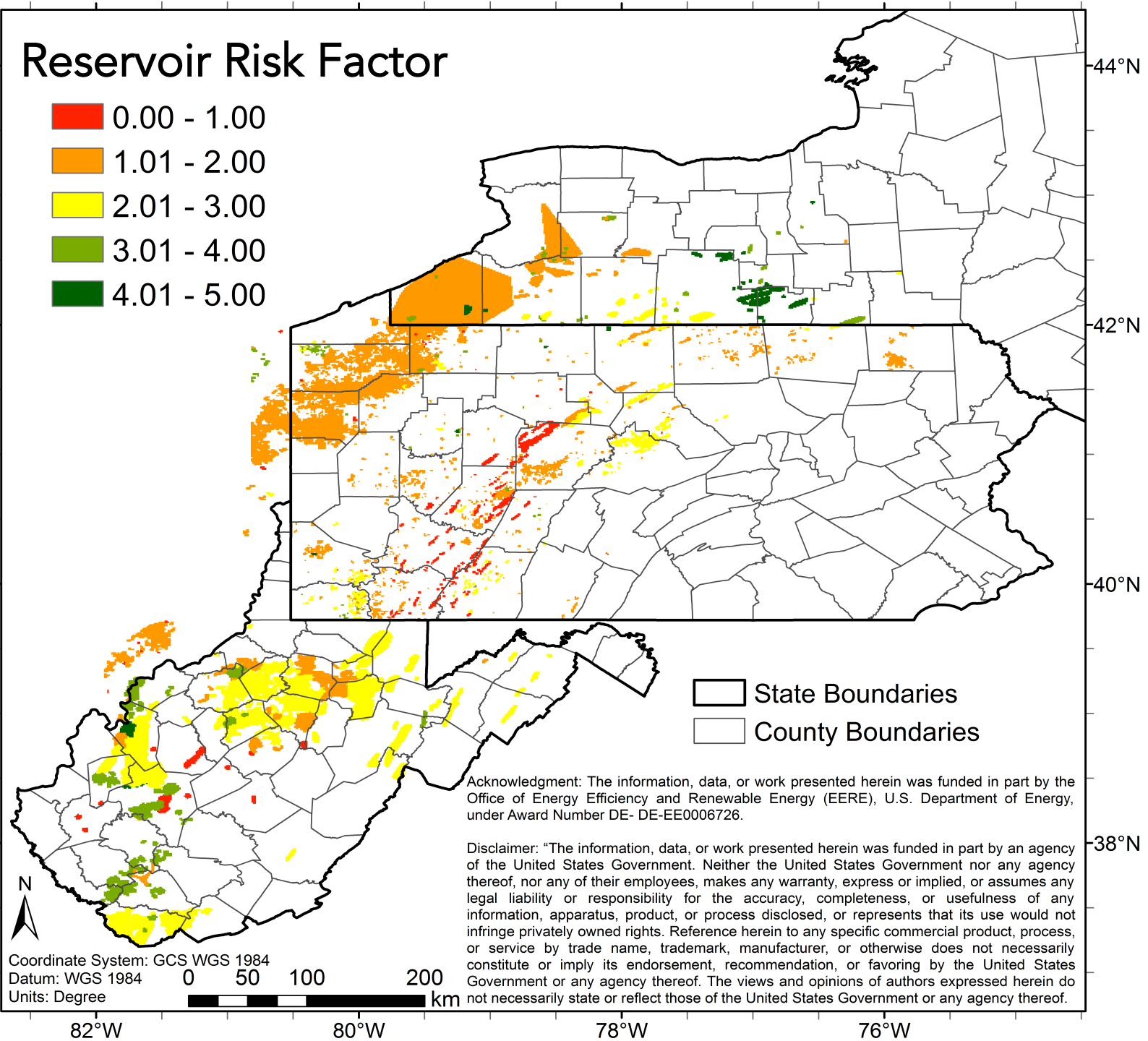
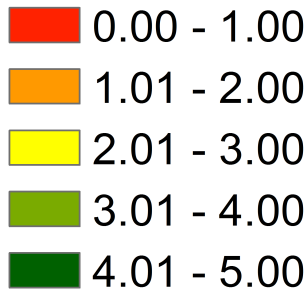
SEISMIC

UTILIZATION

Thermal Risk Factor (depth to 80°C)



Reservoir Risk Factor



State Boundaries
County Boundaries

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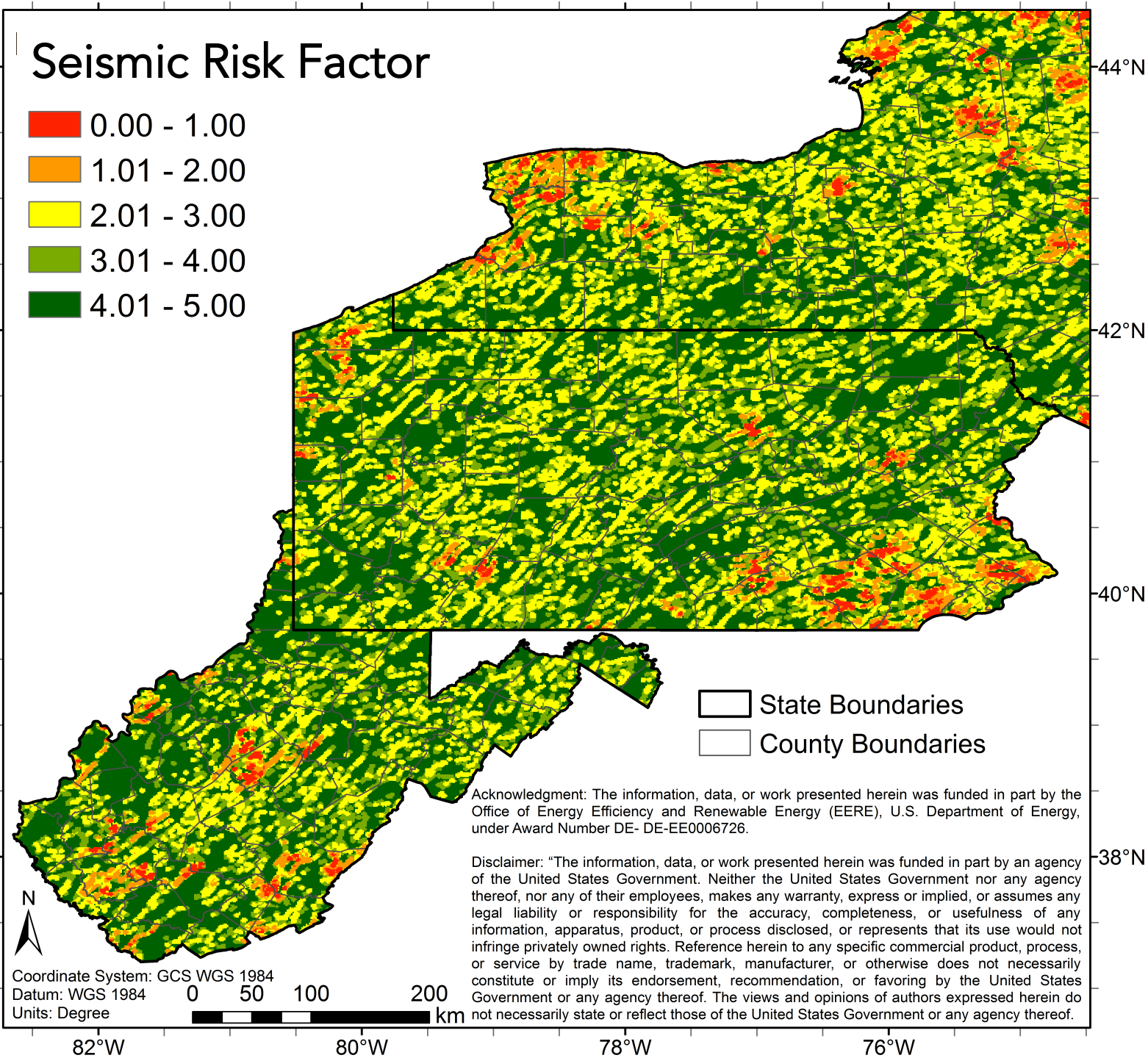
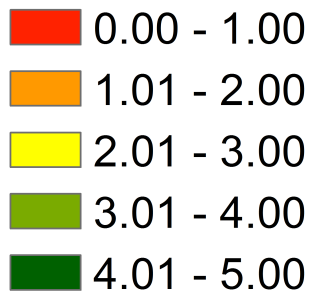
THERMAL

RESERVOIRS

SEISMIC

UTILIZATION

Seismic Risk Factor



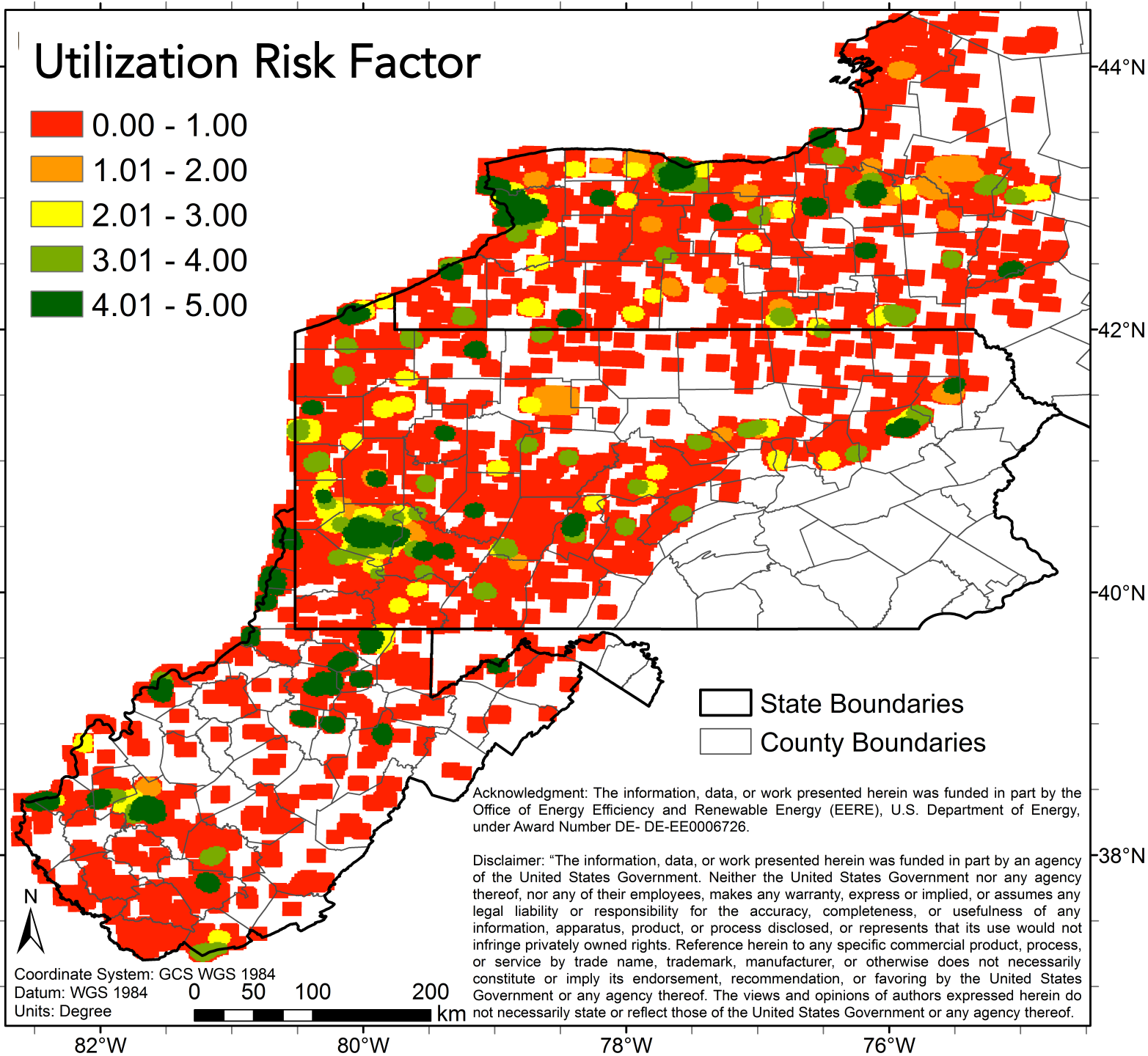
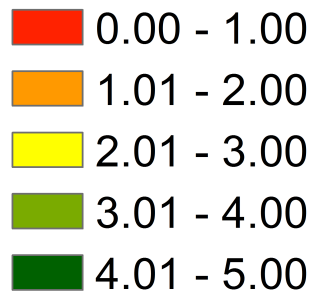
THERMAL

RESERVOIRS

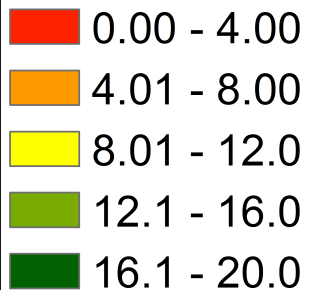
SEISMIC

UTILIZATION

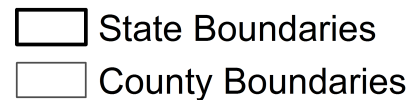
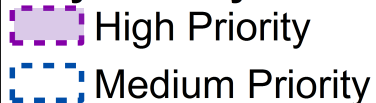
Utilization Risk Factor



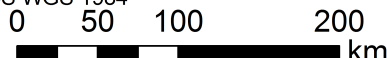
Play Fairways



Play Fairways



Coordinate System: GCS WGS 1984
Datum: WGS 1984
Units: Degree



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THERMAL

RESERVOIRS

SEISMIC

UTILIZATION

44°N

42°N

40°N

38°N

82°W

80°W

78°W

76°W

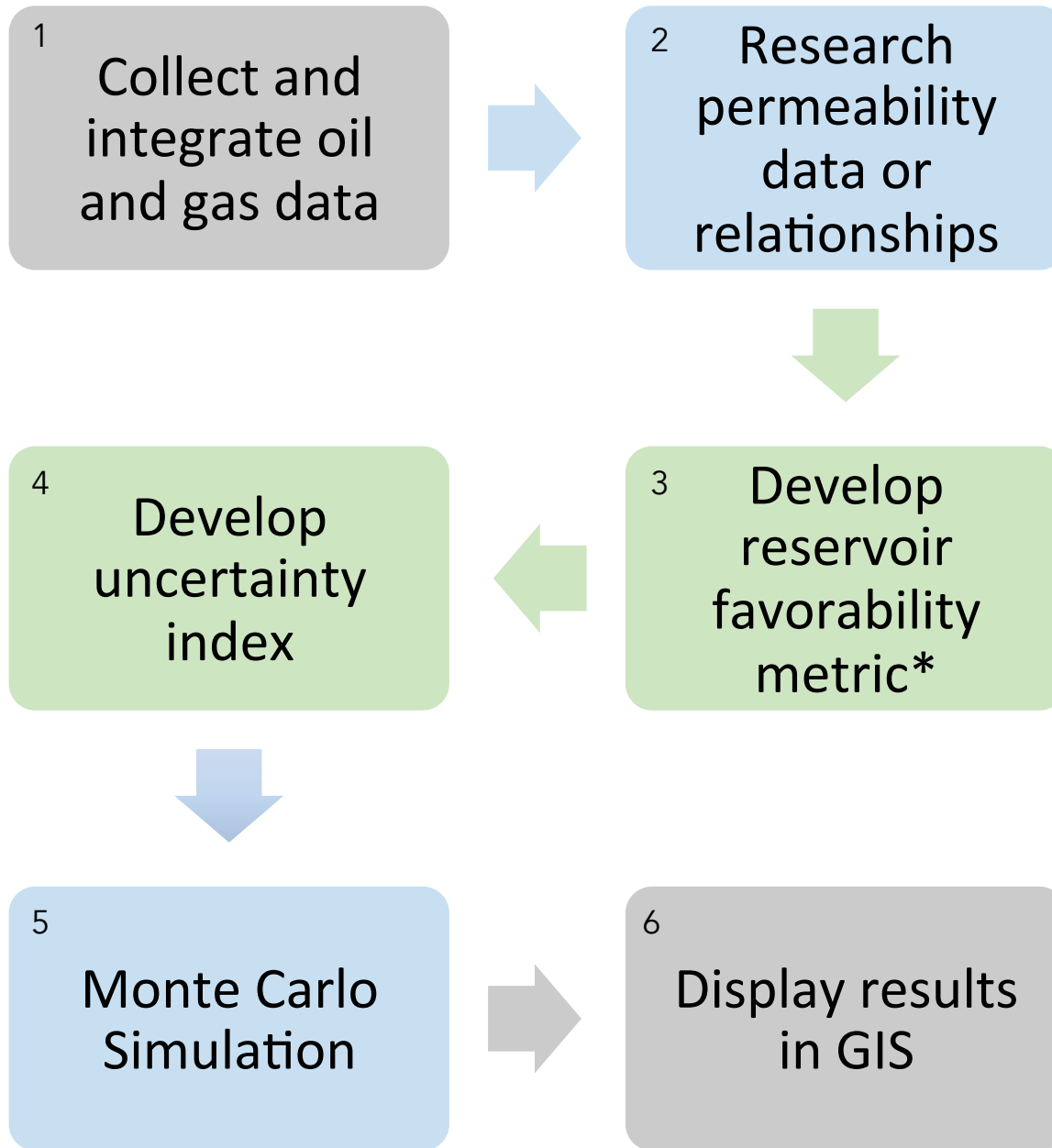
Reservoirs Task

Methods and Results

Reservoir Analysis Goals

1. Map out all reservoirs in study area that have produced hydrocarbons
2. Quantify reservoir favorability using available reservoir data
3. Quantify uncertainty for all reservoirs

Methods



*Available data:

- Porosity
- Permeability
- Thickness
- Depth

Flow Rate → Reservoir favorability?

Well Productivity Index:
Dupuit Eq., Porous Media

$$\frac{Q}{\Delta P} = \frac{2\pi kH}{\mu \ln \left(\frac{D}{r_w} \right)}$$

Q = flow rate

ΔP = pressure drop

k = permeability

H = reservoir thickness

μ = water viscosity

D = distance between wells

r_w = radius of wellbore

Reservoir Productivity Index:
Modified, Porous Media

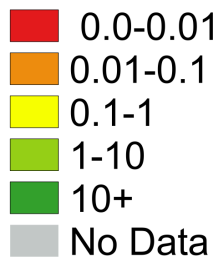
$$\frac{Q}{\Delta P} = \frac{2\pi kH f_a}{\mu}$$

units: L/MPa-s

f_a = area factor

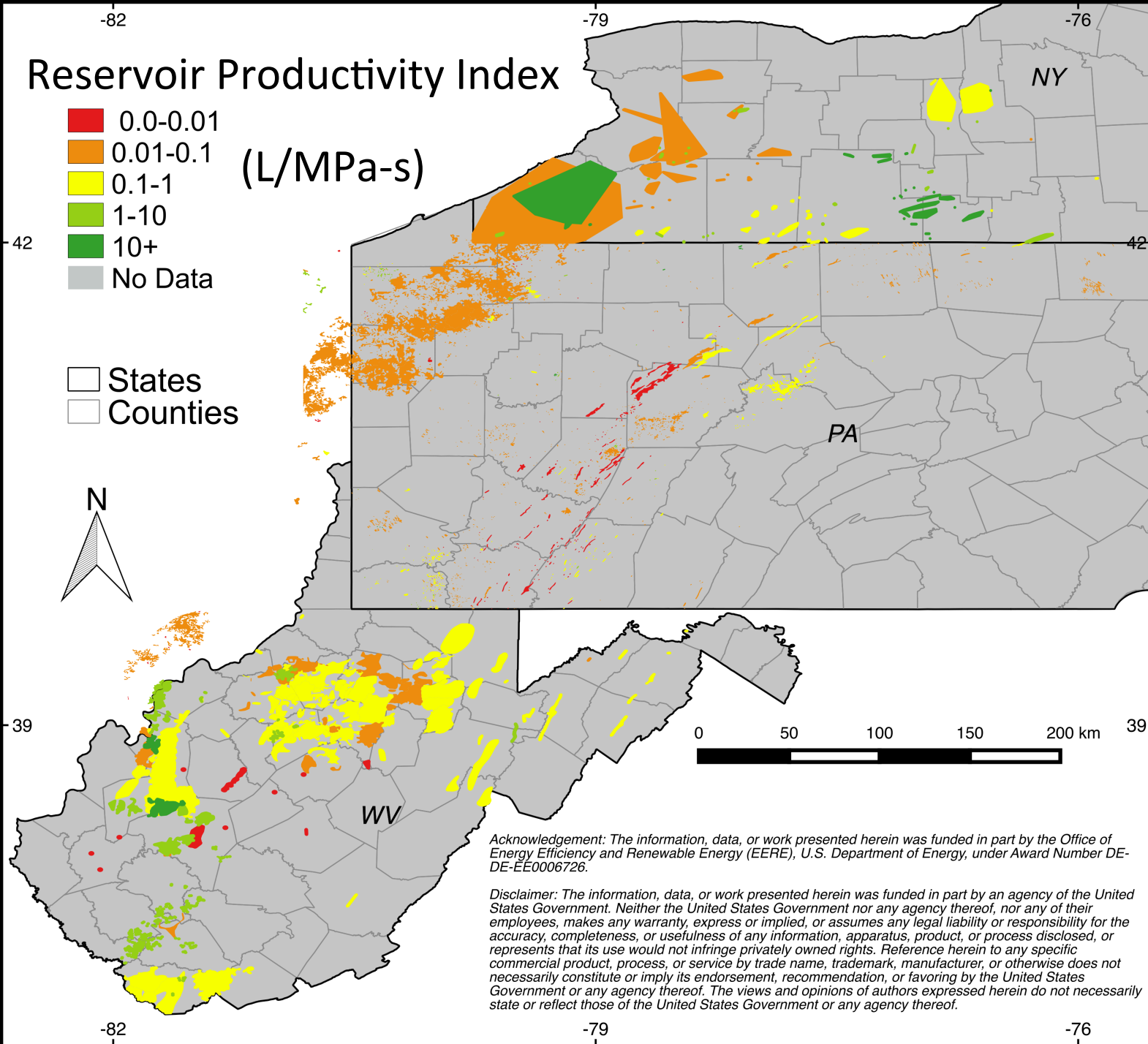
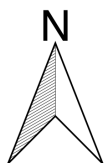
μ = $f(\text{depth})$

Reservoir Productivity Index



(L/MPa-s)

States
Counties



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Lessons Learned—Reservoirs

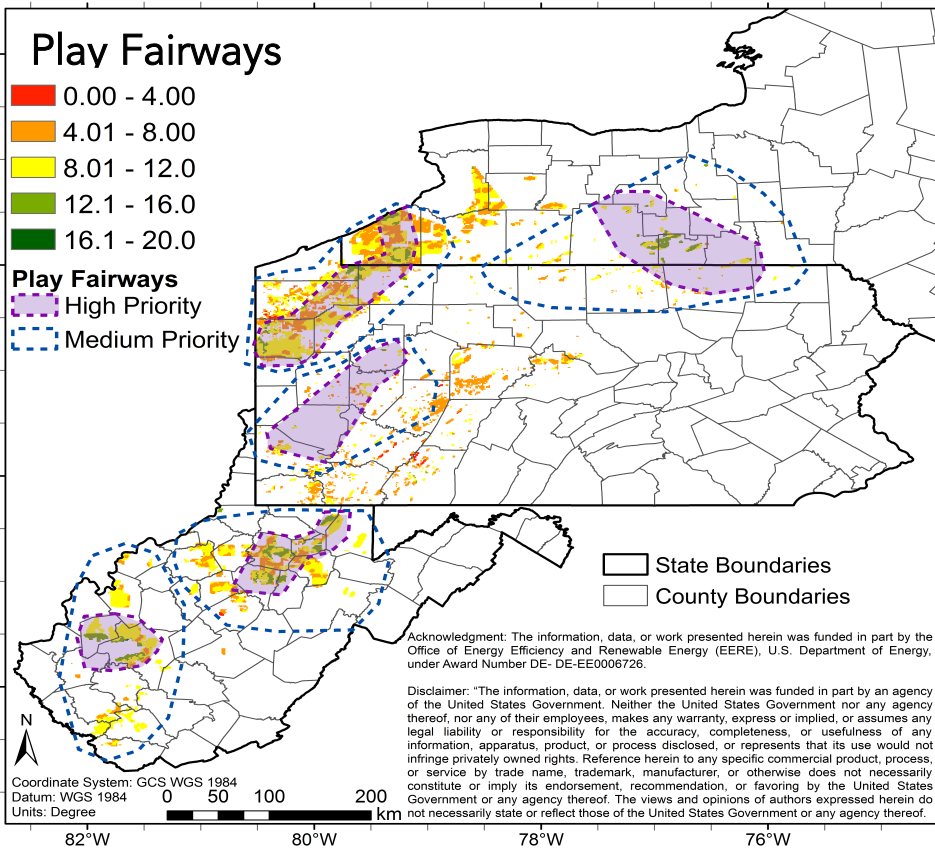
- ✓ Favorability metric not ideal
- ✓ On average low Reservoir Productivity
 - ❖ Permeability and thickness are major factors
- ✓ Low spatial coverage
 - ❖ Hydrocarbon database is limiting
 - ❖ 3D distribution is a challenge
- ✓ Permeability data quantity and quality are barriers
 - ❖ No way to quantify heterogeneity in reservoirs
- ✓ State boundaries present an issue

Future Considerations

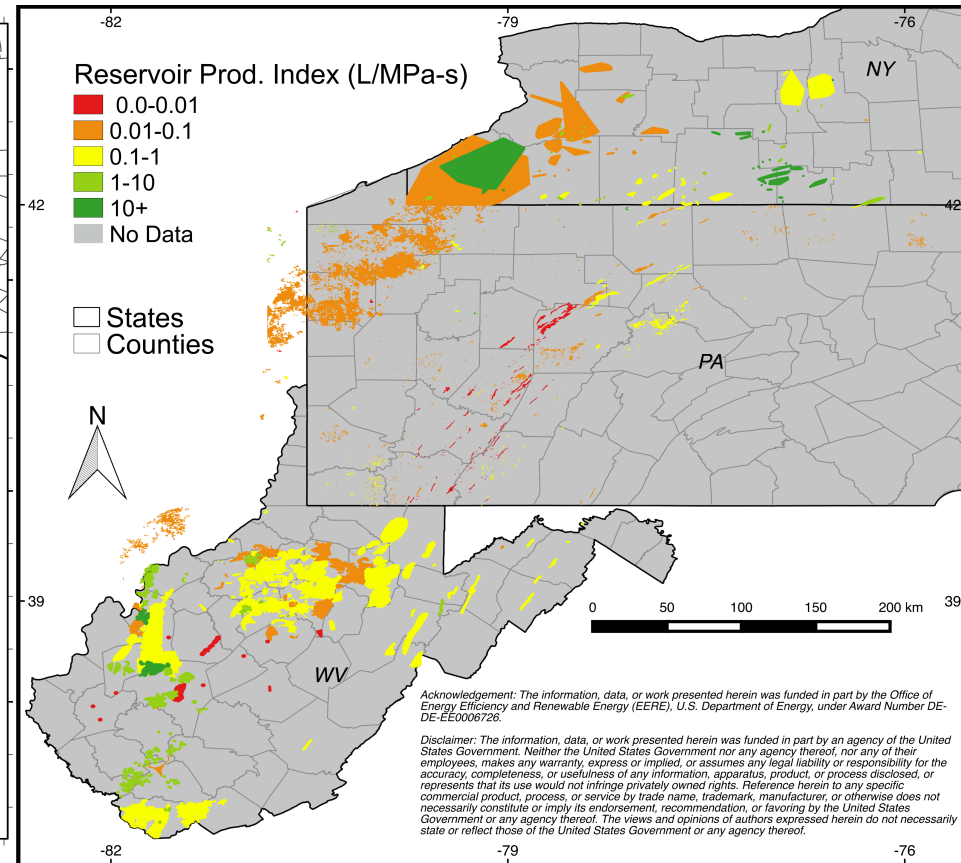
- ✓ Inclusion of “dry” wells and geologic extrapolation
 - ❖ Find the “unknown” reservoirs

- ✓ Reservoir Productivity estimates likely to change with better permeability predictions
 - ❖ Acquiring flow data
 - ❖ Inter-well permeability approximations
 - ❖ Different equation for fractured reservoirs

Conclusions



✓ Play Fairway Analysis is a useful tool



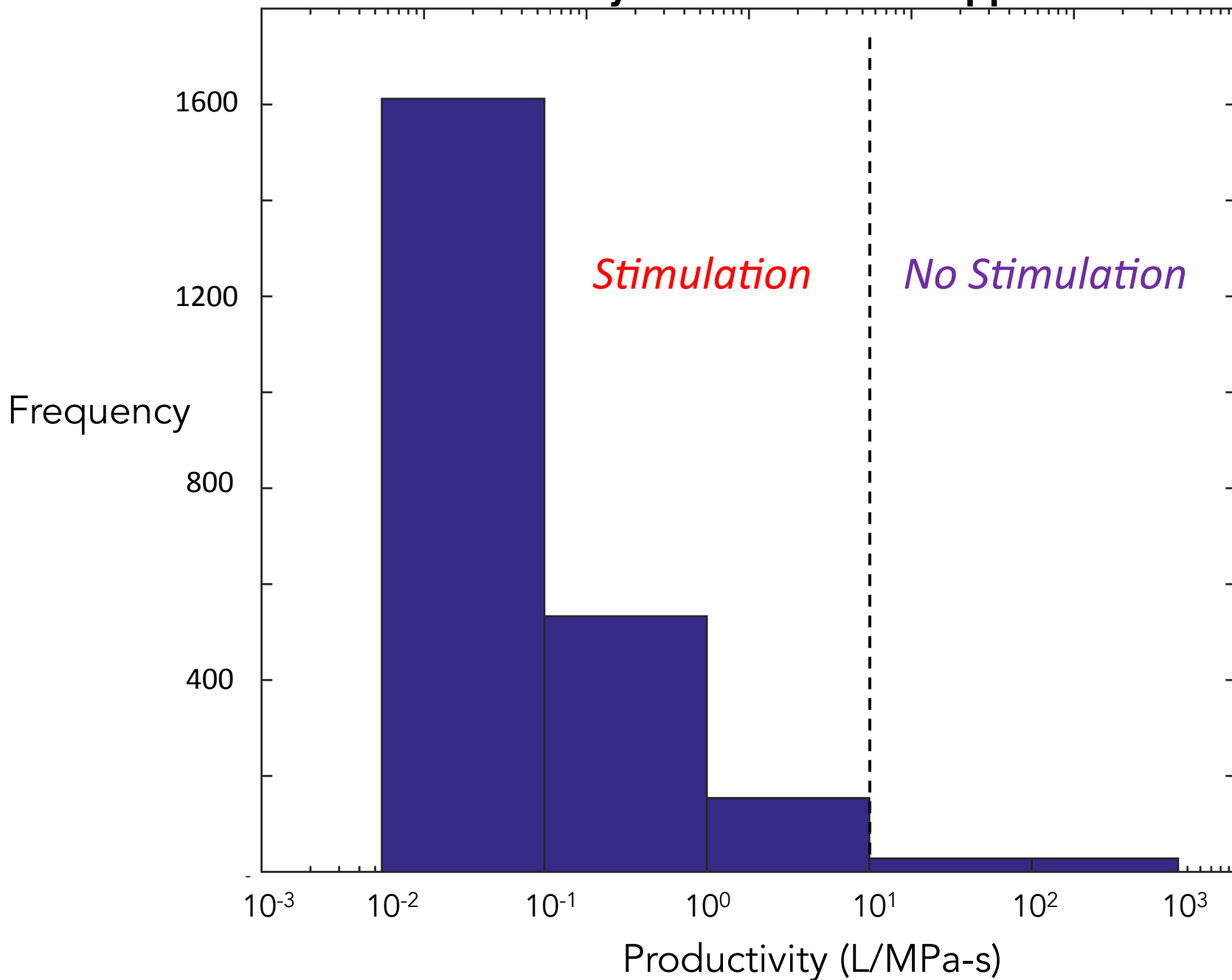
✓ Basin-scale reservoir analysis has challenges but does good job

Thank you! Questions?

Extra Slide

- Best Formations/Plays:
 - Trenton-Black River Dolomite (NY, PA)
 - Lockport Dolomite (PA)
 - Oriskany Sandstone (PA, WV, NY)
 - Newburg Sandstone (WV)
 - Onondaga Pinnacle Reefs (NY)
 - Devonian Unconformity Play (PA)

Reservoir Productivity Distribution for Appalachian Basin



Sensitivity Analysis for Reservoir Productivity Index

