USGS Groundwater Quality Assessment in the Williston Basin

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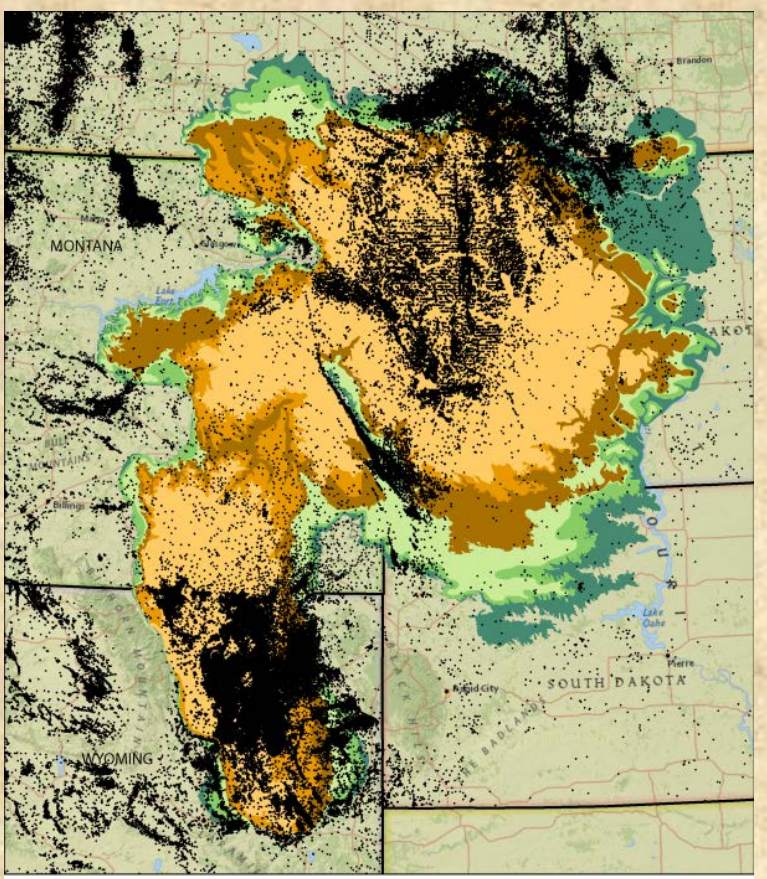
U.S. Department of the Interior
U.S. Geological Survey

Questions

- What are the current conditions of the water resources in the area of energy development?
  - Groundwater
  - Surface water



Oil and gas wells drilled through 2012
(Wyoming is through 2010)

http://mt.water.usgs.gov/projects/WaPR/

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Study Objective

Characterize water-quality conditions of groundwater in the energy development area of Eastern MT and Western ND

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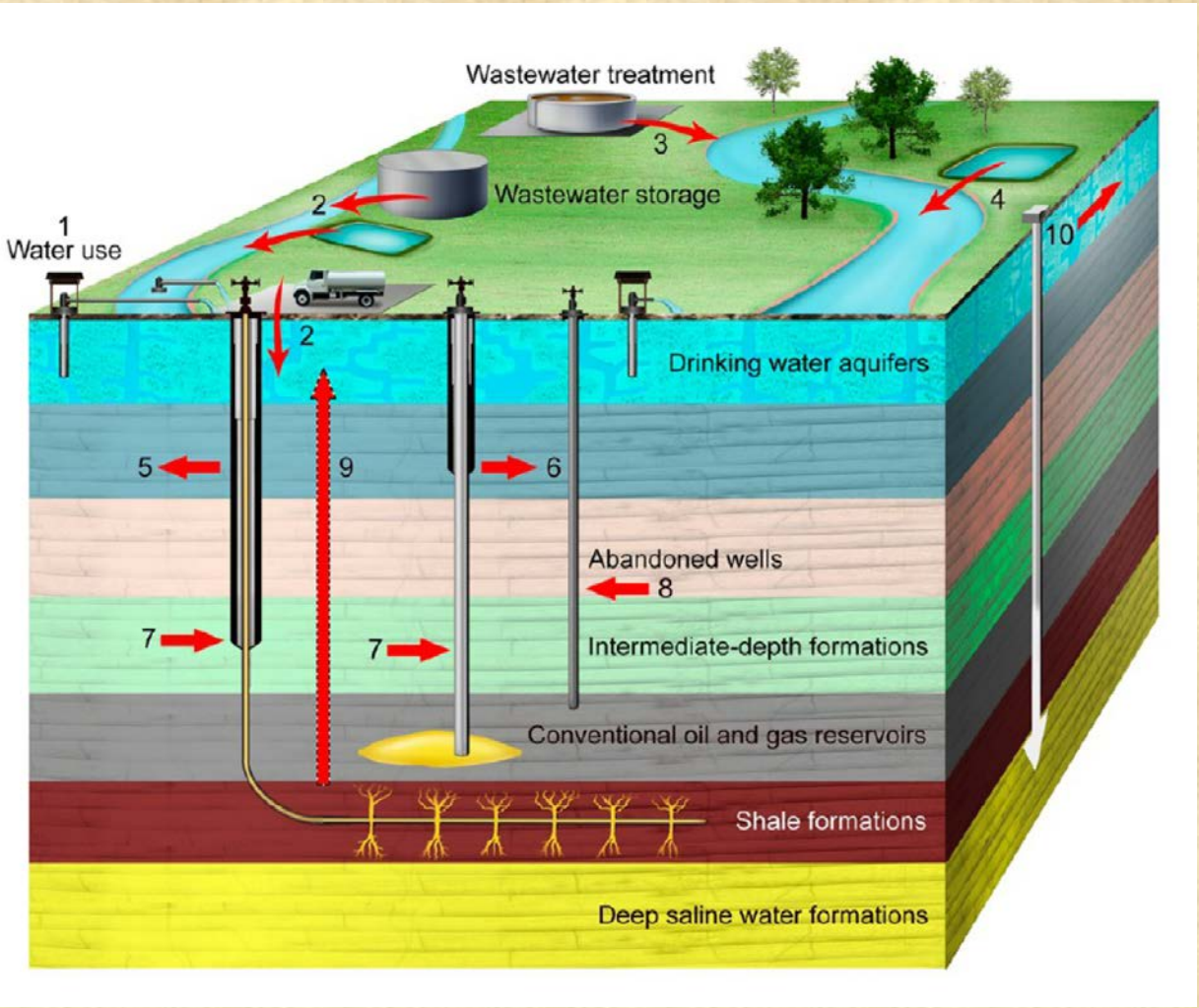
Potential Pathways for Contaminants to Reach groundwater



Vengosh et al. (2014)

Likely pathways…

- Spills and leaks at land surface (2-4)
- Leaking casing/annular space, active and abandoned producing wells (5-8) and injection wells (10)

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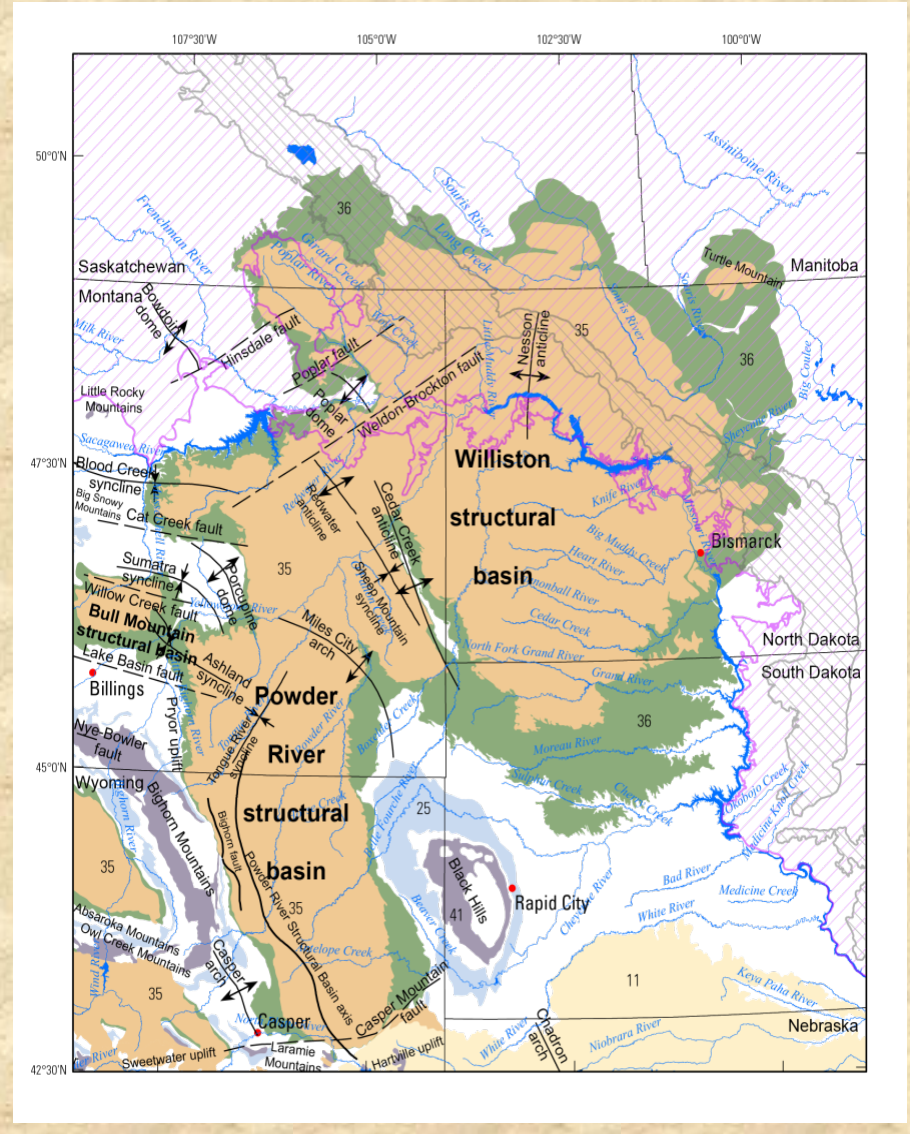
Hydrogeology



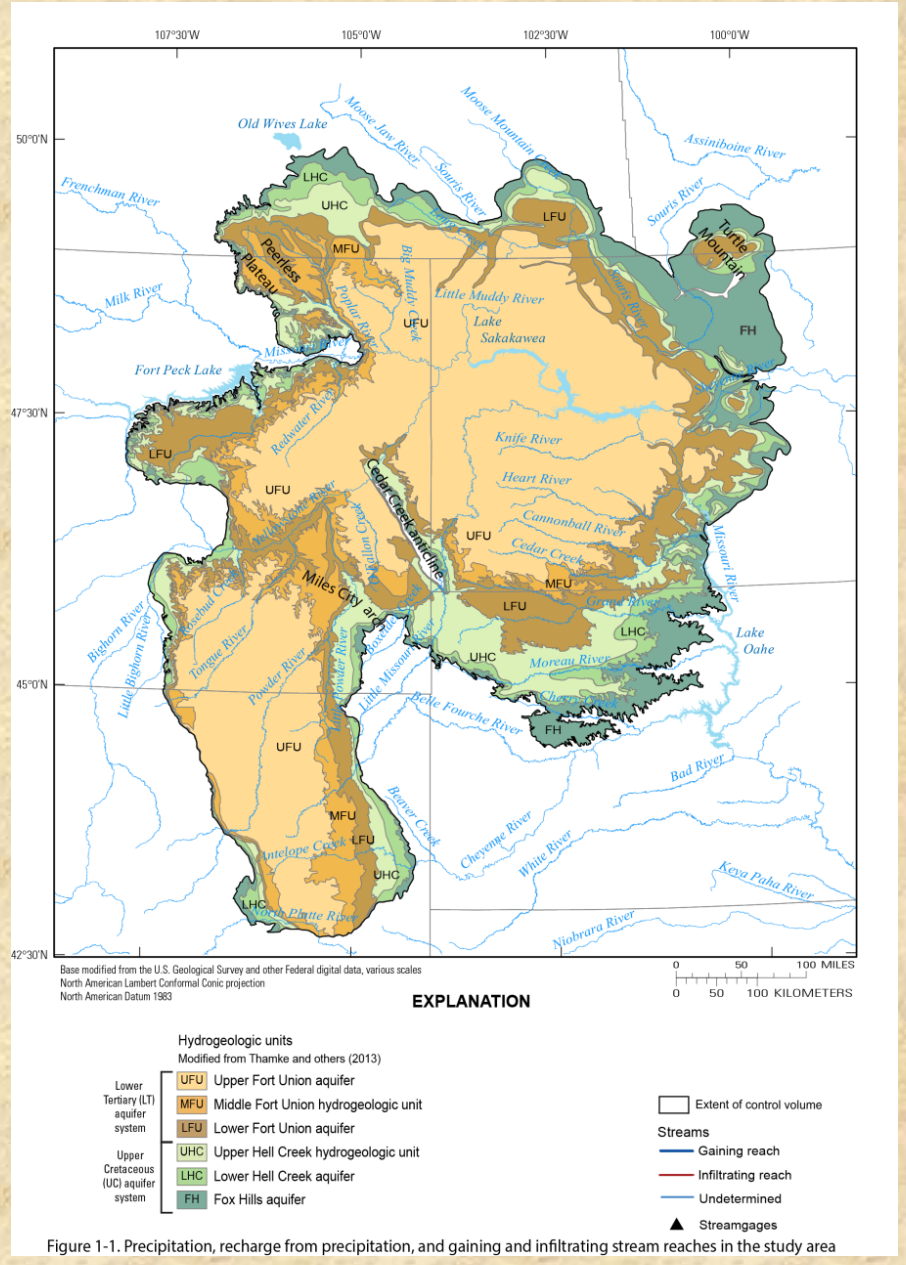


Figure 1-1. Precipitation, recharge from precipitation, and gaining and infiltrating stream reaches in the study area

http://mt.water.usgs.gov/projects/WaPR/

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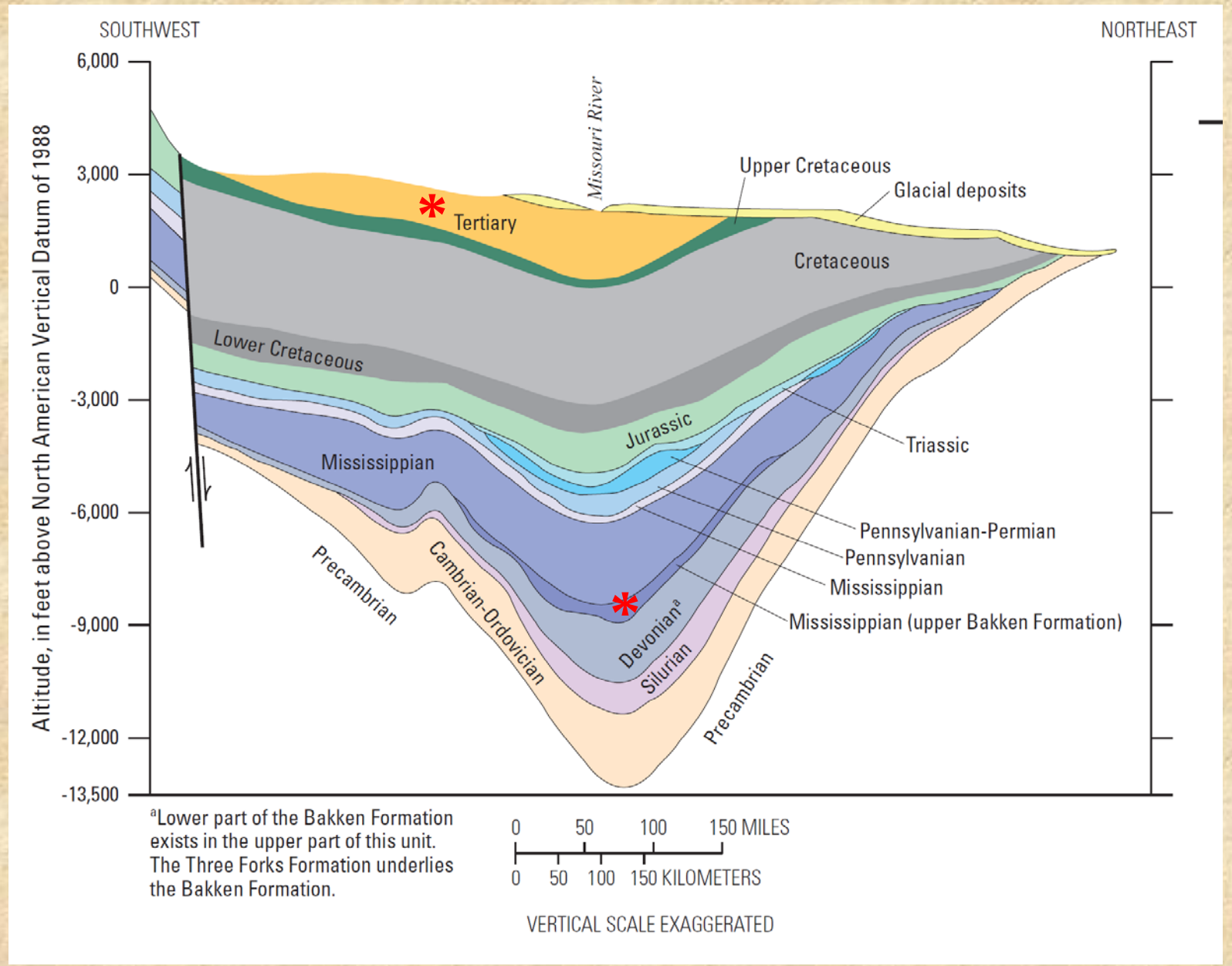

from Long et al. (2014)

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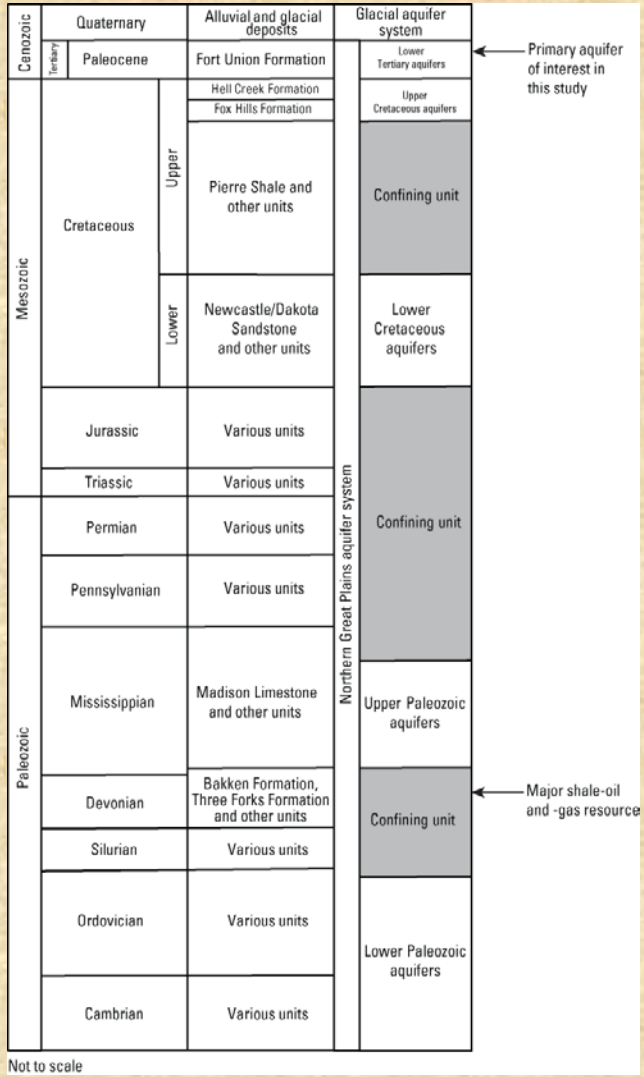
Well Selection

- 30 wells randomly selected in **Upper Fort Union Formation**
  - The Fort Union aquifer is used more broadly for domestic and municipal supplies
  - Fewer water-quality data from the Fort Union aquifer in comparison to those in the upper Cretaceous.
  - Current interest in better understanding the interaction of groundwater between glacial and bedrock aquifers, the shallowest of which is the Fort Union aquifer.
- 4 wells selected in lower units- **Fox Hills and Hell Creek Formations**
  - 2 in relatively low energy development areas
  - 2 in relatively high energy development areas
- Domestic wells selected only
  - Less time and equipment for sampling



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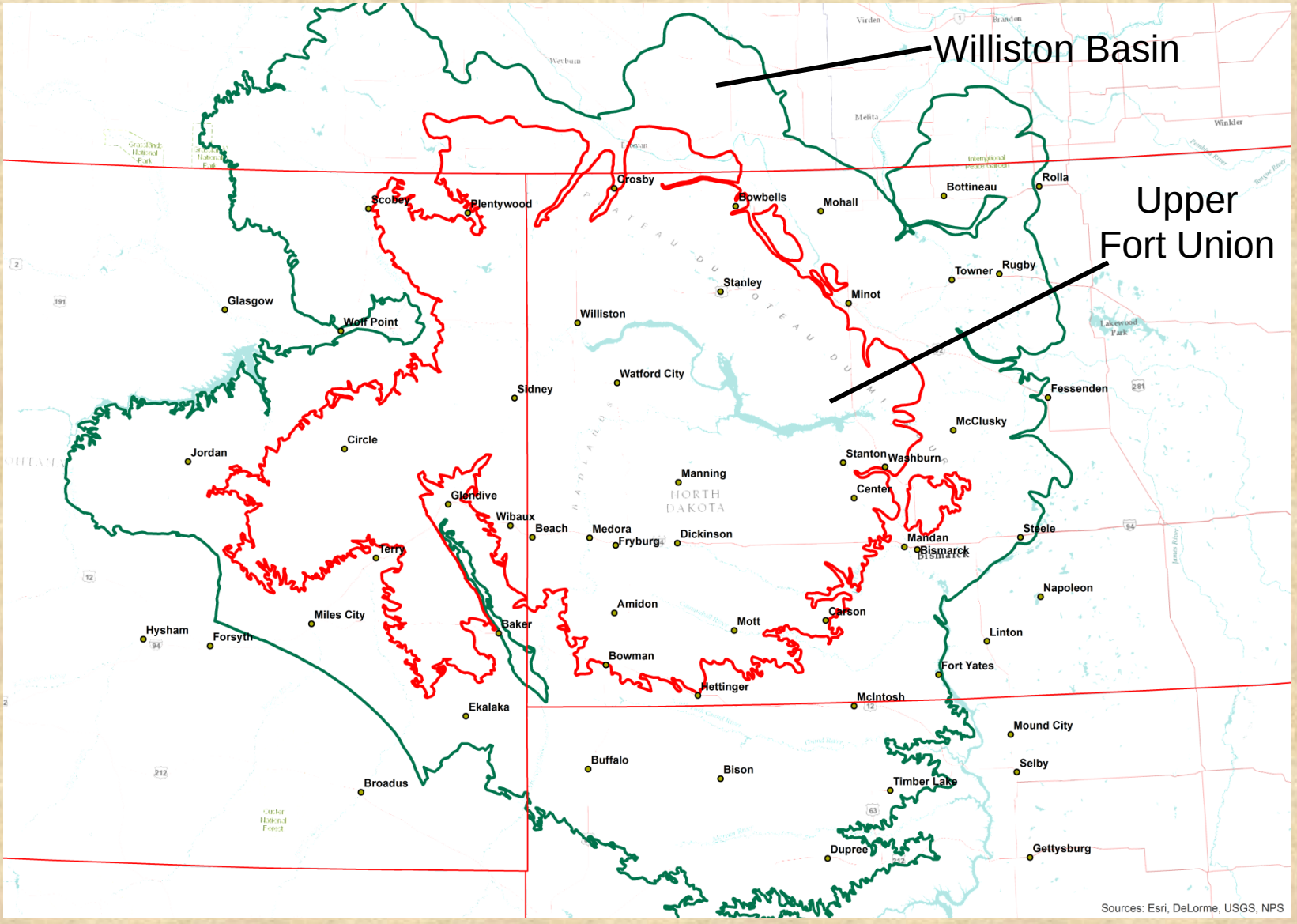
Selection of sampling sites



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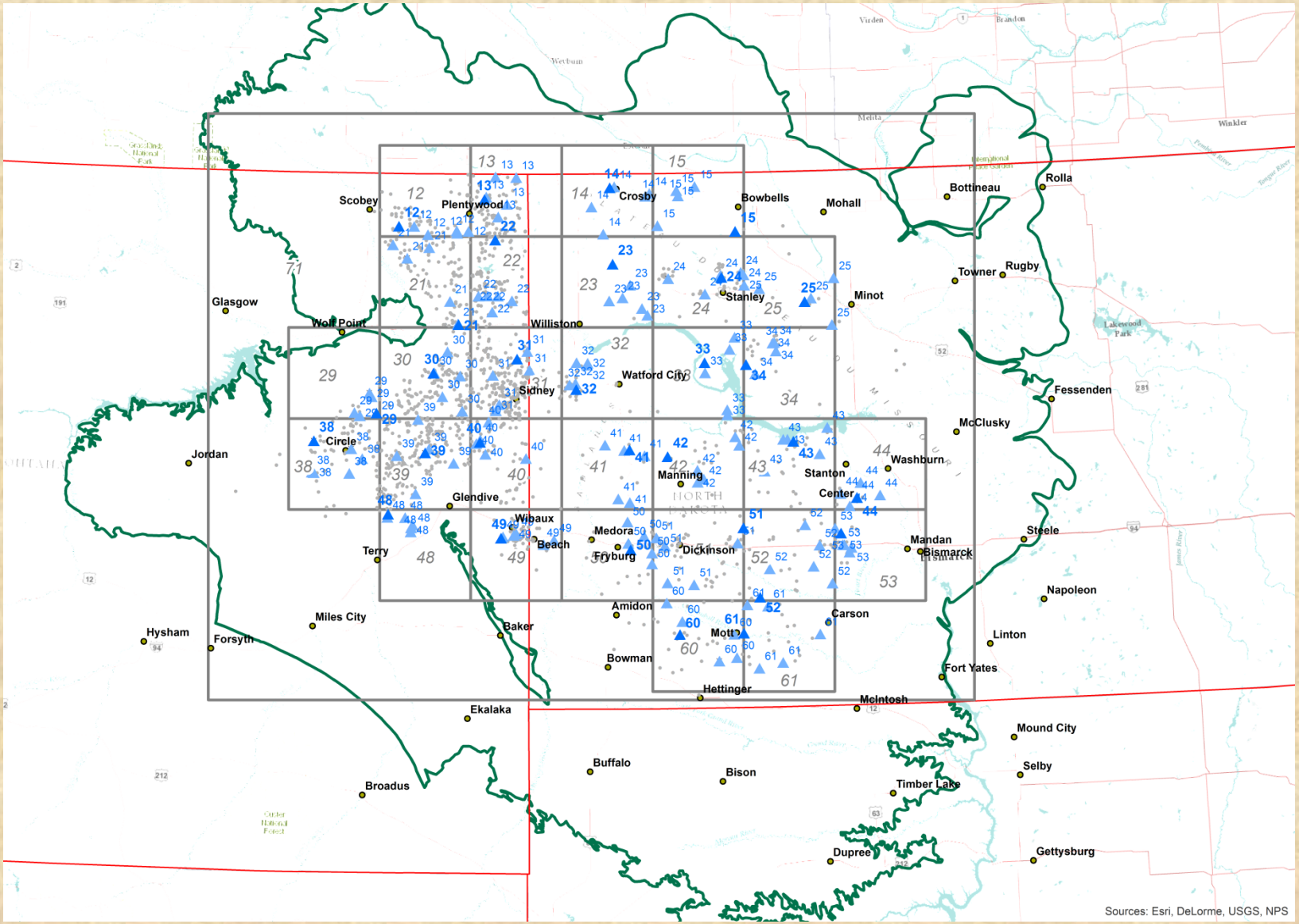
Selection of sampling sites



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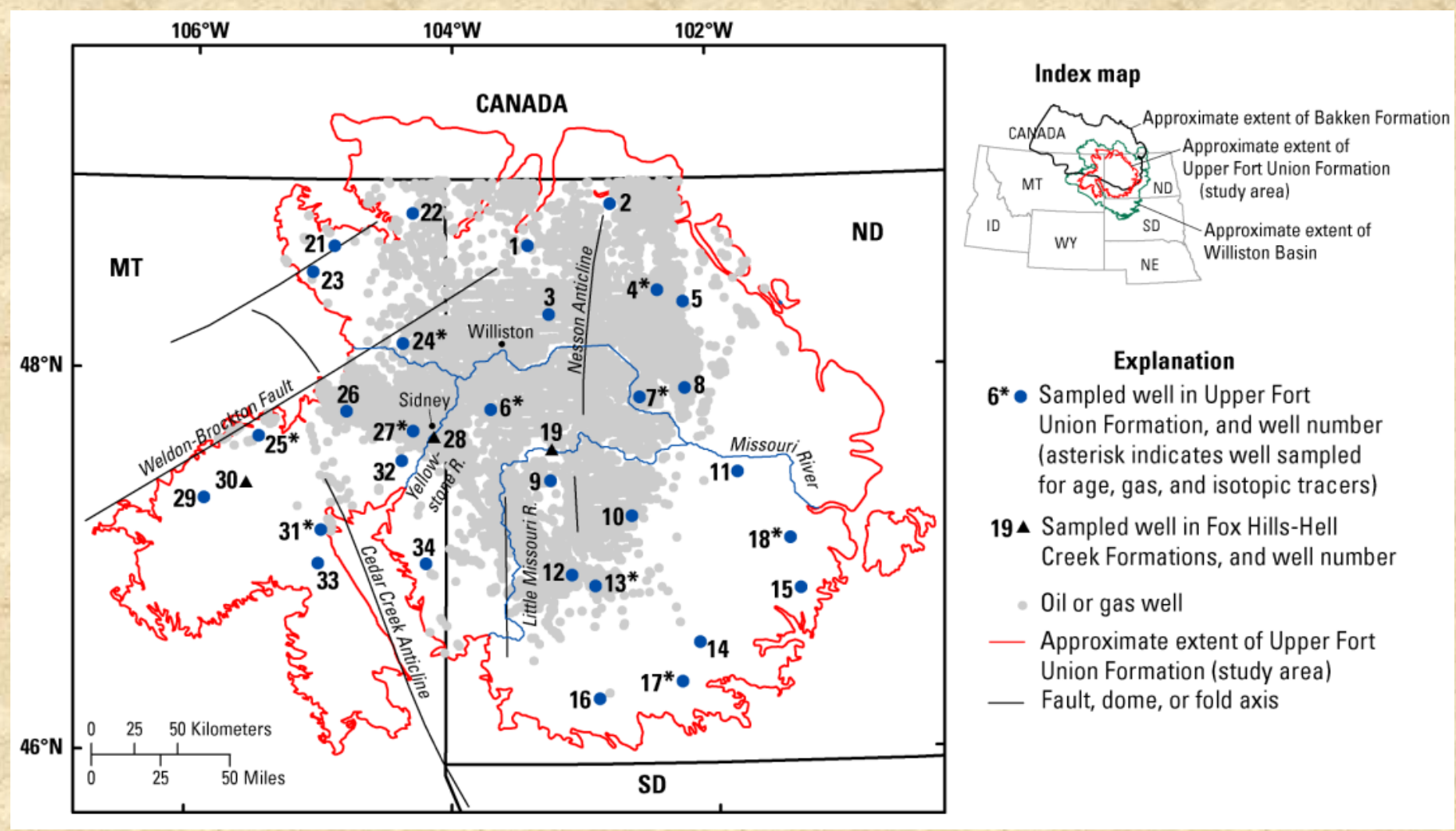
Well Selection - continued



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Sampling Approach

- Samples collected in August-October 2013
- Used standard protocols outlined in USGS National Field Manual http://water.usgs.gov/owq/FieldManual/
- Samples analyzed for:
  - Major ions
  - Trace elements
  - Nutrients
  - Volatile organic compounds (VOCs) (23 compounds)
  - Methane and Ethane
  - Hydrocarbon composition
  - Gasoline Range Organics (GRO) and Diesel Range Organics (DRO)
  - Dissolved organic carbon (DOC)
  - Isotopes (strontium, carbon, hydrogen, oxygen, tritium, sulfur hexafluoride, hydrocarbons)
  - Dissolved gases
  - Noble gases
  - Field measurements (pH, SC, temperature, DO, turbidity, alkalinity, sulfide)

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Results

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Water Quality in the context of Standards

					Concentration			
Constituent	Type of Standard	Standard	Units	Number of samples	Min.	Med.	Max.	Number of wells with a concentration higher than the standard
Arsenic	**MCL**	**10**	**µg/L**	**30**	**<0.08**	**0.26**	**11.5**	**1**
Barium	MCL	2000	µg/L	30	5.26	18.2	223	0
Fluoride	**MCL**	**4**	**mg/L**	**30**	**<0.1**	**0.46**	**4.22**	**1**
Nitrate-N	MCL	10	mg/L	30	<0.04	<0.04	6.47	0
Selenium	MCL	50	µg/L	30	<0.03	<0.09	42.8	0
Uranium	MCL	30	µg/L	30	0.01	0.49	23.2	0
Benzene	MCL	5	µg/L	30	<0.026	<0.026	<0.026	0
Ethylbenzene	MCL	700	µg/L	30	<0.036	<0.036	<0.036	0
Toluene	MCL	1000	µg/L	30	<0.02	<0.02	<0.69	0
Chloride	SMCL	250	mg/L	30	1.68	9.59	162	0
Fluoride	**SMCL**	**2**	**mg/L**	**30**	**<0.1**	**0.46**	**4.22**	**6**
Iron	**SMCL**	**300**	**µg/L**	**30**	**<4**	**112**	**4460**	**11**
Manganese	**SMCL**	**50**	**µg/L**	**30**	**3.72**	**27.4**	**1090**	**11**
Sulfate	**SMCL**	**250**	**mg/L**	**30**	**<0.18**	**362**	**1830**	**17**
Dissolved solids	**SMCL**	**500**	**mg/L**	**30**	**371**	**1135**	**3590**	**29**
Methane	**--**	**10**	**mg/L**	**30**	**<0.00022**	**0.005**	**32**	**4**

MCL – Maximum contaminant level
SMCL - Secondary maximum contaminant level

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Results

- GRO and DRO
  - No values greater than reporting Limit (RL)
- VOCs (23 compounds analyzed)
  - 1 detection of benzene -MT
  - 1 detection of toluene - MT
  - 1 detection of acetone – ND
  - All detections were only slightly above RL

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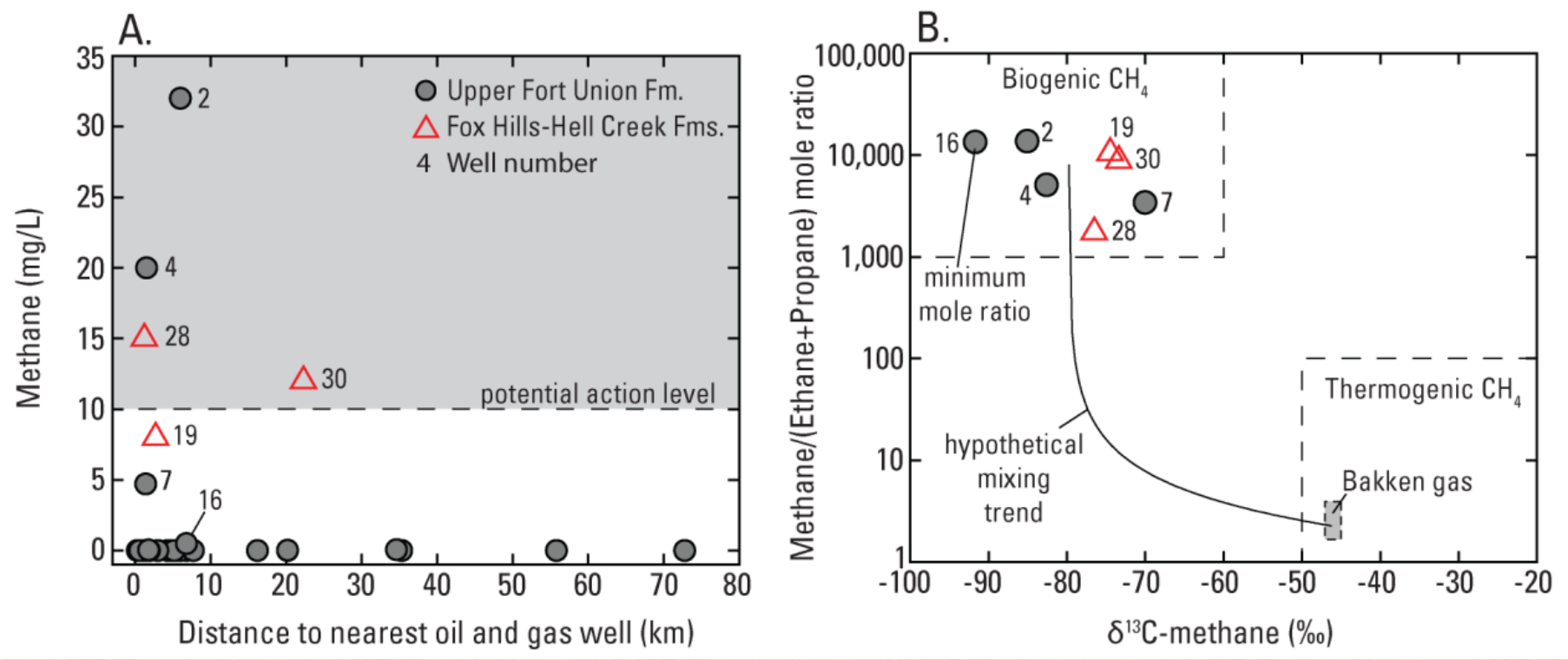
Methane concentrations & sources



Bakken gas composition from Price (1995) and Price and Schoell (1995)

- 18 of 34 wells had detectable methane, 1 well had detectable ethane
- 7 samples had sufficient methane for isotopic analyses (>4 mg/L)

- **Isotopes indicated biogenic gas, or gas from local production in the aquifer**
- **Thermogenic gas is what would be expected to be associated with Bakken oil and from deep hydrocarbon reservoirs**

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Water-Quality Conclusions

- **No indication that energy-development activities affected groundwater quality in the upper Fort Union Formation**
  - Comparison of inorganic and organic chemical concentrations to health based drinking-water standards
  - Correlation analysis of concentrations with oil and gas well locations
  - Isotopic data

- **Limitation:** only 34 wells sampled over a 38,000 mi^2 area
- **Important to consider these results in the context of groundwater age…..**

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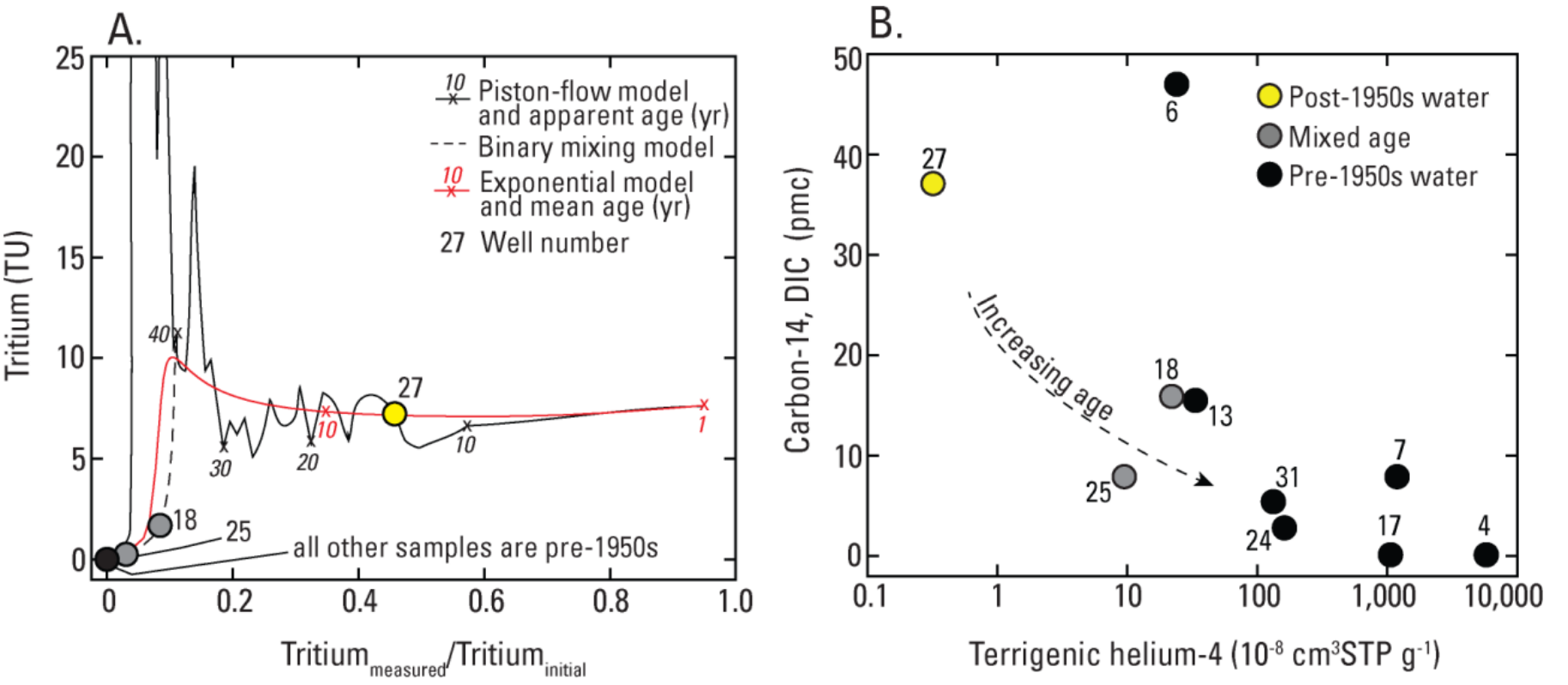
Groundwater age



~25% post-1950s
~15% mixed age
~60% pre-1950s

- Pre-1950s water had median ages of 4,000 – 5,400 years

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Groundwater Age Conclusions

- Groundwater ages in depth zone of the upper Fort Union Formation used for domestic supply **predate recent increases in energy development**
- **Old groundwater ages indicative of slow groundwater velocities (10 to 25 meters per year)**
- **Domestic wells not suited for detecting local contamination from spills or oil well activities**
  - **wells located > ~0.5 km from O&G wells not suited for detecting contamination from recent subsurface leaks**
  - **Distance to nearest oil and gas well from our domestic wells: 0.3 to 73 km**

Implications:

- **Monitoring needed closer to energy-development activities**
  - **Important for showing effects**
- **Monitoring needed as a long-term commitment**

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Methods and results published:

http://onlinelibrary.wiley.com/doi/10.1111/gwat.12296/pdf

McMahon, P.B., Caldwell, R.R., Galloway, J.M., Valder, J.F., and Hunt, A.G, 2014, Quality and Age of Groundwater in the Bakken Formation Production Area, Montana and North Dakota: Groundwater, v. 53, Issue S1, p. 81-94

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