Energy & Environmental Research Center (EERC)

PRODUCED GAS INJECTION AS MECHANISM TO REDUCE FLARING

EDTC Meeting

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John Harju

Vice President for Strategic Partnerships

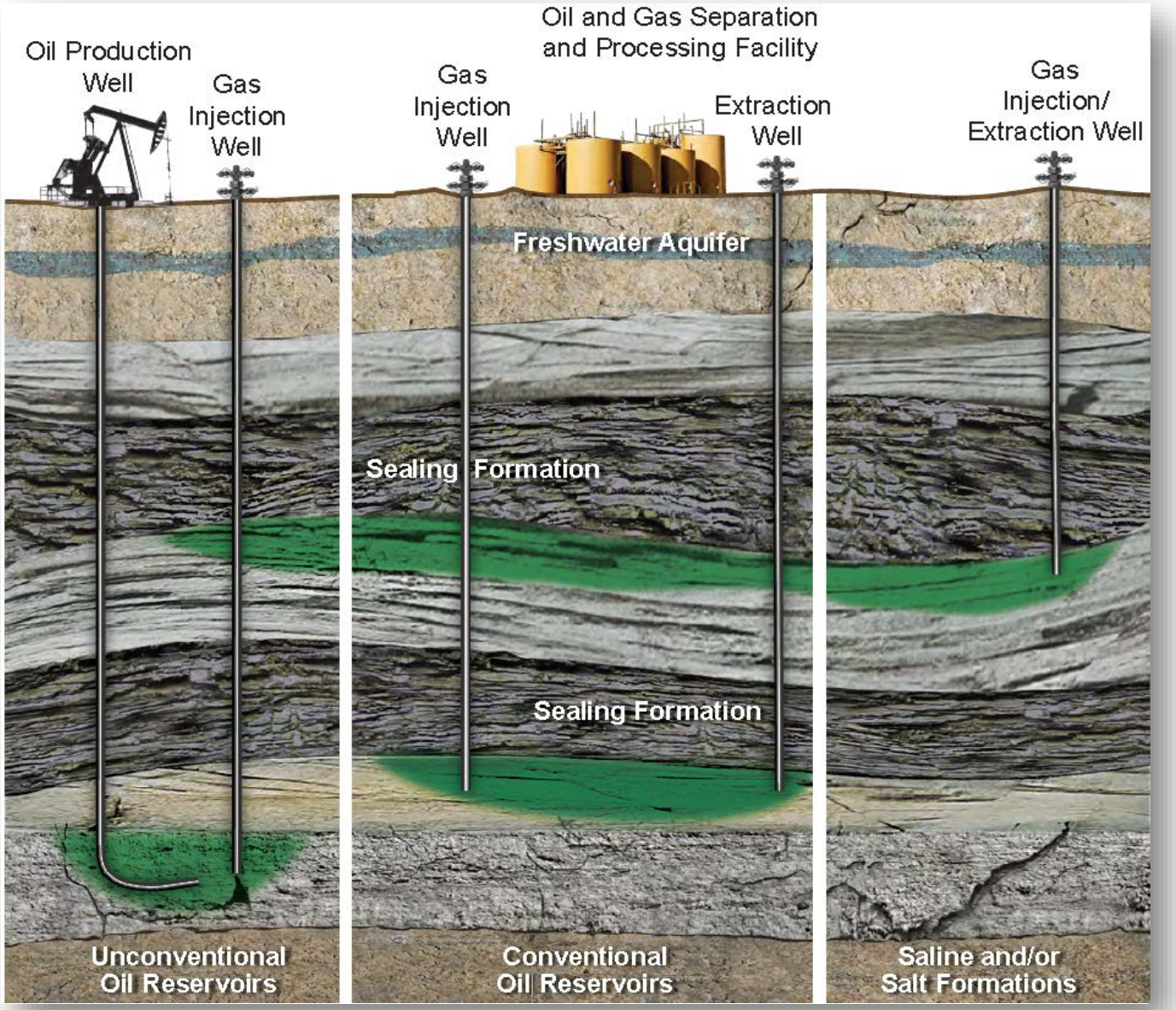
PRODUCED GAS INJECTION CONCEPT

- Subsurface injection of excess produced gas could be a mechanism to:
  - Meet gas capture requirements and decrease flaring.
  - Reduce curtailed oil production.
  - Facilitate sustained growth in oil production.
- Establishing gas storage infrastructure could also facilitate enhanced oil recovery (EOR) and petrochemical investment.

Image courtesy of Prairie Public.

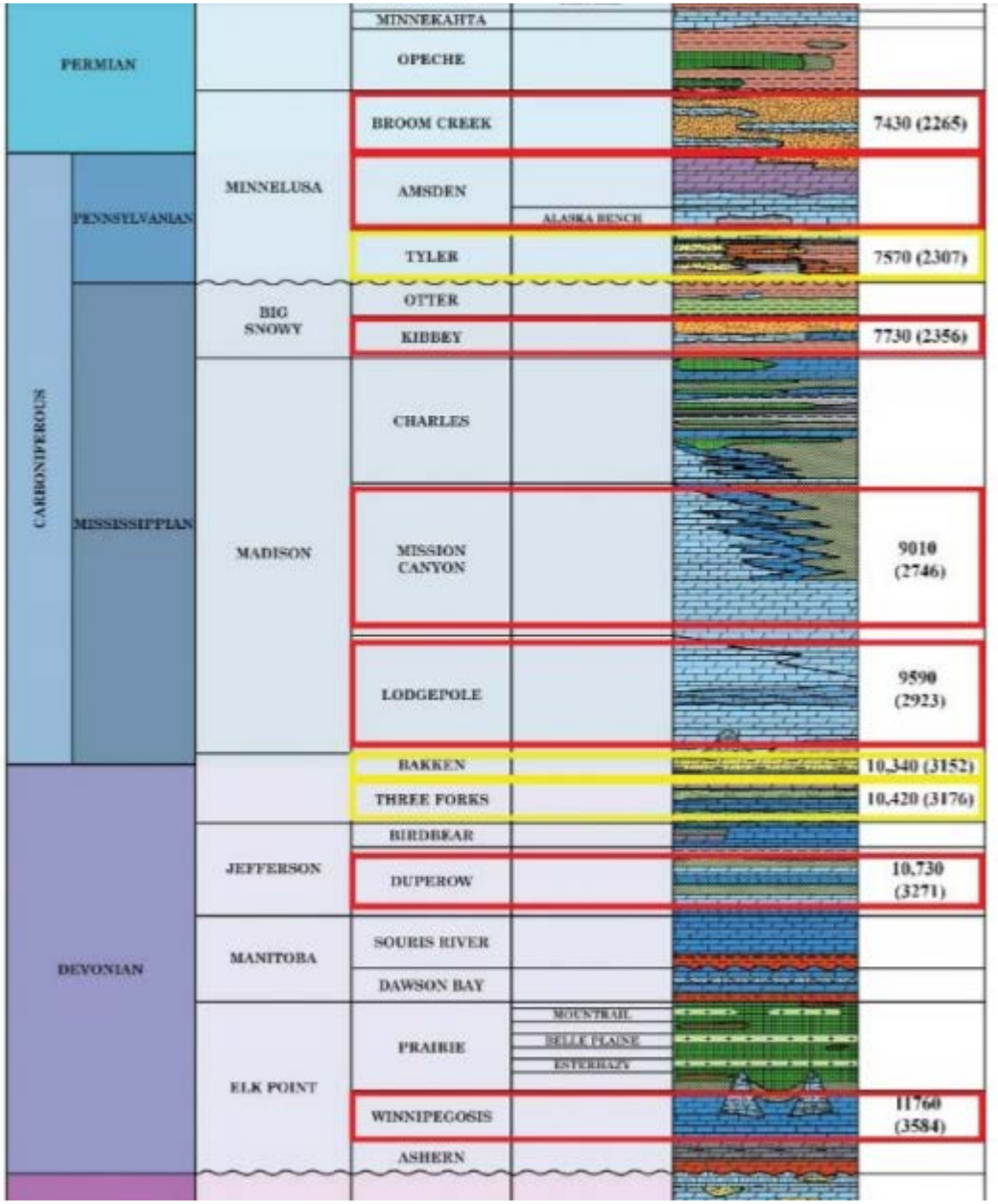
POTENTIAL GAS INJECTION SCENARIOS

- Gas storage into saline or salt formations for future recovery and use.
- Injection into conventional or unconventional hydrocarbon reservoirs for pressure maintenance and/or EOR.



INITIAL ASSESSMENT

- With NDIC funding, the EERC performed a higher-level assessment in late 2018 to evaluate and simulate produced gas injection into the subsurface.
- Focused examination of the Broom Creek Formation (Minnelusa Group), although potential targets for EOR were also summarized.



KEY FINDINGS (INITIAL ASSESSMENT)

- The Broom Creek Formation may be a technically and economically-viable target for temporary produced gas storage in the *southern* portion of the core Bakken area.
- Gas recovery factors from temporary storage range from 47 to 63% in the most realistic scenarios, which include constrained rates of gas production and/or reuse of the same storage reservoir to facilitate additional well development.
- Water production rates during gas recovery range from 500 to 2,900 bbl/day.

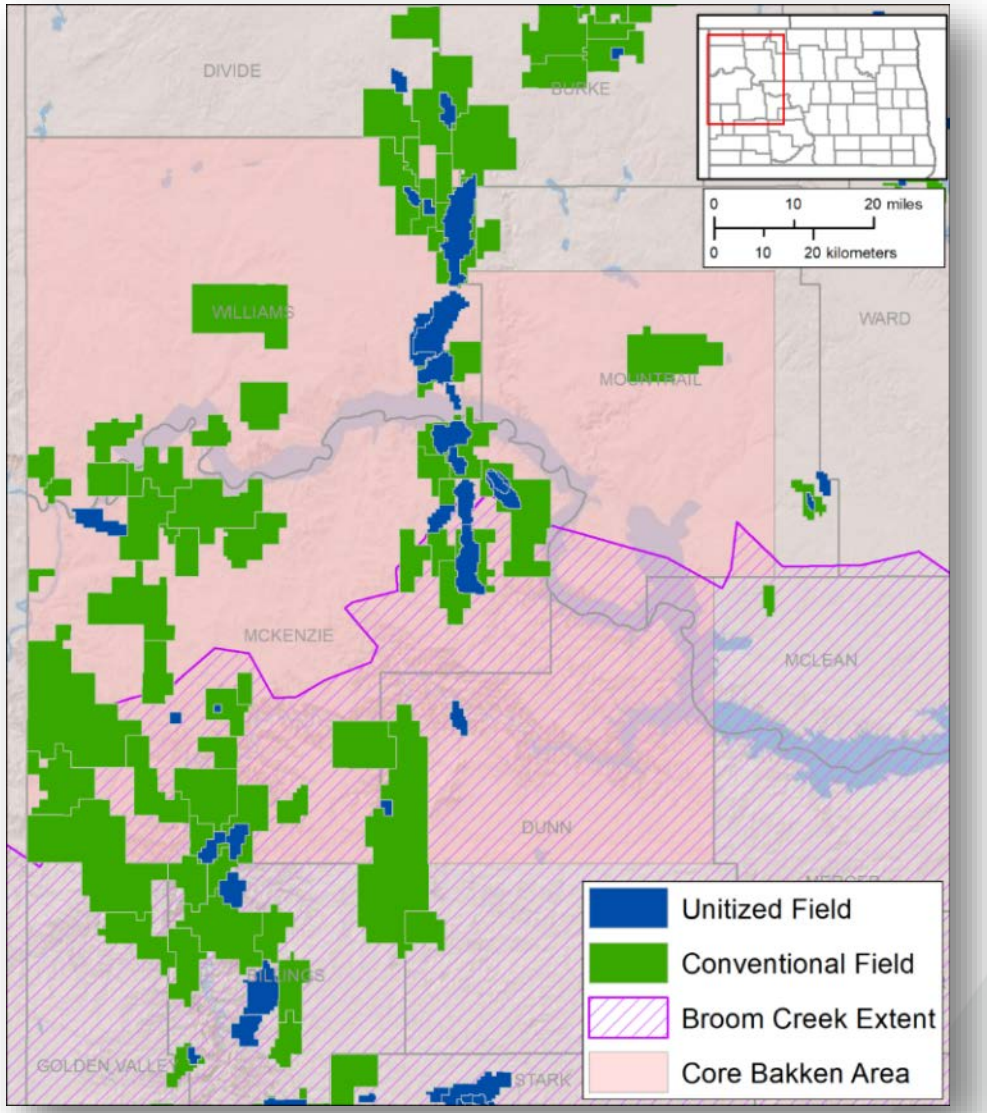
Source: North Dakota Department of Health

KEY FINDINGS (INITIAL ASSESSMENT, CONT.)

- The potential gross economic benefit of unconstrained oil production from a single well with no gas capture capacity could be as high as $41 million over a 2-year period (or $200 million for 5 wells on a pad) if this approach were applied proactively for well pad development (assuming $59/bbl oil prices).
- Estimated capital cost for development of a gas injection site able to fully capture and handle the gas from 5 new wells (average of 10 MMscf/day) was $15.7 million ($2.15/Mscf of injected gas). Operational costs could add an additional $1 – $3 million/year.

POTENTIAL EOR TARGETS

- Proximal conventional oil fields
  - Economic benefits associated with EOR, plus demonstrated ability to contain hydrocarbons.
  - Regulatory framework for HC gas injection into conventional fields already exists.
  - This option could be complicated by the gas supply volumes, proximity and consistency.
- Reinjection into the Bakken
  - Benefits include EOR and pressure maintenance.
  - Regulatory framework is simplified if gas production and injection occurs within the same DSU.
  - Conformance can be an issue.



2019 LEGISLATION

- Section 25 of House Bill 1014 stated that $6MM will be made available to the EERC “for pilot projects relating to the underground storage of produced natural gas.”
- Goal is to partner with North Dakota oilfield producers on up to three pilot projects to define and assess the key technical, economic, and regulatory components of produced natural gas (“produced gas”) injection into geologic targets in the Williston Basin.

Photo: Grand Forks Herald

EXPECTED OUTCOMES

- Demonstration of up to 3 different pilot projects, including:
  - Gas storage in a saline formation.
  - Gas injection into a conventional oil field.
  - Gas injection into the Bakken/Three Forks.
- Provision of key information to the state, the oil and gas industry, and other interested parties needed to assess the techno-economic viability of produced gas storage and/or injection into the subsurface as a means of:
  - Achieving gas capture requirements.
  - Expanding Bakken oil production.
  - Conserving the state's resources.

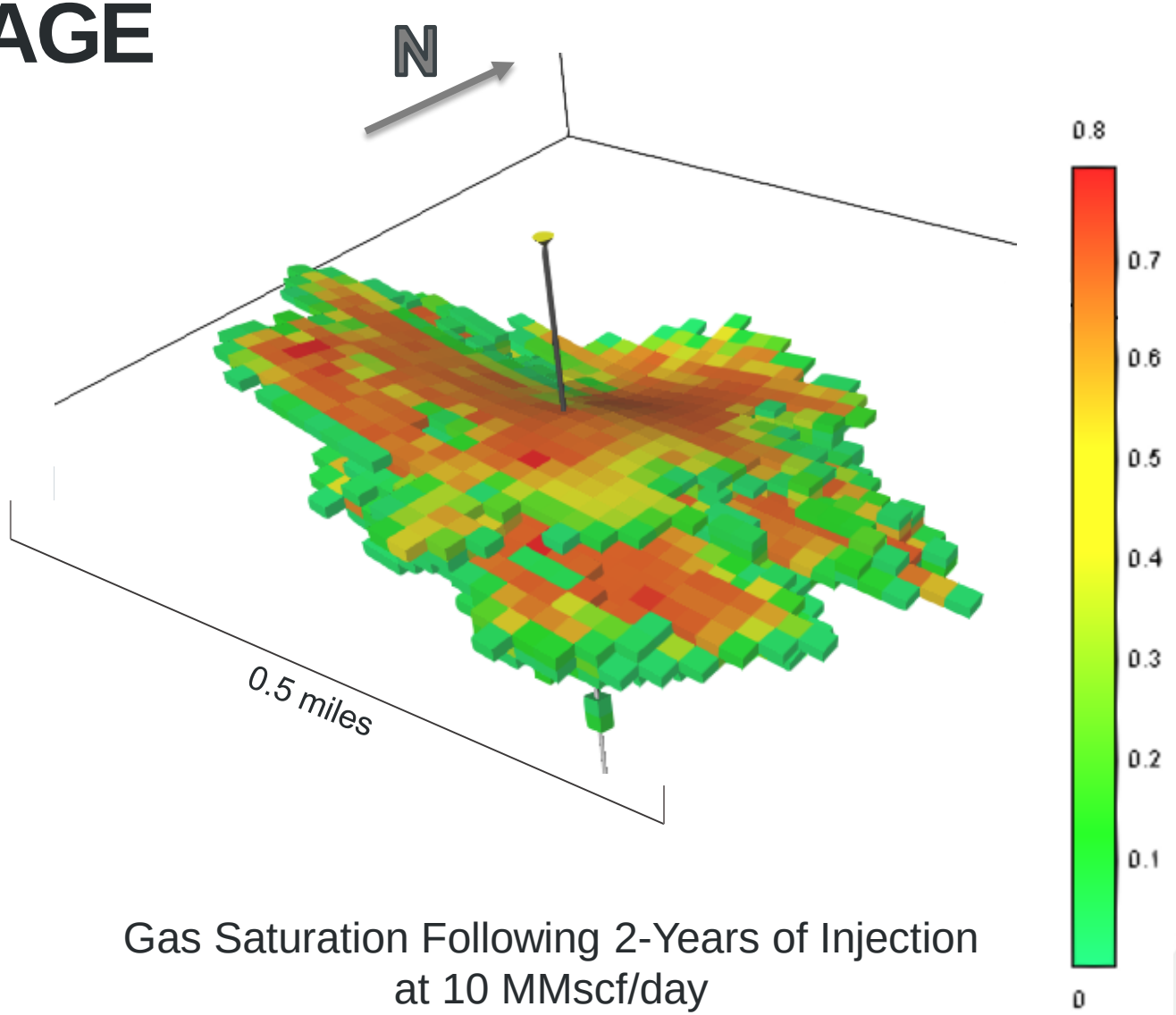
CURRENT ACTIVITIES

The EERC is partnering with XTO Energy (ExxonMobil) on an initial assessment of two pilot projects, including:

- Temporary produced gas storage in the Minnelusa Group (Broom Creek and Amsden Formations).
- Produced gas injection in the Bakken/Three Forks for EOR.
- Potential 3rd effort in an adjacent conventional XTO operated field,

MINNELUSA GAS STORAGE

- The EERC is assisting XTO with an initial evaluation of the concept.
- Activities include:
  - Modeling and simulation to evaluate gas injection rates, volumes and plume extents.
  - Assessment of surface facility needs, such as gas conditioning and compression.
  - Advisement on the permitting process.
  - Facilitation of meetings with the ND DMR, Tax Commissioner's office and ND Trust Lands.



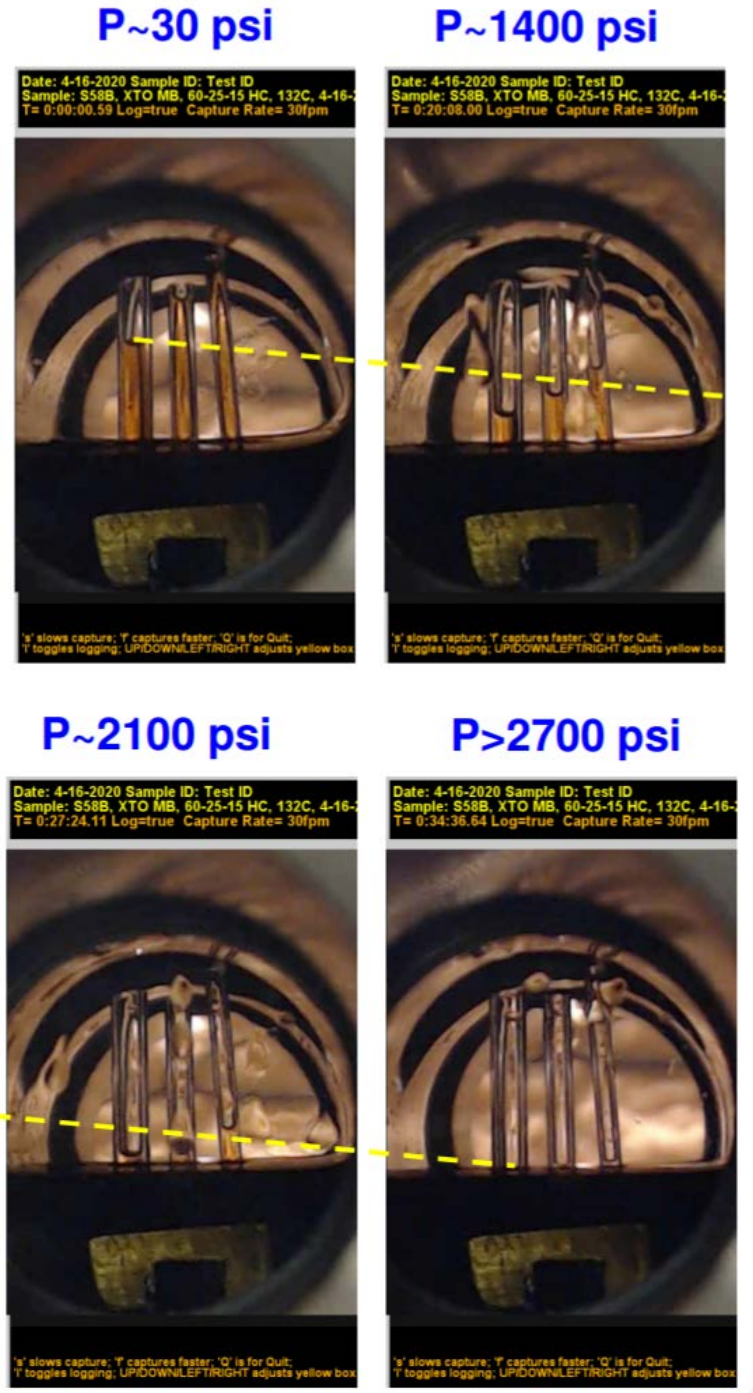
Gas Saturation Following 2-Years of Injection at 10 MMscf/day

INITIAL LEGISLATIVE CONSIDERATIONS

- Tax Considerations
  - Gross production tax is due when gas is produced (NDCC 57-51-02.2)
    - ♦ Temporary Exemption: NDCC 57-51-02.6
      - Allows 2 years and 30 days exemption if natural gas liquids are removed
    - ♦ Future Consideration: A provision to allow a gas tax exemption for gas storage purposes.
      - The tax exemption could be permanent or tax would be due when the gas is extracted from the storage reservoir.
- Pore Space Amalgamation
  - The ND Century Code does not address pore space ownership for temporary gas storage
  - Project developers are proceeding by acquiring 100% of the pore space rights
    - ♦ Carbon Storage (NDCC 38-22-08 subsection 5) requires 60%
    - ♦ Oil and Gas Unitization (NDCC 38-08-09.5) requires 55%

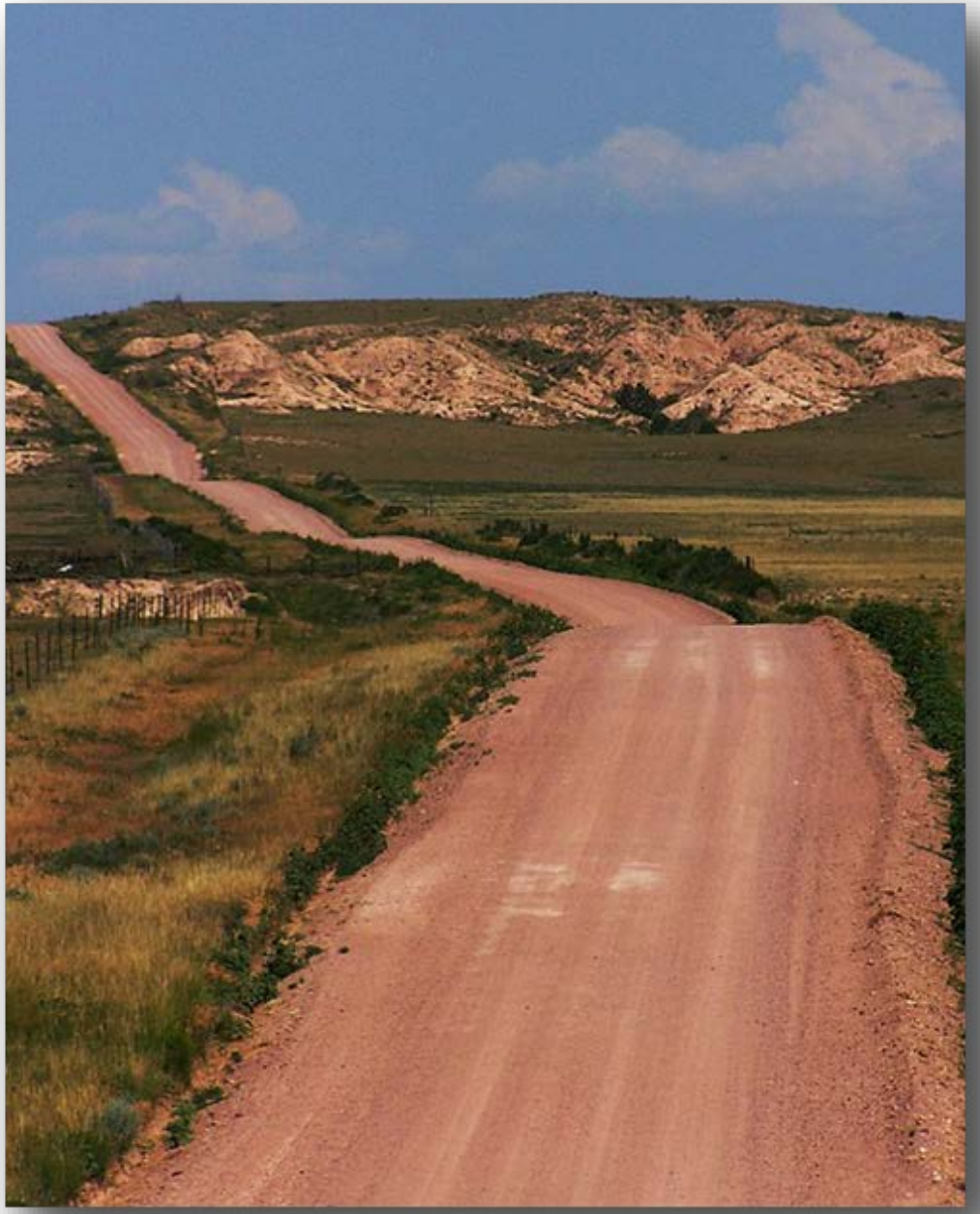
BAKKEN/THREE FORKS EOR PILOT

- The permit for this project has already been approved through the NDIC.
- The EERC has been assisting XTO with the following:
  - Modeling and simulation.
    - ♦ Entails very complicated simulation due to the complexity of fracture networks.
  - Laboratory testing to evaluate the effects of produced gas (methane, ethane and propane) on Bakken crude properties.



NEXT STEPS

- XTO is using the data provided by the EERC on the Minnelusa gas storage project, coupled with a cost-benefit analysis, to decide if they will implement the project.
- The EERC will continue to assist XTO with technical support for the produced gas EOR project.
- The EERC is working on a broader assessment of the concept in various storage targets across the Bakken play.



Energy & Environmental Research Center (EERC)

Produced Water Management Through Geologic Homogenization, Conditioning, and Reuse

OVERVIEW OF PROGRESS TO DATE

- Update to 2016 “Bakken Water Management and Potential Outlook” completed and submitted to NDIC and DOE on 2/28/20.
- Developing plan to engage with operating partners on Activity 1 – Produced Water Assessment.
- Started collection of water samples from BEST project site.
- Acquiring supplies for column testing for Activity 2.

BAKKEN WATER MANAGEMENT REPORT HIGHLIGHTS

- Freshwater demand:
  - 2008: 13.5 million bbl/yr (~567 million gal/yr)
  - 2018: 314 million bbl/yr (~13.2 billion gal/yr)

- Increase in volumes of fluid used in well stimulations:
  - 2008: 20,000 bbl/well (~840,000 gal per well)
  - 2018: 217,000 bbl/yr (~9.1 million gal per well)

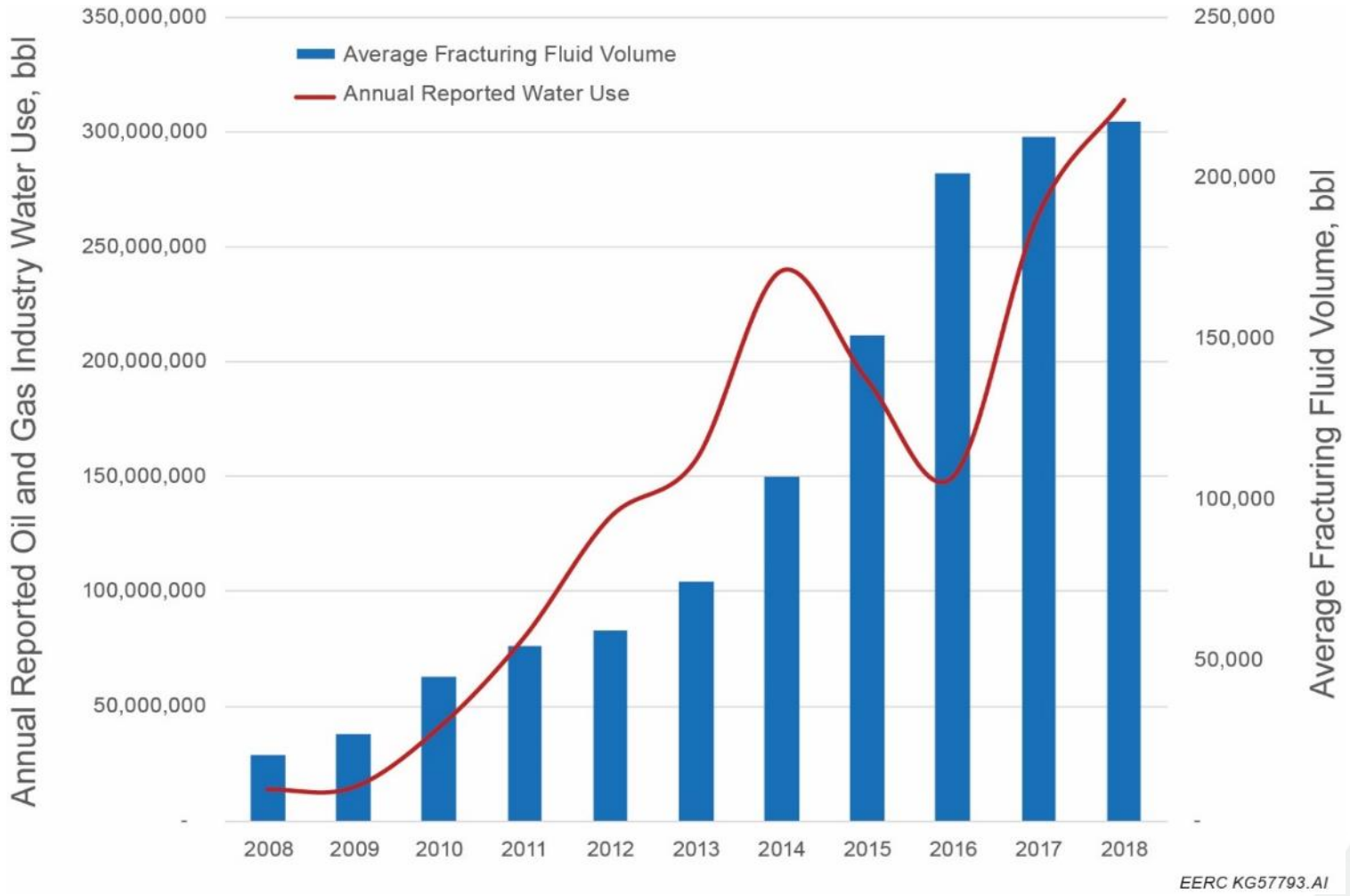


Figure: Plot of industrial water use from permitted sites for oil-related activities for 2008 through 2018 (data source: North Dakota State Water Commission, 2019, Enverus).

BAKKEN WATER MANAGEMENT REPORT HIGHLIGHTS

Trend in Produced Water Generation in the Bakken Since 2008*

Year	Total Producing Bakken Wells	Total Produced Water, million bbl	Average Annual Produced Water per Well, bbl
2008	893	6.4	7,167
2009	1,362	12.2	8,957
2010	2,141	32.6	15,227
2011	3,391	64.1	18,903
2012	5,189	135.3	26,074
2013	7,160	194.1	27,109
2014	9,339	283.9	30,399
2015	10,787	337.4	31,278
2016	11,444	313.3	27,377
2017	12,390	367.9	29,693
2018	13,595	485.6	35,719

* Data source: North Dakota Industrial Commission, 2019.

BAKKEN WATER MANAGEMENT REPORT HIGHLIGHTS

- Produced Water Disposal Volumes:
  - 2008: 106.8 million bbl/yr
  - 2018: 601.9 million bbl/yr

- Alternative methods to recycling and reusing produced water in the Bakken could reduce freshwater demand and improve long-term techno-economic sustainability of oil and gas production in North Dakota

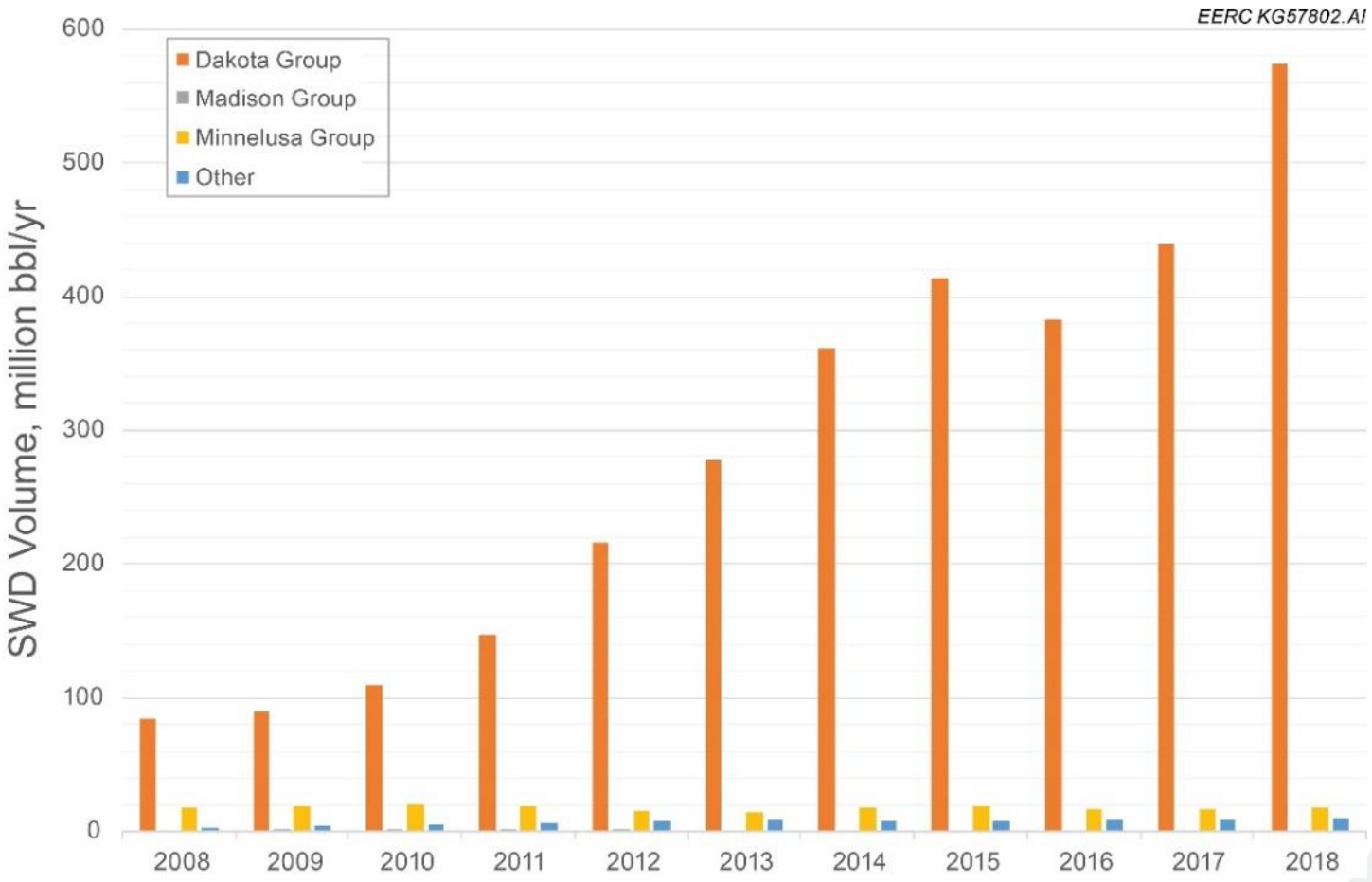
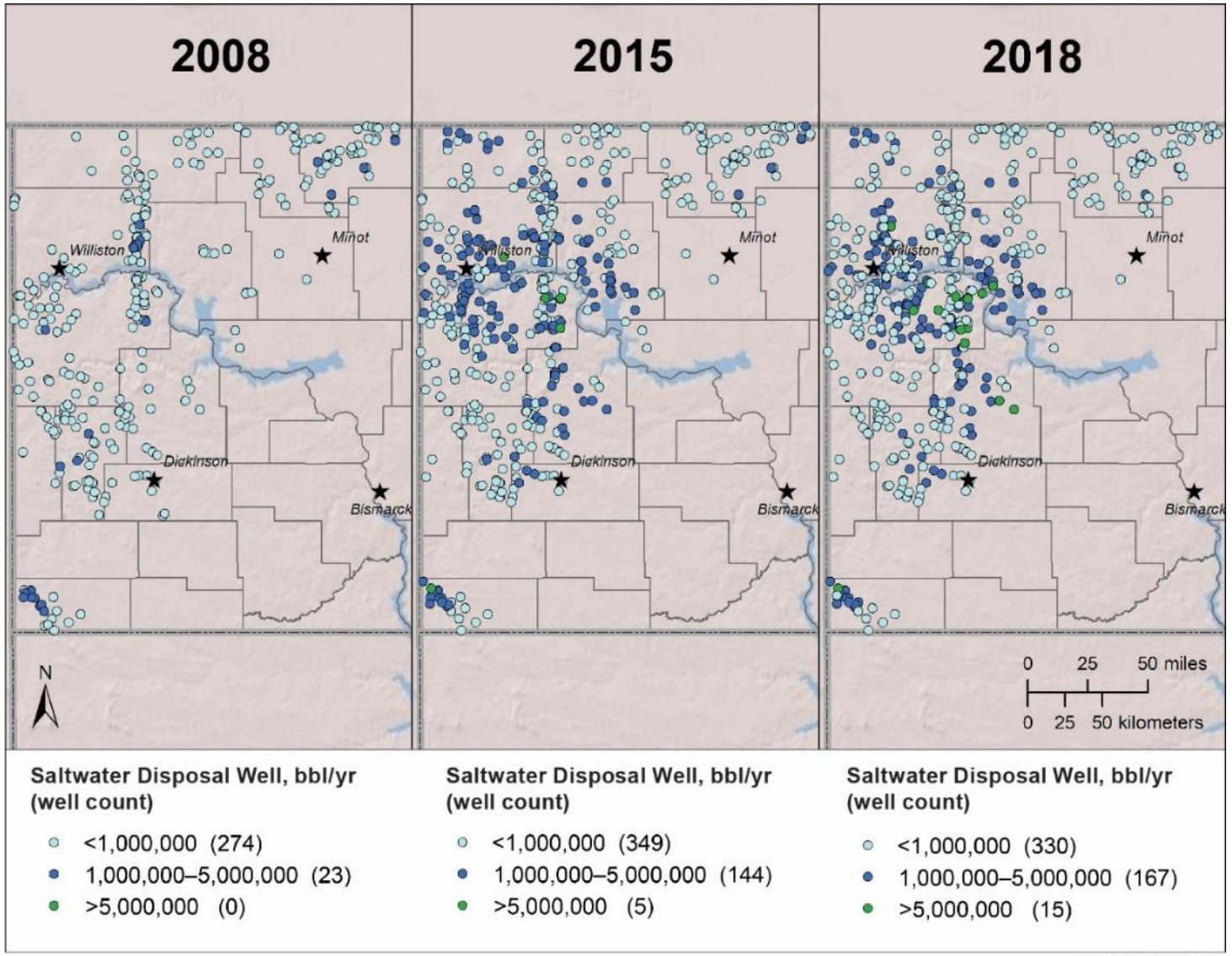


Figure. Annual SWD injection volume by geologic group from 2008 to 2018 (data source: North Dakota Industrial Commission, 2019).

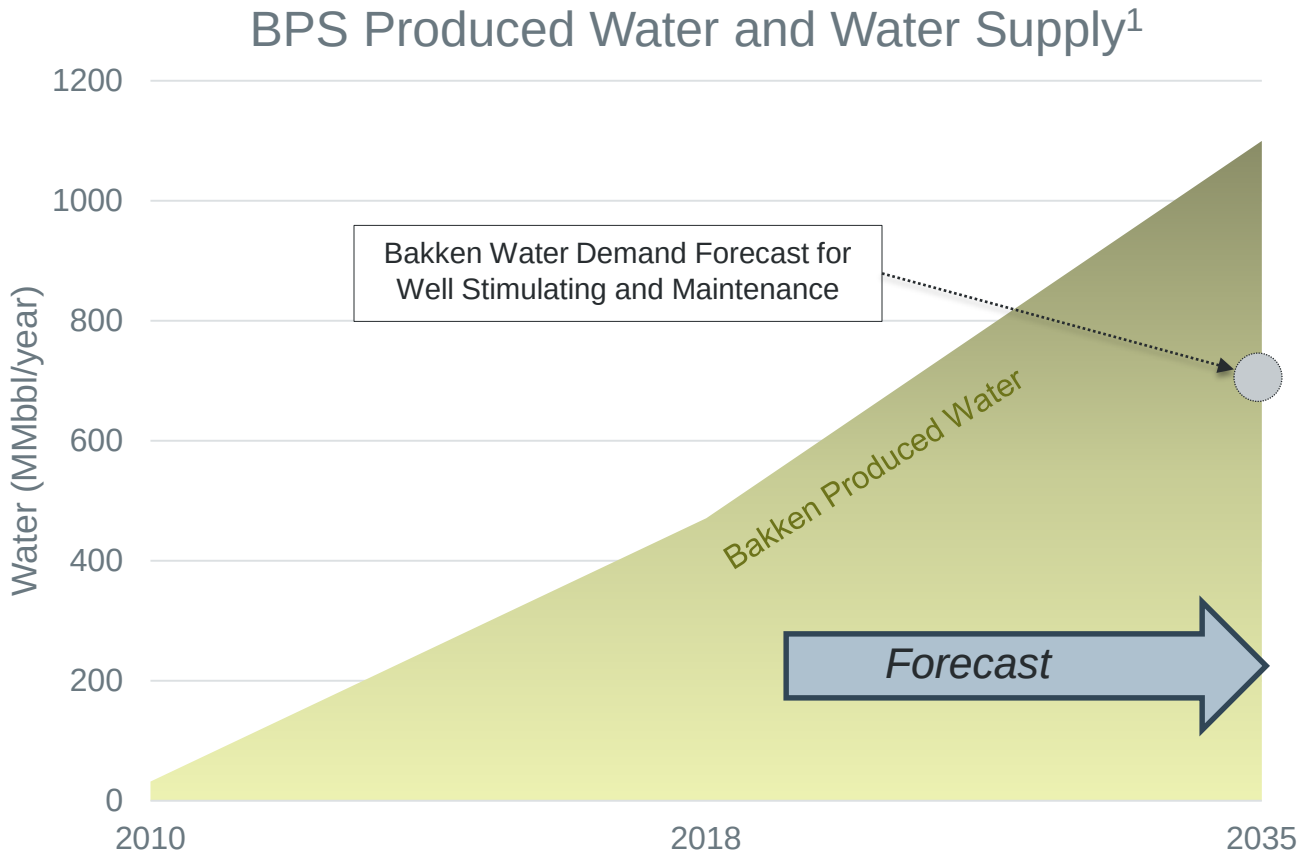
2008 – 2018: ACTIVE SWD WELLS BY LOCATION



EERC KG57804.AI

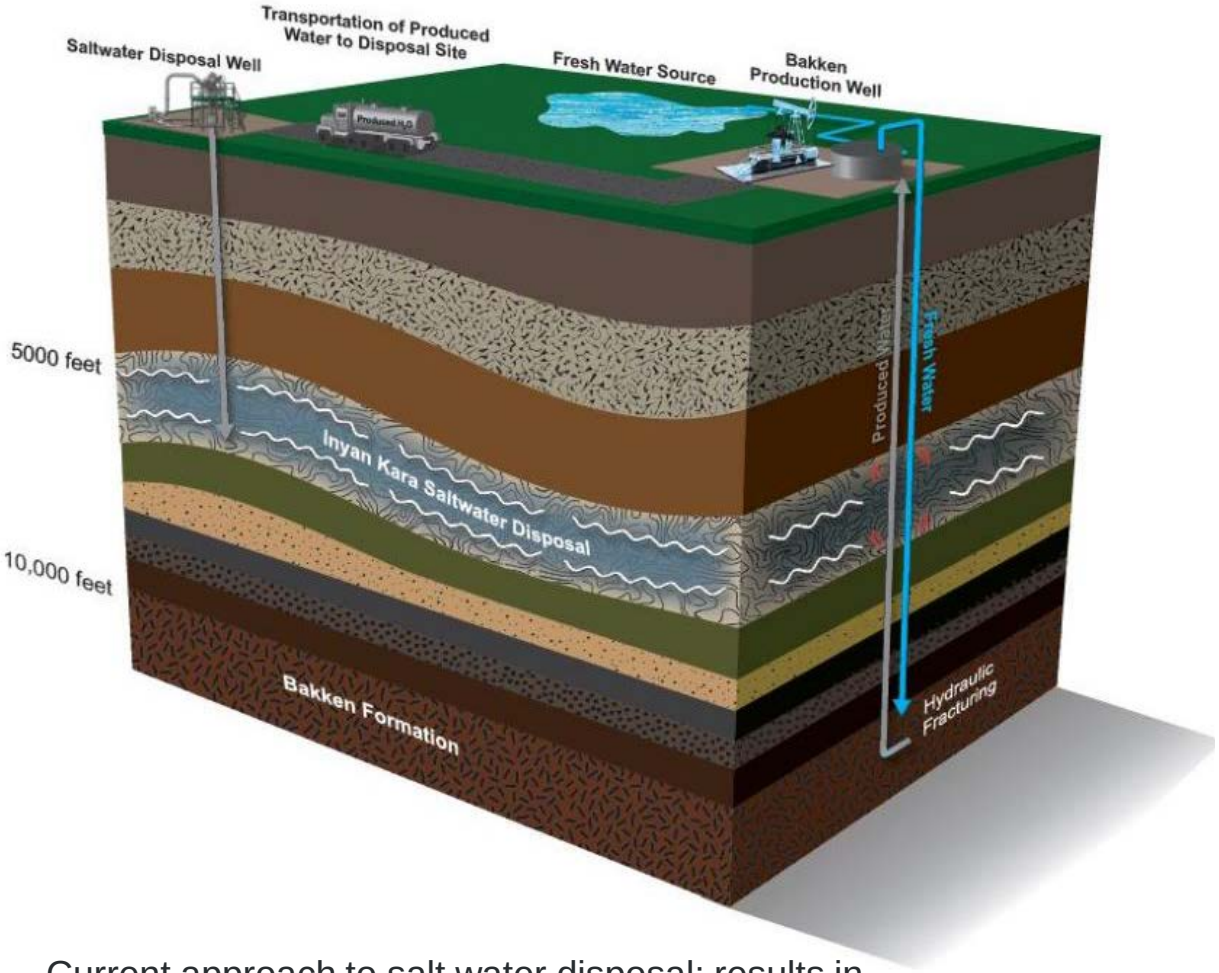
AN EMERGING ISSUE

- Produced water management (including flowback water) represents a significant economic and technical challenge for oil and gas production.
- Produced water volumes associated with Bakken petroleum system (BPS) production in North Dakota have increased dramatically since 2010.[1]
- Freshwater demand is projected to surpass 700 million barrels by 2035.

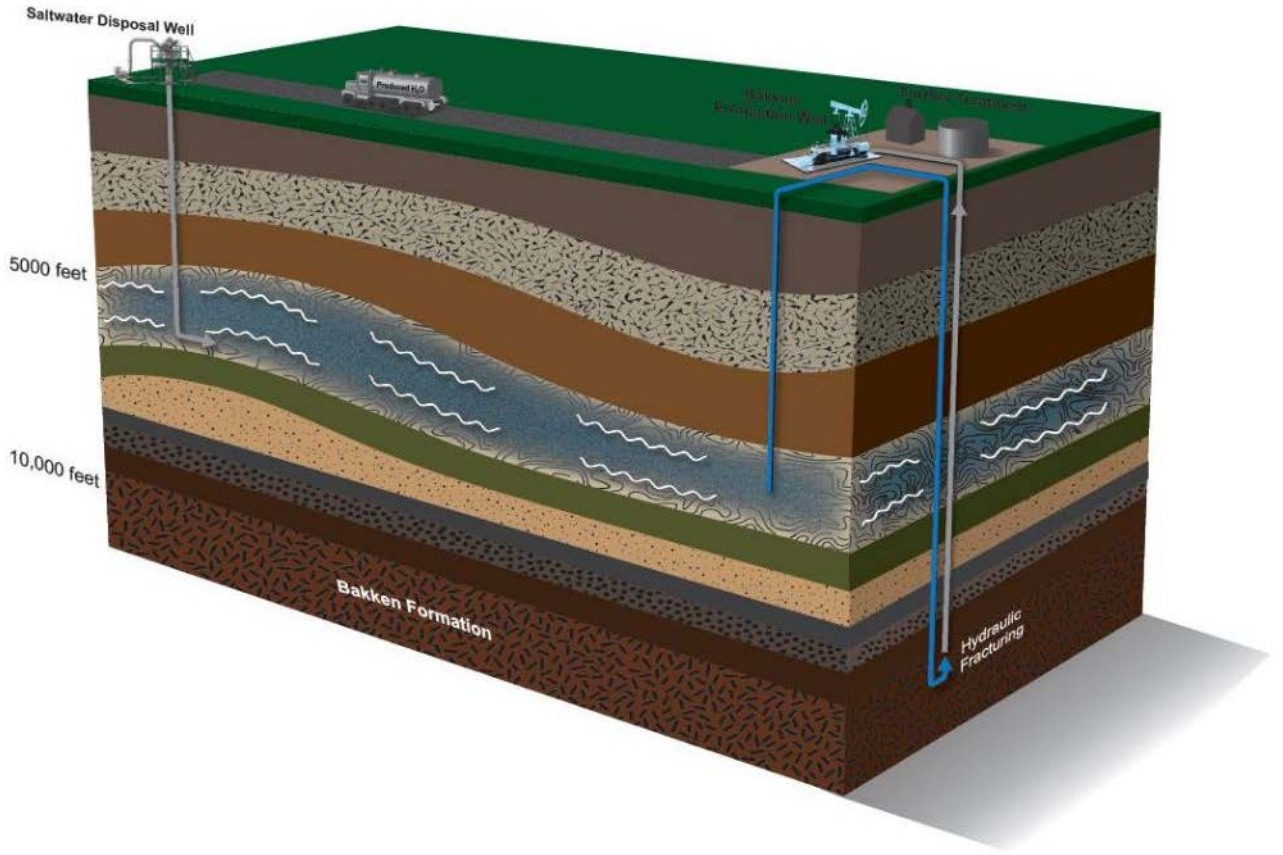


[1] Kurz, B.A., Stepan, D.J., Glazewski, K.A., Stevens, B.G., Doll, T.E., Kovacevich, J.T., and Wocken, C.A., 2016, A review of Bakken water management practices and potential outlook: Final report for members of the Bakken Production Optimization Program, EERC Publication 2016-EERC-03-11, Grand Forks, North Dakota, Energy & Environmental Research Center, March.

GHCR APPROACH



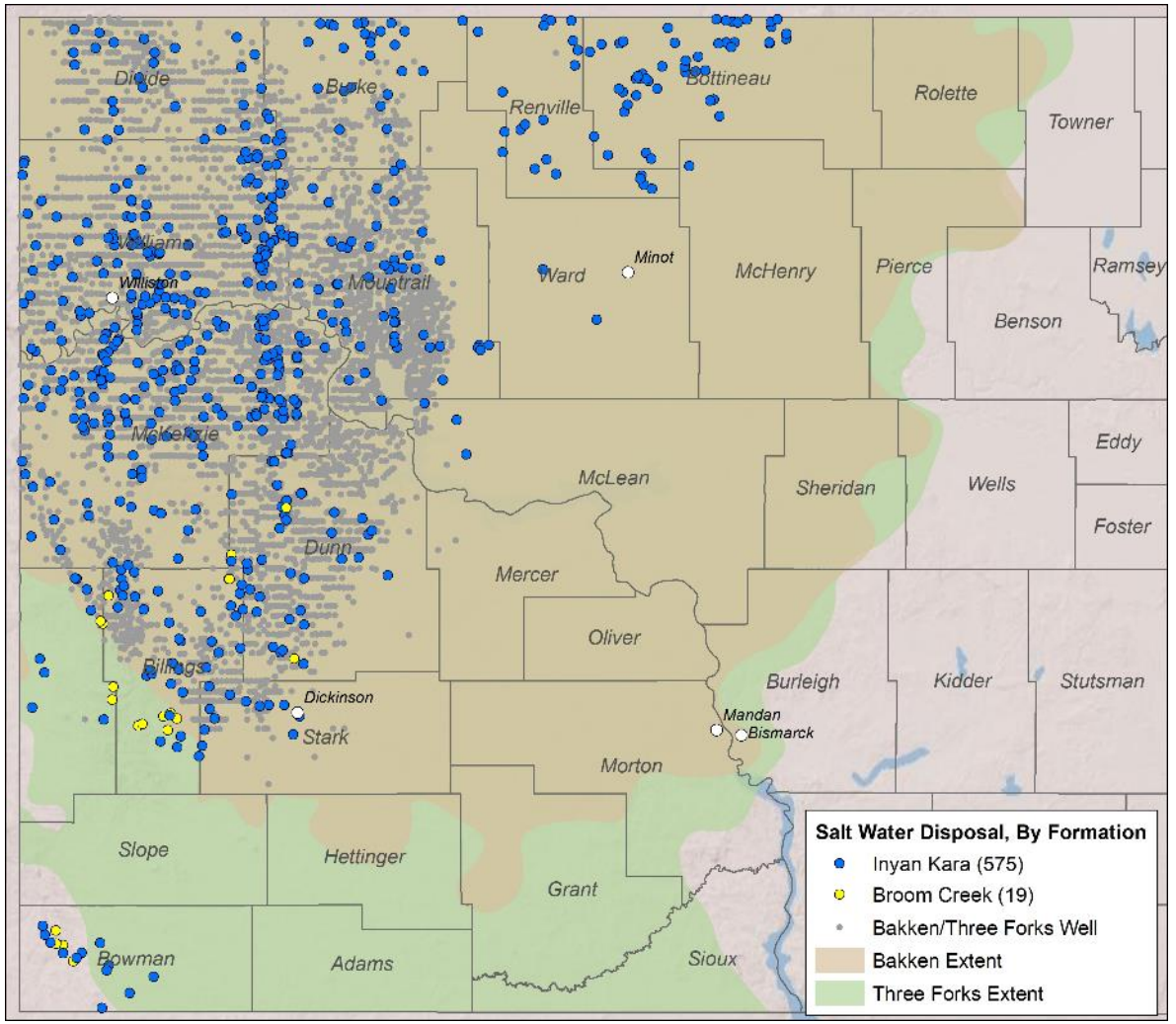
Current approach to salt water disposal; results in pressurization



Geologic homogenization, conditioning, and reuse (GHCR); circumvents limitations of current approach and reduces freshwater demand

THE CHALLENGE

- ND saltwater disposal (SWD) is already resulting in localized areas of high pressure in the Inyan Kara.
  - ♦ Intermediate casing string increases drilling costs by $300K–$700K per well as a result of Inyan Kara pressurization.
  - ♦ Sufficient capacity to continue to meet SWD demand?
  - ♦ 25,000–70,000 additional wells forecast to develop BPS.
  - ♦ Essentially no recycling/reuse to date.
- Produced water treatment and reuse are constrained by:
  - – Variability and extremely high salinity.
    - ♦ ~ 250,000–350,000 mg/L TDS fluids
  - – Large-volume storage in open containers is challenged/constrained.
    - ♦ Regulatory and environmental considerations with attendant costs



Texas, Oklahoma, and other oil- and gas-producing regions with limited freshwater supplies and/or factors constraining injection volumes is a harbinger to an emerging need for SWD alternatives for the prudent management of produced water.

John Harju
Vice President for Strategic Partnerships
jharju@undeerc.org
701.777.5157

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

www.undeerc.org
701.777.5000 (phone)
701.777.5181 (fax)

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