

Brine Contamination to Aquatic Resources from Energy Development in the Williston Basin

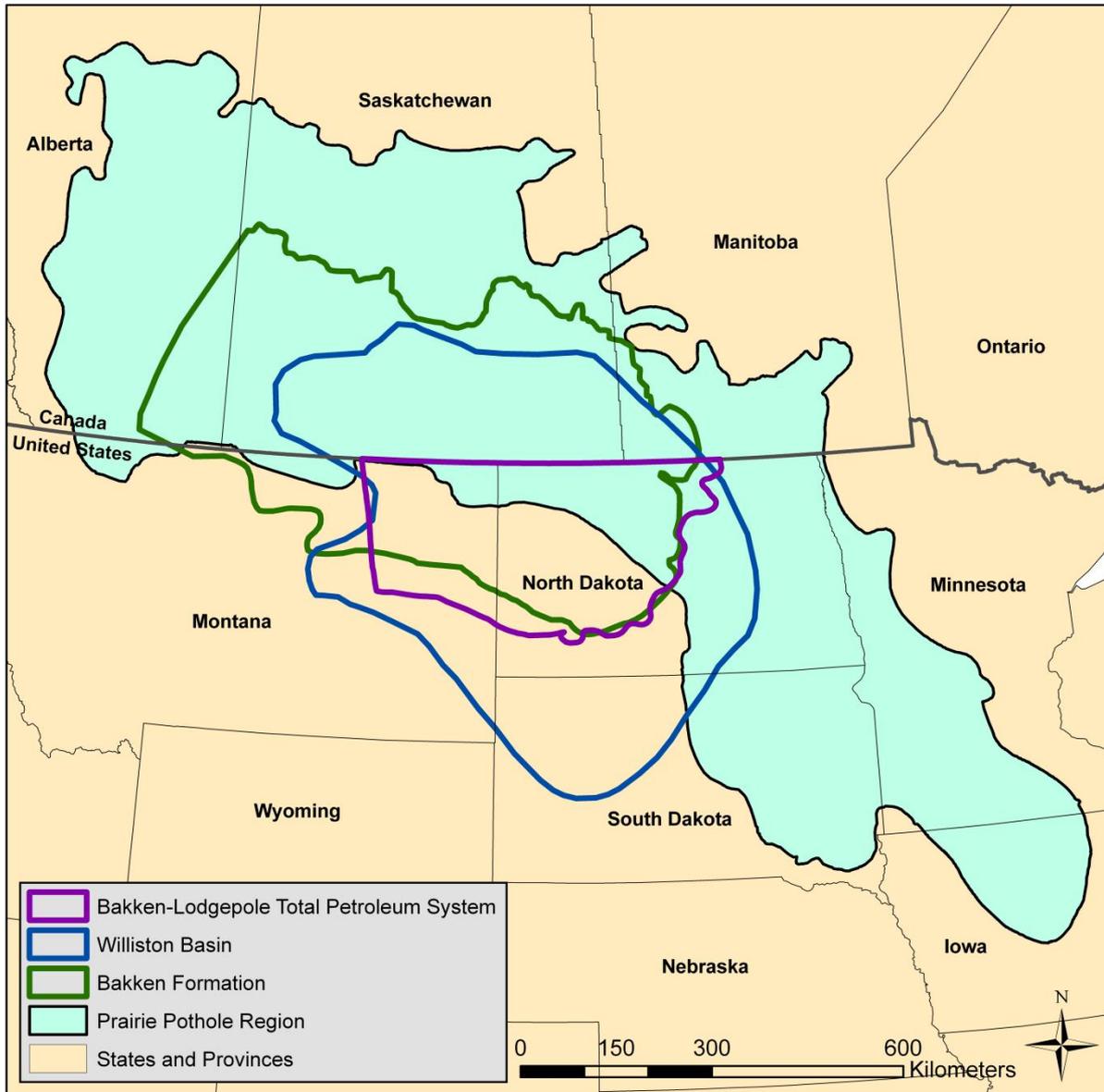
Brian Tangen, Robert Gleason, Tara Chesley-Preston,
Todd Preston, Bruce Smith, Joanna Thamke

Science Team about Energy and Prairie Pothole Environments - STEPPE

- **Robert Gleason, USGS Northern Prairie Wildlife Research Center**
- **Tara Chesley-Preston, USGS Northern Rocky Mountain Science Center**
- **Todd Preston, USGS Northern Rocky Mountain Science Center**
- **Bruce Smith, USGS Crustal Geophysics and Geochemistry Science Center**
- **Brian Tangen, USGS Northern Prairie Wildlife Research Center**
- **Joanna Thamke, USGS Montana Water Science Center**
- **Dynamic project web site: <http://steppe.cr.usgs.gov/>**

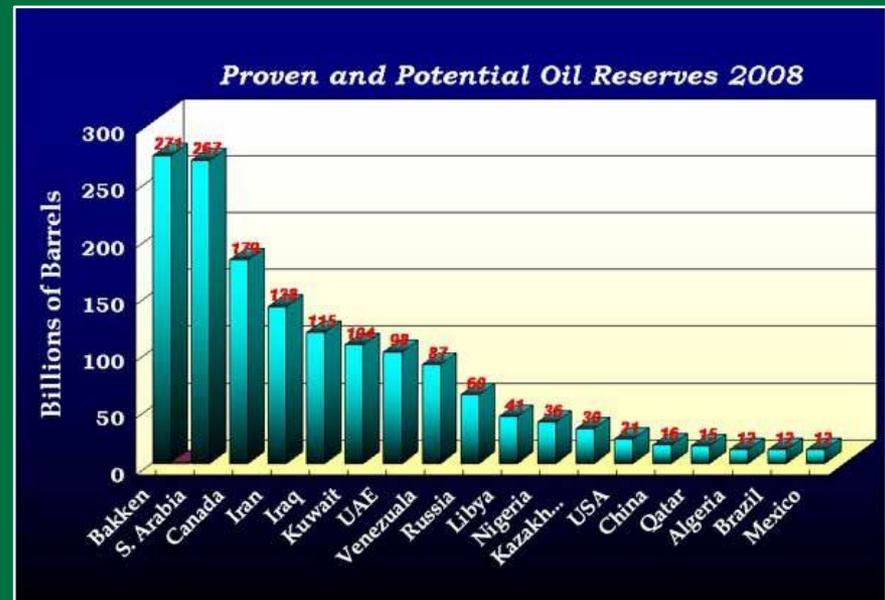
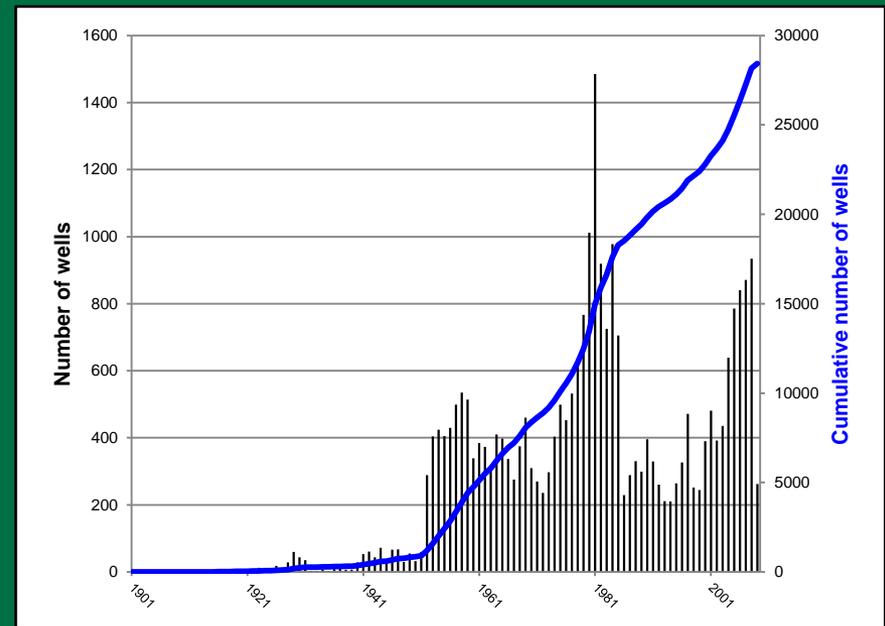
Overview

- Regional “oil boom”
 - Economic factors, drilling techniques
- Williston Basin
 - Bakken, Three Forks
- Previous research = contamination of aquatic resources from coproduced waters (brine)
- Information lacking:
 - Proximity of wells to aquatic resources
 - Brine movement



Williston/Bakken

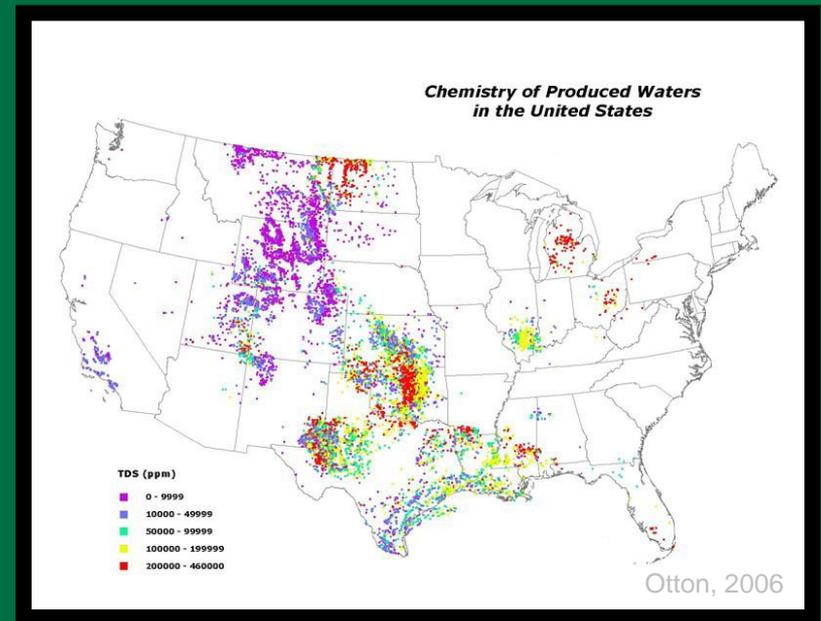
- Leading domestic oil-producing region for more than half a century
- Bakken Formation contains some of the greatest potential oil reserves in the world
- Production increasing
- USGS Assessment
 - <http://pubs.usgs.gov/fs/2008/3021/>



American Association of Petroleum Geologists:
<http://www.aapg.org/explorer/2010/10oct/bakken1010.cfm>

Brine

- Co-produced with oil
- TDS >35,000 mg/L
- 10 bbl brine / bbl oil
- Brines in Williston Basin among highest levels of TDS in U.S.



Chemistry of natural and produced waters

Natural waters

- Often contain high levels of TDS
 - $<10,000$ mg/L
- Na, Mg, SO_4 , and HCO_3

Produced waters

- TDS $>$ natural waters
 - 100,000 to $>380,000$ mg/L
- Enriched in Na and Cl



Brine disposal

- Deep geologic units via disposal wells
- Historically, directly into surface waters or earthen evaporation pits
- Pits regulated in the 1970's
- Sources:
 - Storage pits
 - Transport pipelines
 - Storage tanks
 - Tanker trucks



Aquatic resources

- Pothole wetlands
- Streams
- Stock ponds



Environmental risks

Operational activities

- Infrastructure construction
- Use of unlined reserve pits during drilling
- Contamination by release of co-produced fluids

Brine impact

- Raises salinity levels and alters the natural composition
- Impact the plant, invertebrate, and amphibian communities
- Make the water unsuitable for domestic livestock

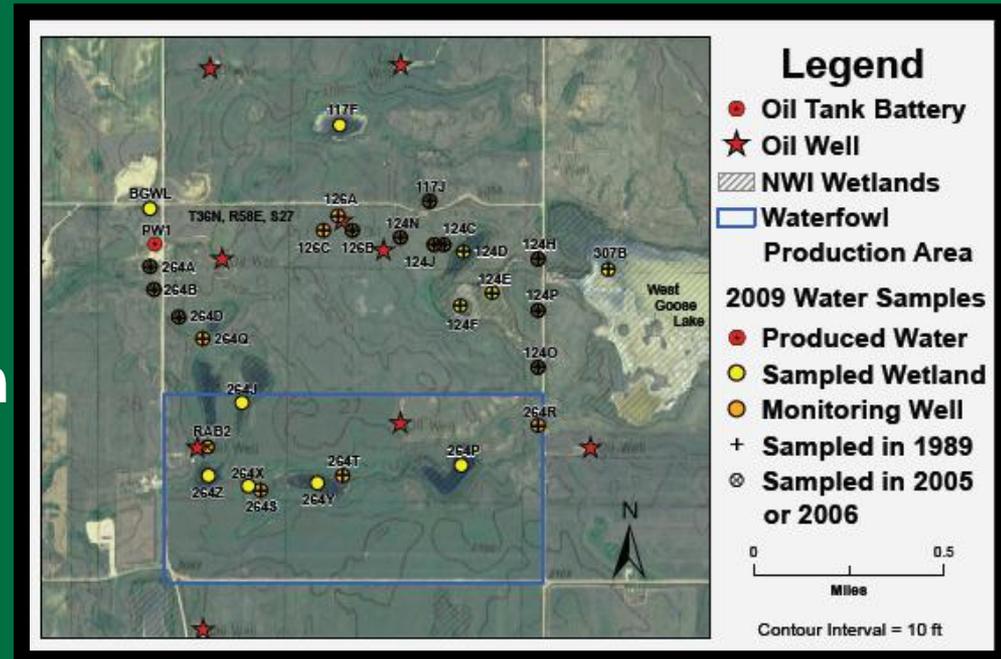
Study objectives

- Field investigations
- Spatial evaluation



Goose Lake site

- Located in NE Montana
- Coarse-grained fluvial outwash deposits
- Field surveys in 1989, 2005, 2009
- Extensive contamination in surface waters and groundwater



Oil field investigations

- Assess new and previously monitored field sites to evaluate and quantify the rate and extent of brine movement

Water quality monitoring

- Major ions
- Chloride contamination index (CI)
 - Distinguishes between naturally-elevated chloride concentrations and brine-elevated chloride concentrations
 - Values above 0.035 indicate contamination from produced waters.

EM-31 and EM-34 surveys

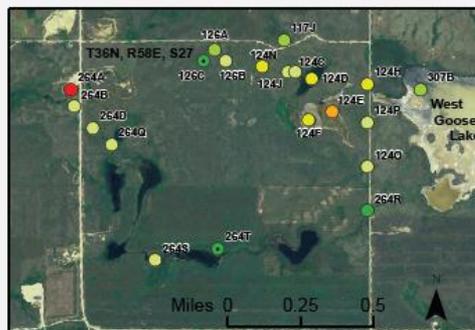
- Records apparent electrical conductivity
- Reflects the subsurface electrical properties of soils and pore fluids

Goose Lake site

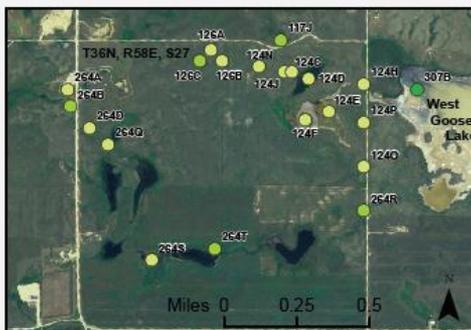
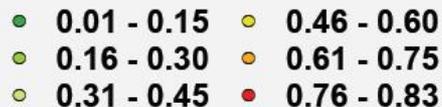
Chloride Contamination Index (CI)

- CI values have decreased (19 samples)
- Values still indicate contamination in all 24 sites
- 2 sites show new contamination in 2009
- Results suggest continued migration of brines

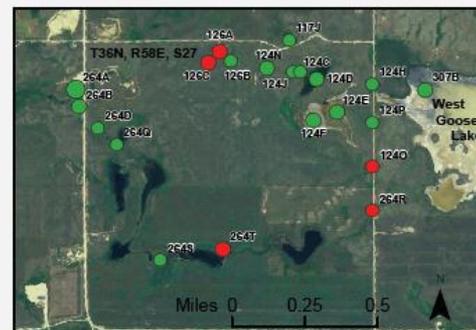
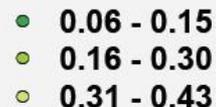
1989, 2009, and Temporal Changes in Contamination Index Values, Goose Lake Field, MT



1989 Contamination Index



2009 Contamination Index



Change in Contamination Index



Strontium isotope analysis

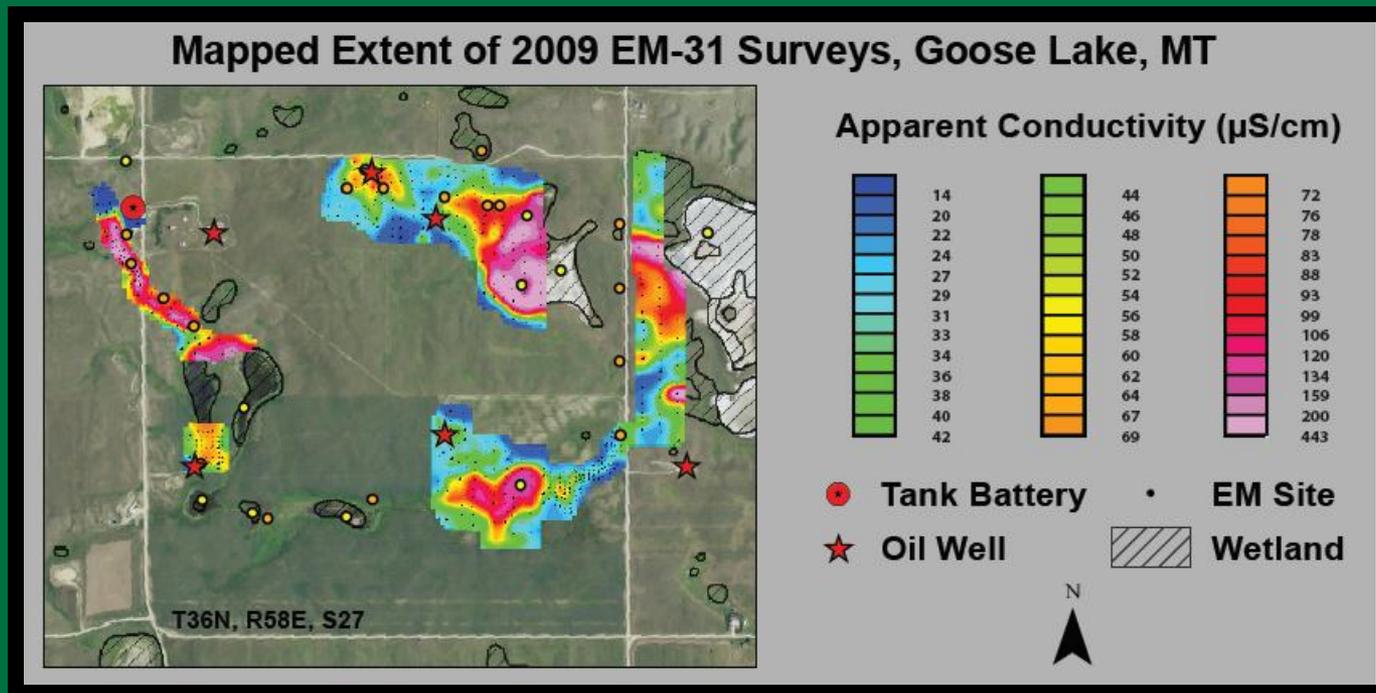
- Sr contents of fresh water and produced water differ by several orders of magnitude
- Sr isotopes are sensitive indicators of small amounts of produced water contamination
- Ratios do not change with evaporation
- Mixing systematics allow calculation of degree of contamination



Goose Lake site

EM surveys

- Show complex lateral and vertical geometries
- Influenced by hydrologic parameters



Spatial / GIS investigations

Compilation of spatial databases

- Well demographics
- Wetlands/streams
- Ownership
- Soils/geology

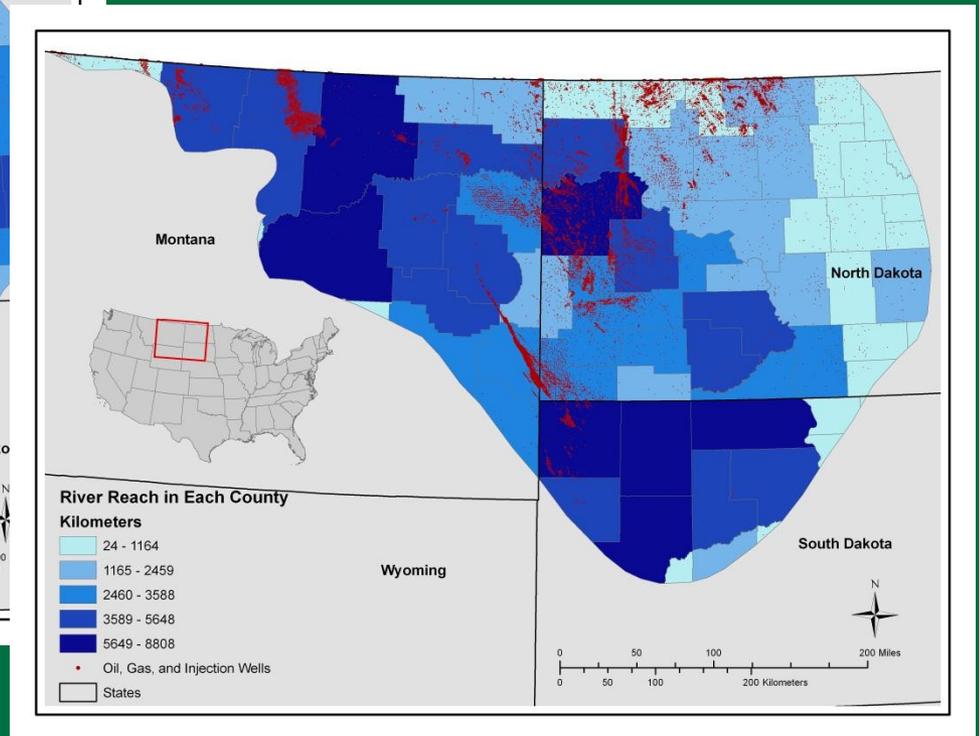
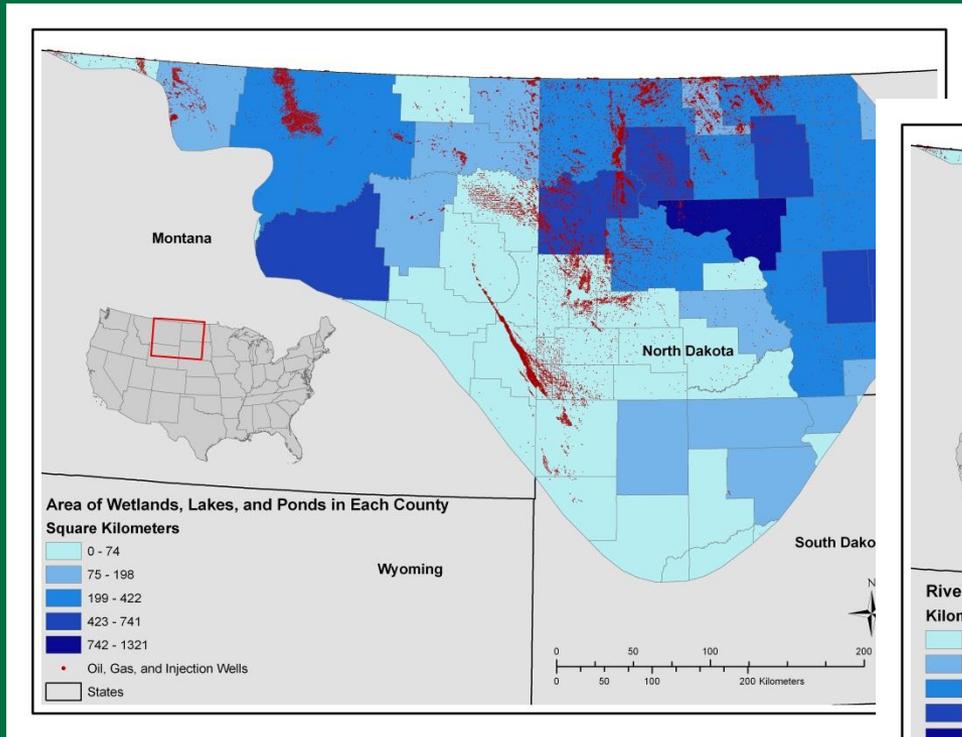
Regional distribution of wells & aquatic resources

- Identify areas (e.g., counties, USFWS lands) most at risk

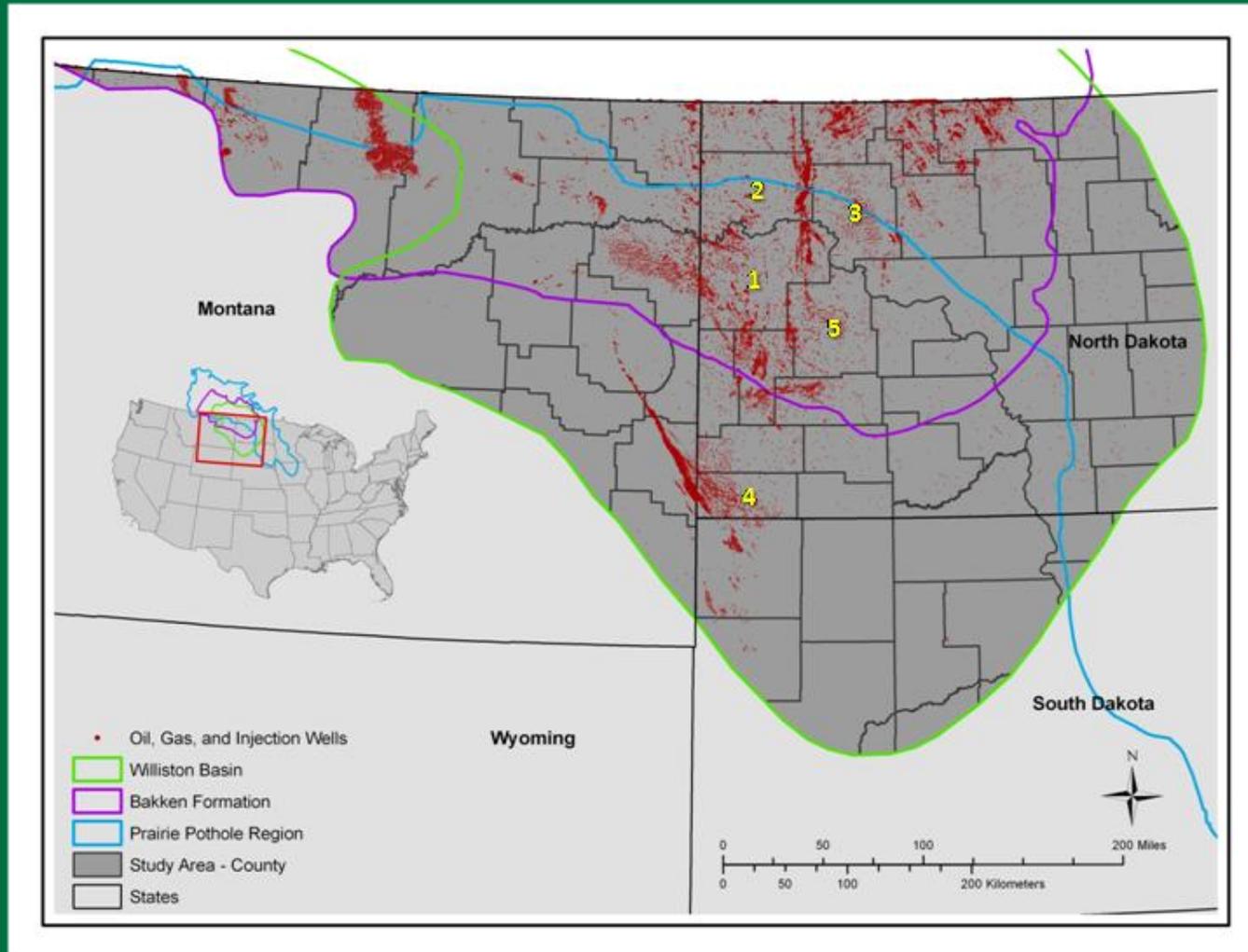
Proximity analyses

- Proximity of wells & aquatic resources

Spatial depiction



County-level assessment



PPR proximity analyses

- Buffered around oil wells
 - 1/4, 1/2, 1-mile
- We identified ~300,000 wetlands and >600 km of streams within 1 mile of oil wells in the PPR
- >60,000 of wetlands and ~80 km of streams were within one-quarter mile of wells in the PPR
- Proximity of wells to aquatic resources located on USFWS lands

Decision Analysis workshop

- Research team
- Stakeholders and land managers
- Identify needs / data dissemination



QUESTIONS?

<http://steppe.cr.usgs.gov/>