

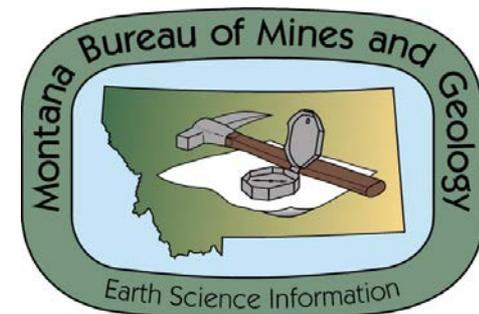
Water Needs and Availability for Hydraulic Fracturing in the Bakken Formation, Eastern Montana

Water needed for energy developments in the Mountain West may limit the Nation's ability to address energy security issues. The Idaho National Laboratory is partnering with the Montana Bureau of Mines and Geology on a water-energy assessment of one of the most important, rapidly expanding, developments of unconventional fossil fuel resources in the western U.S., the Bakken formation of eastern Montana and western North Dakota

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¹ Idaho National Laboratory

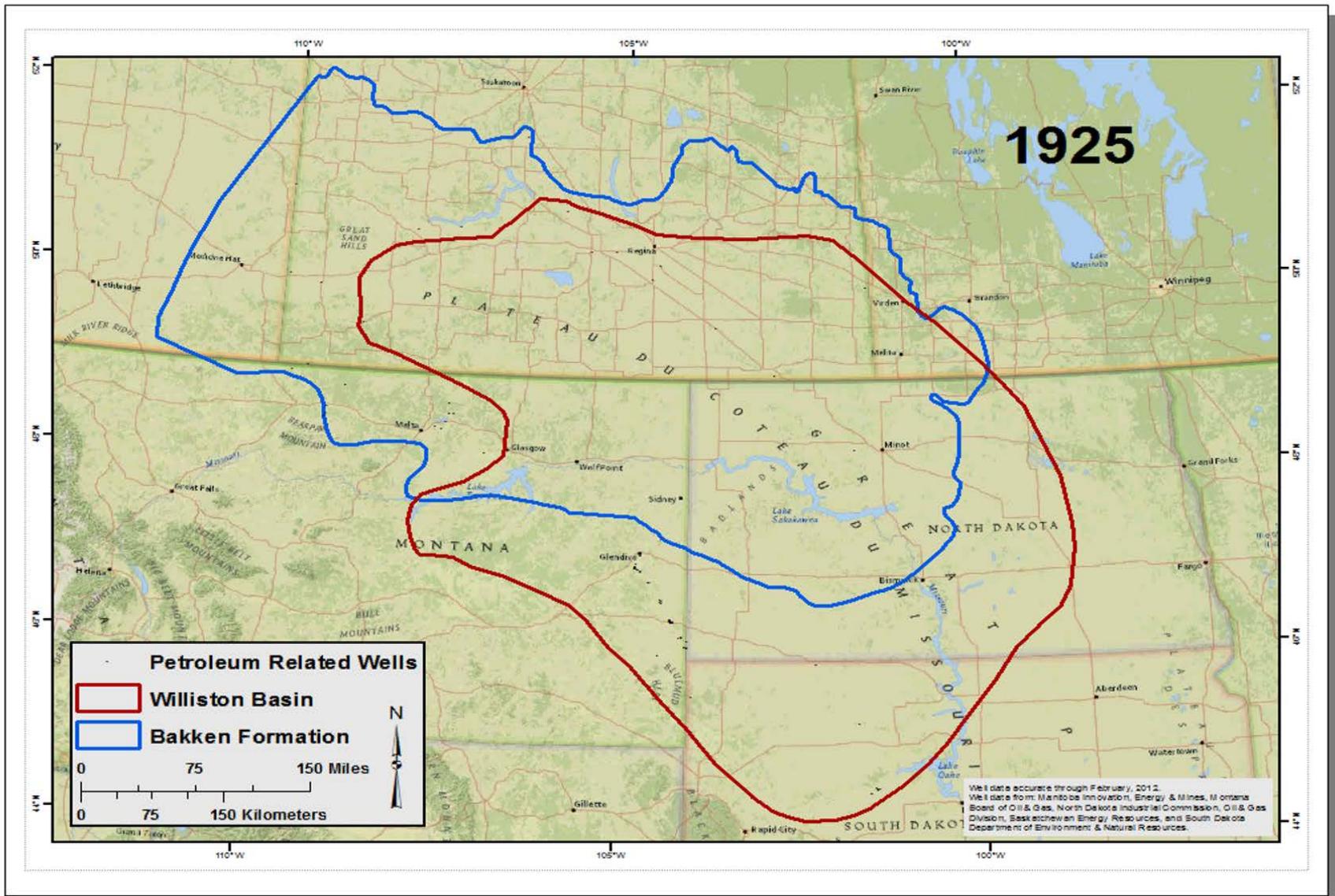
² Montana Bureau of Mines and Geology



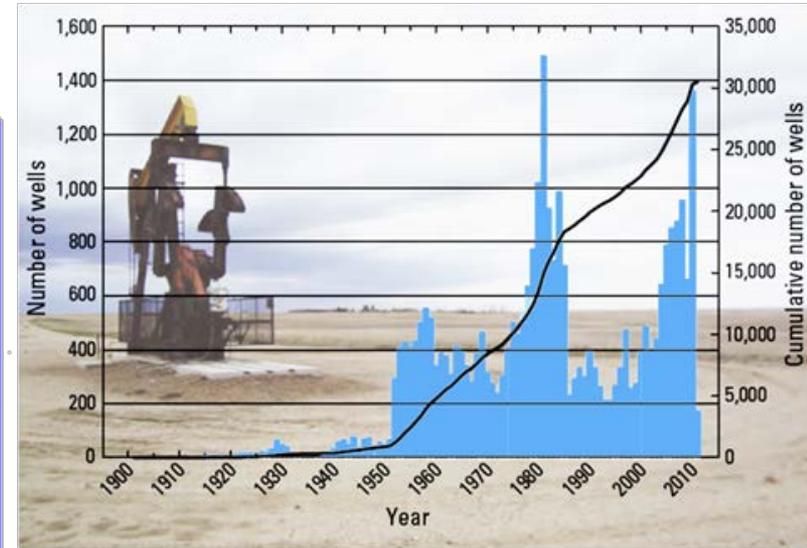
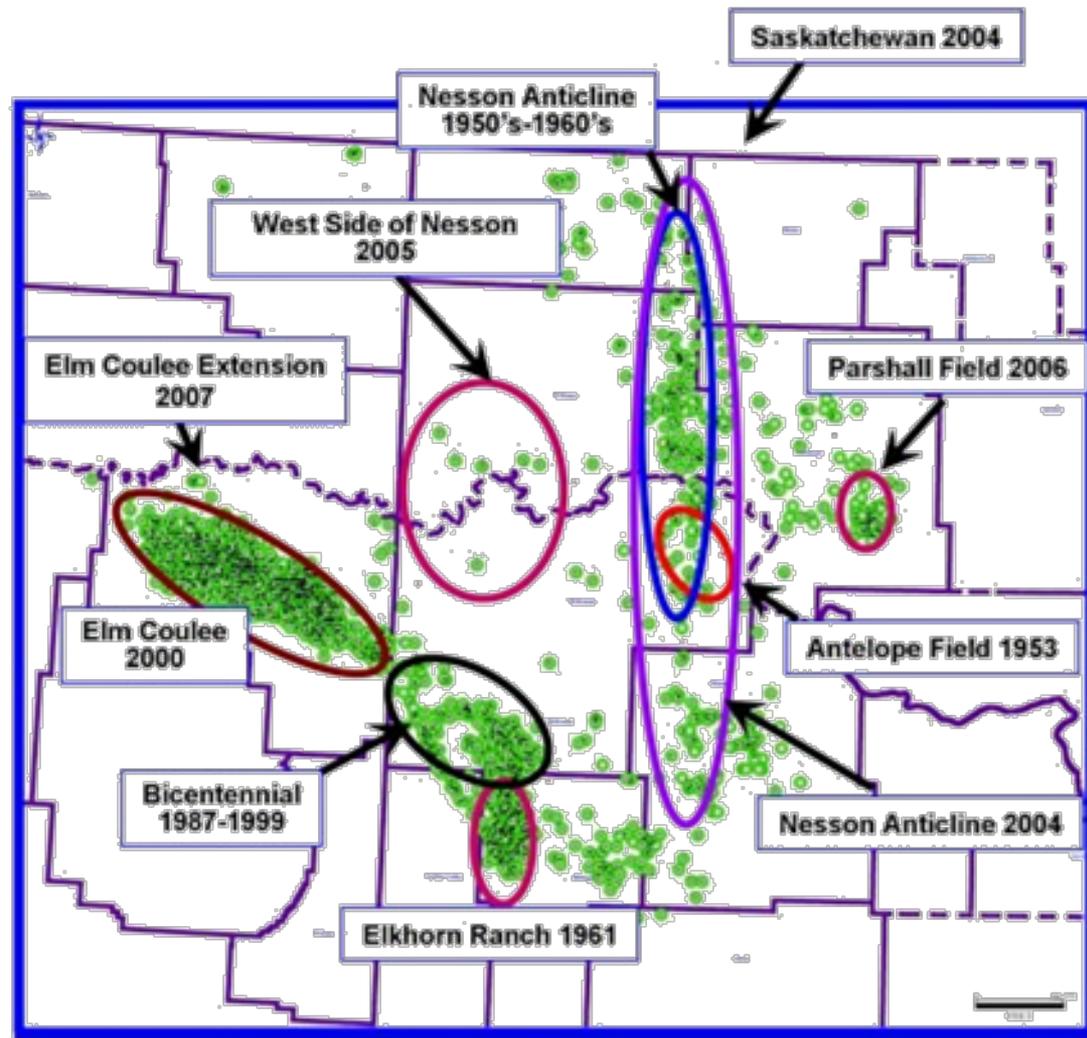
www.inl.gov



Williston Basin Oil and Gas Development



Williston Basin Historical Bakken Drilling & Production

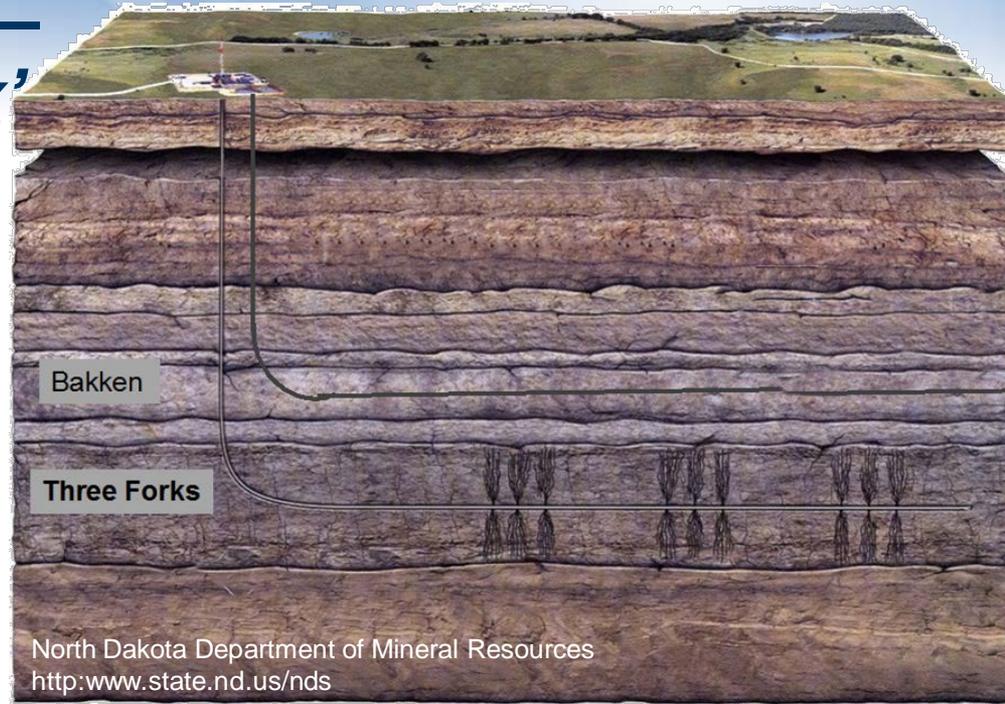


- 1950 to late-1980s – vertical drilling
- 1987 to 2000 – upper Bakken horizontal drilling
- 2000 – Middle Bakken horizontals
- 2001 – Two section horizontals
- 2006 – Introduction of swell packers
- 2008 – Introduction of cemented liners

Bingham Exploration Company Analyst Day
Austin, TX, April 18, 2008

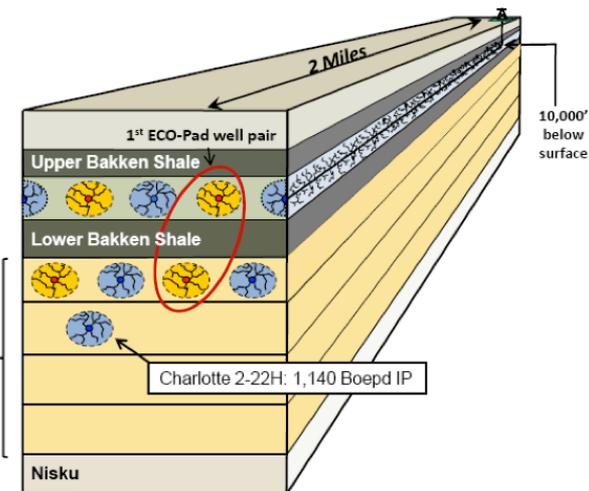
Bakken Hydrofracturing – where Oil and Water ‘Mix’

- USGS (2013) Bakken/Three Forks assessment
 - ~7.4 billion bbl of oil
 - 6700 billion ft³ natural gas
 - 0.53 billion bbl natural gas liquids
- NDSWC
 - ~2,500 new oil wells per year for the next 15-25 years
 - Average water demand estimated at 2-4 million gallons per well
 - Estimated annual oil field water demand > 22,400 billion acre-feet



Bakken Development Plan

- Original dual-zone development plan
 - 8 wells per 1,280 acres – 4 MB, 4TF
 - 603,000 Boe EUR per well (avg. 24.5 stages/completion)
 - ECO-Pad[®] design: 2 wells south, 2 wells north
- Additional Three Forks potential



Water Management Issues Associated with Bakken Oil Shale Development in Western North Dakota

Robert Shaver

**Water Appropriations Division
North Dakota State Water Commission**

SUMMARY

- We are not depleting aquifers in western North Dakota to provide water for oil field applications**
- More groundwater is available for oil field use but it cannot be permitted in a timely manner because of hydrologic system uncertainty**
- The water demand for oil field industrial use is being met but more efficient distribution could be achieved if the USACOE would allow access to the Missouri River from Lake Sakakawea**
- Aquifer storage and recovery may be an option for storing ephemeral streamflow

When is it Montana's turn?

August 3rd, 2010 rhonda Posted in [Uncategorized](#) |



The United States Geological Survey (USGS) declared the Bakken Shale the largest continuous oil accumulation it has ever assessed. And so far North Dakota is reaping the lion's share of the spoils.

But Keith Kohl, editor of "Energy and Capital," thinks that Montana is due for a renaissance after production dropped from 99,000 bo/d in 2006 to 76,000 bo/d in 2009. "Montana became the forgotten step-child in the US oil industry," Kohl wrote.



Exploration

Rhonda Duey, Senior Editor

Bakken Oil Patch Expanding into Montana

Posted by: [Tony Kennedy](#) | Updated: November 1, 2012 - 4:59 PM

[0 comments](#) | [print](#)

Wednesday May 29, 2013
StarTribune

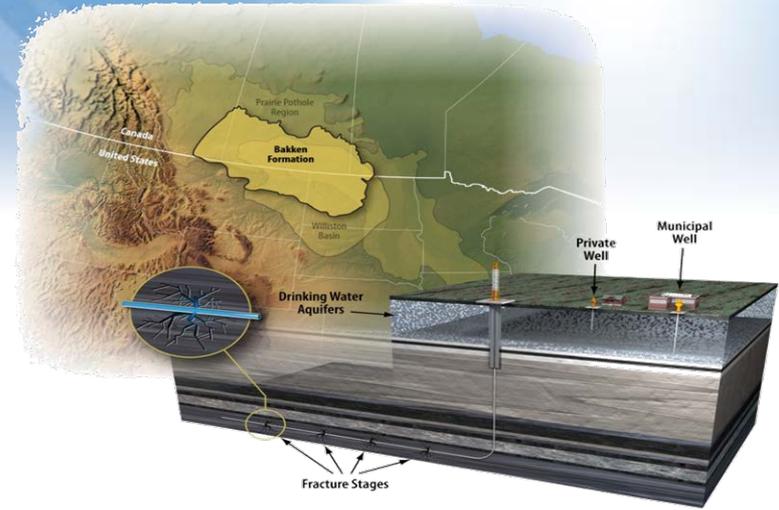
Despite short-term, localized swings in frac sand activity in Minnesota and Wisconsin, the long-term, underlying demand for the mineral continues to soar.

Just last week, the [U.S. Bureau of Land Management](#) auctioned oil and gas leases for 94,676 acres of land in northeastern Montana.

The \$16 million auction sets up a major new territory for hydraulic fracturing, the drilling technique that is about to make America the world's leading producer of crude oil.



INL - Montana Bureau of Mines & Geology Project



Strategic preparation for increasing shale oil development in Montana

- Evaluate projected water needs for hydraulic fracturing
- Characterize the Fox Hills/Hell Creek aquifer
- Compare water needs with water availability and develop an approach for optimizing water usage with respect to aquifer sustainability
- Evaluate potential impact to the aquifer from contamination associated with hydraulic oil extraction

Competing Water Management Goals

- Protect water supplies from overdevelopment to maintain current water availability for
 - Ranching
 - Agriculture irrigation
 - Drinking water
- Allow water use for energy development to allow regional economic growth

Water Sources & Management Issues

- Surface water,
 - Small streams unreliable
 - Major rivers water plentiful, but US Army COE has constrained access
- Artesian aquifers (Fox Hills/Hell Creek)
 - Up to 200 gpm
 - Longterm decline associated with flowing wells
- Glacial-fluvial aquifers
 - Up to 500 gpm, but limited in extent
 - Pumping can induce intrusion from more saline aquifers
- Non-potable brine
- Reuse



Current water handling costs

	Cost, \$/bbl
Acquisition Costs	
Raw Water	\$0.25–\$1.05
Transportation	\$0.63–\$5.00
Disposal Costs	
Transportation	\$0.63–\$9.00
Deep-Well Injection	\$0.50–\$1.75
Total Costs	\$2.00–\$16.80

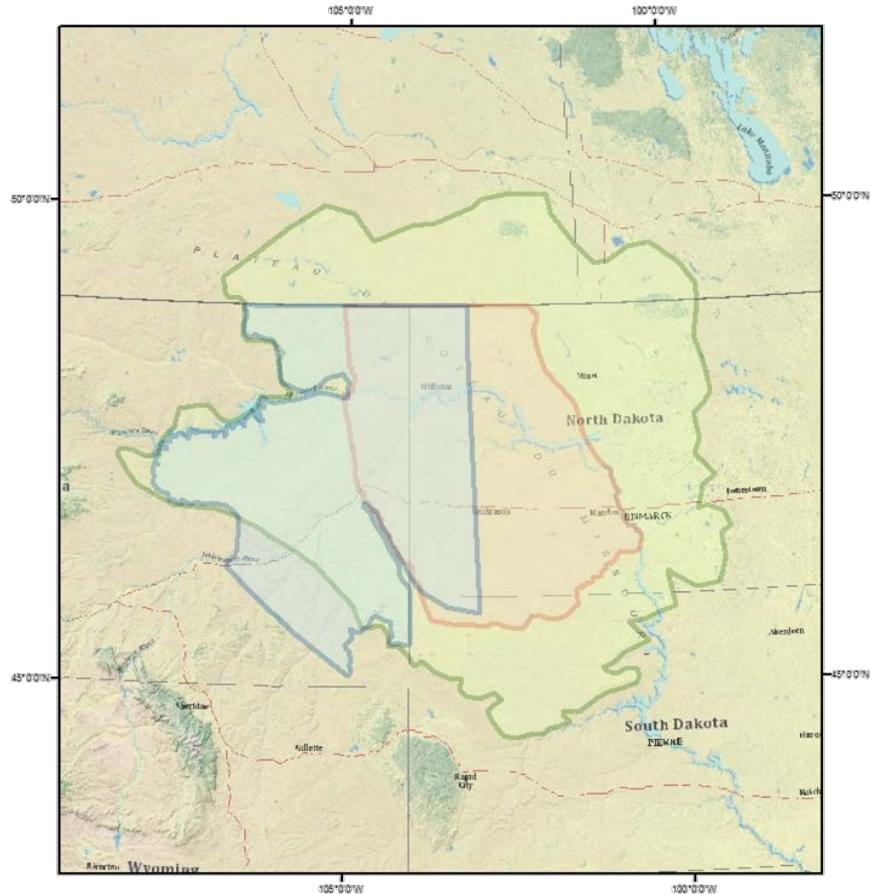
<http://www.nd.gov/ndic/ogrp/info/g-018-036-fi.pdf>

Leverage groundwater modeling efforts of other agencies through interagency collaboration

- Share data
- Discuss interpretation issues & problems
- Compare results of different estimation approaches
- Discuss future needs for groundwater modeling and oil development impacts

Williston Area Aquifer Model Consortium

- North Dakota State Water Commission
- USGS 'Lower Tertiary and Upper Cretaceous aquifer system groundwater availability study' ()
- Montana Bureau of Mines and Geology
- Idaho National Laboratory



Williston Area Aquifer Model Consortium
Approximate model extents
July 11, 2012

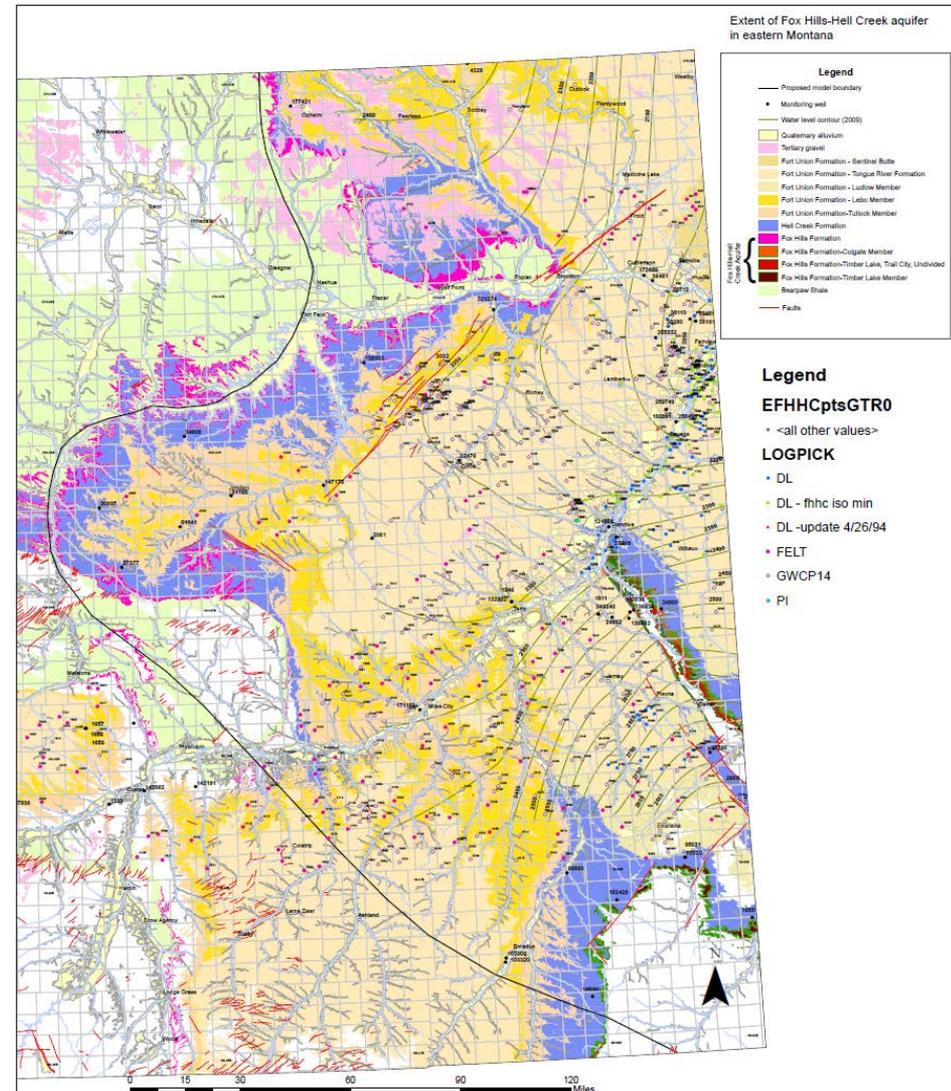
Explanation	
	MBMG_INL_Model_Extent
	USGS_Model_Extent
	NDSWC_Model_Extent

Evaluate projected water needs for hydraulic fracturing

- Develop GIS layer describing parameters likely to promote development in Montana, including, for example
 - Permits drawn
 - Producing formation thickness
 - Depth to producing formation
 - Stress distribution
- Develop realistic water extraction scenarios based on
 - Distance (\$) to nearest water source
 - Water cost at source
 - Water depot density data from ND
 - Trends in oil development and water usage in other regions of Bakken / Three Forks development

Characterize the Fox Hills/Hell Creek aquifer

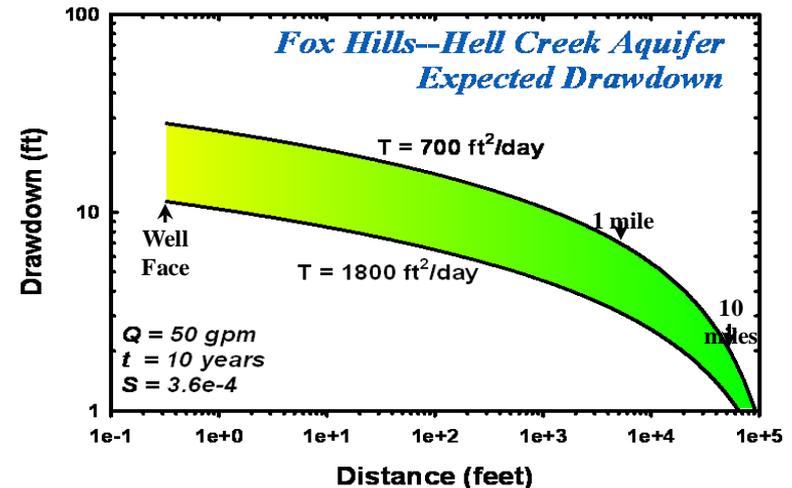
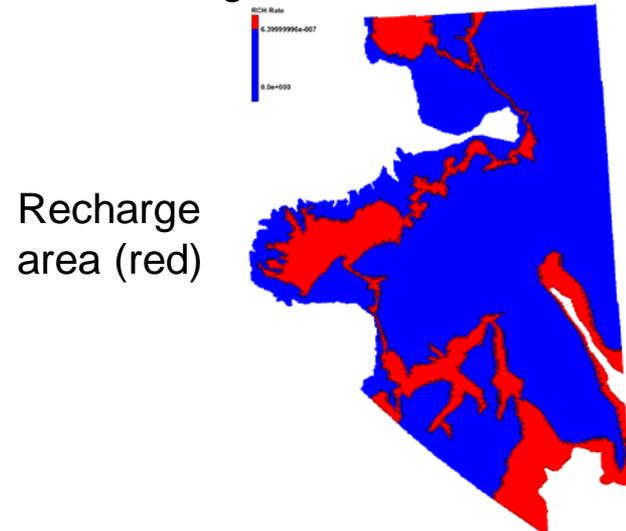
- Establishment of a monitoring network and expansion of current monitoring program
- Collection of water quality and aquifer property data necessary for aquifer characterization and model development
- Collection of current agricultural and industrial water-use data for the Fox Hills/Hell Creek aquifer; potential recharge sources and rates to the aquifer.



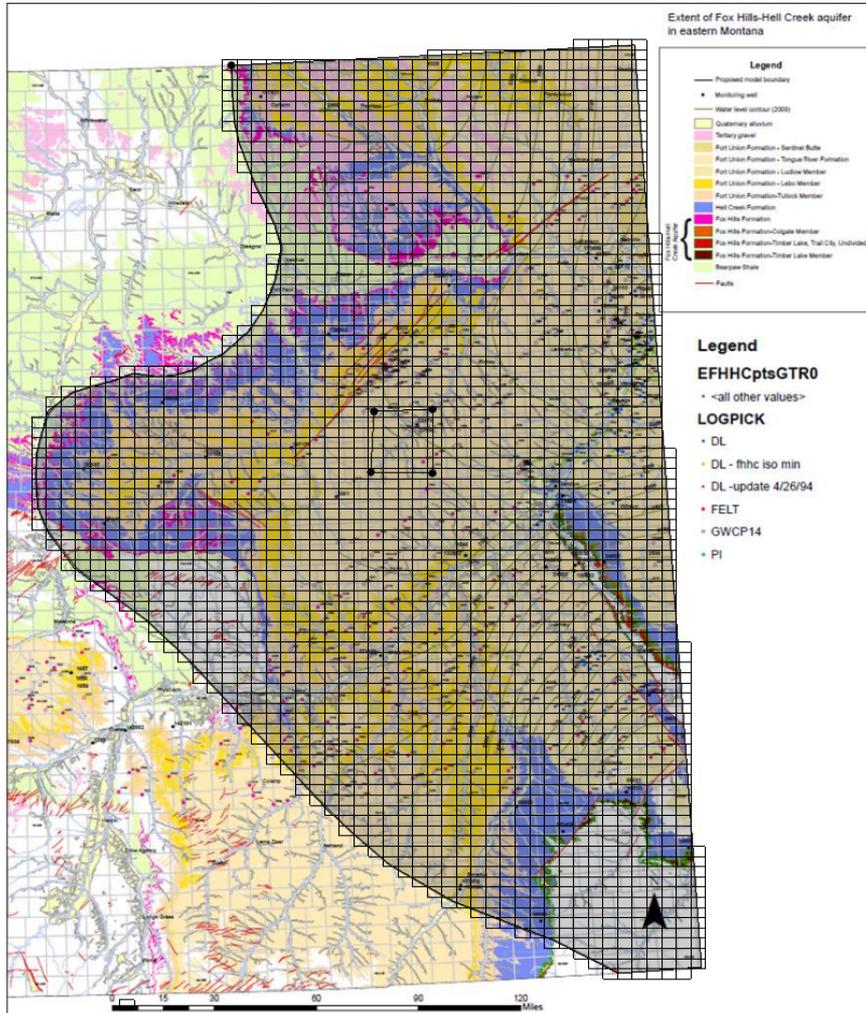
Develop groundwater model to examine sensitivity of Fox Hills / Hell Creek aquifer to groundwater extraction

- Develop transient groundwater flow model calibrated to observed hydrologic conditions (MODFLOW)
- Produce aquifer vulnerability map by examining sensitivity to withdrawal and sensitivity of existing use to drawdown
- Examine sensitivity of conclusions to boundary conditions, recharge estimates and other model assumptions

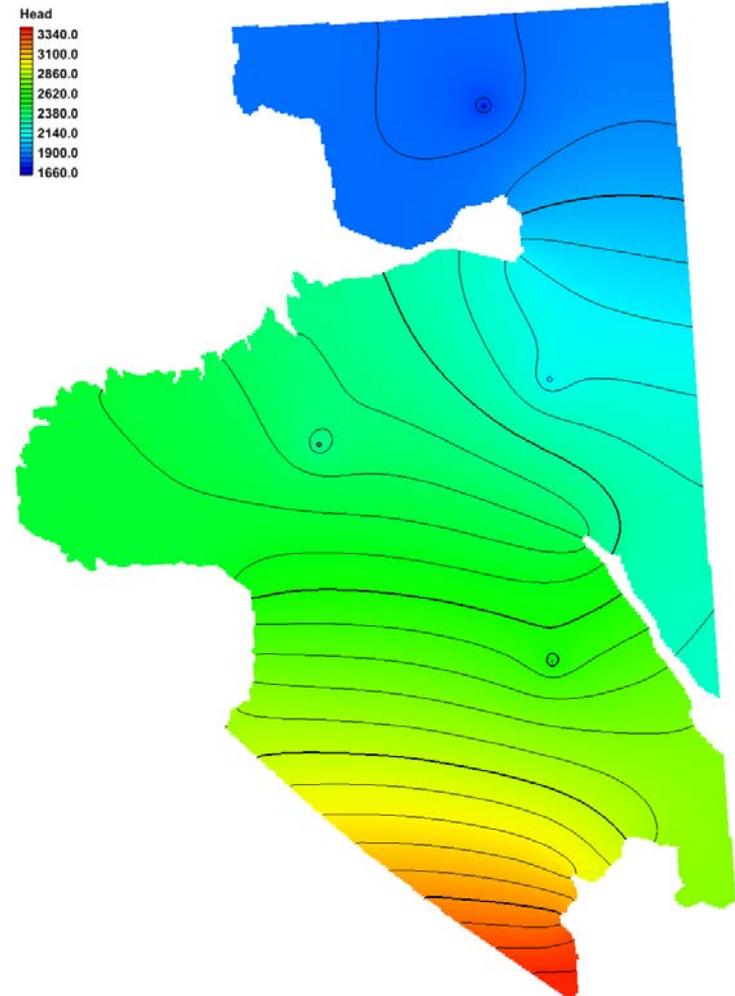
Recharge area assessment



Preliminary results of aquifer modeling



Model Domain



Hydraulic head distribution with pumping wells.

Compare water needs with availability

- Compare water extraction scenarios to groundwater vulnerability map
- Identify extraction scenarios that provide reasonably low cost water for hydrofracturing while minimizing impacts to other users
- Identify key areas for which additional data would allow more robust decision making analysis

Evaluate potential impact to aquifers from contamination

- Contamination potential associated with hydro-fracturing in poorly constructed oil well or other contaminant releases from leaking wells.
- Task to include particle tracking model simulations to evaluate the risk over a range of aquifer conditions.



Final products

- Dedicated modeling to evaluate the potential impacts to the aquifer associated with energy development.
- Focus-area models to test different impact scenarios based on hydraulic fracturing water demand functions.
- Evaluation to consider the potential impact on the aquifer caused by surficial contaminant releases
- Final report describing systematic approach for defining (1) the potential limits on energy resource development due to water availability and (2) approaches and benefits for mitigating impacts to groundwater resources associated with energy resource development.



Williston Basin – Hydraulic Fracturing



Vern Whitten photos, North Dakota Department of Mineral Resources

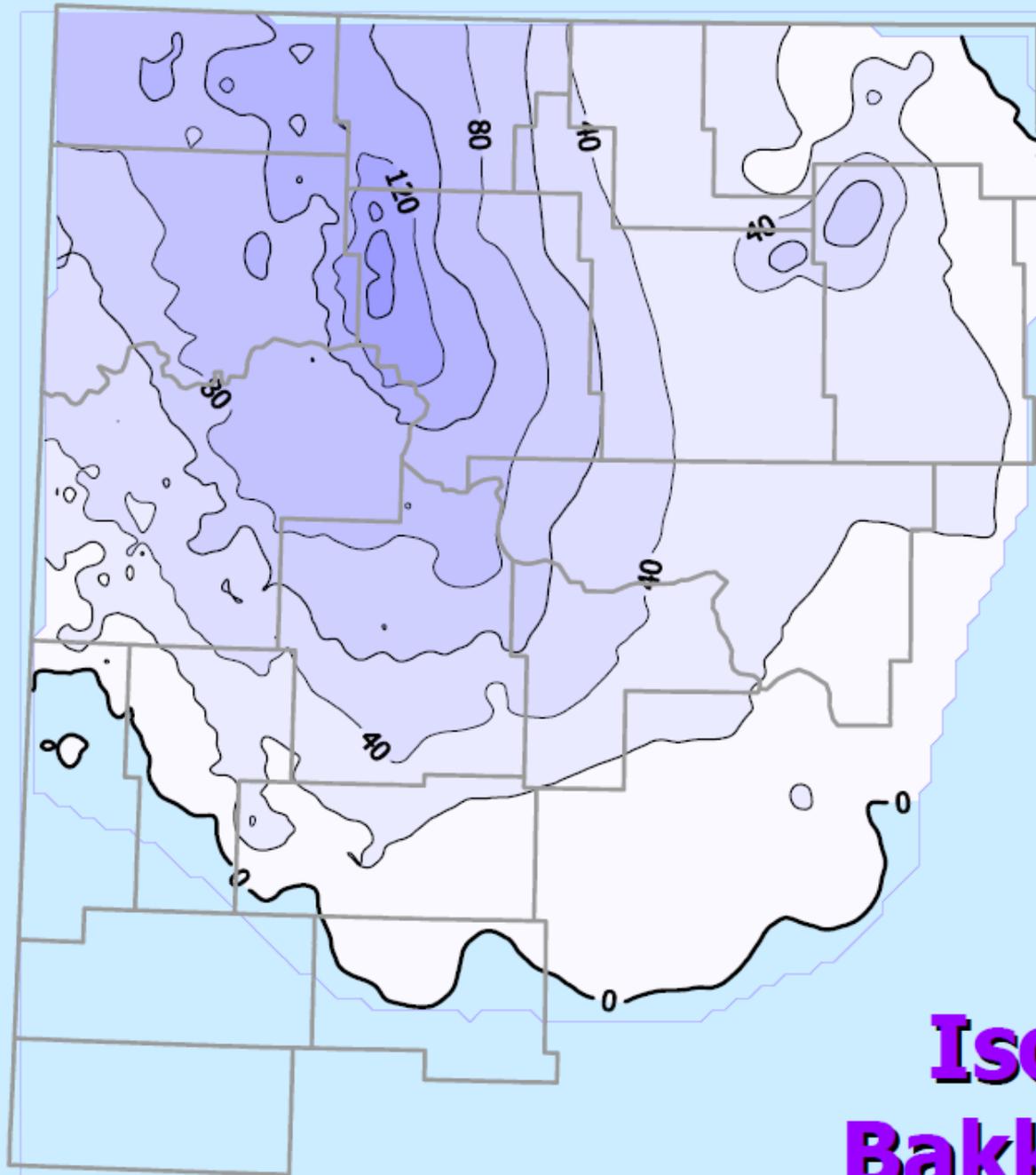
<i>Aquifer (2)</i>	<i>Depth (ft)</i>	<i>Composition</i>	<i>Yield³ (gal/min)</i>	<i>Dissolved⁴ Solids (mg/L)</i>	<i>Quality</i>
Alluvial <i>Commonly used in heavily populated areas; subject to contamination</i>	0-200	loose sand, silt, clay	10-1,000	300-2,500	good-excellent
Fort Union <i>Most commonly used aquifer in eastern Montana, although water from most wells drilled here exceed federal drinking water standards for total dissolved solids,</i>	250-9,000	coal or sandstone	< 15	500-5,000	fair
Fox Hills/Hell Creek <i>Underlies Fort Union aquifer</i>	1,200-2,500	sandstone	20-50	† excellent	
Judith River	100- 1,200	coal seams, sandstone, shale	50-100	160-27,000	fair
Eagle/Virgelle <i>Used often in central Montana, but depth and poor water quality limit use in eastern Montana</i>	200-700	sandstone	50-500	800-1 ,500	good
Kootenai	500- 1,000	sandstone	10-300	200- 14,000	fair
Swift <i>Mainly oil exploration holes used for stock water</i>	3,000-5,000	sandstone, shale	50	500-4,000	fair
Madison <i>Underlies entire Great Plains. Very high quality near Big Springs at Lewistown; low in northeast Montana where high yields can be used for industrial purposes.</i>	300-16000	limestone	20-6,000	500-300,000	poor-excellent

1. Adapted from *Montana Water Quality Guidebook*. 1993. Montana State University Extension Service, page 3.
2. Alluvial aquifers are located throughout Montana; others in chart are deeper formations east of the Continental Divide.
3. A water right permit is required for wells that produce more than 35 gallons per minute.
4. Federal drinking water standards permit a maximum of 500 mg/L Total Dissolved Solids in public supplies.

MT-ND Middle Member Bakken Play

Julie LeFever, NDGS

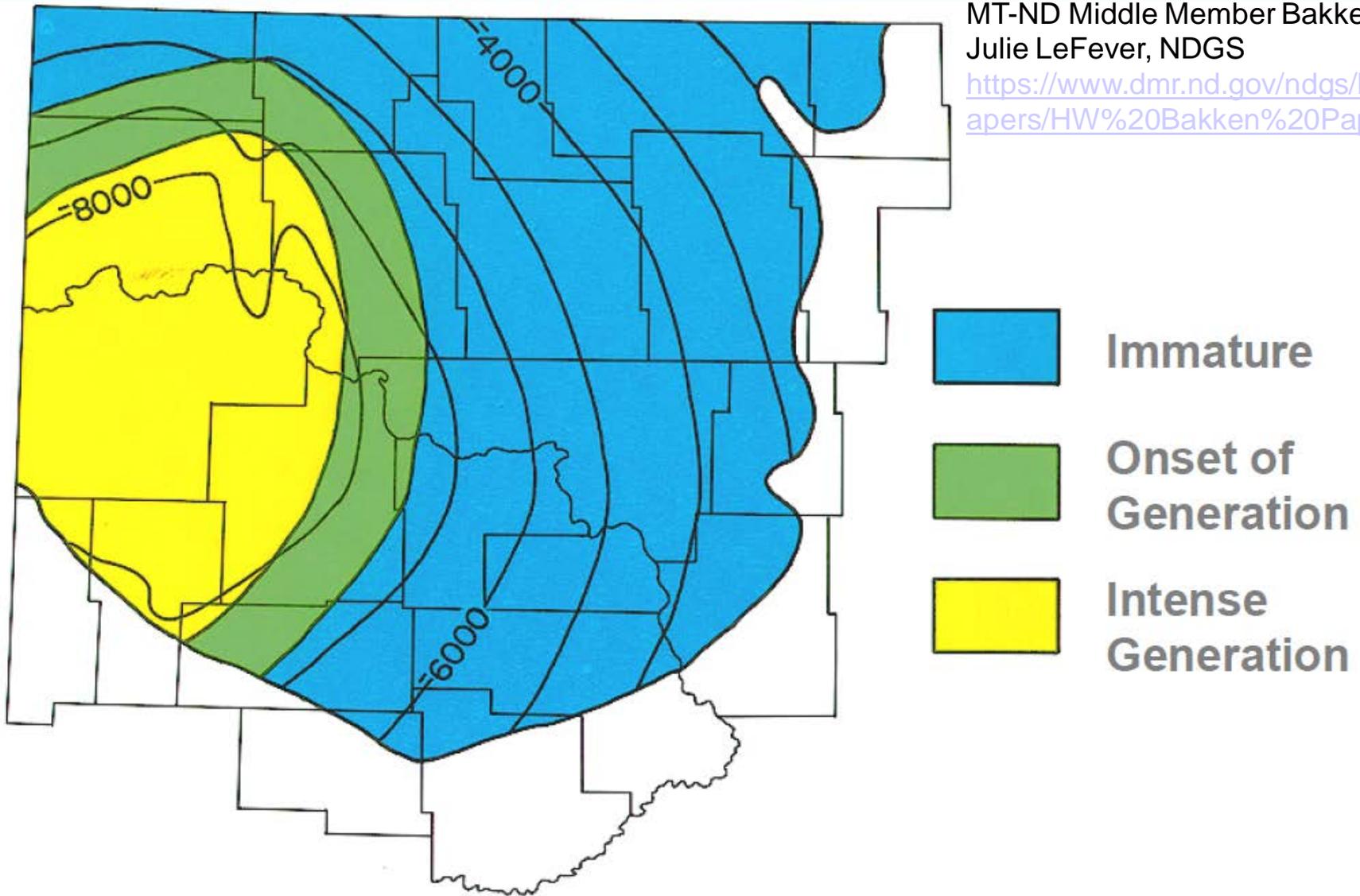
<https://www.dmr.nd.gov/ndgs/bakken/Papers/HW%20Bakken%20Paper.pdf>



**Isopach of the
Bakken Formation**

MT-ND Middle Member Bakken Play
Julie LeFever, NDGS

<https://www.dmr.nd.gov/ndgs/bakken/Papers/HW%20Bakken%20Paper.pdf>



Source Rock Maturity Zones