APPENDIX S

Energy & Environmental Research Center

# SUMMARY OF THE BAKKEN WATER ASSESSMENT REPORT

Friday, September 23, 2016

Water Topics Overview Committee
Bismarck, North Dakota

Bethany Kurz

Critical Challenges. Practical Solutions.

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# ACKNOWLEDGMENTS


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- EERC Project Team – Dan Stepan, Brad Stevens, Kyle Glazewski, Tom Doll, Justin Kovacevich, and Chad Wocken.
- Special thanks to the NDIC Department of Mineral Resources (DMR) and the North Dakota State Water Commission (ND SWC)/ND Office of the State Engineer for provision of information and data sets that were used as part of this assessment.

# ASSESSMENT GOALS

- Provide a snapshot of current water management practices and trends in the Bakken. (Assessment conducted in early 2015.)
- Evaluate the capacity of water supply and disposal facilities to accommodate current and projected demand.
- Discuss technological advances that could affect future water use practices in the Bakken.
- Assess the “need” for future water-recycling and reuse scenarios.
- Outline one or more future water management strategies that could help optimize surface operations.

# KEY CHANGES THAT HAVE AFFECTED WATER MANAGEMENT IN THE BAKKEN OVER THE PAST DECADE

- Significant changes in completions designs and associated water use:
  - Single-stage fracturing → multiple-stage fracturing
  - Longer laterals
  - Linear gels → crosslinked gels → slickwater
- Increased access to freshwater supplies and greatly improved water supply infrastructure
- Multi-well pads
- Improved salt-tolerant fracturing fluids

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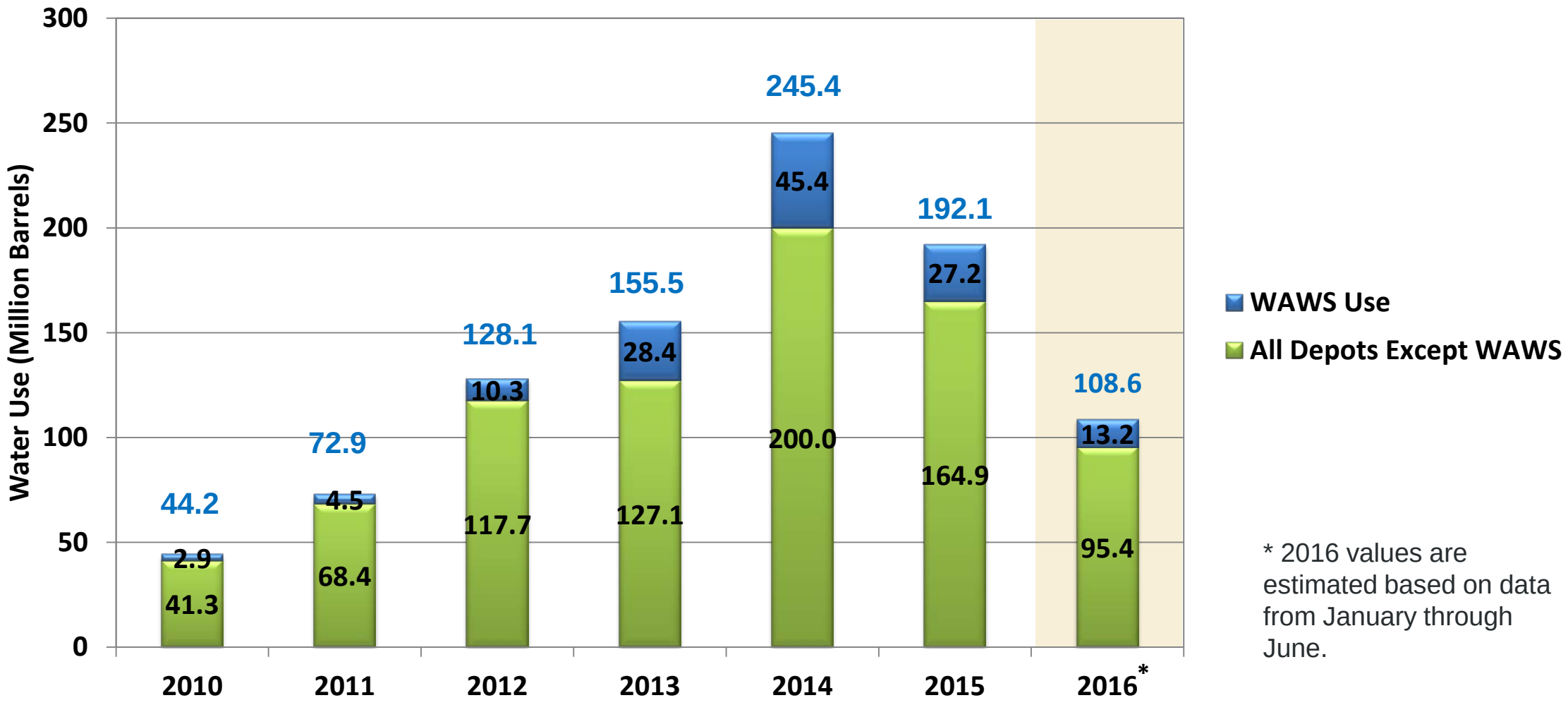
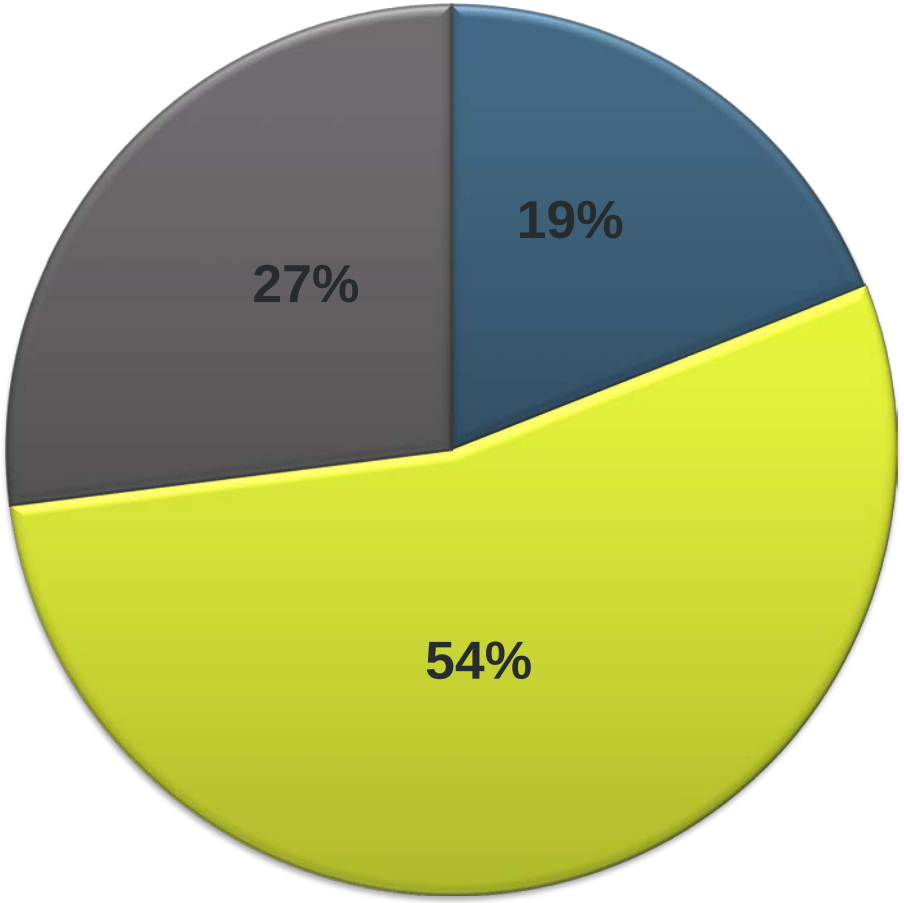
# REPORTED BAKKEN WATER DEPOT USE: 2010 – 2015




* 2016 values are estimated based on data from January through June.

Data provided by the ND Office of the State Engineer, Sept. 16, 2016

# REPORTED BAKKEN WATER DEPOT USE BY SOURCE TYPE - 2014



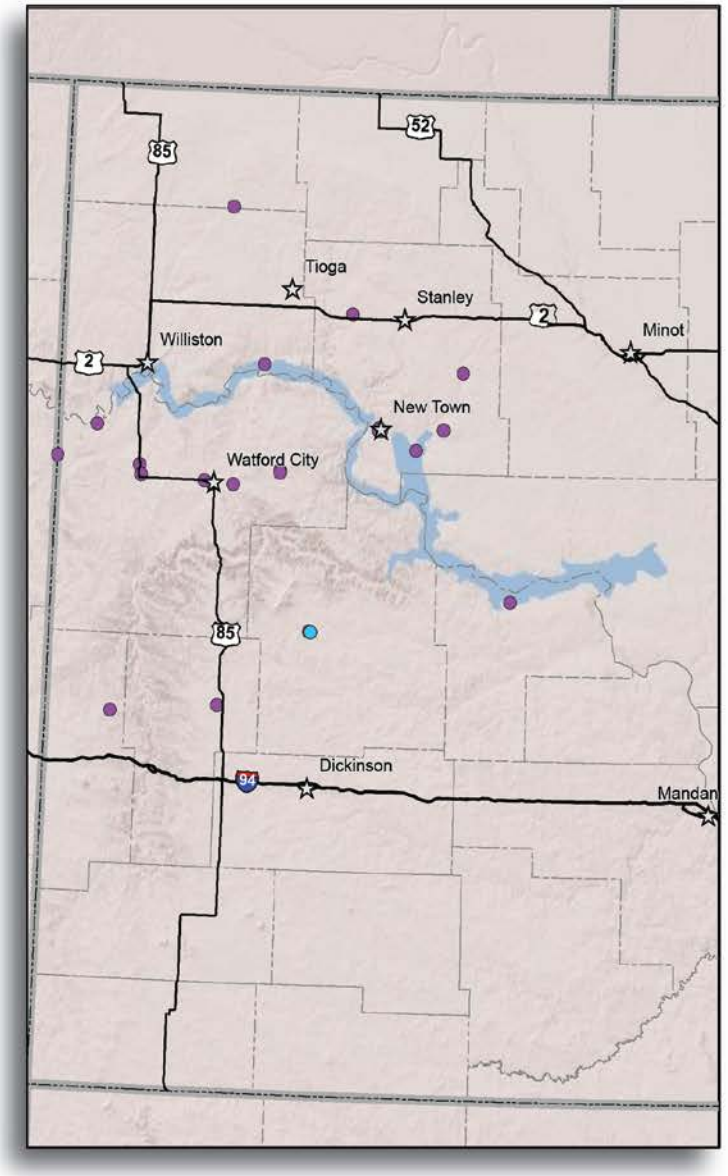

**Total 2014 Water Depot Use in the Bakken Region:**

**245.4 Million Barrels (MMbbl)**

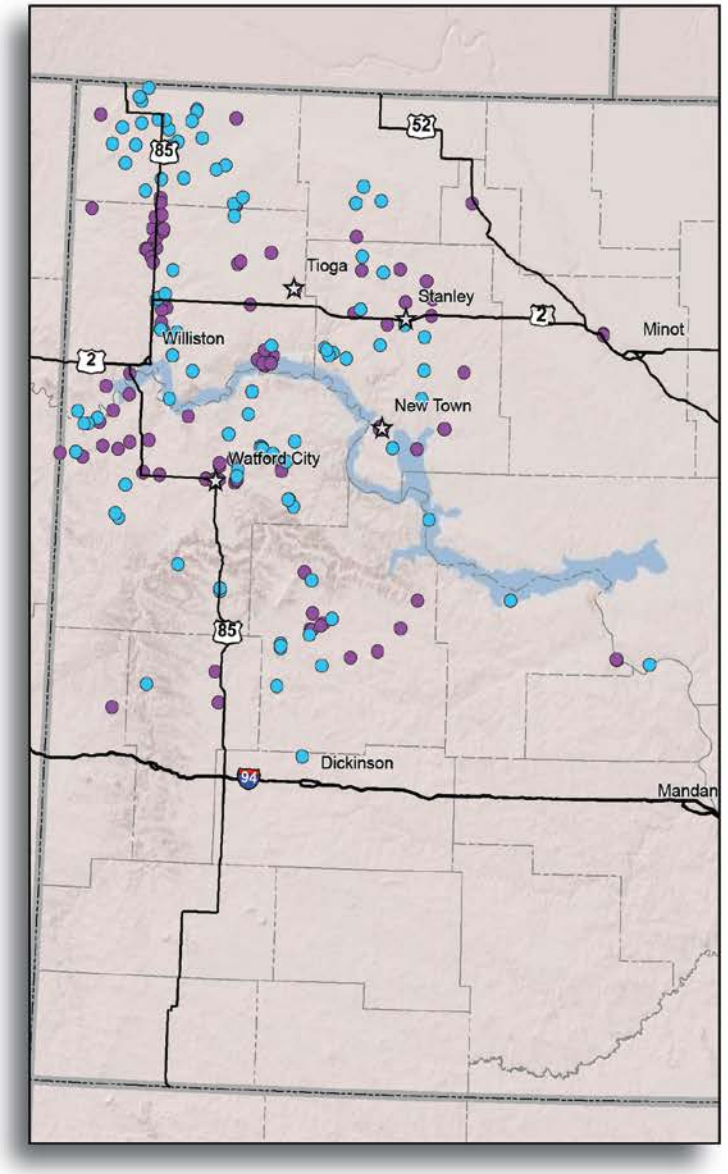
- Surface Water (WAWS) = 45.4 MMbbls
- Surface Water (All Remaining Permits) = 132.7 MMbbls
- Ground Water Permits = 67.3 MMbbls

Data provided by the ND Office of the State Engineer, Sept. 16, 2016

2008




2013




| Active Water Supply Locations By Year | 2008 | 2010 | 2013 |
|---|---|---|---|
| Water Permit | 23 | 48 | 121 |
| Temporary Permit | 2 | 4 | 108 |

0 25 50
miles

Data Source: ND SWC

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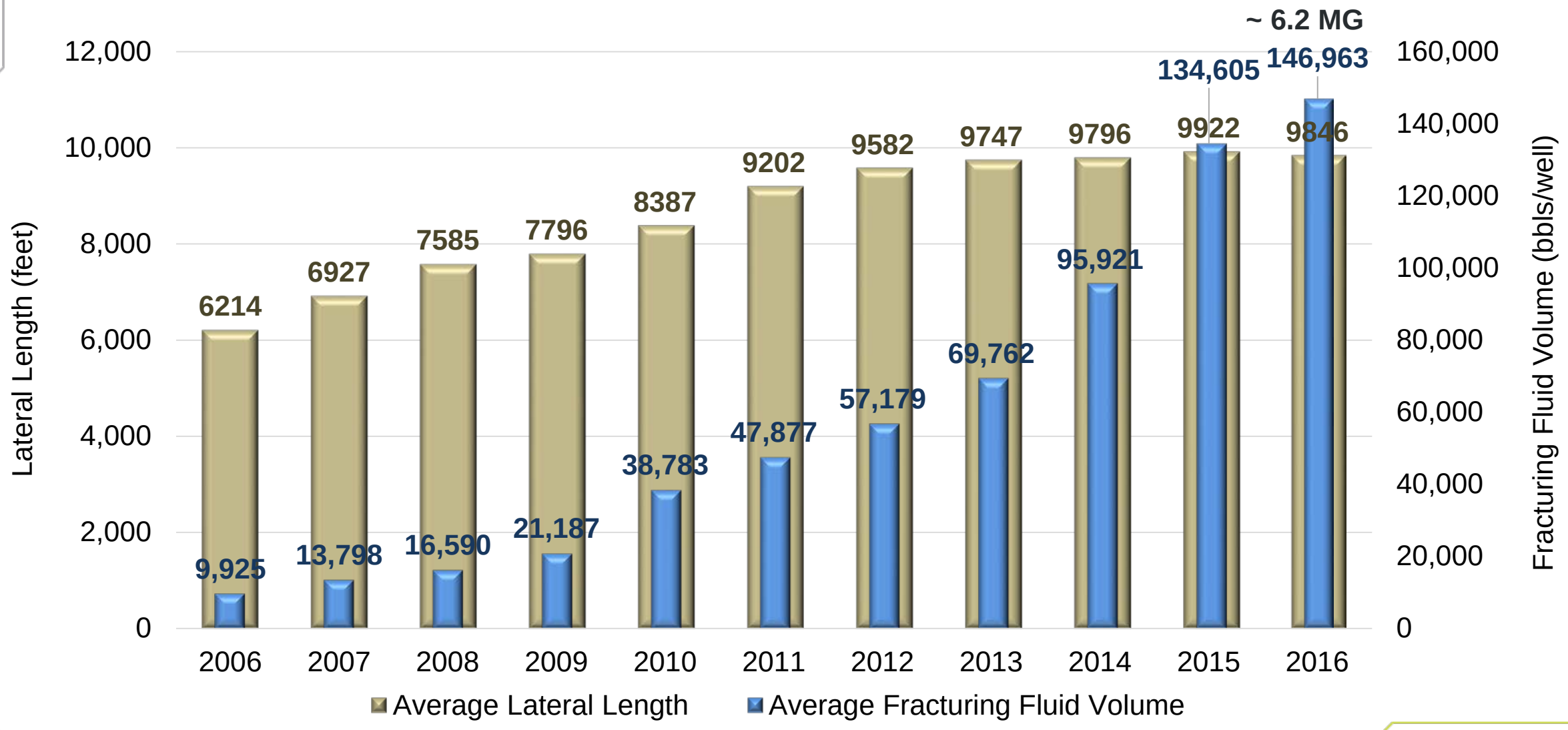
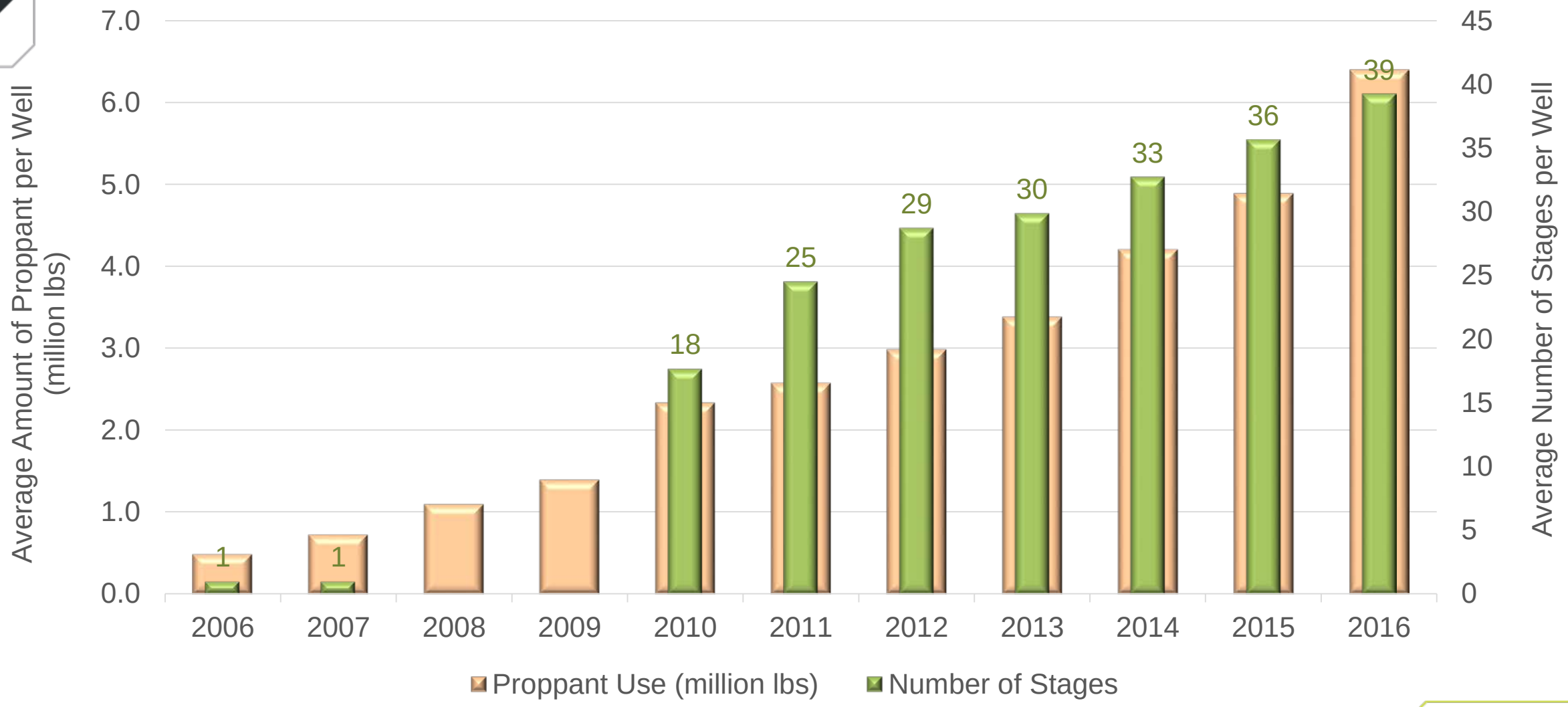
# TRENDS IN LATERAL LENGTH AND FRACTURING FLUID VOLUMES



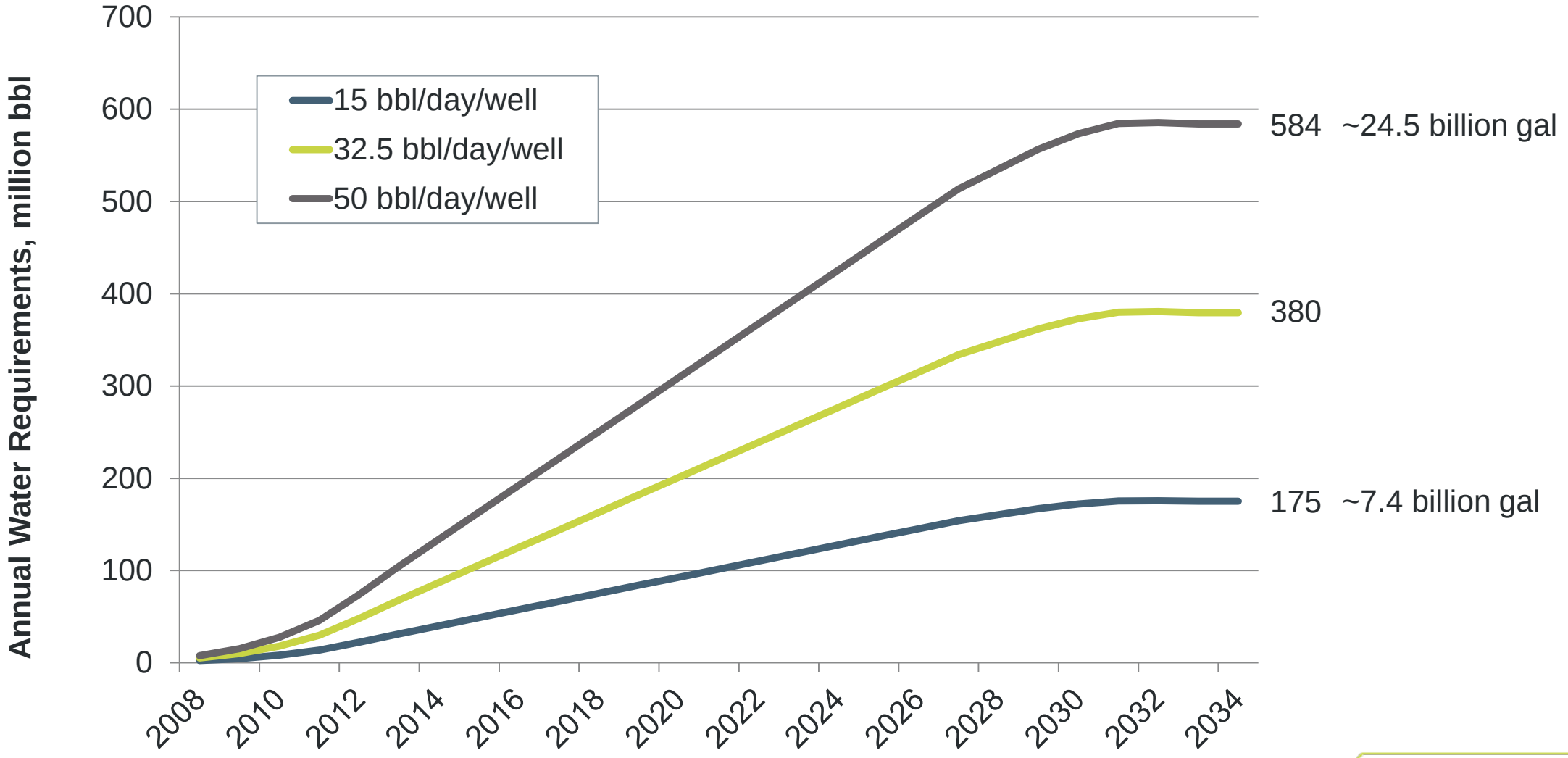
# TRENDS IN PROPPANT USE AND FRACTURING STAGES



# MAINTENANCE WATER NEEDS

- Also called brine dilution and well flushing.
- DMR estimates ~15 bbl (630 gal) per day per well.
- EERC partners have indicated higher volumes are sometimes used – 30–50 bbl (1260–2100 gal) per day per well.
- Initial EERC projection assumed (based on activity in late 2014/early 2015):
  - 2000 new wells drilled per year until 2035.
  - 20% of wells require no maintenance water.
  - 80% of wells require maintenance water that ranges from a low of 15 bpd/well to a high of 50 bpd/well.
  - An average well lifetime of 20 years.

# PROJECTED FUTURE MAINTENANCE WATER NEEDS



# EERC'S INITIAL MAINTENANCE WATER ESTIMATES MAY BE HIGH

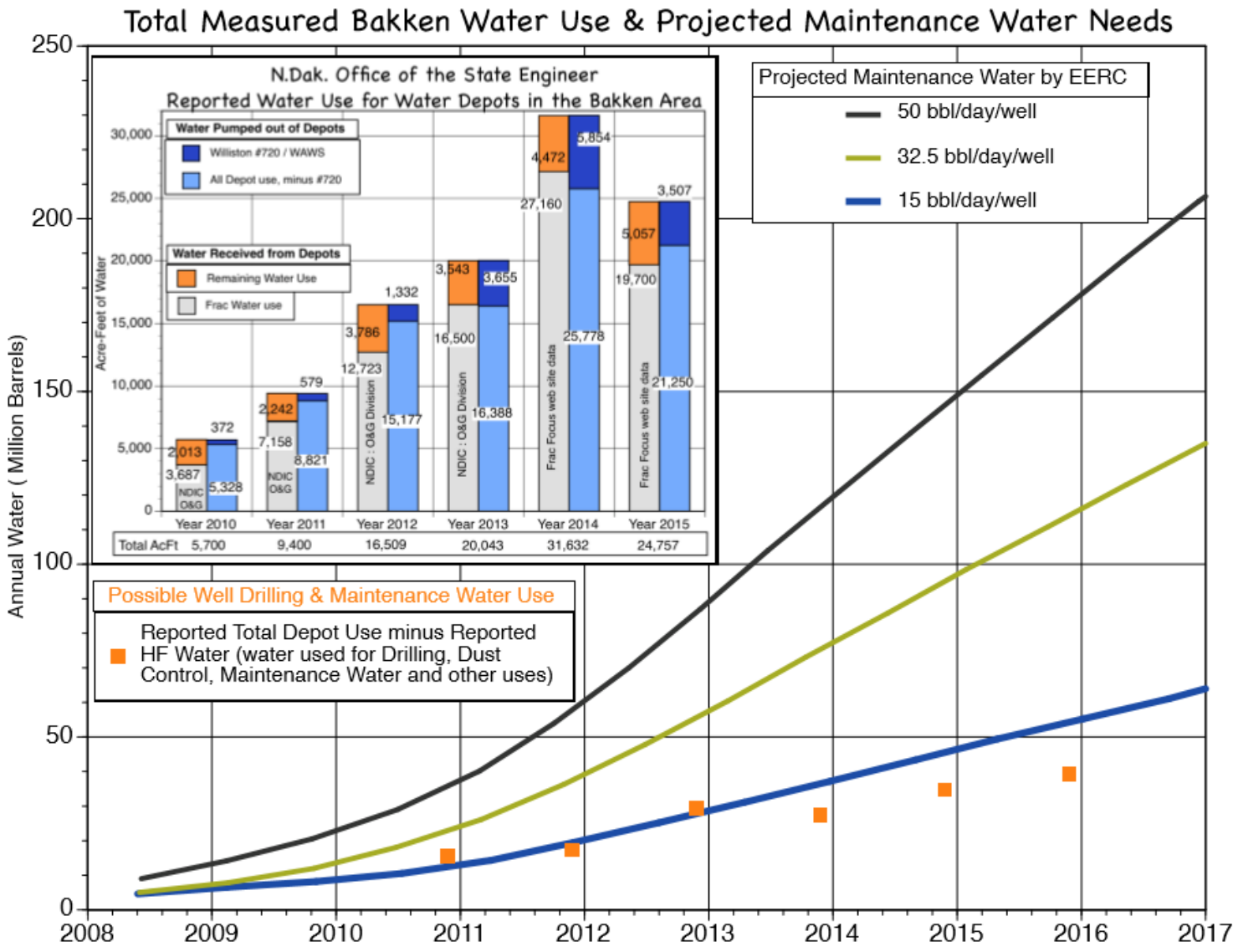
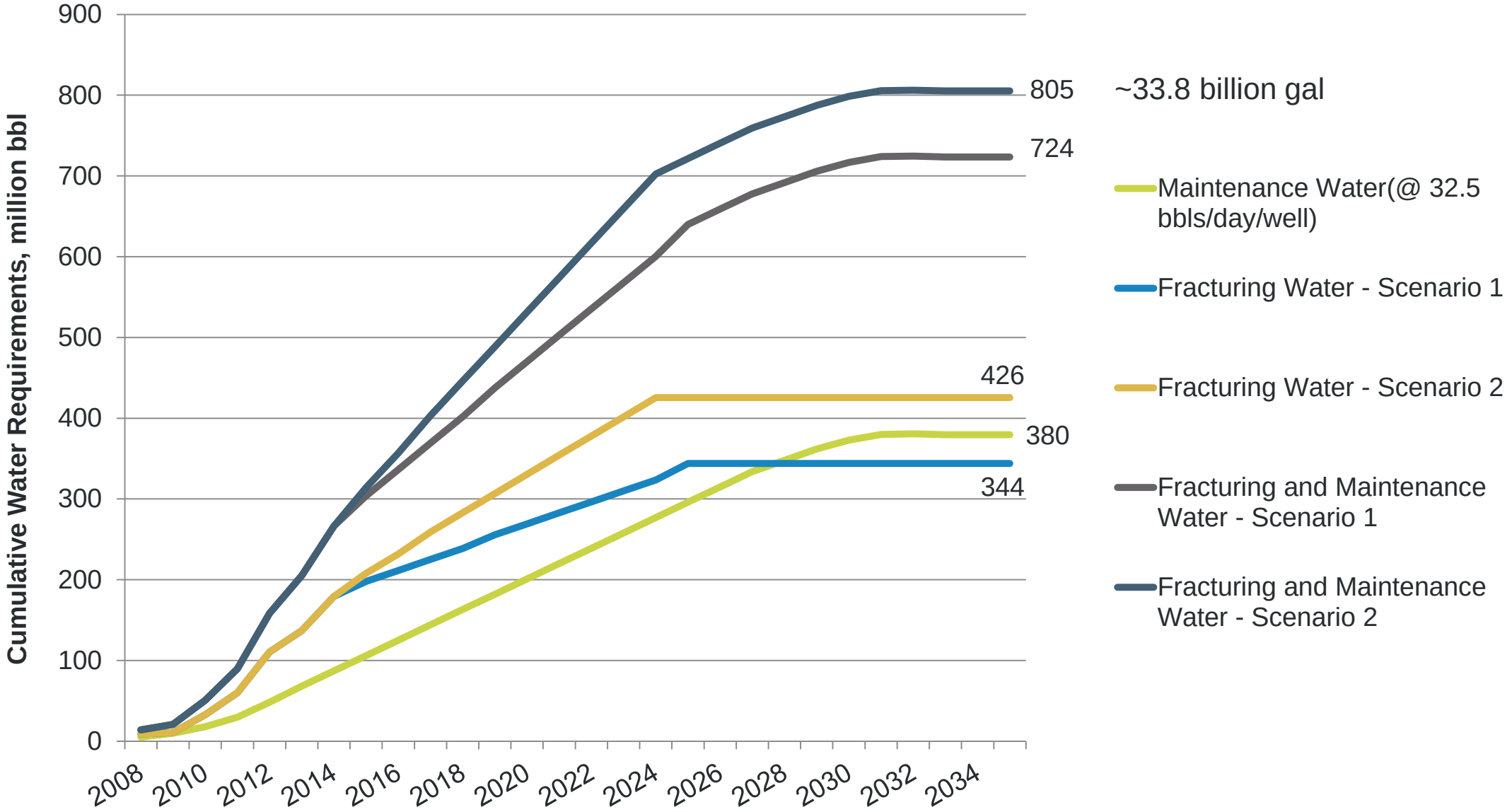



Chart provided by the ND Office of the State Engineer (Mike Hove), Sept. 2016.

# PROJECTED FUTURE FRACTURING WATER NEEDS

- Assumed freshwater is used for well stimulation.
- Assumed 2000 new wells drilled per year until 2035.
- Scenario 1:
  - Assumed 4% annual increase in slickwater stimulations for the next 10 years.
- Scenario 2:
  - Assumed 7% annual increase in slickwater stimulations for the next 10 years.
- Assumed that after 10 years, a plateau is reached.

# PROJECTED FUTURE FRACTURING AND MAINTENANCE WATER NEEDS

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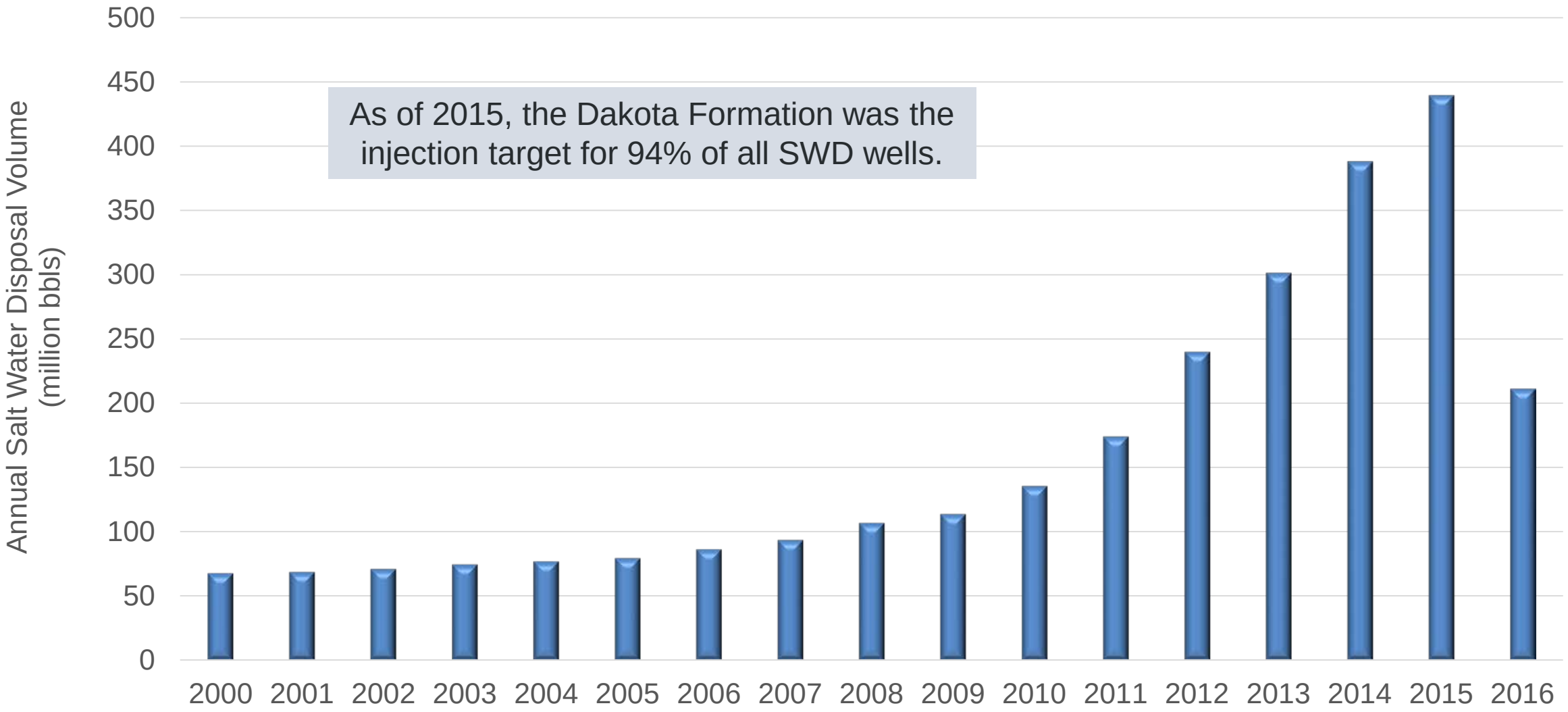
# SALTWATER DISPOSAL (SWD) IN NORTH DAKOTA




As of 2015, the Dakota Formation was the injection target for 94% of all SWD wells.

**Data Source: ND SWC**



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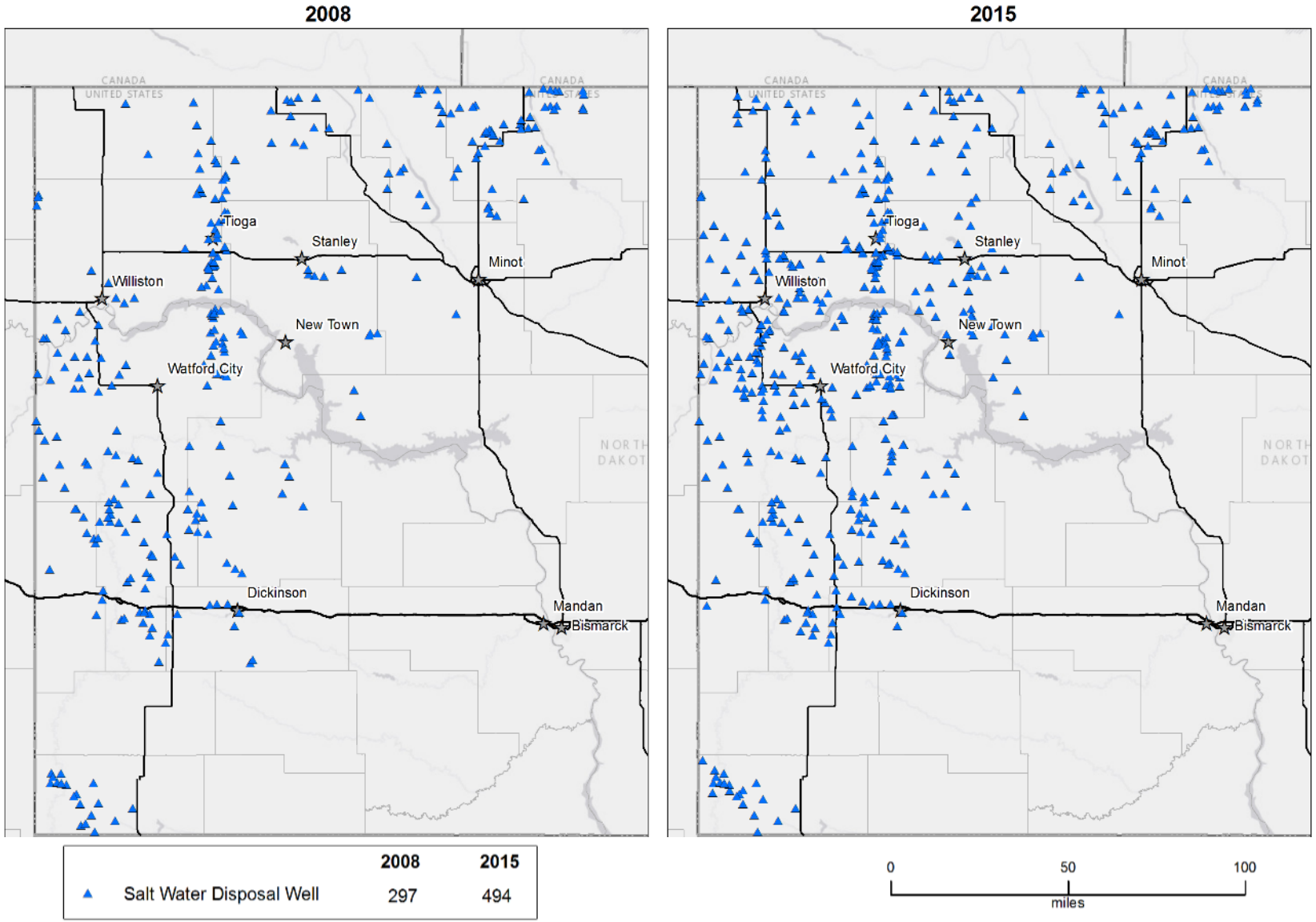
# SWD WELLS IN THE DAKOTA




Data Source: ND SWC



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# BAKKEN PRODUCED WATER

| Year | Total SWD,[1] million bbl/yr | Bakken Produced Water Volume, million bbl/yr | % of Total SWD from Bakken Produced Water |
|---|---|---|---|
| 2008 | 107 | 6 | 6 |
| 2009 | 114 | 12 | 11 |
| 2010 | 136 | 33 | 24 |
| 2011 | 174 | 64 | 37 |
| 2012 | 239 | 130 | 54 |
| 2013 | 301 | 190 | 63 |
| 2014 | 388 | 281 | 72 |
| 2015 | 439 | 334 | 76 |

[1] Data Source: ND SWC

# PROJECTED BAKKEN PRODUCED WATER GENERATION

- Assumes 2000 wells drilled per year.
- Based on average Bakken produced water volumes for 2012–2014 (~26,000 bbl/year/well).

| Year | Estimated Number of Bakken Wells | Estimated Annual Bakken Produced Water Generation, million bbl |
|---|---|---|
| 2020 | 21,183 | 551 |
| 2025 | 31,183 | 811 |
| 2030 | 39,290 | 1021 |
| 2035 | 40,000 | 1040 |

# ESTIMATED FUTURE DISPOSAL NEEDS

2014 disposal volumes: ~386 million bbl in 487 SWD wells.

- Average annual injection volume per SWD well: 793,000 bbl.

| Year | Add'l Disposal Wells Needed for Produced Water Disposal | Add'l Disposal Wells Needed for Maintenance Water Flowback | Total Estimated Add'l Disposal Wells Needed |
|---|---|---|---|
| **2025** | 671 | 372 | **1043** |
| **2035** | 998 | 479 | **1477** |

# TECHNOLOGICAL ADVANCES RELATED TO WATER-RECYCLING/REUSE FEASIBILITY

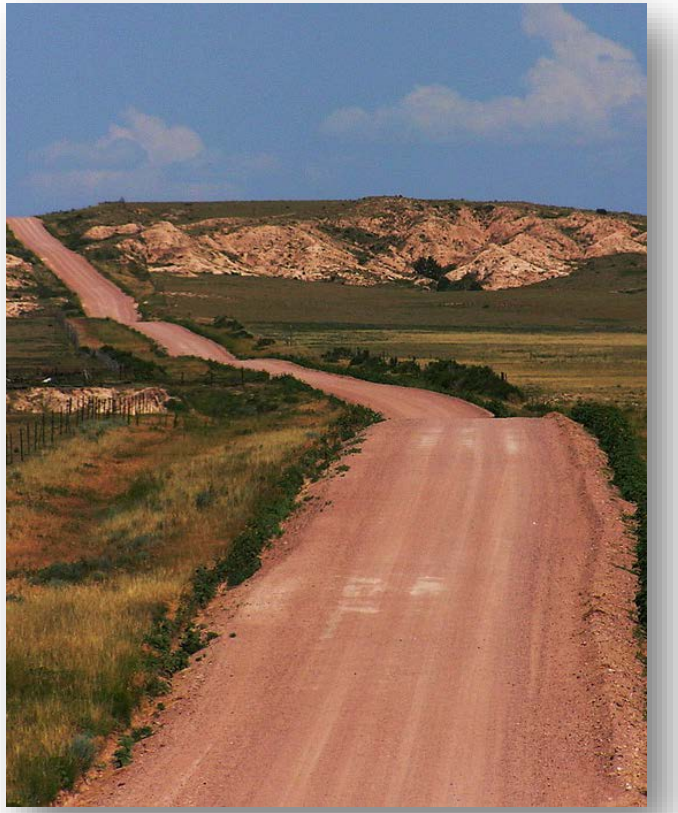
- Development of more robust salt-tolerant fracture fluid systems.
  - Treatment to potable quality not required.
  - Suspended solids and iron removal sufficient in many cases.
- Potential for novel treatment (forward osmosis).
- Increased saltwater-gathering pipelines and centralized storage facilities.

# WATER-RECYCLING AND REUSE DETERRENTS

- Relatively inexpensive freshwater supplies.
- Expanded freshwater supply infrastructure.
- Relatively abundant water supplies in the Missouri River system.
- Numerous deep-well disposal sites, and no major concerns with induced seismicity.
- High Bakken formation water salinity.
- Logistics and safety issues with large volumes of saltwater storage and regulations preventing open tank or pit storage.

# WATER-RECYCLING AND REUSE DRIVERS

- High transportation costs.
- Issues associated with trucking.
  - Road maintenance costs.
  - Dust generation and air emissions.
- Projected future freshwater demand and large volumes of produced water generation.
- Potential occurrence of a drought that limits freshwater availability.



# FUTURE DISPOSAL CONCERNS

- Does the Dakota Sandstone have the capacity to handle future disposal needs?
- Where might we run into disposal issues (because of geology, proximity to other wells, pressurization)?
- Are there areas that we should target for siting of future SWD wells?

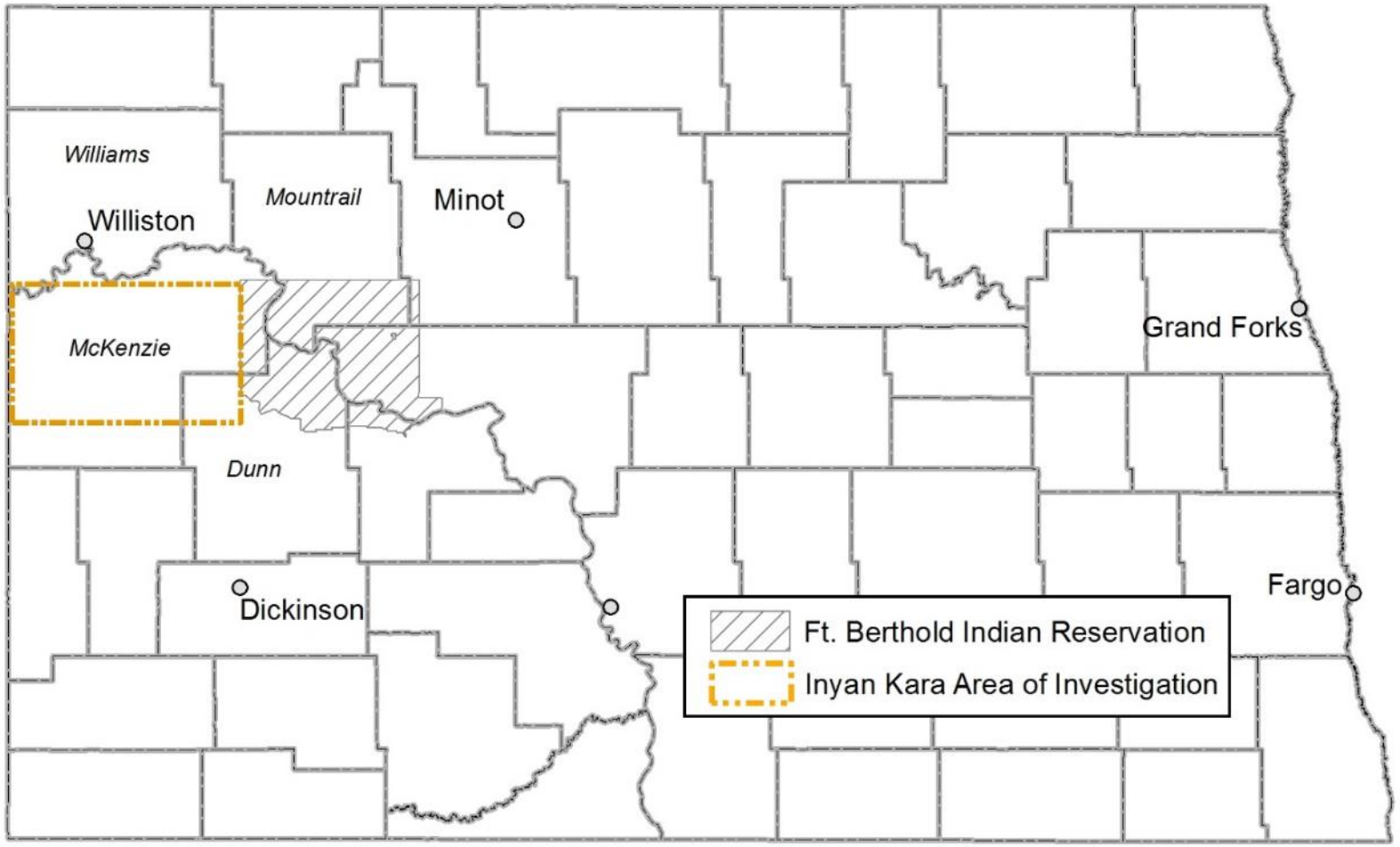
Photo: VWS Oil and Gas

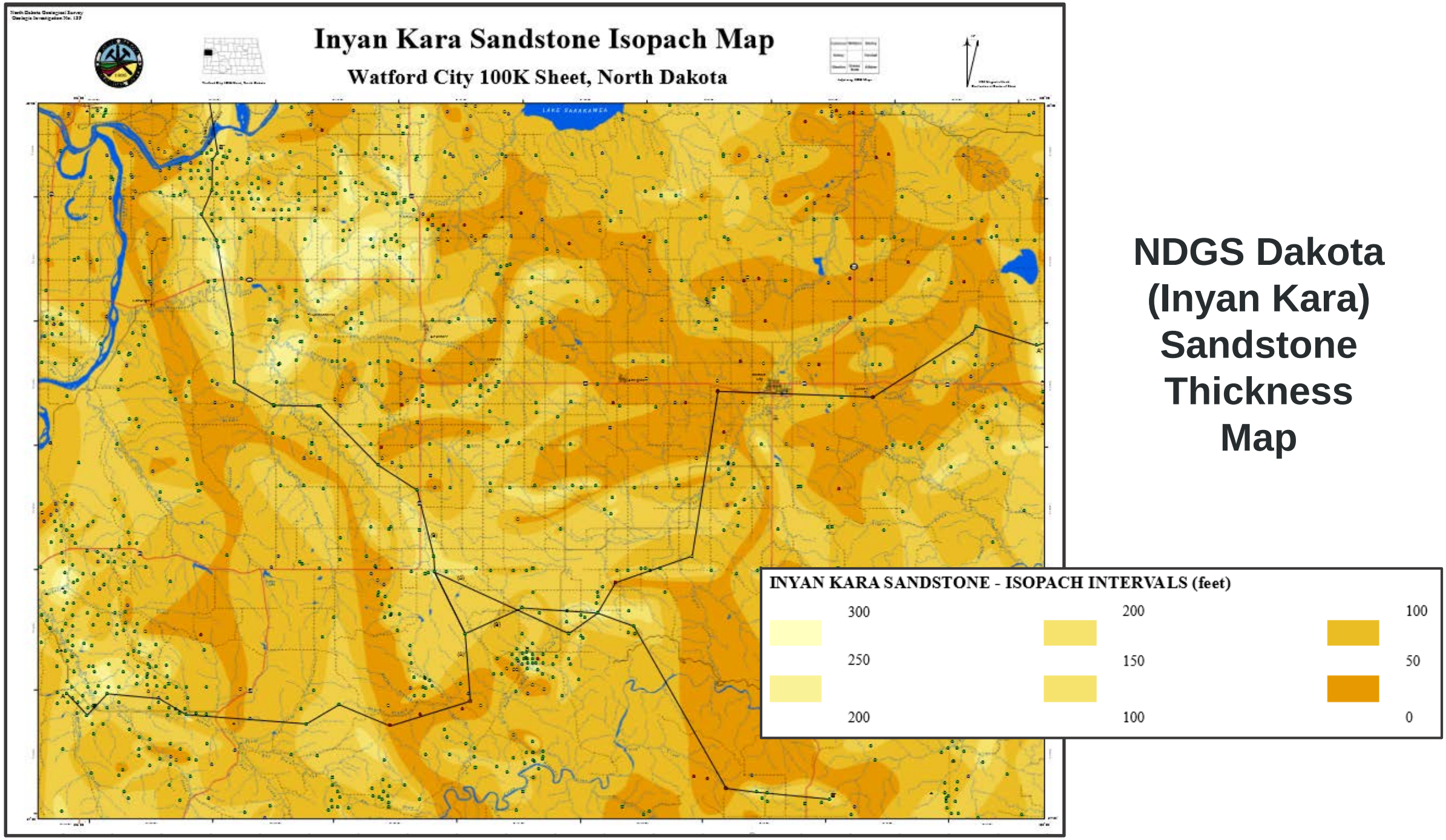
# DAKOTA SANDSTONE (INYAN KARA) SWD CAPACITY ASSESSMENT

- Goals:
  - To evaluate the disposal capacity of the Dakota.
  - To predict locations where additional disposal may be optimal or problematic based on formation geology and proximity to existing SWD wells.
- Includes collaboration with DMR/North Dakota Geological Survey (NDGS) which has a project under way to map the clean sand intervals within the Dakota.
- Approach is to develop a more detailed geologic model within the area currently mapped by NDGS as well as broad-scale geologic modeling for the remaining Bakken region.

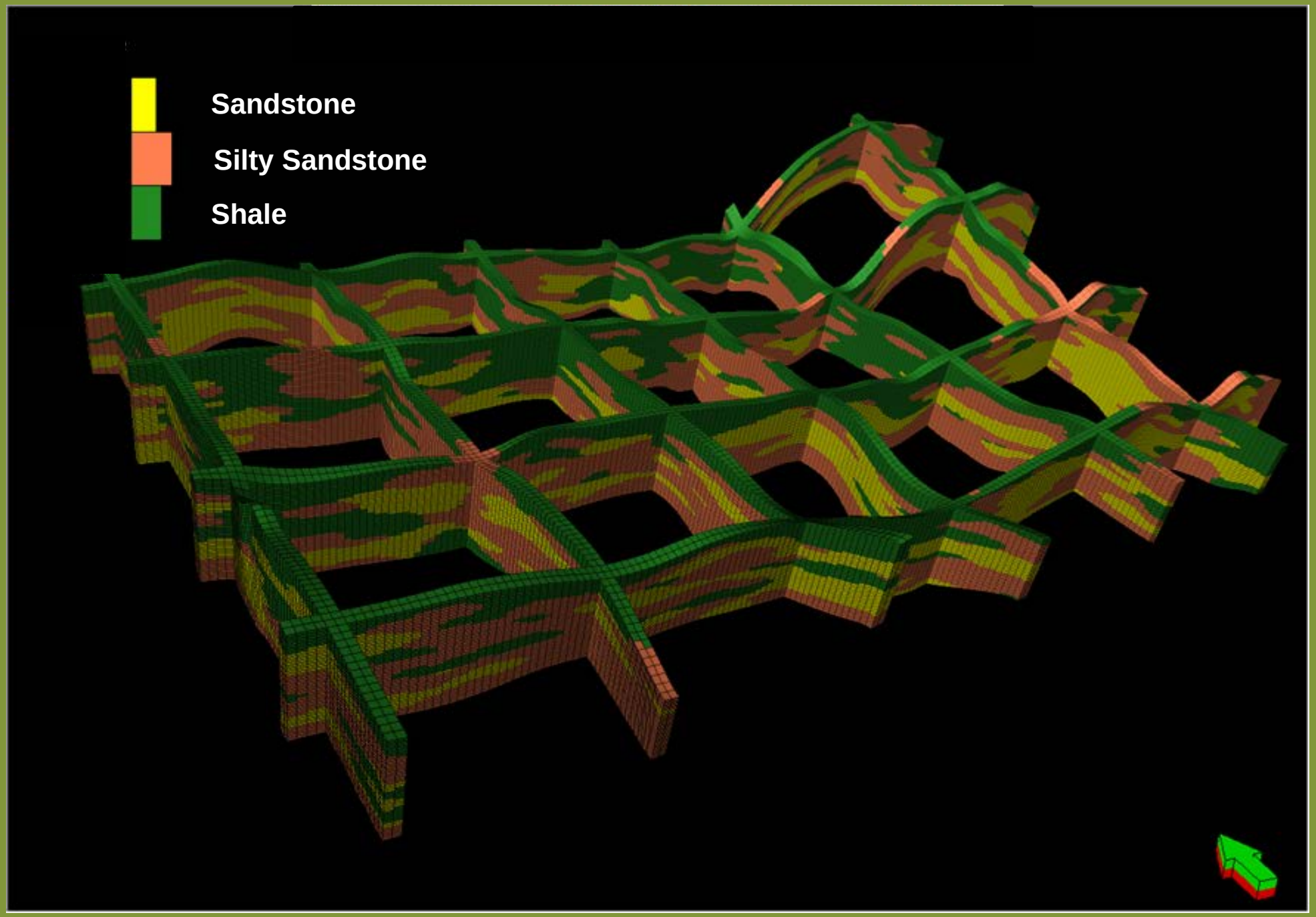
# DAKOTA (INYAN KARA) DETAILED MODELING EXTENT

~2400 square miles






# NDGS Dakota (Inyan Kara) Sandstone Thickness Map


Sandstone
Silty Sandstone
Shale

# ONGOING MODELING AND RELATED WORK

- The models will be used to simulate several scenarios, including current practices and multiple potential future scenarios.
  - This will aid in identifying areas that may experience pressurization issues in the future and to target areas for future SWD well siting.
- Efforts are under way to use decline curve analysis to better understand how water (and oil and gas) production varies from field to field over time.
  - This will allow us to more accurately estimate what future produced water volumes may look like.
- An evaluation of potential alternate SWD targets is proposed as an activity through Phase 2 of the Bakken Production Optimization Program.

http://travelnd.areavoices.com/2011/05/12/add-american-landmarks-to-your-summer-travel-plans/

# CONTACT INFORMATION

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

**www.undeerc.org**
701.777.5050 (phone)
701.777.5181 (fax)

**Bethany Kurz**
**Principal Hydrogeologist**
bkurz@undeerc.org