APPENDIX E

UNITIZATION AND ENHANCED RECOVERY TECHNIQUES

ND State Legislature
Interim Taxation Committee
Bismarck, ND
April 27, 2016

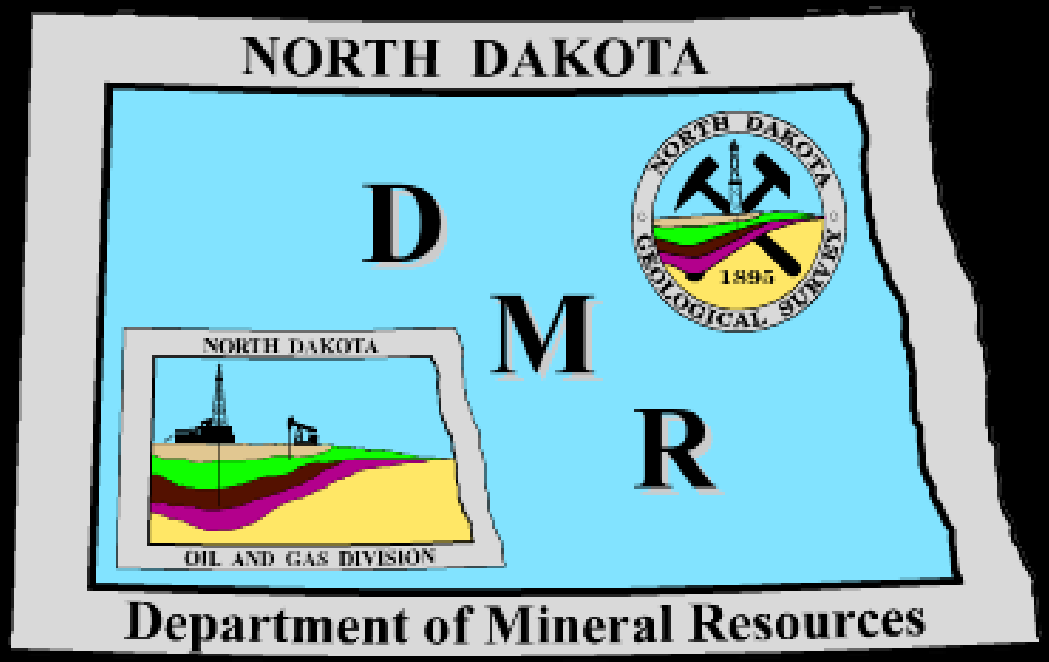
NORTH DAKOTA
D M R
Department of Mineral Resources

Unitization and Enhanced Oil Recovery

- Unitization Process
- Units Approved
- EOR Results
- Bakken Development
- Bakken EOR Potential

Bruce E. Hicks
Assistant Director
NDIC-DMR-OGD
Bismarck, ND

North Dakota Department of Mineral Resources



https://www.dmr.nd.gov/oilgas/ *https://www.dmr.nd.gov/ndgs/*

600 East Boulevard Ave. - Dept 405
Bismarck, ND 58505-0840
(701) 328-8020 *(701) 328-8000*

https://www.dmr.nd.gov/oilgas/ | dmr.nd.gov

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North Dakota | North Dakota vs Vermont ... | North Dakota vs Vermont ... | County Info | 64th Legislative Assembly ... | An error has occurred | Bismarck News, Weather, ...

North Dakota nd.gov Official Portal for North Dakota State Government

Services

- Rules & Regulations
- Policies & Guidance
- Forms
- Hearing Dockets
- Active Drilling Rigs
- Daily Activity Reports
- Information Center
- Confidential Well List
- General Statistics
- Seismic
- Well Search
- Report a Spill/Incident
- Gathering Pipelines
- GIS Map Server
- Publications
- Surface Mineral Owner
- Basic Services
- Premium Services
- Electronic Filing
- Related Links
- FAQ & Web Help
- Employment Opportunities

Contact Us

- Employee Directory
- Email Addresses

NORTH DAKOTA
OIL AND GAS DIVISION

Welcome to the North Dakota Industrial Commission, De
and Gas Division, home p

Please check out the new Information Center and Pol

Proposed Rule Changes and Adoption of New Rules

Rule Changes Full Notice

General Guidelines for Temporary Abandonment of Wells

Bakken and Three Forks Information!

Available on the ND Petroleum Council web site are the Surface Owner Information Center, the Royalty O

The Oil and Gas Division regulates the drilling and production of oil and gas in North Dakota. Our mission is to encourage and promote the development, production, and utilization of oil and gas in the state in such a manner as will prevent waste, maximize economic recovery, and fully protect the correlative rights of all owners to the end that the landowners, the royalty owners, the producers, and the general public realize the greatest possible good from these vital natural resources.

Phone: (701) 328-8020
Fax: (701) 328-8022
Mail:
NDIC Oil and Gas Divisi
600 East Boulevard Ave
Bismarck, ND 58505-08
General Shipping:
NDIC Oil and Gas Divisi

Activity | https://www.... | Department ... | Inbox - bhick... | 35 Reminders | Activity Upd...

https://www.dmr.nd.gov/oilgas/informationcenter.asp

Surface and Mineral...

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North Dakota nd.gov Official Portal for North Dakota State Government

Related Links

- Active Drilling Rigs
- Daily Activity Reports
- Confidential Well List

Information Center

The Director's Cut is an update on current activity in the North Dakota oil patch from the Director of the Department of Mineral Resources.

Tentative Director's Cut Dates

Director's Cut - 02/17/2016
Director's Cut Archive
Director's Cut Webinars

Recent Presentations

View press releases from the Oil and Gas Division

Oil and Gas Division Program Descriptions:

This section of the Information Center is dedicated to program descriptions within the Oil and Gas Division. We will be adding descriptions as they become available, so check back for further information.

Underground Injection Control Program

[DMR Home] [Disclaimer] [Privacy] [Security] [Feedback]

Activity | Surface and ... | Department ... | Inbox - bhick... | 35 Reminders | Activity Upd...

Unitization and Enhanced Oil Recovery

- **Unitization Process**
- Units Approved
- EOR Techniques & Results
- Bakken Development
- Bakken EOR Potential

Unitization Process

NDCC Sec 38-08-09.3

- **Project substantially increases oil recovery**
- **EOR unnecessary for approval**
- **Voluntary and Statutory Units**
  - **both require Commission approval**

Unitization—Statutory Approval

NDCC Sec 38-08-09.5

- **60% mineral interest owner approval**
- **60% working interest owner approval**
- **NDIC approval**

Unitization and Enhanced Oil Recovery

- Unitization Process
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Units Approved

- 127 Units approved
  - 124 EOR w/fluid injection
    - Most water injection
    - high pressure air (8)—fire flood
    - also propane, CO_2, polymers, N_2, + other fluids
  - 3 created to increase reserves w/o injection
    - Little Missouri-Pierre Unit—shallow gas reservoir
    - Cedar Creek-Pierrre Unit—shallow gas reservoir
    - Corral Creek-Bakken Unit

Bakken Units

- Corral Creek-Bakken Unit
  - Effective 1-1-2012
  - 30,884 acres
  - increased reserves over 5 million barrels of oil
  - 81 wells originally planned
  - 122 wells drilled currently
  - 194 wells currently planned
  - EOR not planned initially
    - EOR only after due notice and hearing
- Grail-Bakken Unit
  - 24,947 acres
  - failed to achieve 60% MIO approval

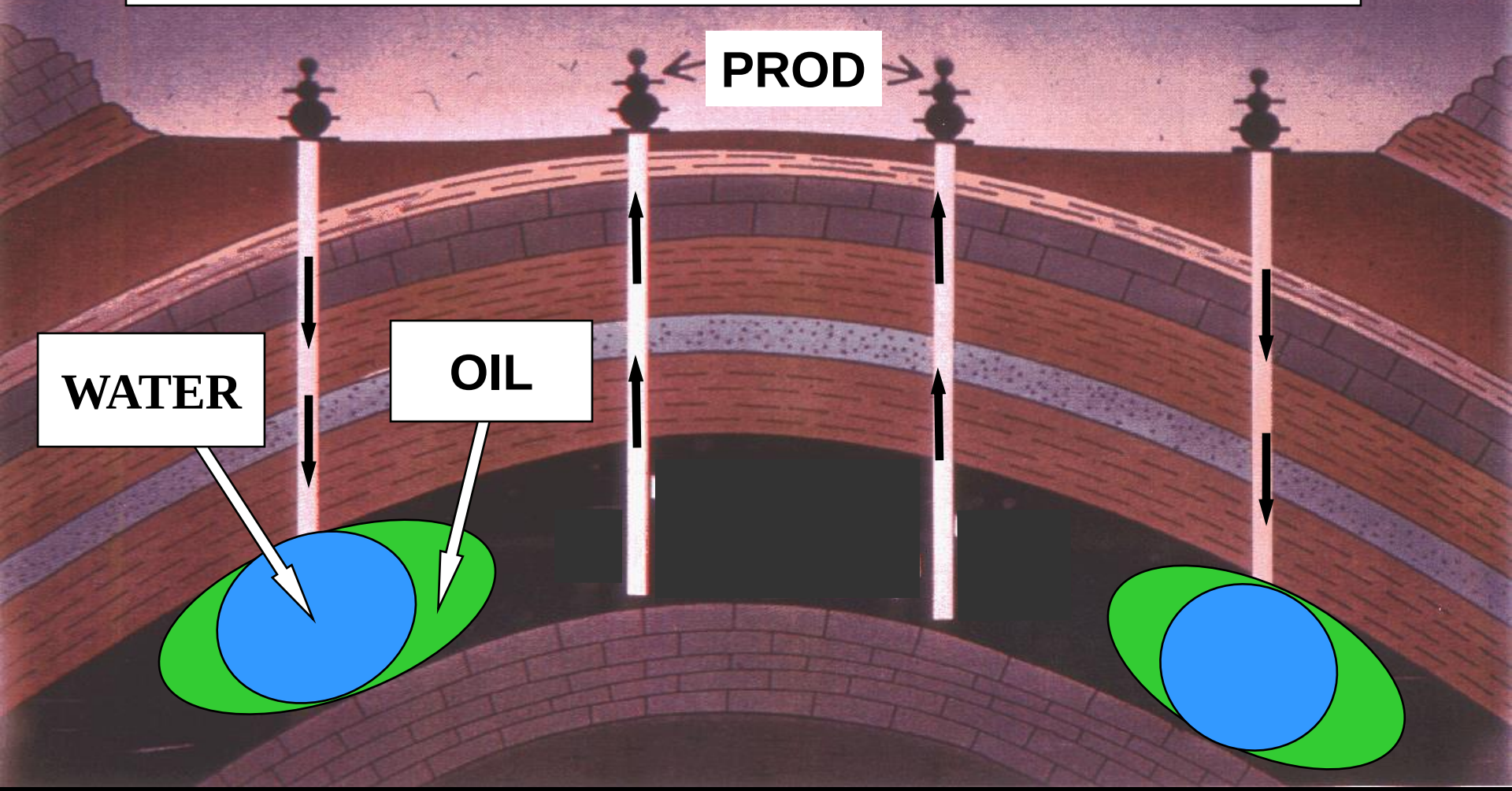
Unitization and Enhanced Oil Recovery

- Unitization Process
- Units Approved
- **EOR Techniques & Results**
- Bakken Development
- Bakken EOR Potential

Unitization and Enhanced Oil Recovery

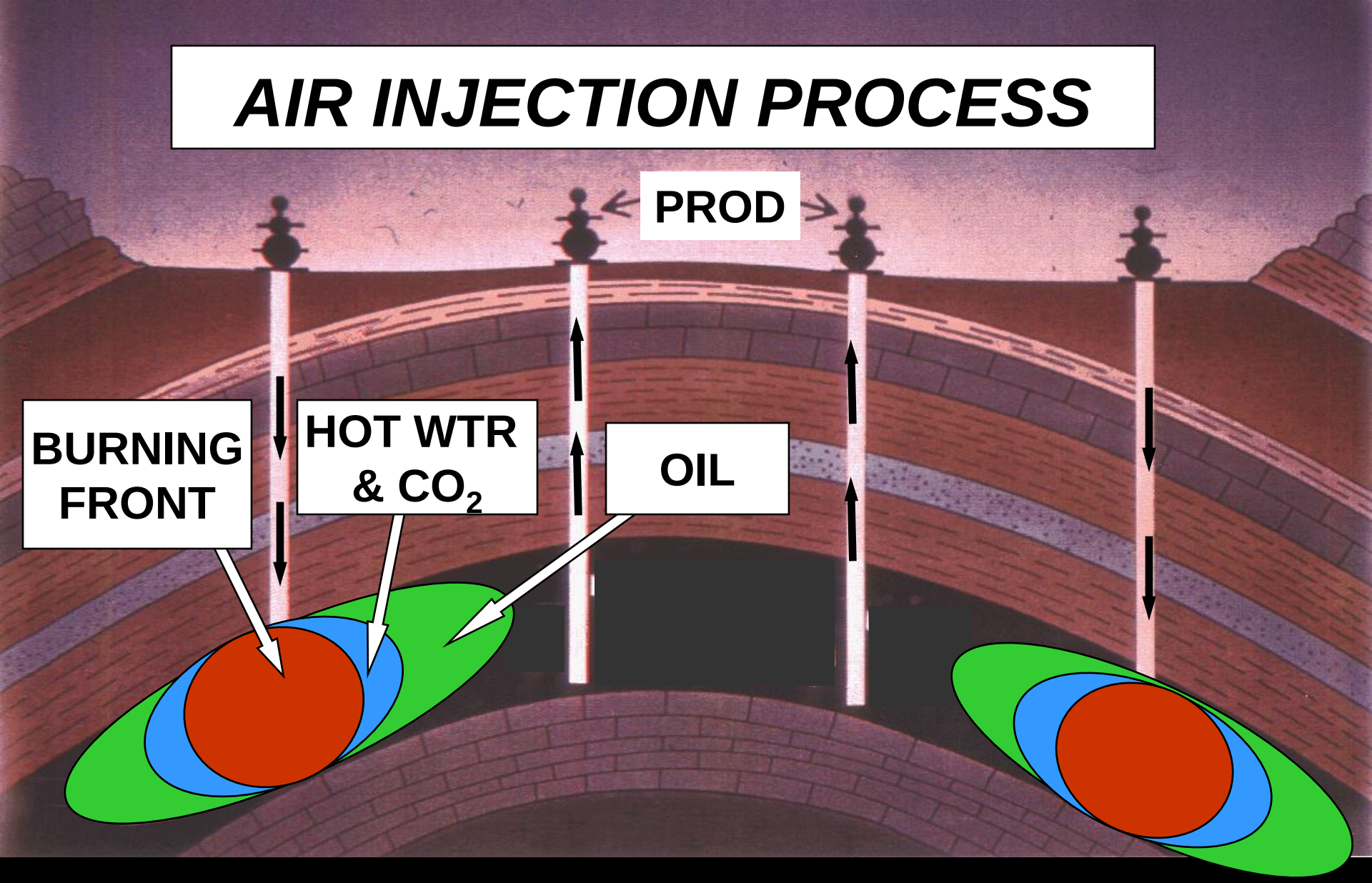
- Conventional Oil Reservoir
  - Primary 15% recovery
  - Secondary add 15% recovery
  - Tertiary add 10% recovery
  - 40% recovery of Original Oil in Place (OOIP)
- Unconventional Oil Reservoir
  - Bakken-Three Forks Formations
  - 3% Primary recovery / well
  - Secondary & Tertiary recovery ?

WATER INJECTION PROCESS



N. D. I. C.
Oil & Gas Div.

AIR INJECTION PROCESS



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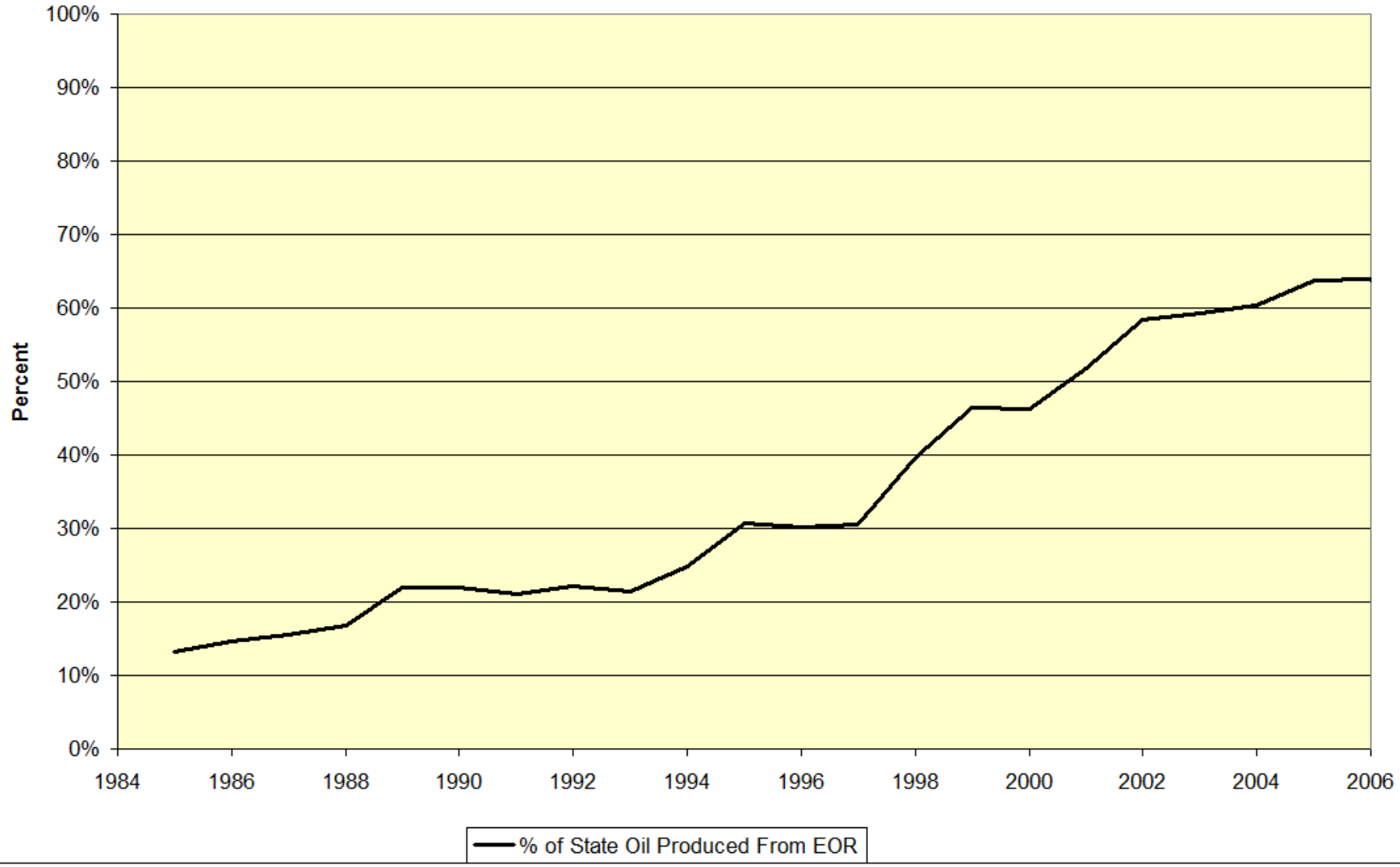
Unit Production



MS Viewer - Windows Internet Explorer

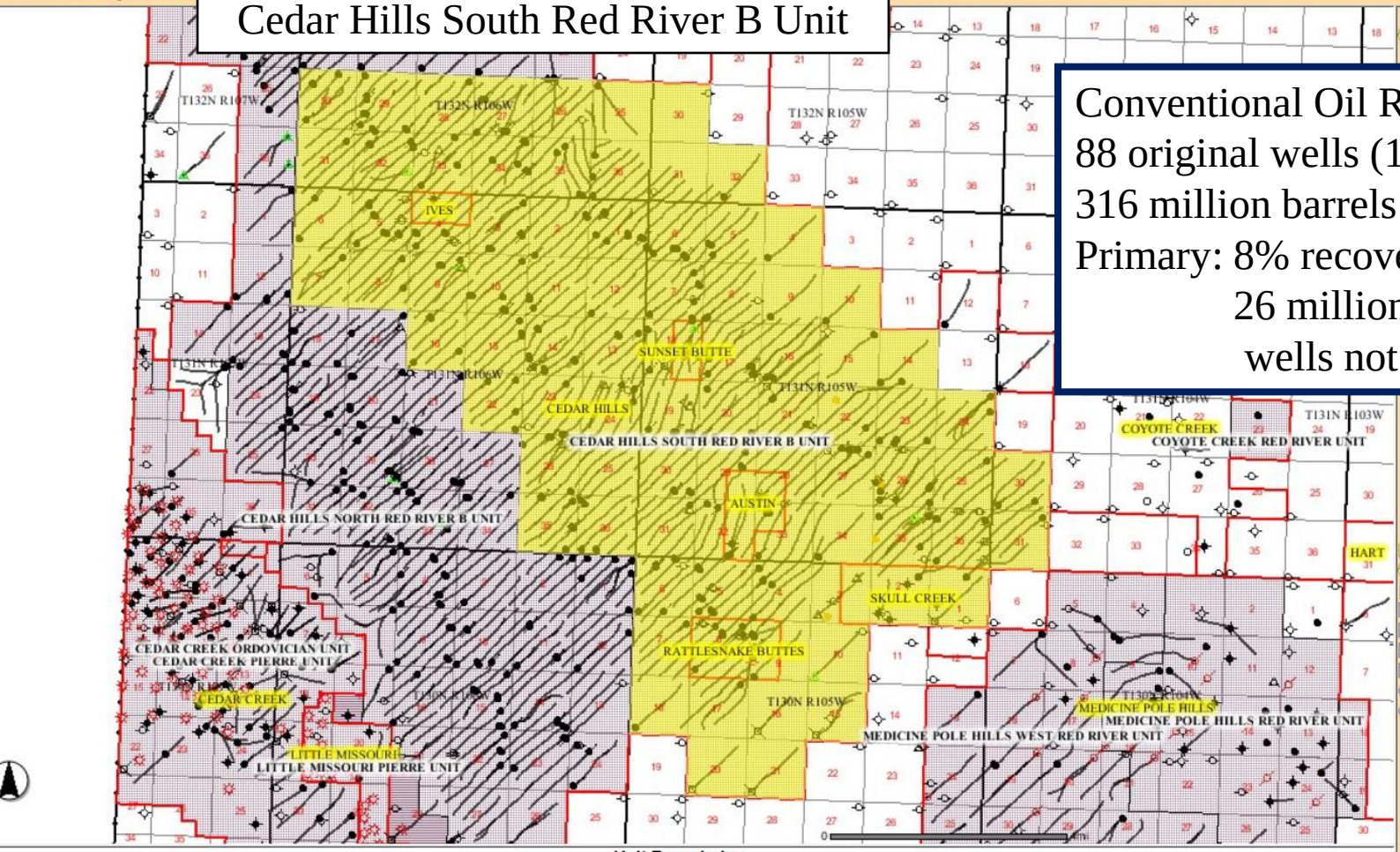
GIMSSub/viewer.htm

Subscription: ArcIMS Viewer

Download Shape Files

Cedar Hills South Red River B Unit

Conventional Oil Reservoir
88 original wells (1H/640)
316 million barrels OOIP
Primary: 8% recovery of OOIP
26 million bo
wells not fraced



ND OIL & GAS LAYERS
Oil and Gas
Wells
Topo/DRG 100k
NAIP 2014

Refresh Map
Auto Refresh

Help:
A closed group, click to open.
An open group, click to close.
A map layer.
A hidden group/layer, click to make visible.
A visible group/layer, click to hide.
A visible layer, but not at this scale.
A partially visible group, click to make visible.
An inactive layer, click to make active.
The active layer.

Unit Boundaries

Rec	Name	Unitized Formations	Operator
1	CEDAR HILLS SOUTH RED RIVER B UNIT	Red River B	DENBURY ONSHORE, LLC

Map Data Last Updated : 4/19/2016

125%

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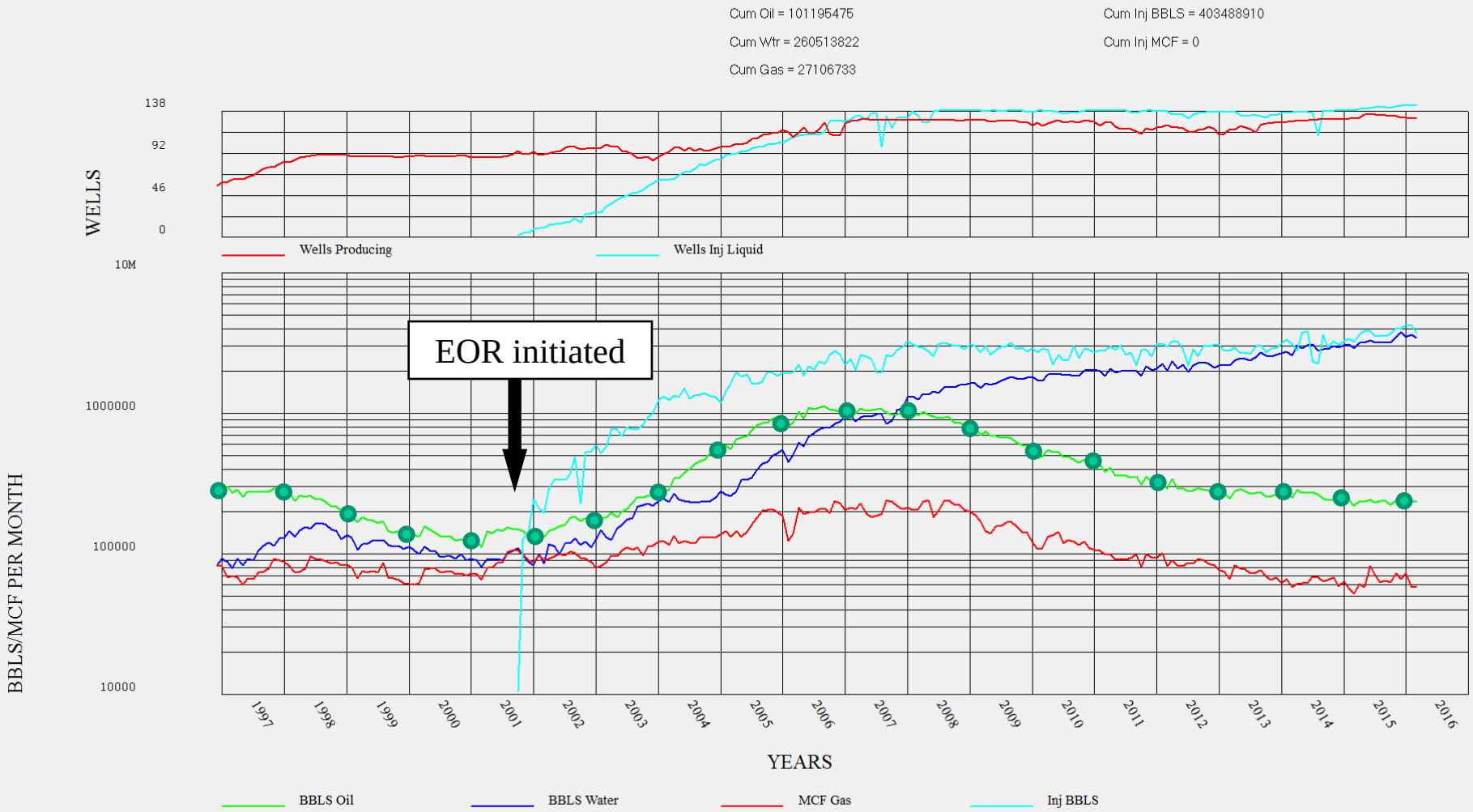
4/25/2016

Cedar Hills South Red River B Unit



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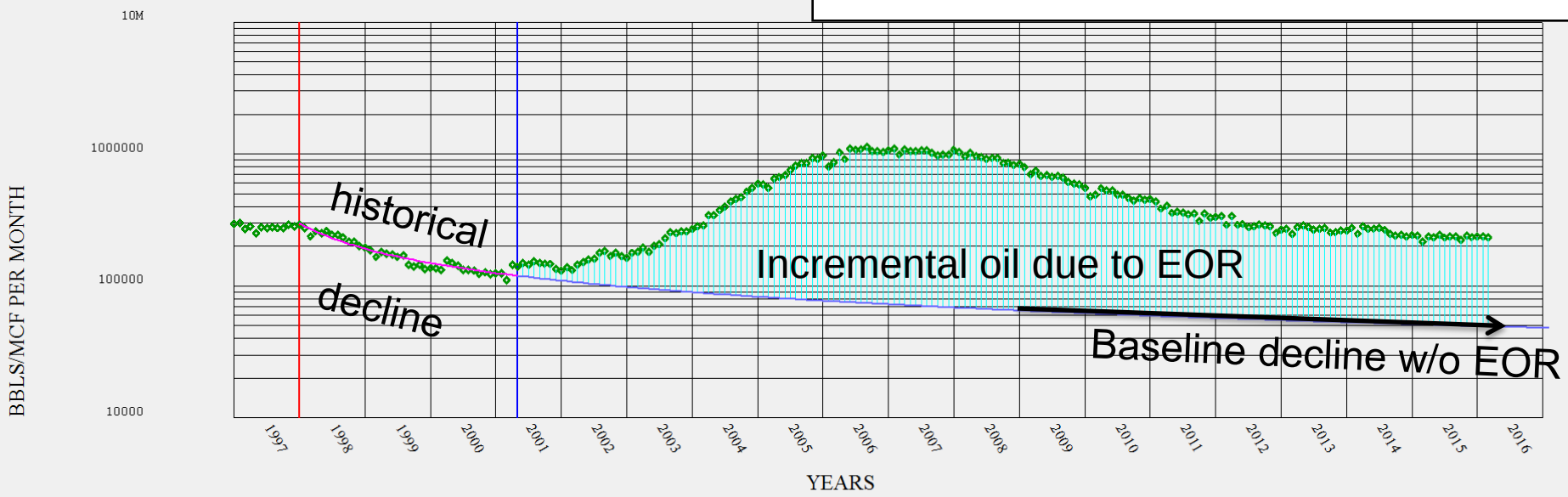
Cedar Hills South Red River B Unit

Incremental Oil Determination
- establish historical decline
- project baseline decline w/o EOR
- calculate oil above the base

Cedar Hills South-RR ”B” Unit
- EUR w/o EOR = 26 mil bo
- current Incremental = 74 mil bo
- current oil cum = 101 mil bo



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Unitization and Enhanced Oil Recovery

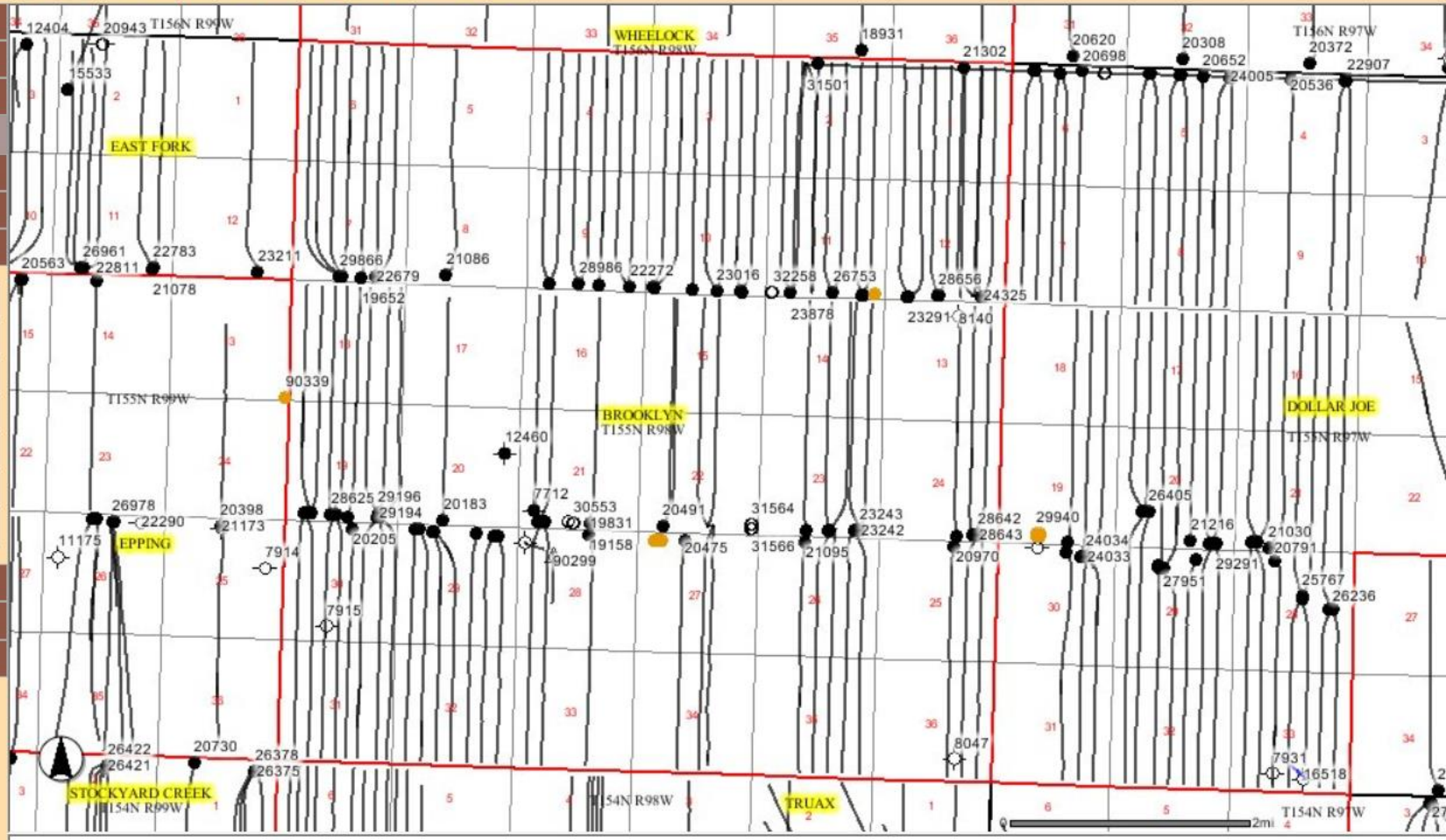
- Unitization Process
- Units Approved
- EOR Techniques & Results
- **Bakken Development—encourages EOR**
  - **Uniform Spacing—orderly development**
  - **Energy Corridors**
- Bakken EOR Potential

Oil and Gas Subscription: ArcIMS Viewer - Windows Internet Explorer

https://www.dmr.nd.gov/OaGIMSSub/viewer.htm

Oil and Gas Subscription: ArcIMS Viewer

- Legend / Layers
- Overview Map
- View Entire State
- Previous View
- Clear Selection
- Search
- Create PDF
- Zoom In
- Zoom Out
- Pan
- Rect Identify
- Select Object
- Buffer
- Distance
- Find Well
- Find Field / Unit
- Find Section



Zoom In

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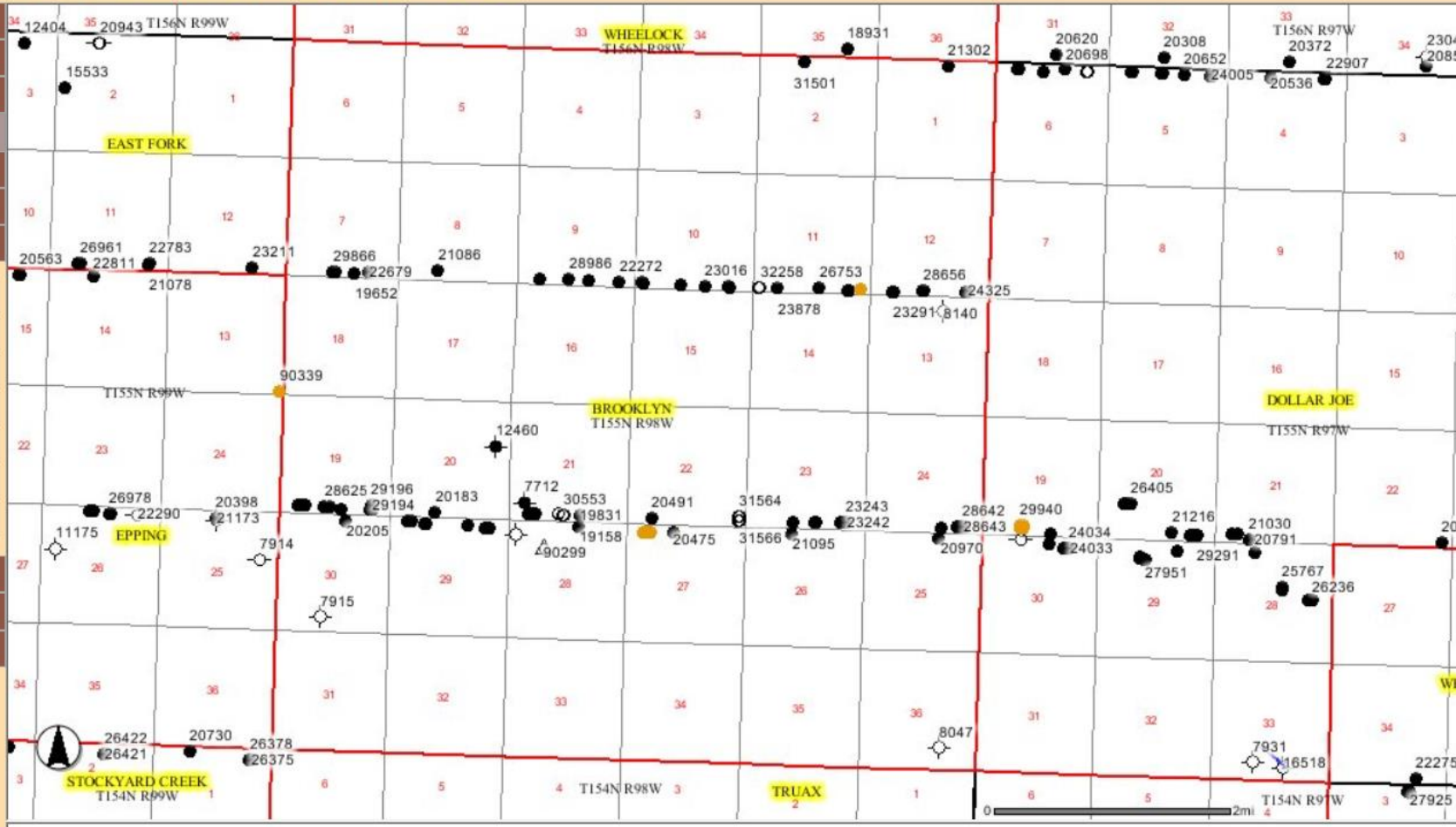


Zoom In

Vern Whitten Photography

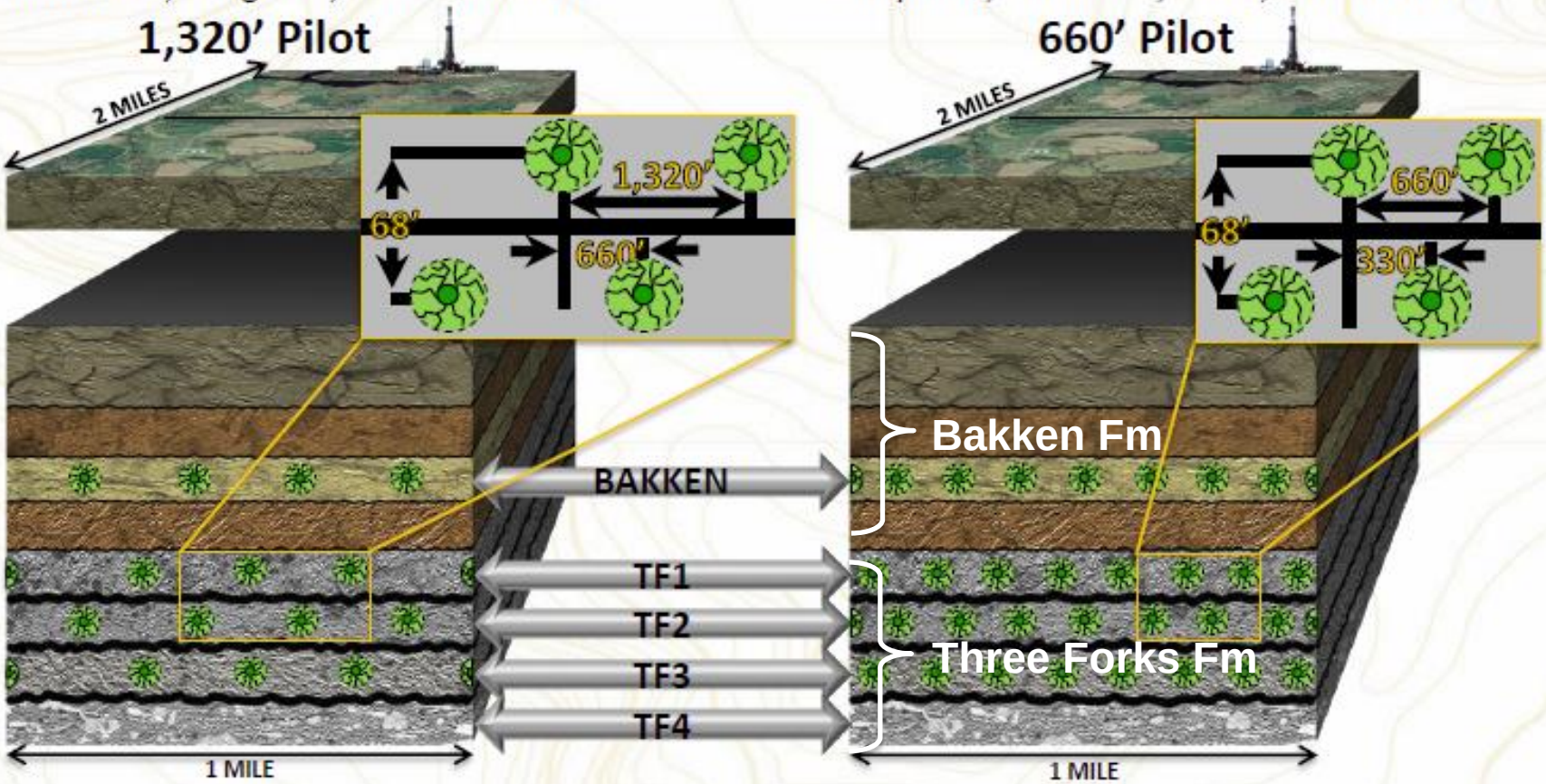
1,320' & 660' Pilot Density Projects: 2013-14

Hawkinson, Tangsrud, and Rollefstad

1,320' Pilot

Wahpeton, Lawrence, Mack, and Hartman

660' Pilot



- 3 project areas
- 1,320 ft. same-zone spacing
- 34 new wells (gross)

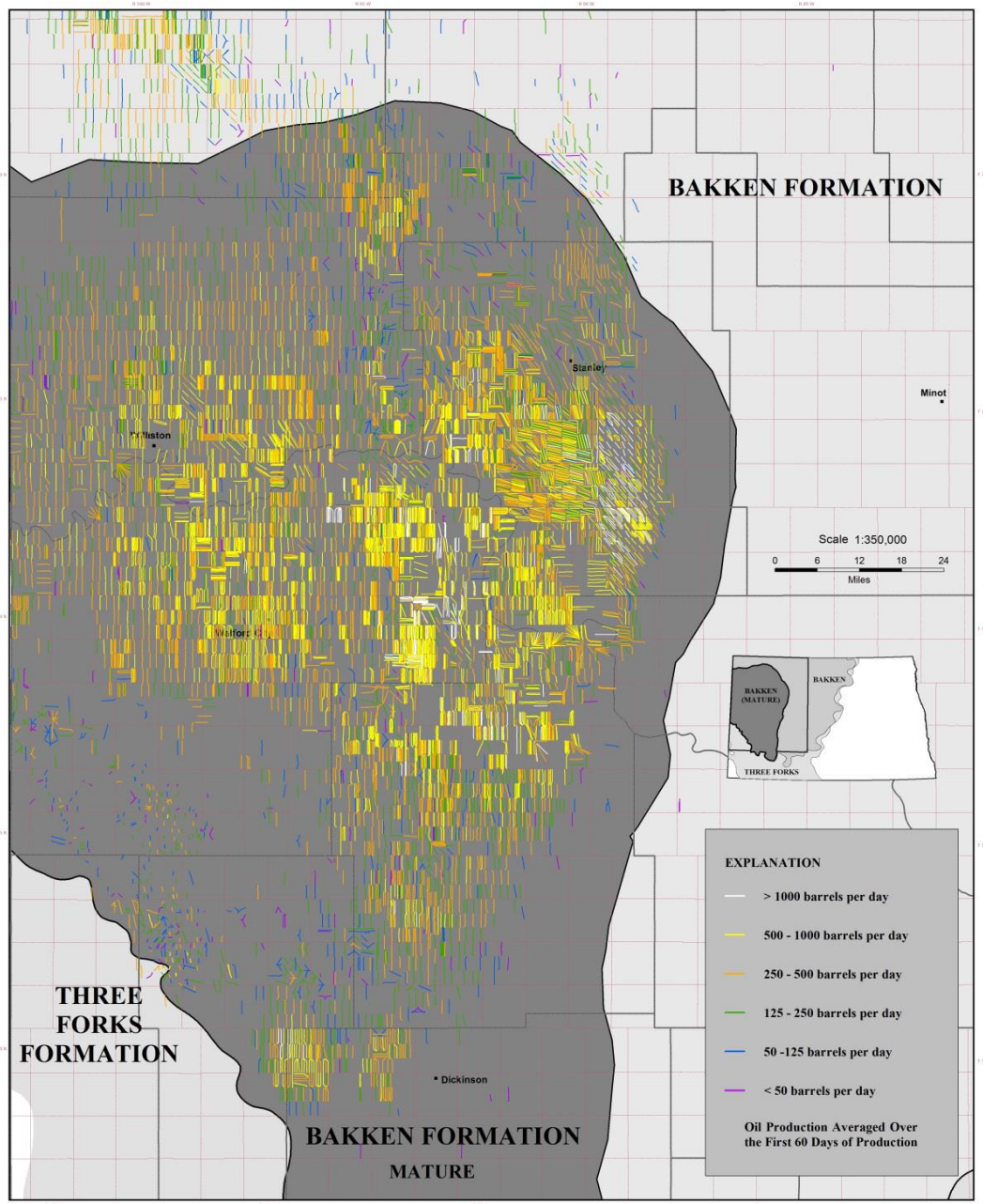
- 4 project areas
- 660 ft. same-zone spacing
- 31 new wells (gross)

North Dakota Geological Survey
Geologic Investigations No. 149 - Jul 2015

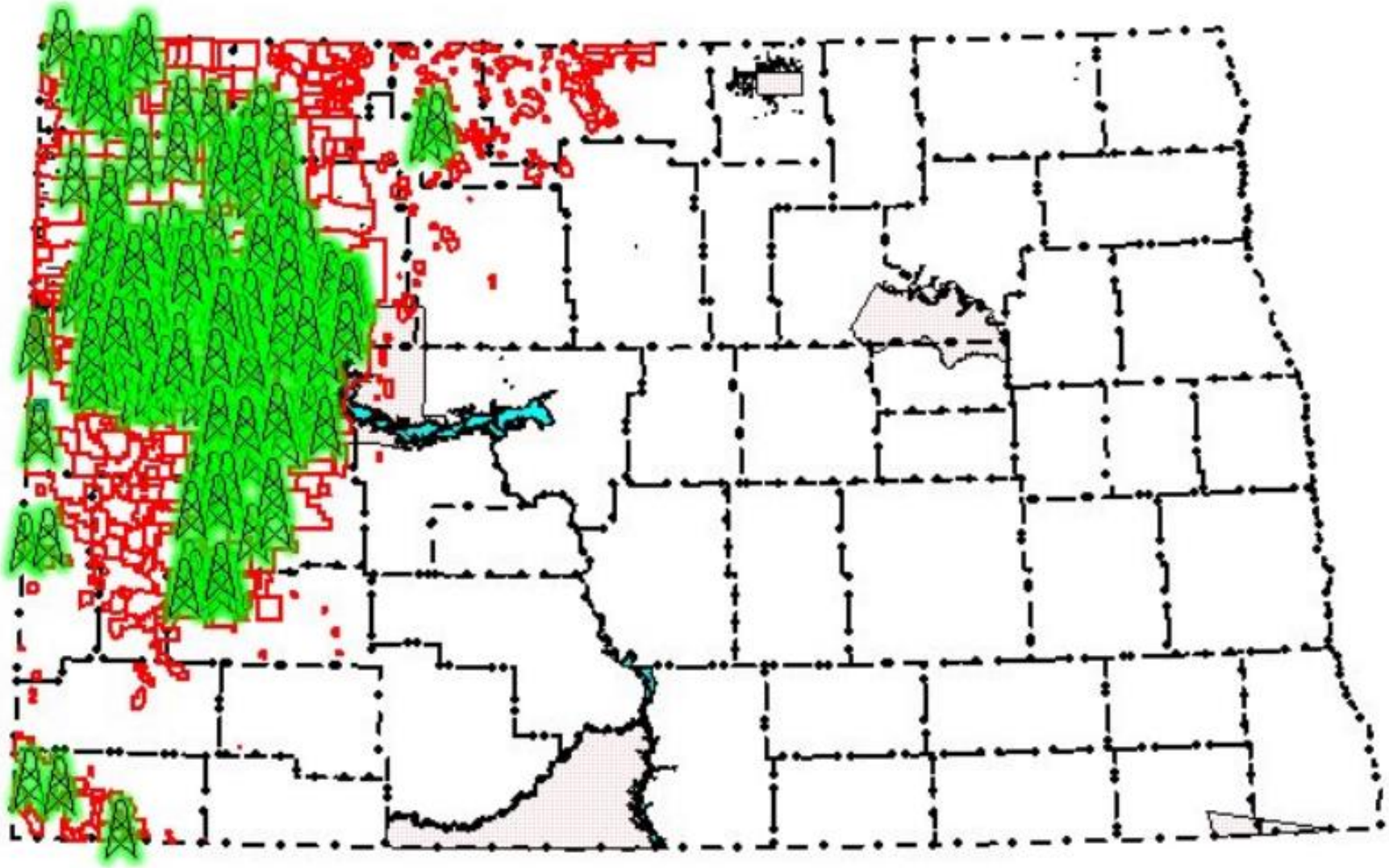
Edward C. Murphy, State Geologist
Lynn D. Helms, Director Dept. of Mineral Resources

First 60 Day Average Bakken Horizontal Production by Well

July 2015



NORTH DAKOTA – 191 DRILLING RIGS – DECEMBER 2014



Current drilling activity is focused

in Mountrail, Dunn, McKenzie, and Williams Counties.

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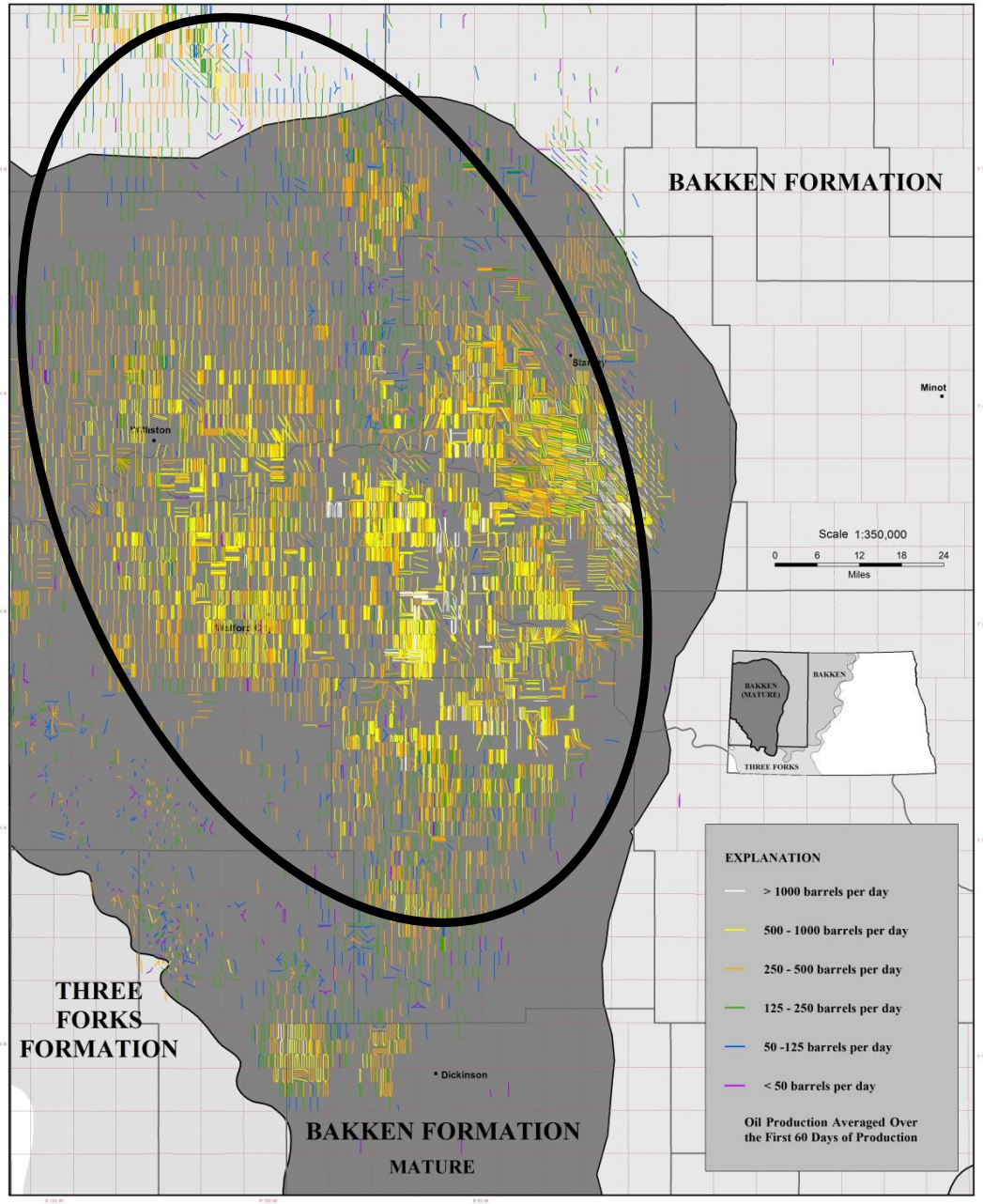
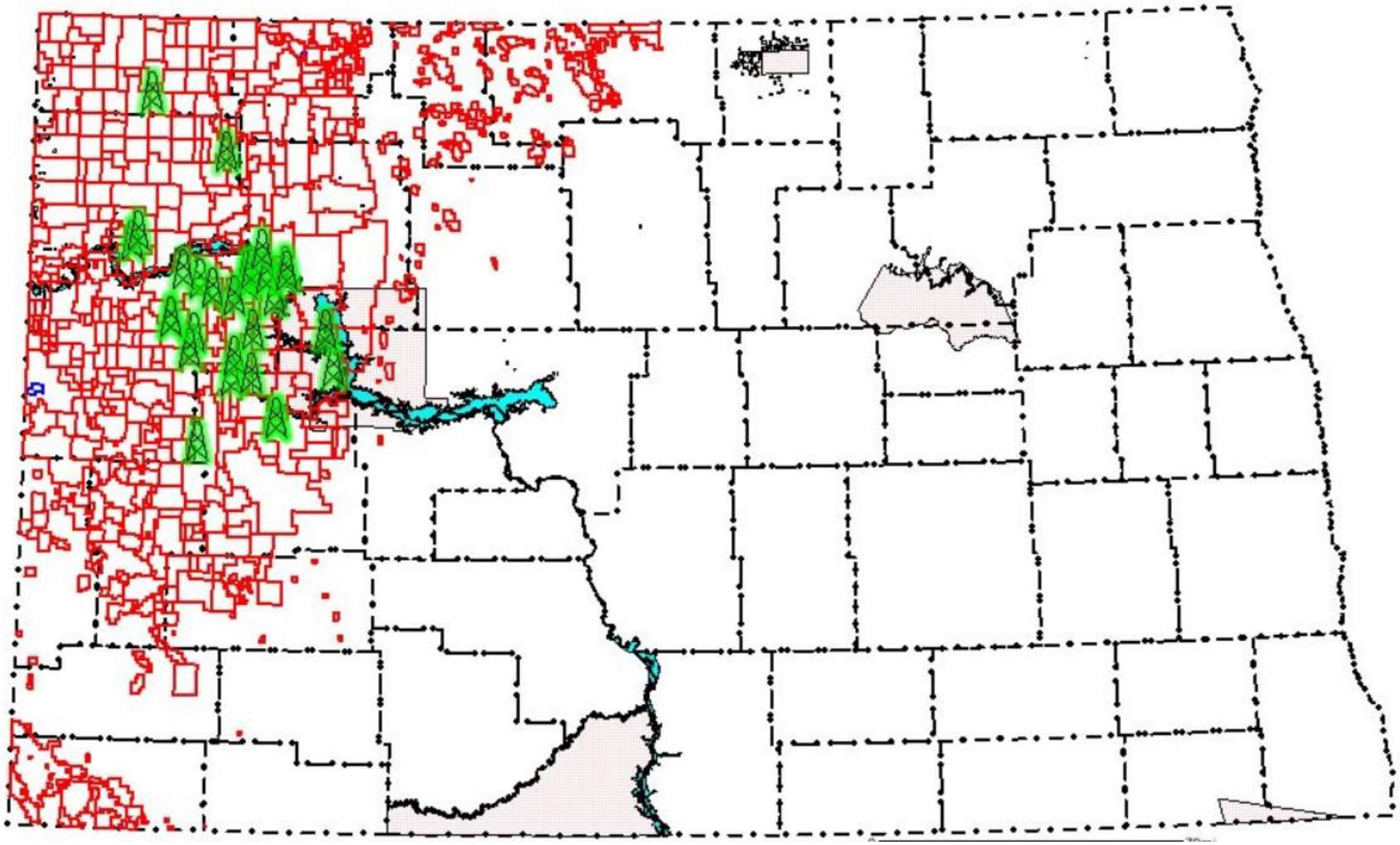


NORTH DAKOTA – 27 DRILLING RIGS – APRIL 2016



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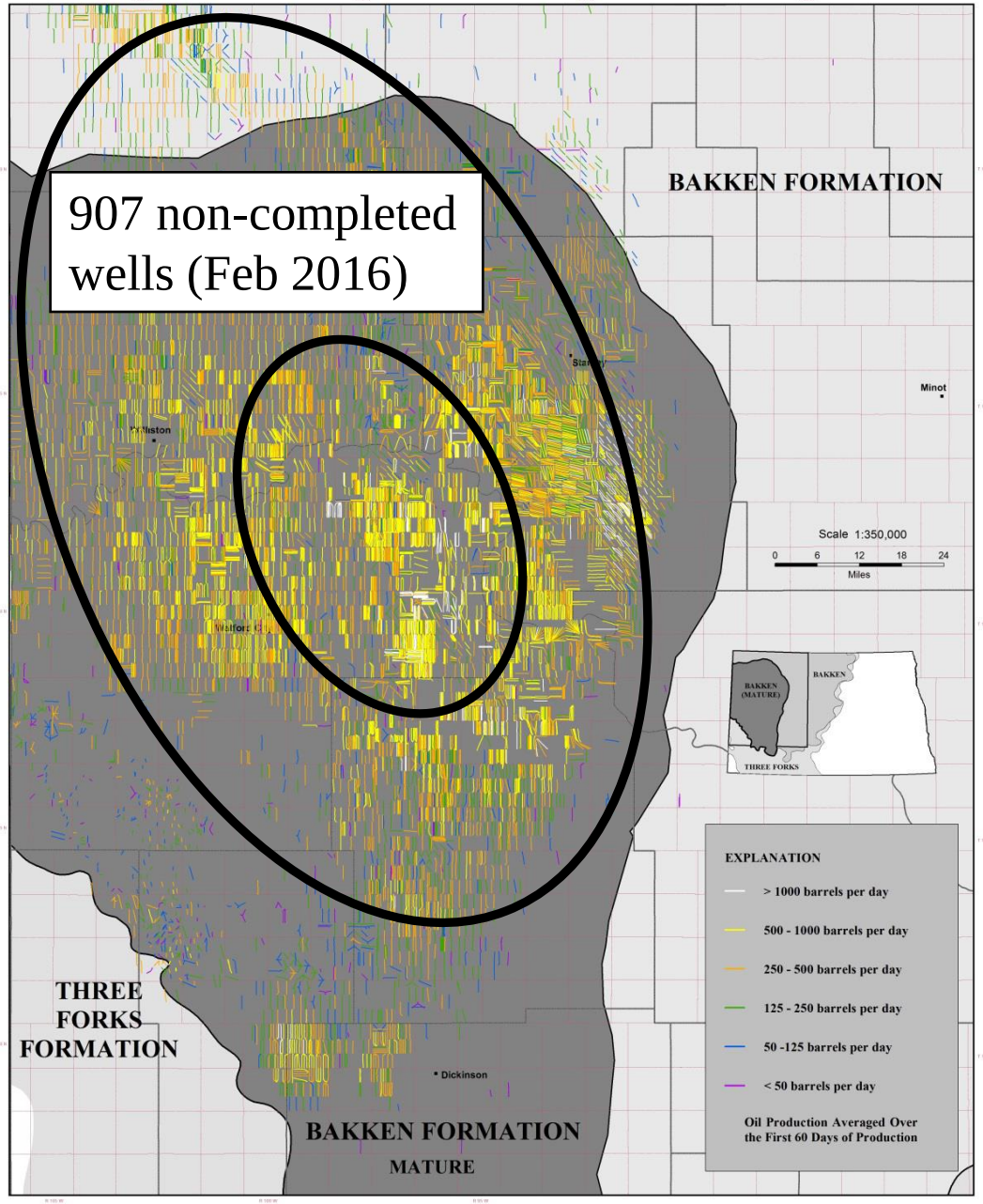
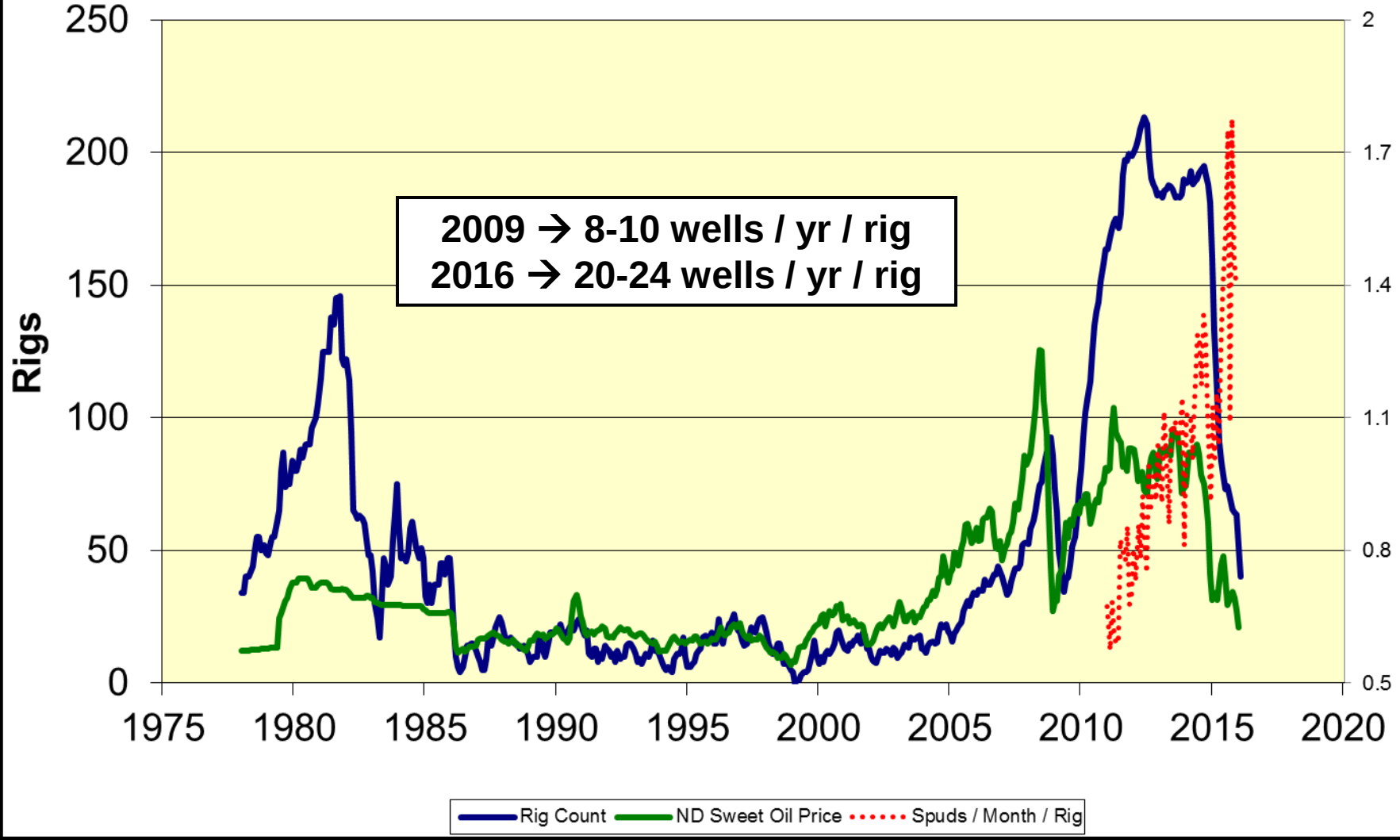
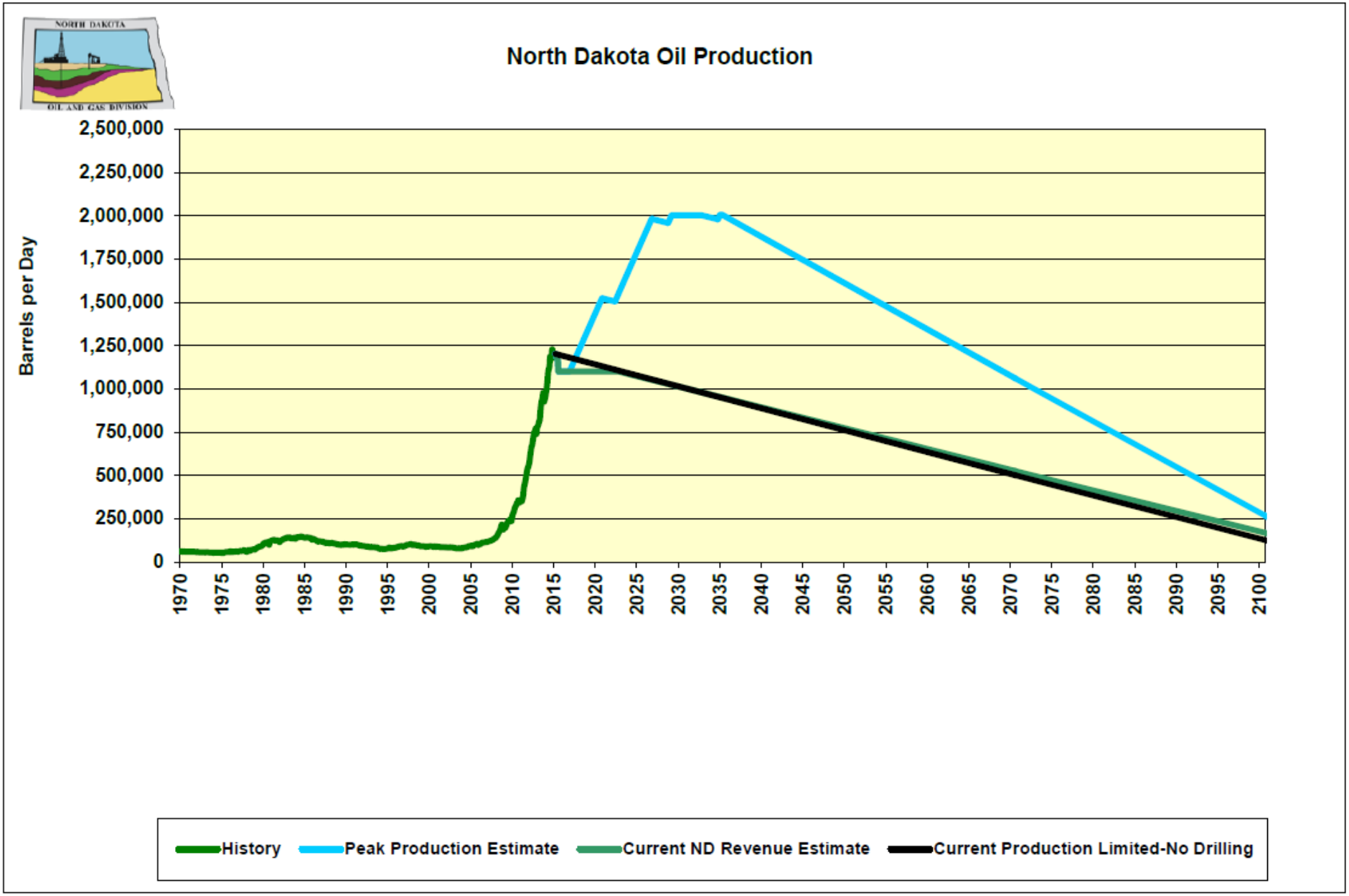


North Dakota Average Monthly Rig Count




NORTH DAKOTA
OIL AND GAS DIVISION
North Dakota Oil Production
Barrels per Day
2,500,000
2,250,000
2,000,000
1,750,000
1,500,000
1,250,000
1,000,000
750,000
500,000
250,000
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
2080
2085
2090
2095
2100
History
Peak Production Estimate
Current ND Revenue Estimate
Current Production Limited-No Drilling

WELLS

- 13,012 wells producing (Feb 2016)
  - 10,898 Bakken (84%)
- 40,000 additional development wells
  - 100 rigs – another 20 years
- Bakken Pool: 4 targets = more wells

Unitization and Enhanced Oil Recovery

- Unitization Process
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- EOR Techniques & Results
- Bakken Development
- **Bakken EOR Potential**

Bakken/Three Forks EOR Potential

- **Pilot projects**
  - **CO_2 injection**
  - **water injection**
  - **projects small-scale and usually inconclusive**
  - **further testing must be conducted**
- **> 300 billion barrels OOIP**
  - **every 1% of EOR = 3 billion barrels**

  (note: cum oil prod from 1951-2015 = 3.3 bil bo)

Reclaimed Location