Geostatistical Analysis of the Bakken Petroleum System: Oil and Water Production

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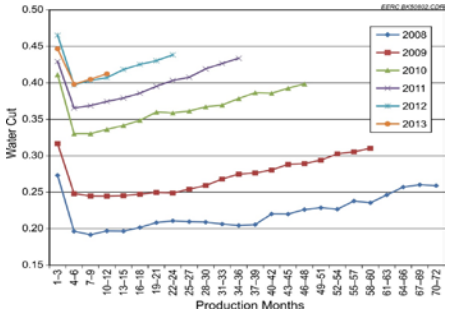
THE UNIVERSITY OF NORTH DAKOTA

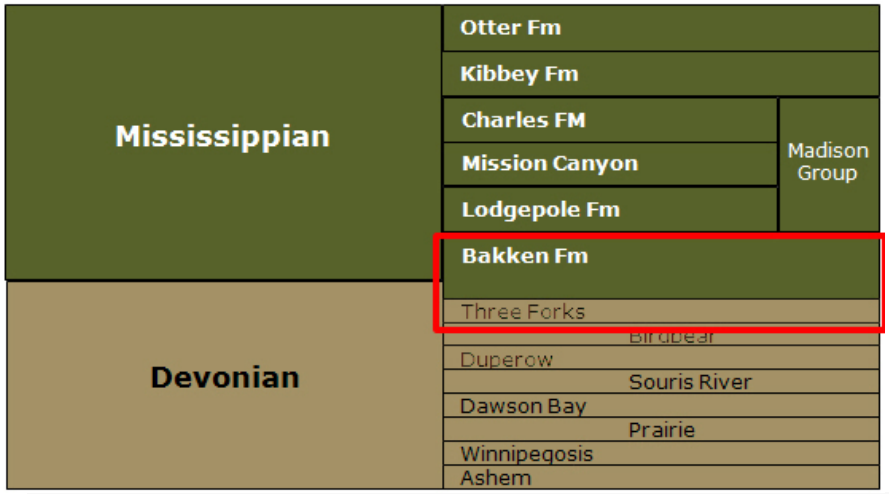
Utility of GIS

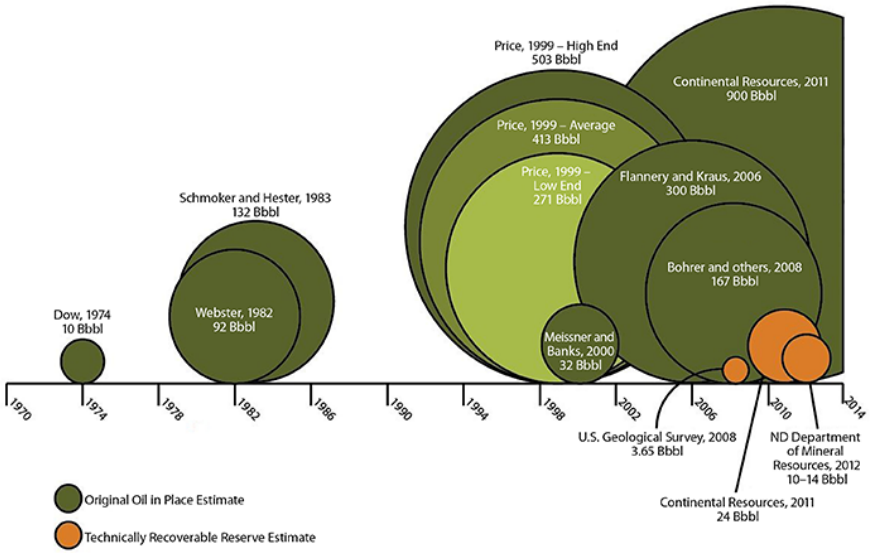
- How can GIS help us analyze petroleum production trends in the Bakken Petroleum System?
- What are the practical applications of GIS in our study area?

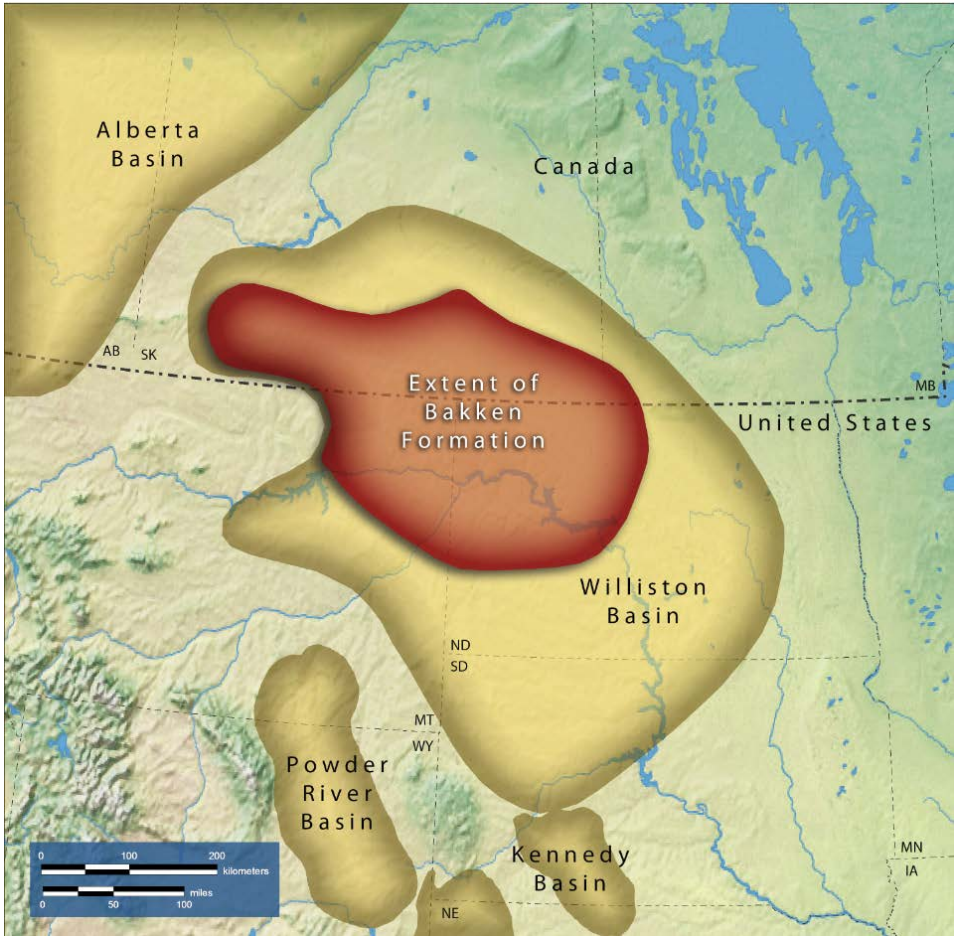
Year	Total SWD,[1] million bbl/yr	Bakken Produced Water Volume, million bbl/yr	% of Total SWD from Bakken Produced Water
2008	107	6.4	7
2009	114	12.1	11
2010	136	32.6	24
2011	174	63.8	37
2012	239	134.7	54
2013	301	193.3	63
2014	386	280.6	73
2015	441	331.1	75



Bakken Petroleum System







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Project Background

Bakken Production Optimization Program Goals

- Maximize oil production from Bakken and Three Forks wells by employing an “all-of-the-above” approach
  - Advanced reservoir characterization
  - Improve drilling/stimulation/completion/production techniques and sequences
  - Optimize wellsite surface operations
    - Reduce costs
    - Reduce development and operation impacts to surrounding landowners
    - Reduce demands on surrounding infrastructure and water sources

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Bakken Water Management

- Report updated water management taking place since early Bakken activity (~2008–2014).
- Bakken development rapidly changed the need for increased water supply and disposal options.
- How can GIS be used to answer questions about water management?

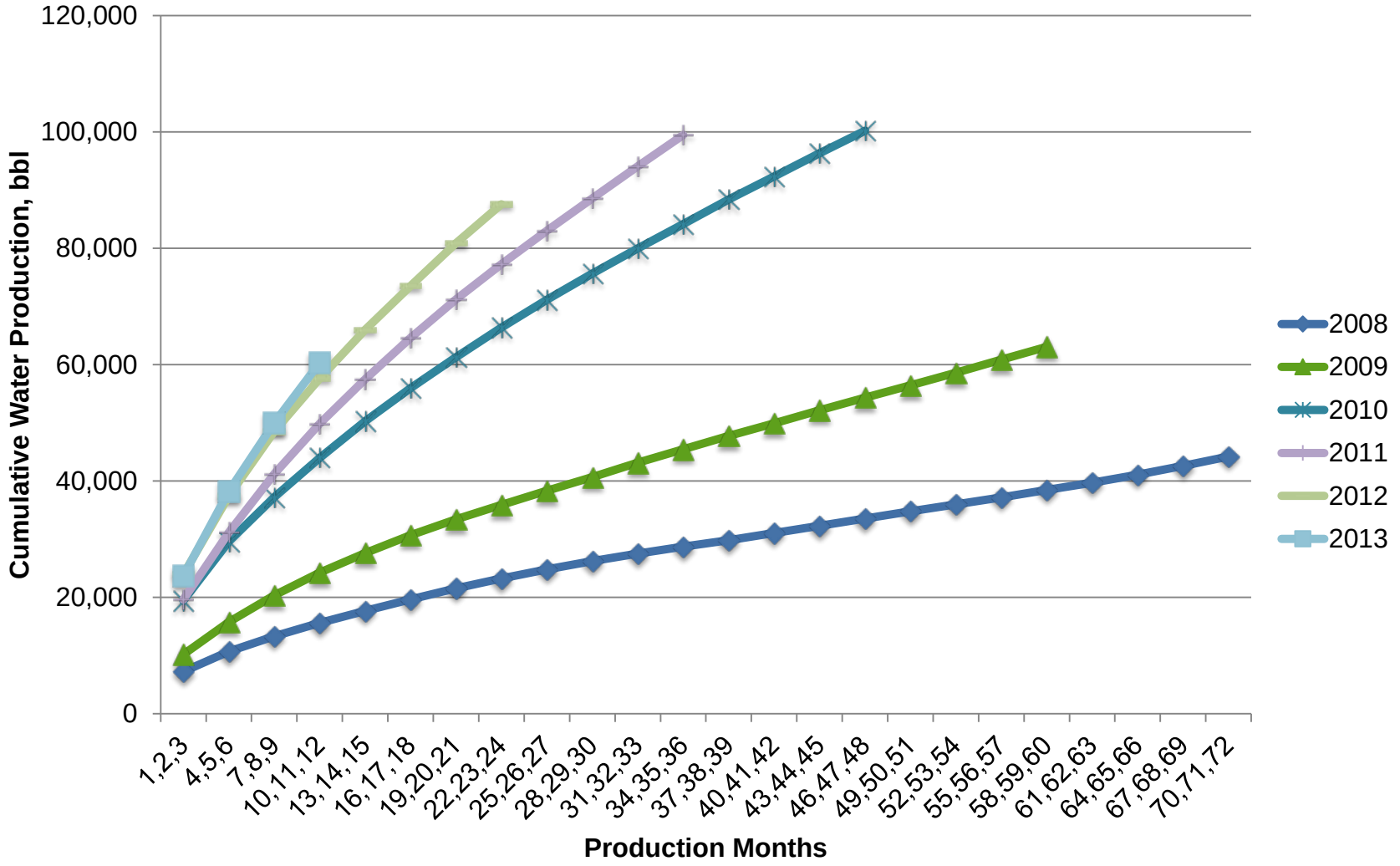
Data Acquisition

- North Dakota well data is collected from North Dakota Industrial Commission (NDIC) web site.
- Includes:
  - Monthly production values
  - Days of operation per month
  - Location

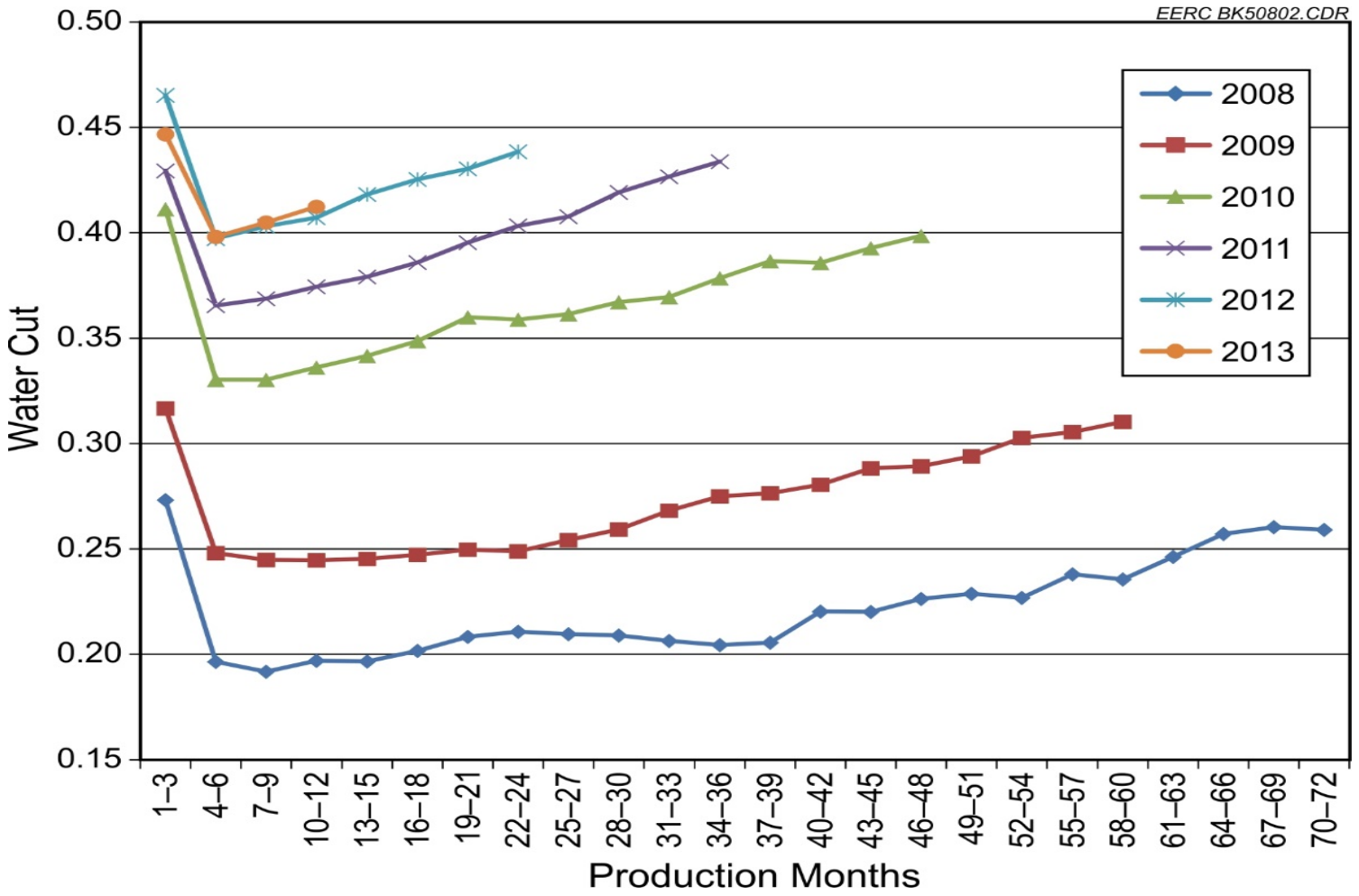
Data Preparation

- Produced water:
  - Assigned year based on first production date.
  - Selected wells producing from Bakken or Three Forks (referred to as “Bakken” wells).
  - Data could be further divided depending on application.
    - Examples include: Quarterly, 1st full 18 months, average daily rates, etc.

Average Bakken Well Cumulative Produced Water

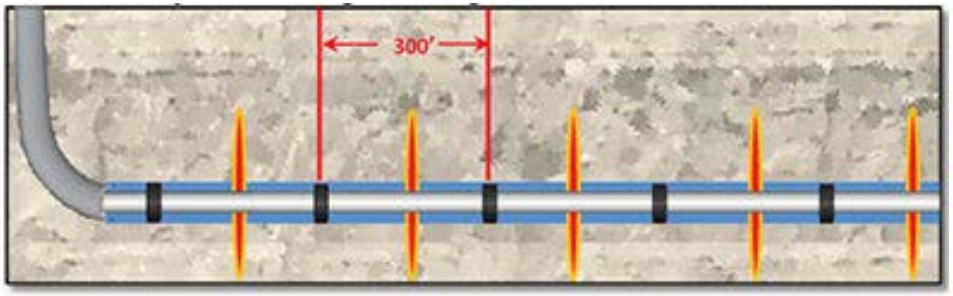


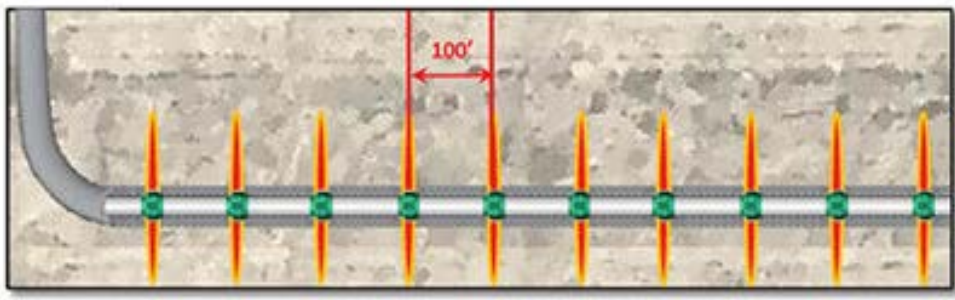
Average Bakken Well Water Cut



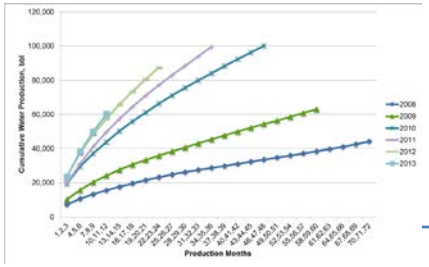
Water Trends

- Trends in produced water and water cut can be attributed to several potential factors including:
  - Improved well stimulation techniques and longer laterals.
  - Decrease in reservoir pressure over time.
  - Three Forks generally has higher water content.
- What about location?

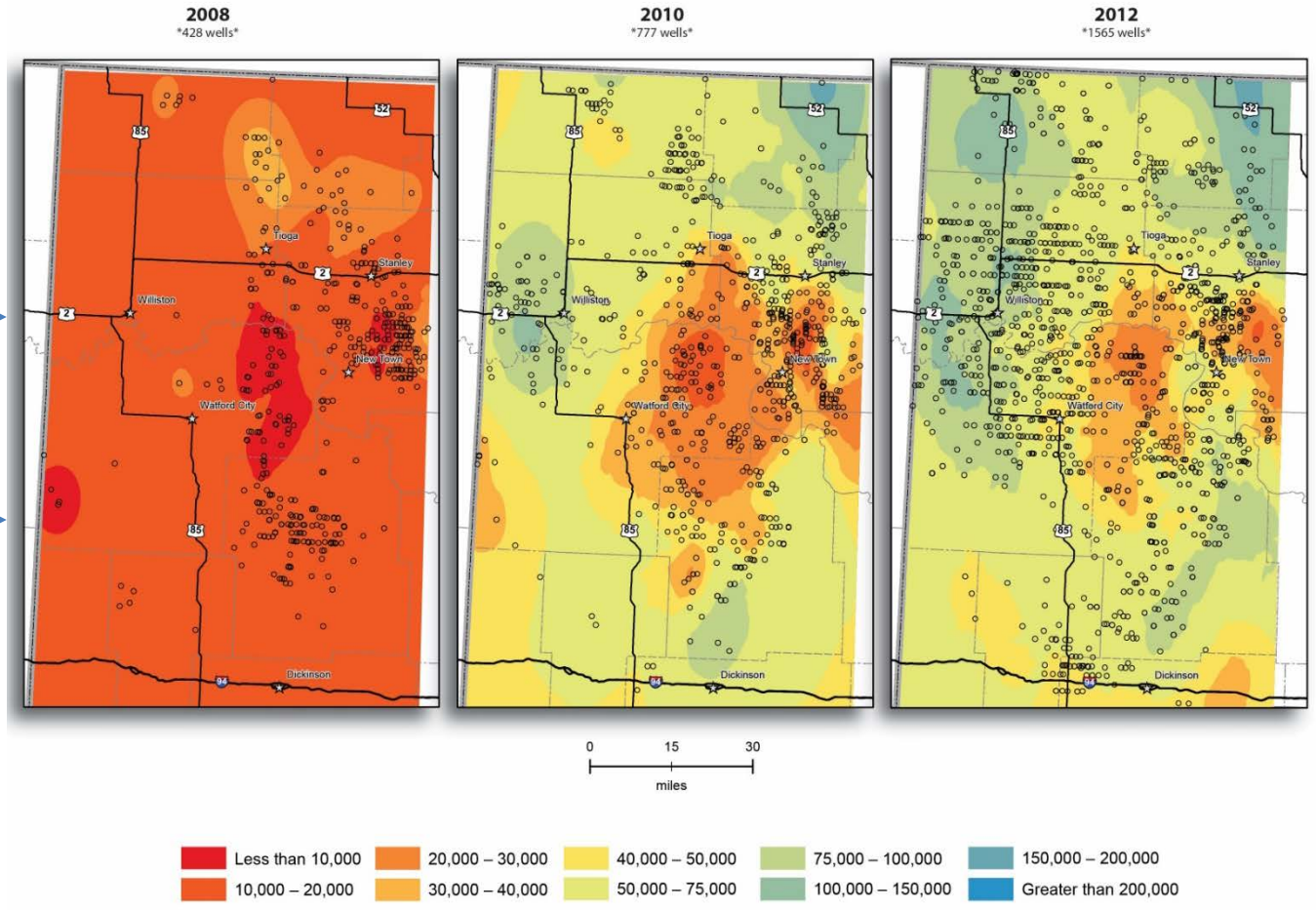




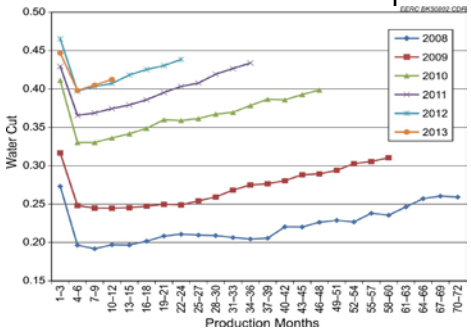
Bakken Produced Water

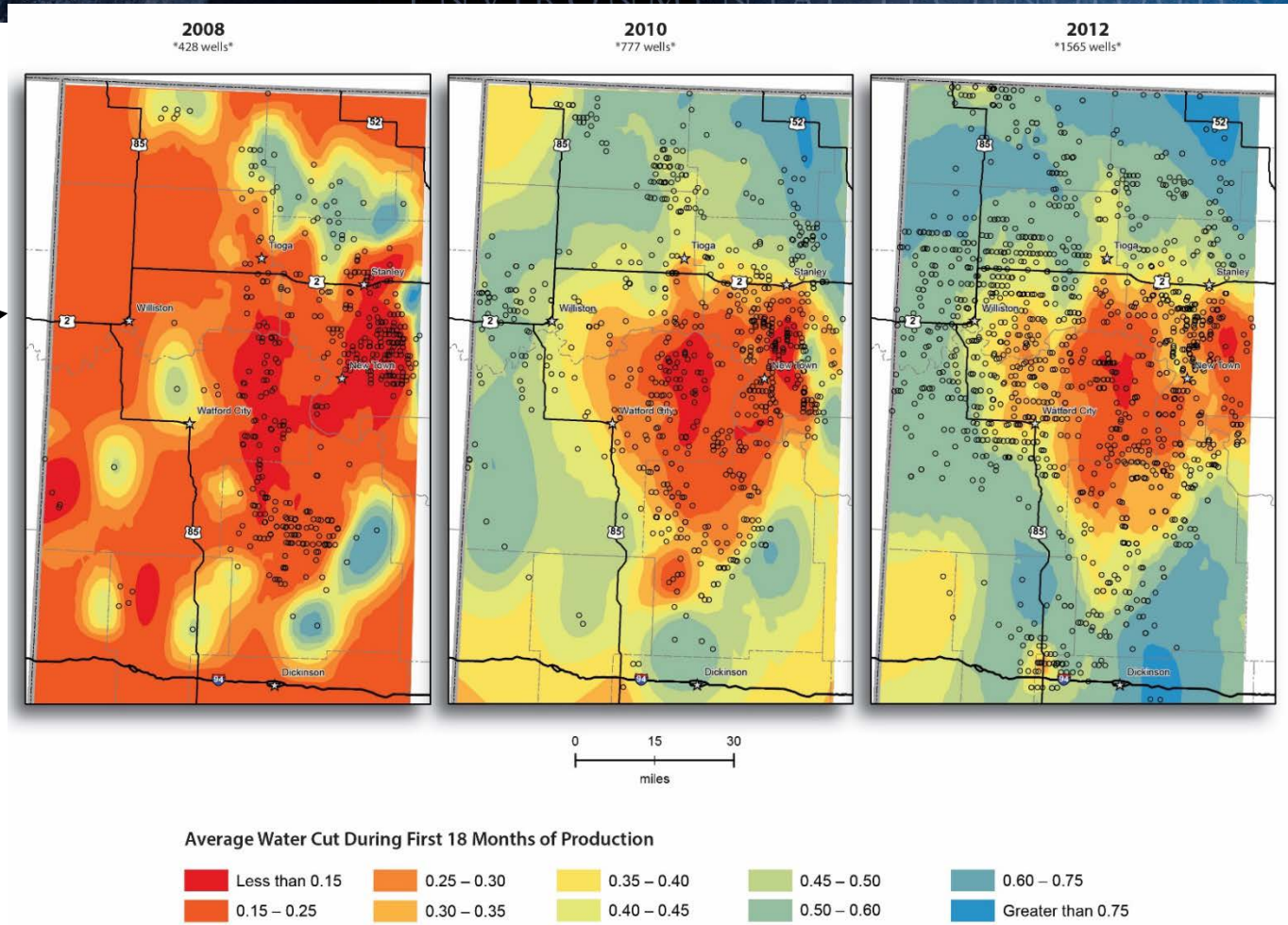


Year	Total Bakken Wells	Bakken Produced Water Volume[1], million bbl/yr	Average Annual Produced Water Generation per Well, bbl
2008	905	6.4	7068
2009	1377	12.1	8820
2010	2159	32.6	15,089
2011	3419	63.8	18,660
2012	5230	134.7	25,754
2013	7199	193.3	26,858
2014	9326	280.6	30,092
2015	10,676	331.1	31,018



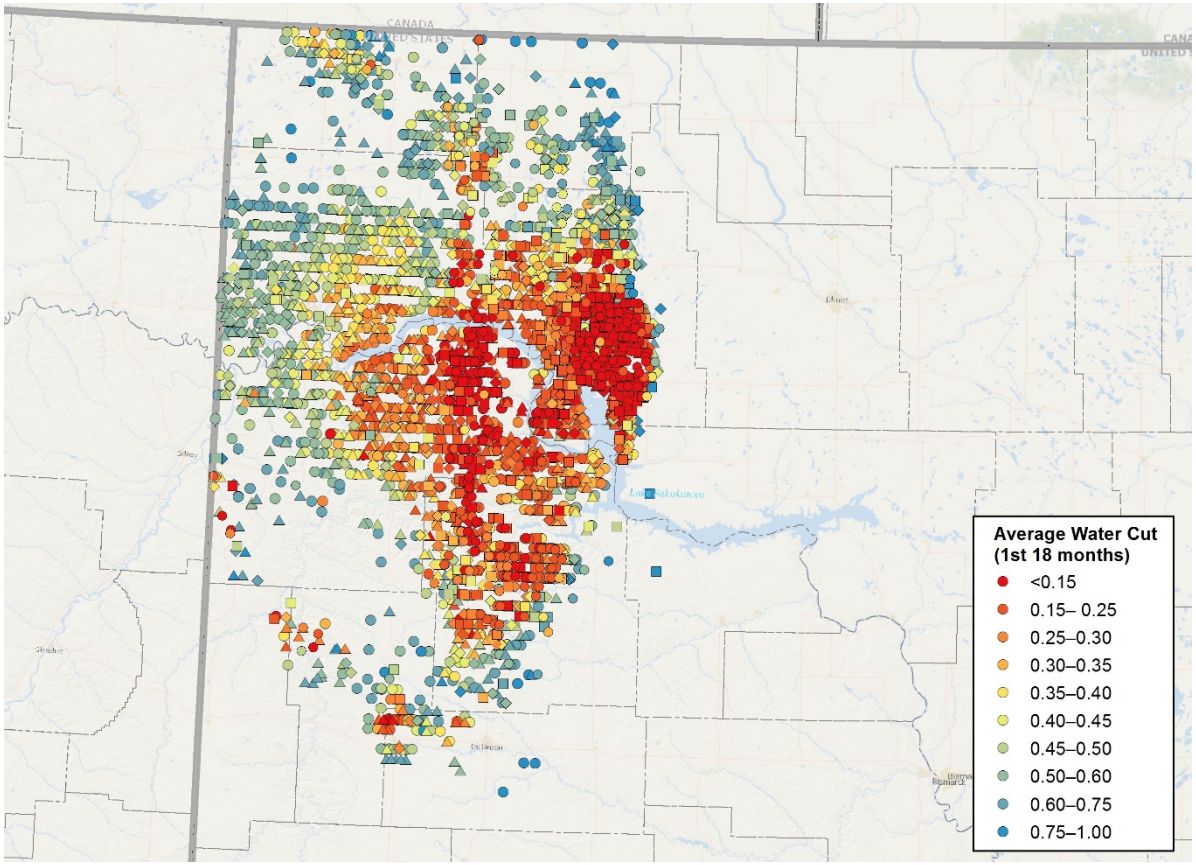
Bakken Water Cut



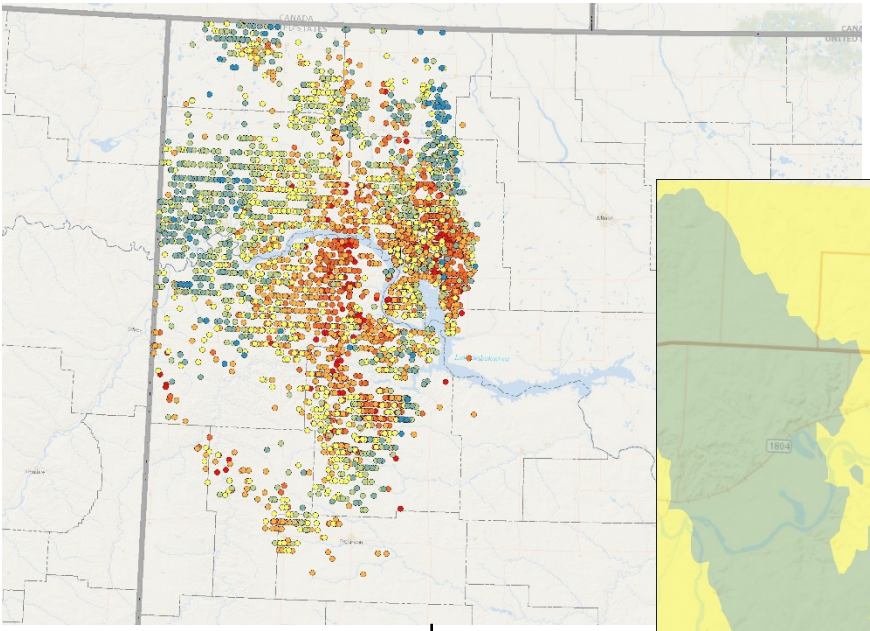


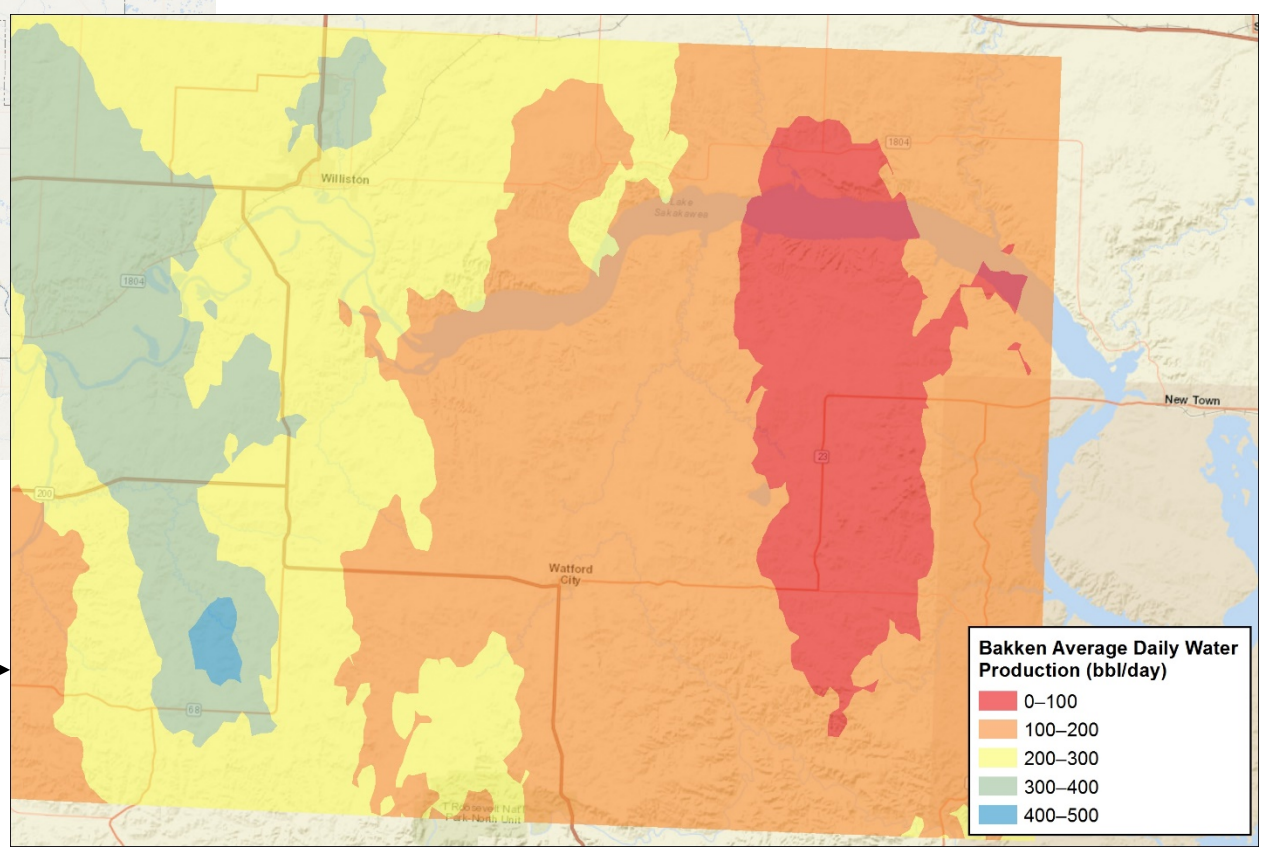
Digging Deeper

- ArcGIS provides geostatistical tools to analyze the data.
- What are other practical applications for the data?



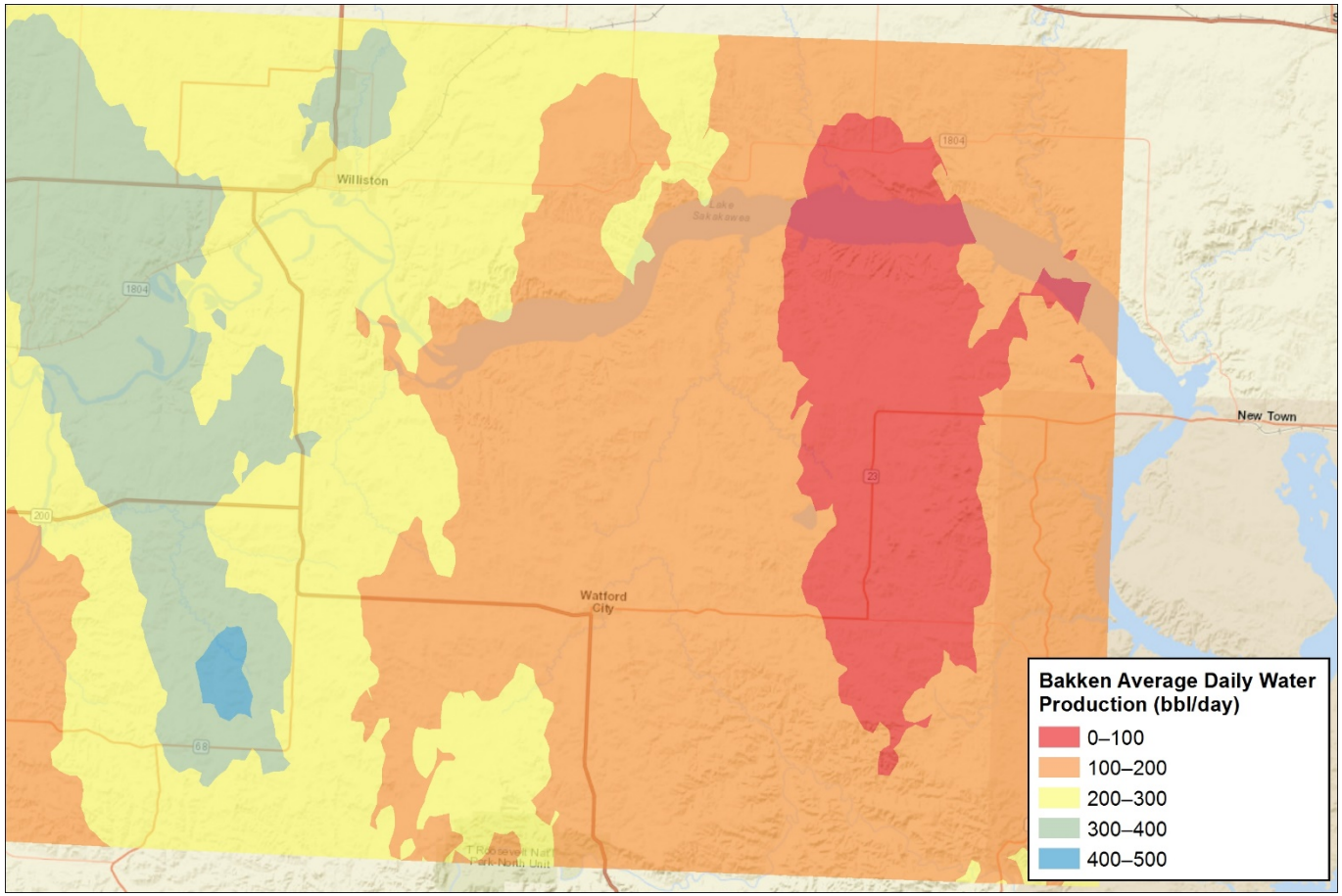
Geostatistical Analysis





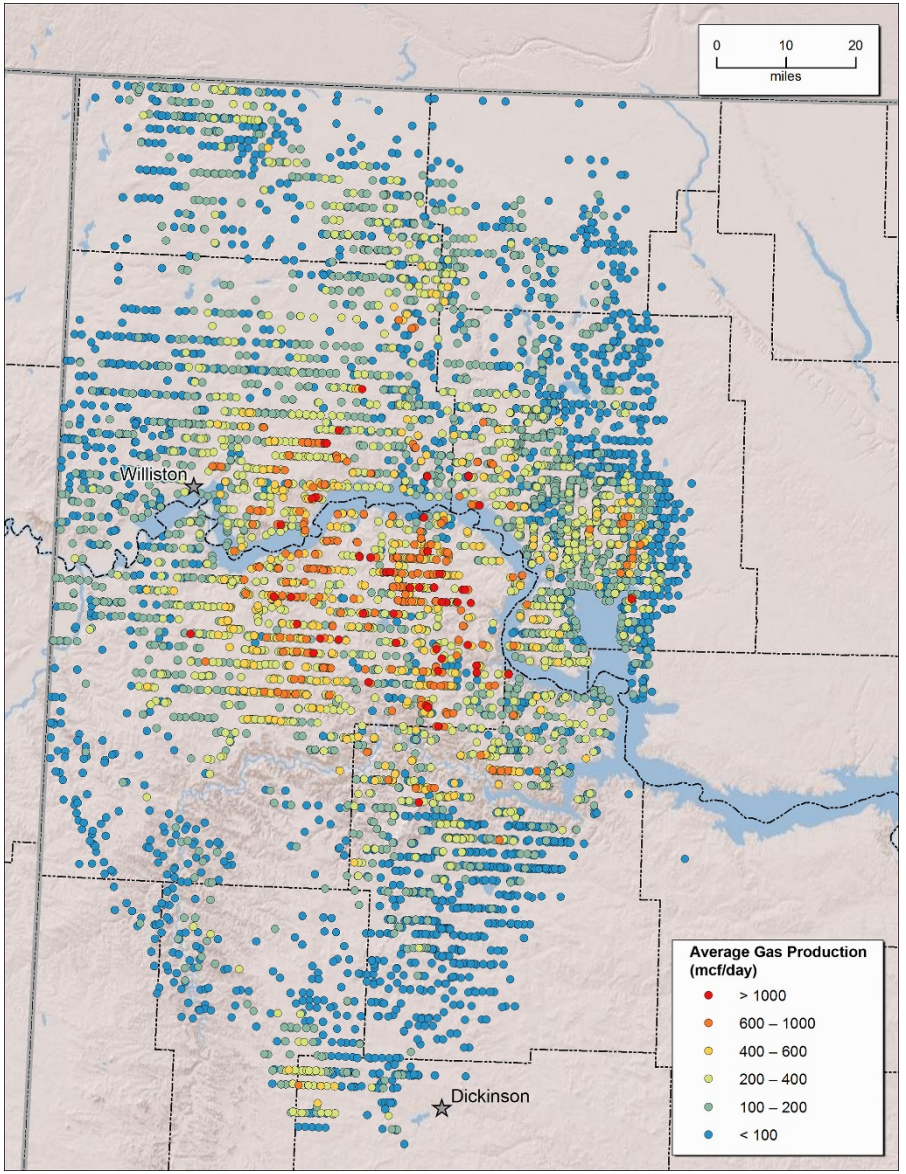
Practical Application

- Allows us to predict what may happen within a region.
- Can be tailored to your particular application.



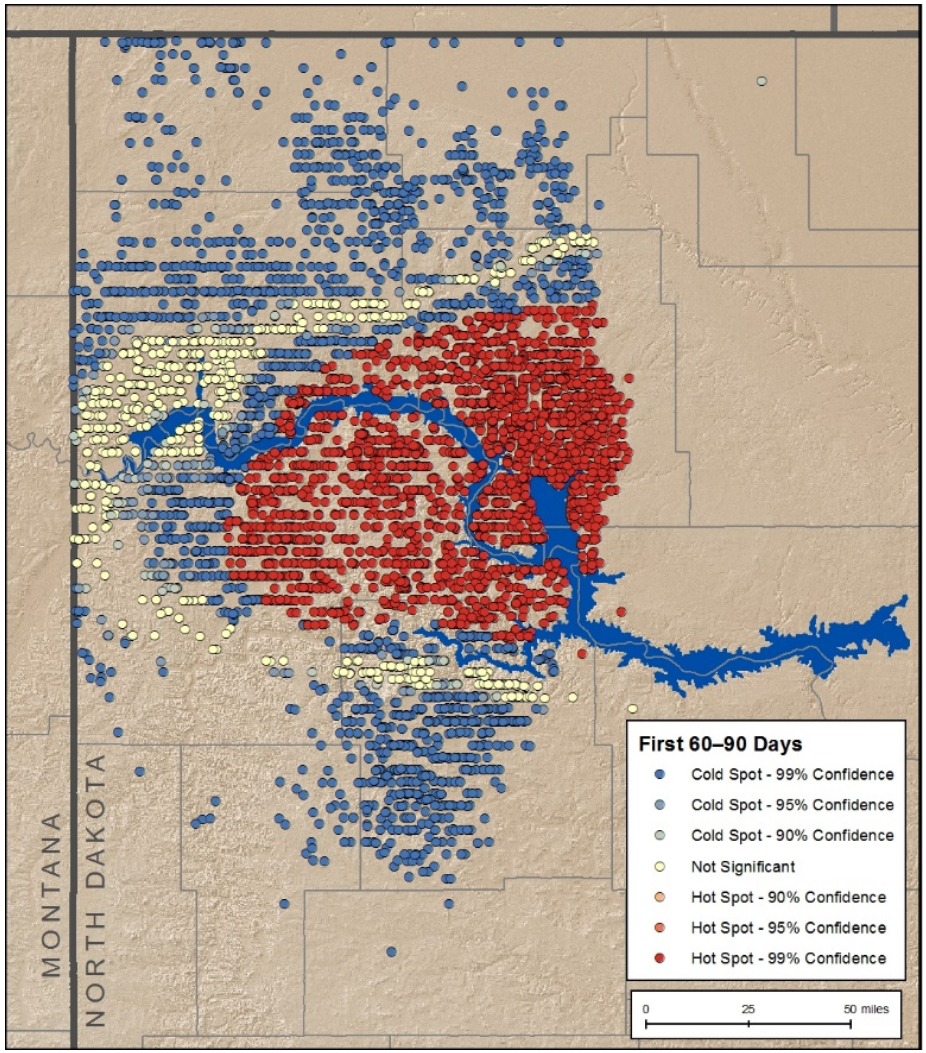
Oil and Gas Production

- Are there areas of production that are statistically significant?
- Used 60-90 day production values.

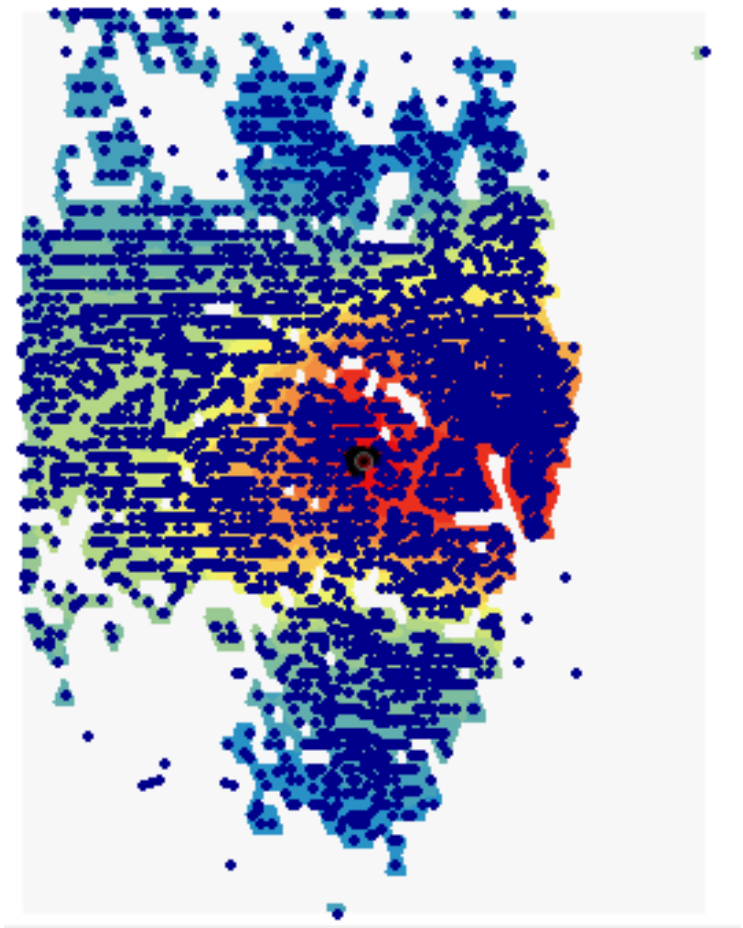


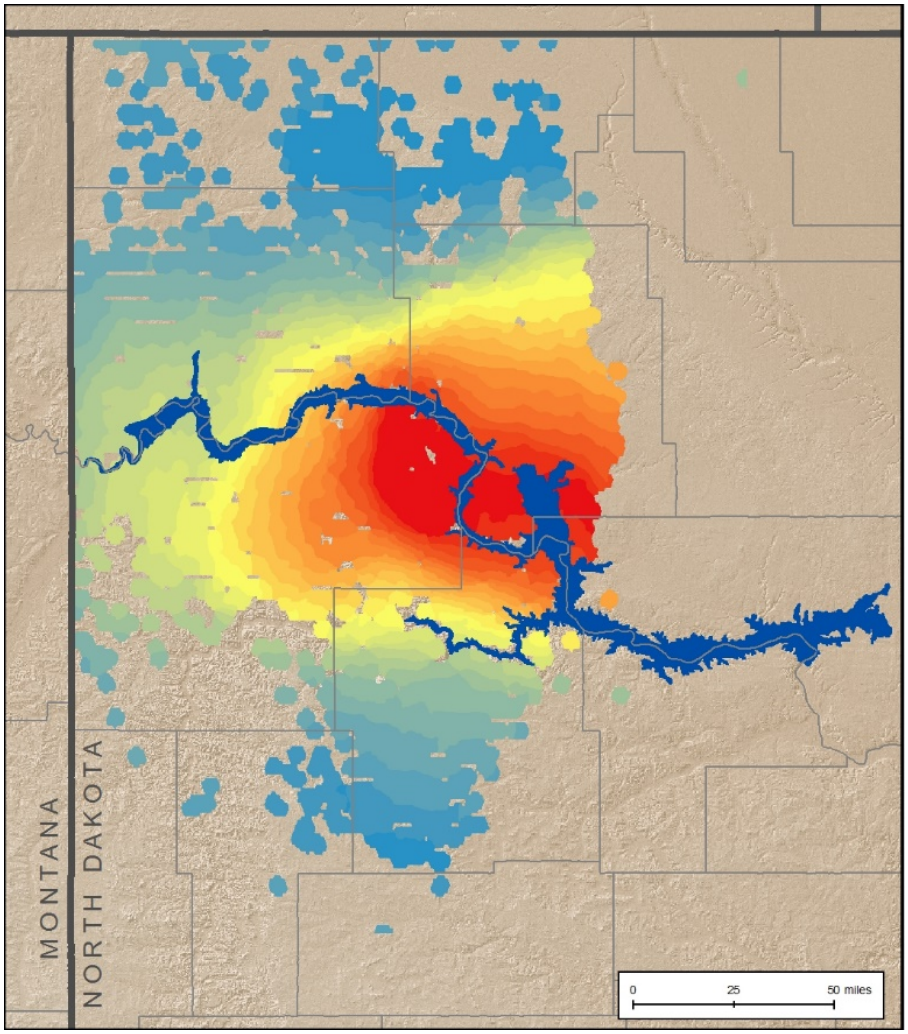
Areas of High Production

- Hot Spot Analysis (Getis-Ord Gi)
  - Identifies statistically significant clusters of high/low values.
  - Output creates a z-score (standard deviation) indicating whether the observed spatial clustering is more pronounced than expected.



Empirical Bayesian Kriging: Using All Z-Score Information





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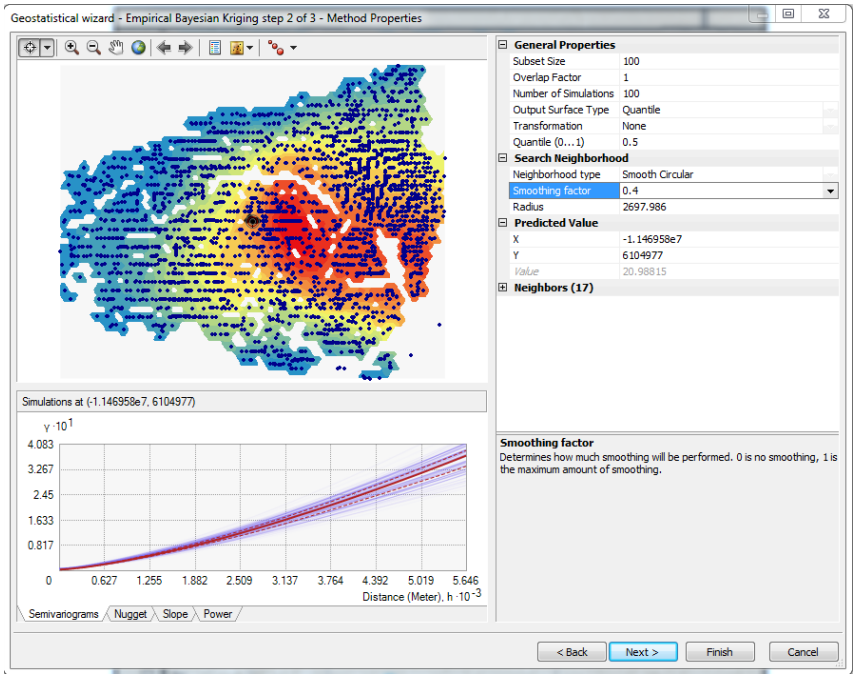
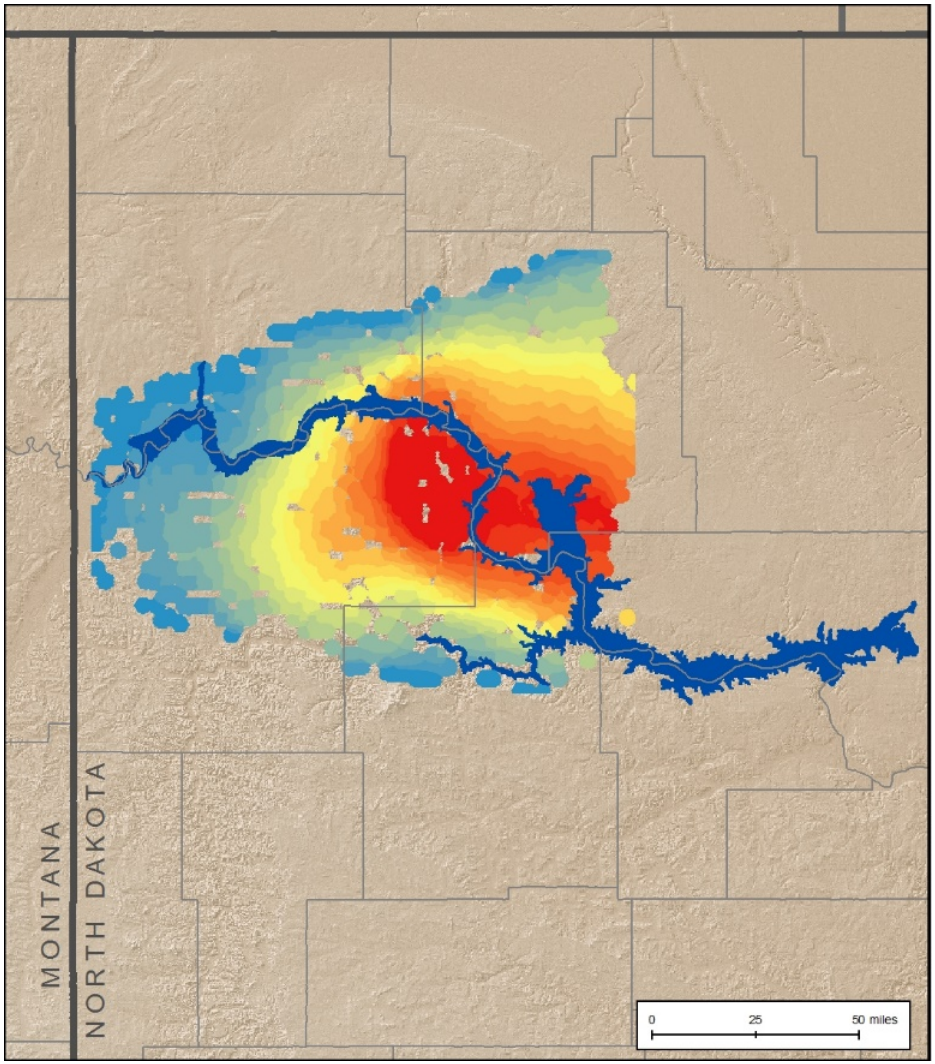
Using Only Positive Z-Score Information





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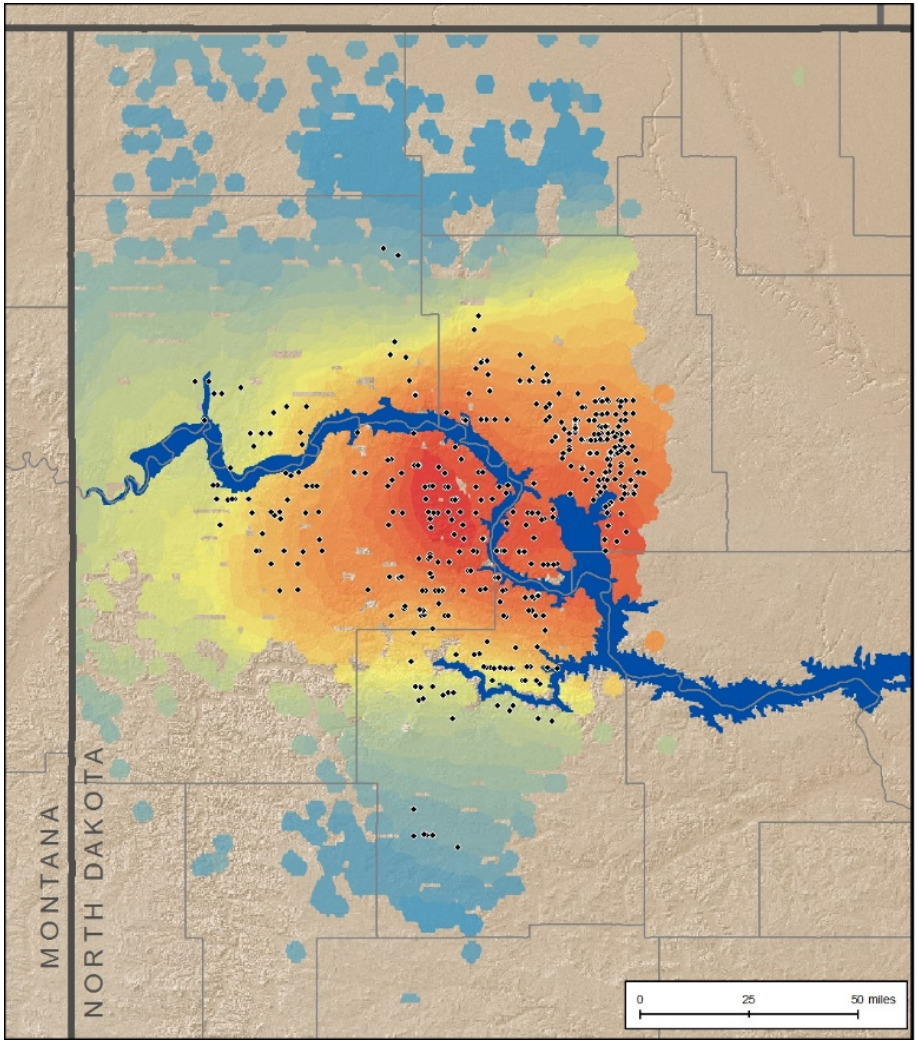
Top 10% of Production Wells

- Wells producing 90,000 or more barrels in the first 60–90 days of production.
  - The outliers to the north and south do not skew the data overall because of the use of hot spot analysis prior to kriging.



Summary

ArcGIS geostatistical tools help with several areas including:

- Exploration/Production
  - Lower water cut
  - High production
- Planning
  - Pipelines, salt water disposal wells, water treatment, etc.
  - Infrastructure and population trends
  - Economics
    - ♦ With lower oil prices, helps target activities.
- Geology
  - Analyzing the production data and trends can verify what we know about the geology of the formation.

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