North Dakota Department of Mineral Resources

http://www.oilgas.nd.gov

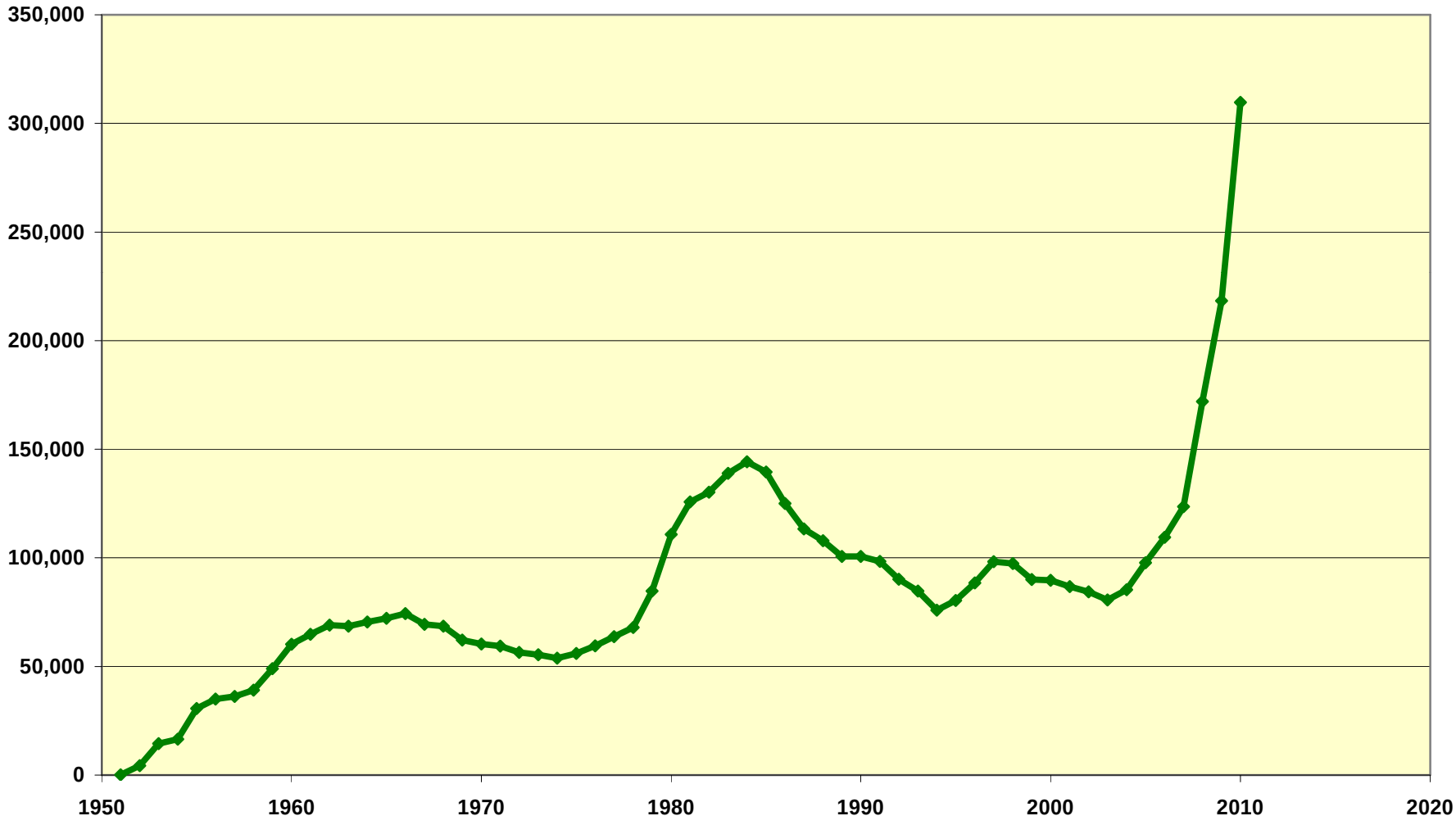
http://www.state.nd.us/ndgs

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

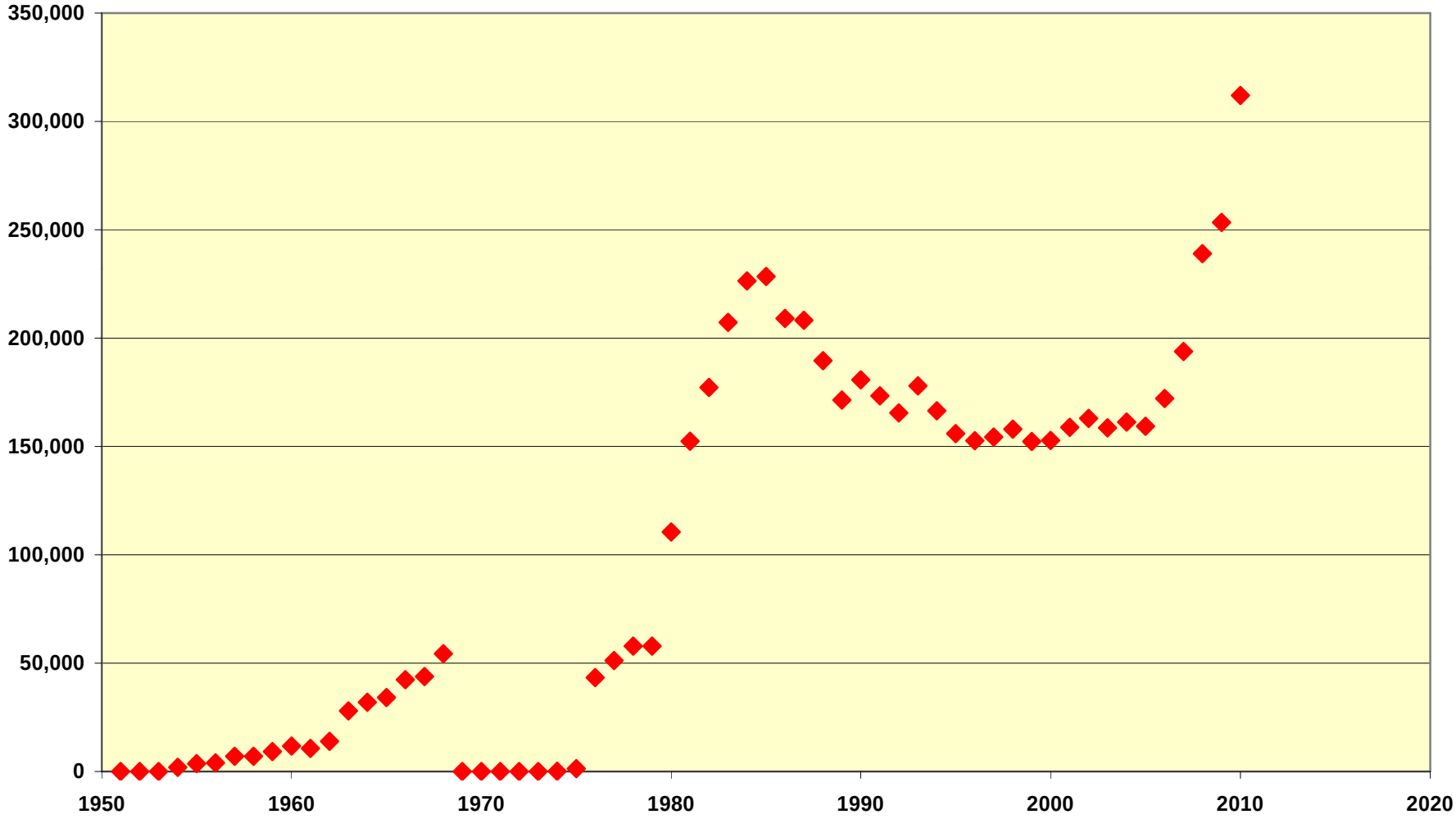
North Dakota 2010 Major Events

- “West of Nesson” code has been cracked
  - 25 to 40 stages
  - high strength proppant
- Tyler Assessment

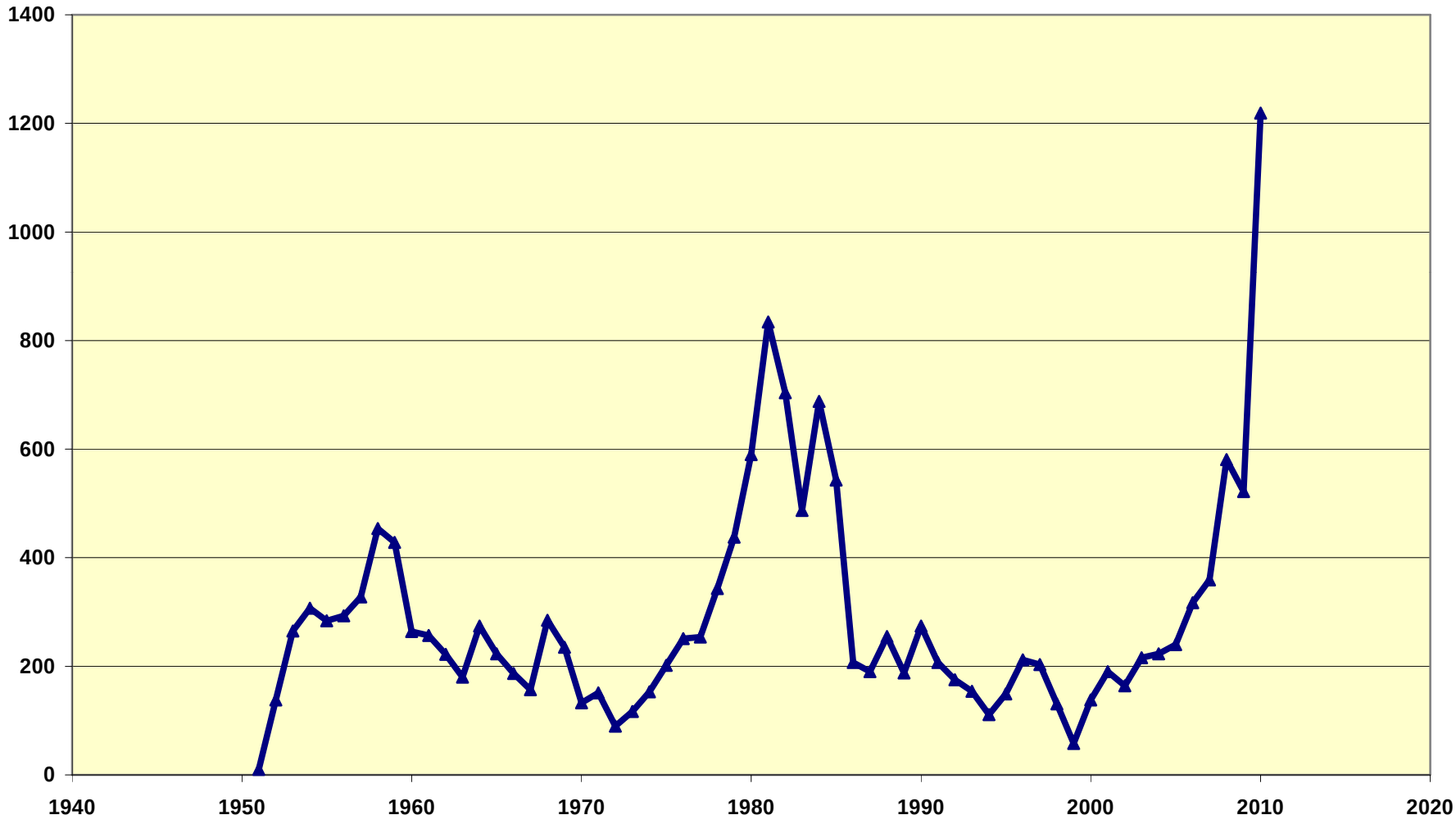
North Dakota Oil Production (Barrels / Day)



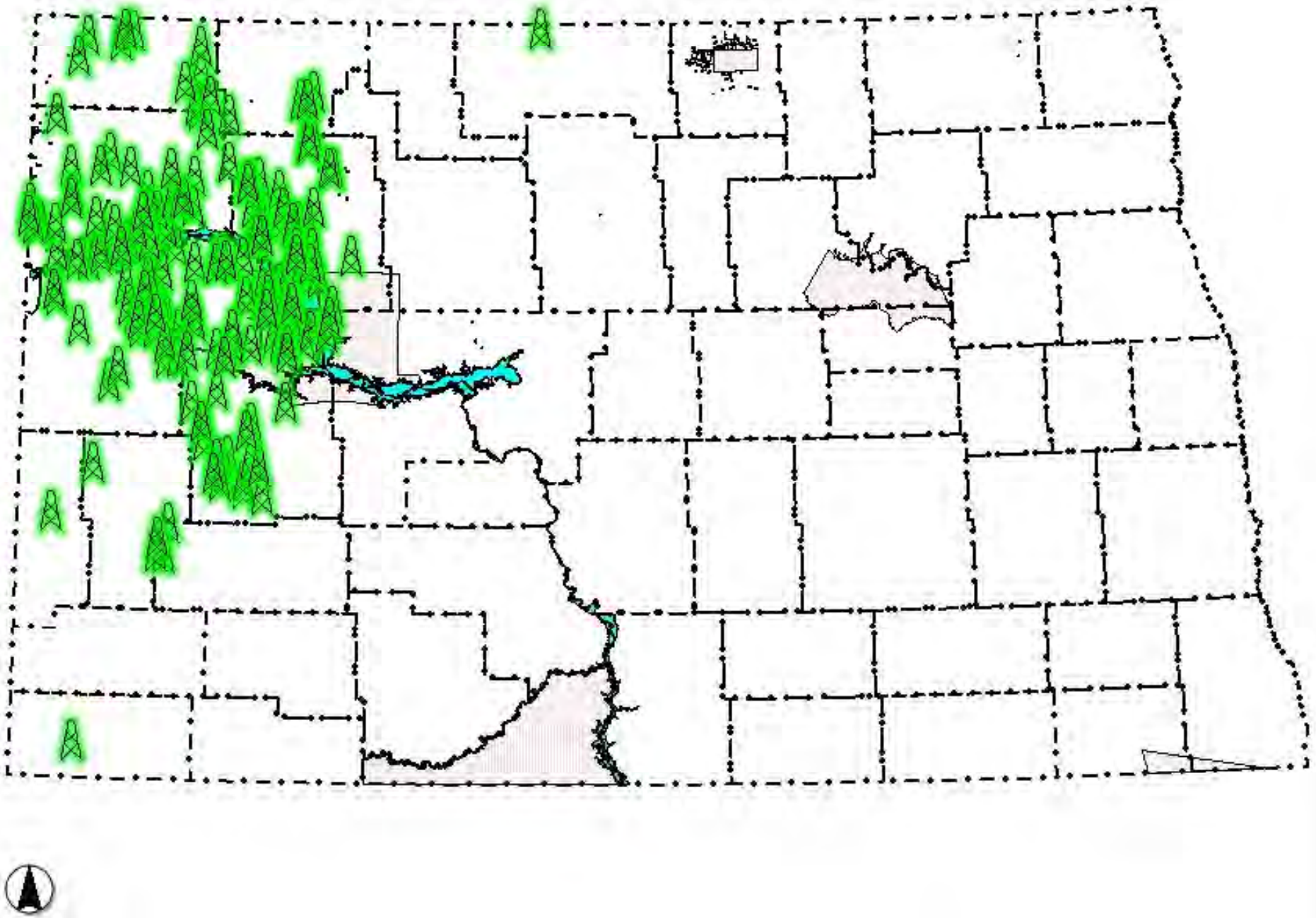
North Dakota Gas Production (MCF / Day)



North Dakota Wells Drilled



175 rigs



North Dakota
2010 Formations Discovered or Revived

- Three Forks
  - 2,227 Bakken Pool wells
    - 1,600 Middle Bakken
    - 356 Three Forks
    - 227 Upper Shale
    - 44 Middle Bakken & Three Forks

- Tyler
  - 1st well planned late 2011

CURRENT CRUDE OIL INFRASTRUCTURE

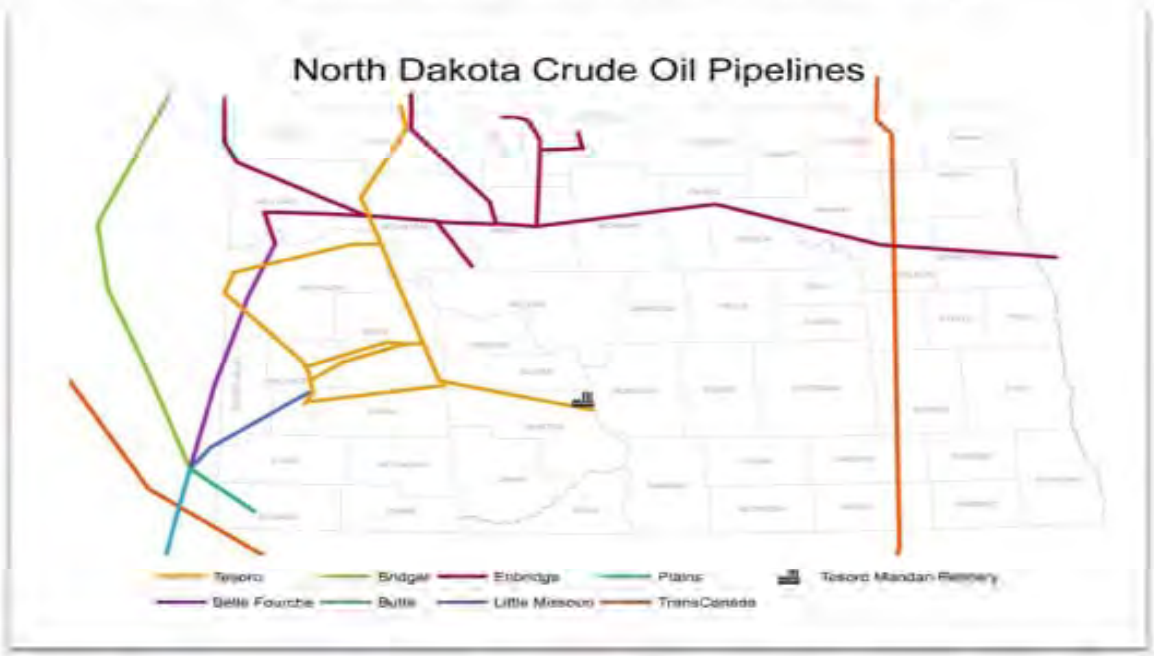
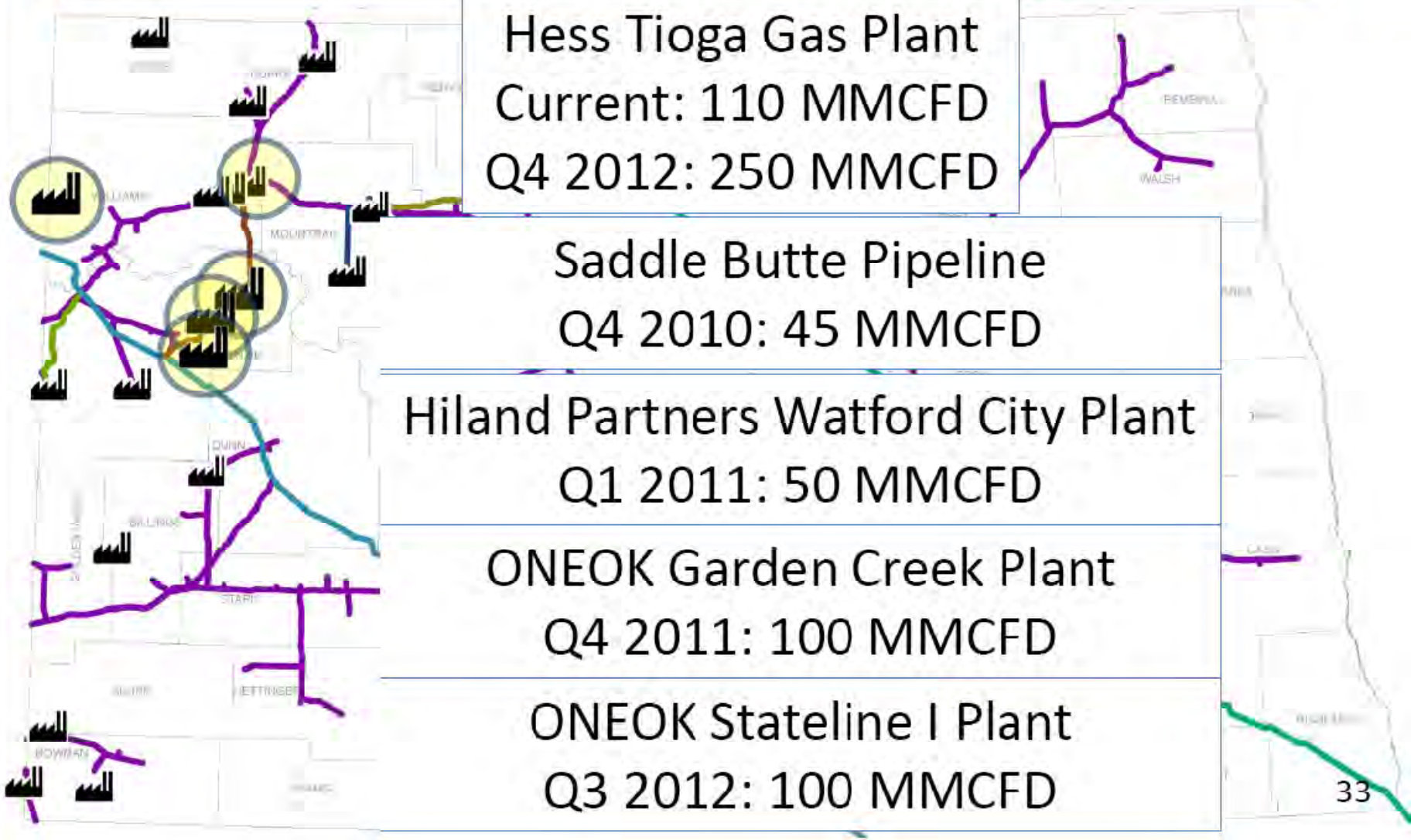


Figure 3. Map of the major crude oil transmission pipelines in the Williston Basin. Small scale gathering pipelines are not included.

Transportation System Capacity, Barrels Per Day	2007	2008	2009	2010
Pipeline Transportation				
Butte Pipeline	92,000	104,000	118,000	118,000
Enbridge North Dakota	80,000	110,000	110,000	161,500
Tesoro Mandan Refinery	58,000	58,000	58,000	58,000
Pipeline Only Total	230,000	272,000	286,000	337,500
Rail Transportation				
Various Sites including: Minot, Dore, Donnybrook, Stampede	-	30,000	30,000	30,000
EOG Rail, Stanley, ND (Up to 90,000 BOPD)	-	-	65,000	65,000
Dakota Transport Solutions, New Town, ND	-	-	-	20,000
Rail Only Total	-	30,000	95,000	115,000
Pipeline and Rail Combined Total	230,000	302,000	381,000	452,500

New or Expanding Gas Plants



Hess Tioga Gas Plant
Current: 110 MMCFD
Q4 2012: 250 MMCFD

Saddle Butte Pipeline
Q4 2010: 45 MMCFD

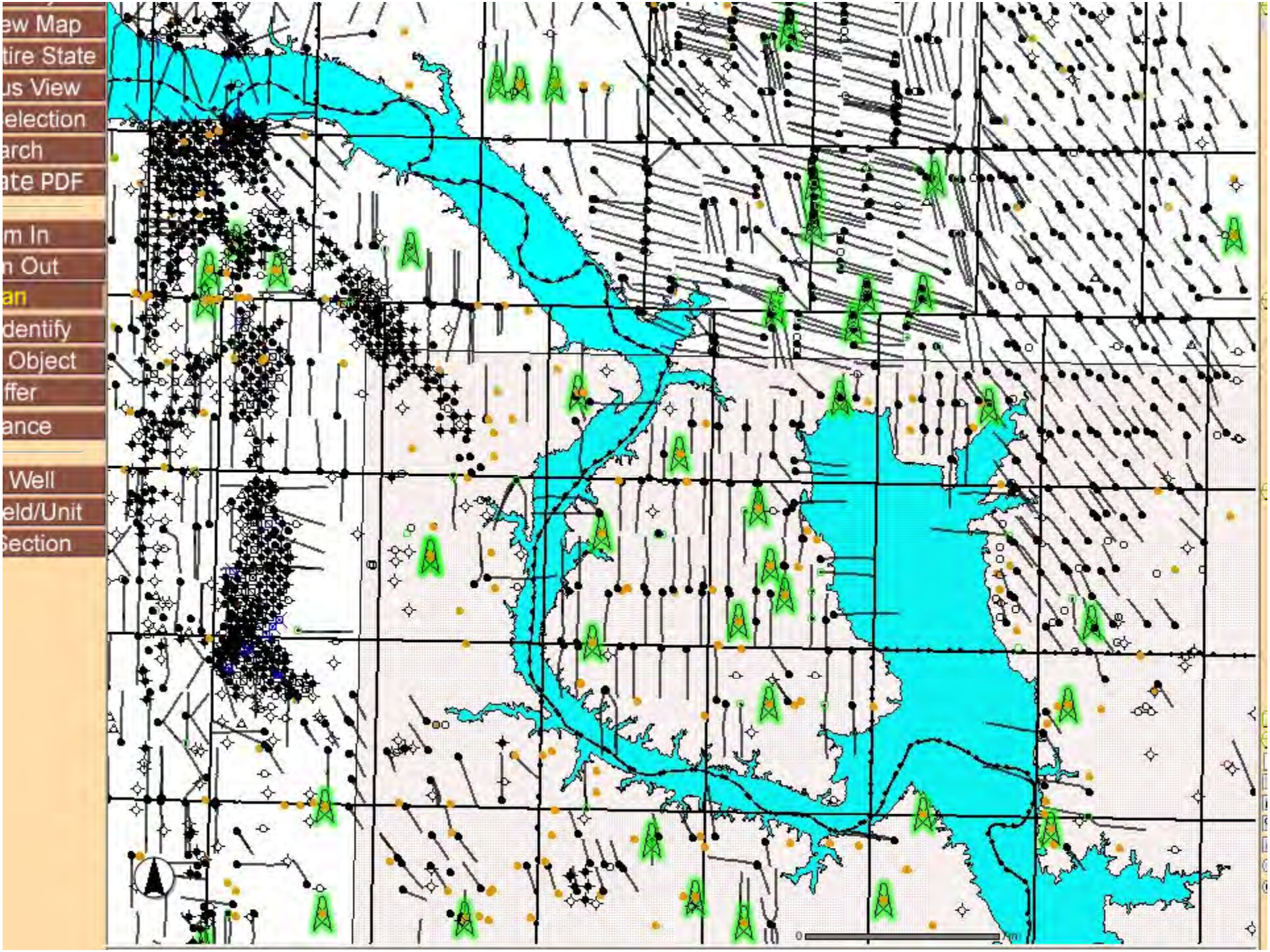
Hiland Partners Watford City Plant
Q1 2011: 50 MMCFD

ONEOK Garden Creek Plant
Q4 2011: 100 MMCFD

ONEOK Stateline I Plant
Q3 2012: 100 MMCFD

North Dakota
Oil & Gas Taxation

- Gross Production Tax
  - 5% on oil
  - July 1, 2010 through June 30, 2011 $0.0914/MCF on natural gas
- Extraction Tax
  - 6.5% on oil
    - 9 exemptions or rate reductions
    - Only Incremental EOR, Tertiary, and Stripper Well currently in effect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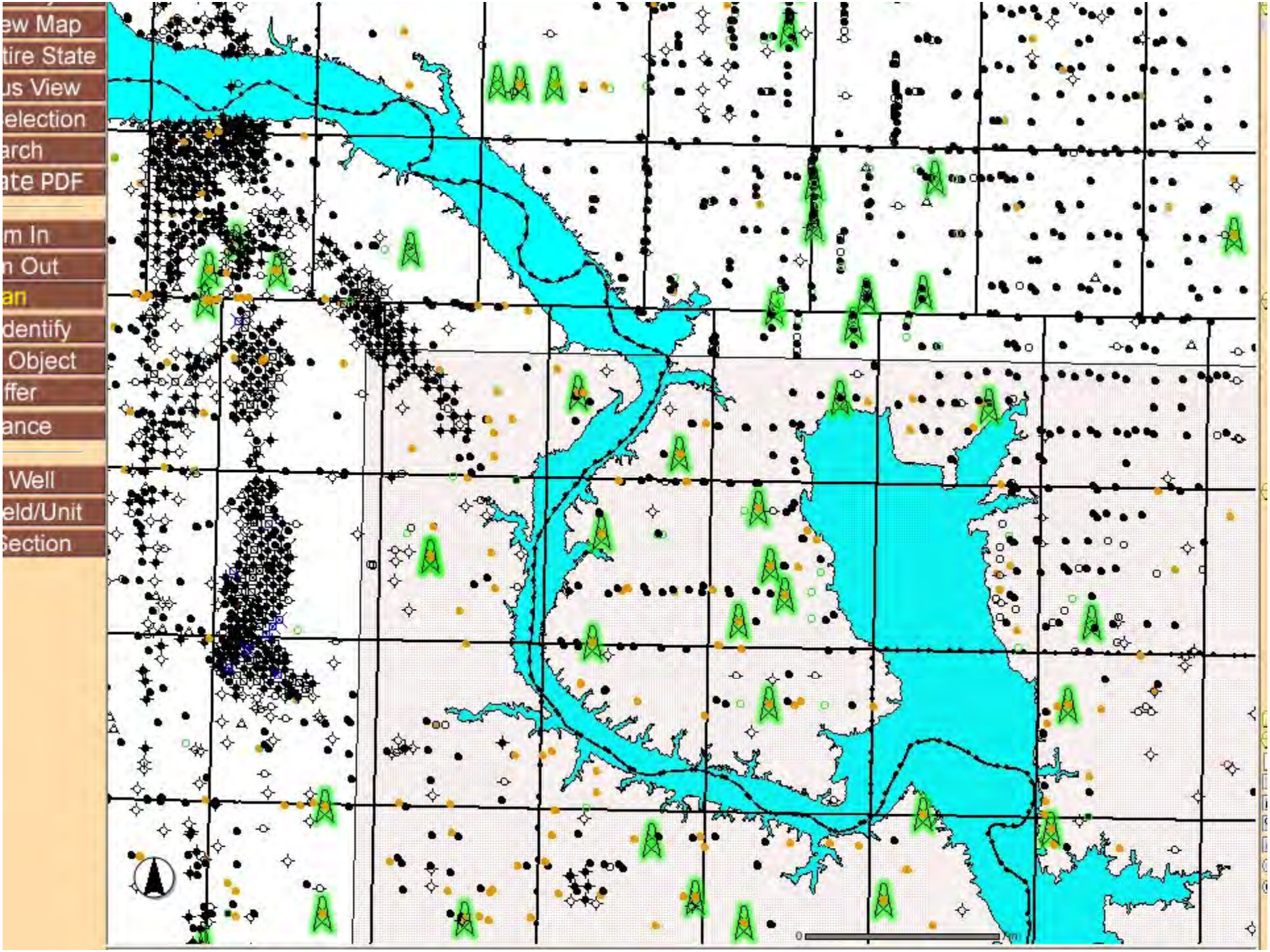
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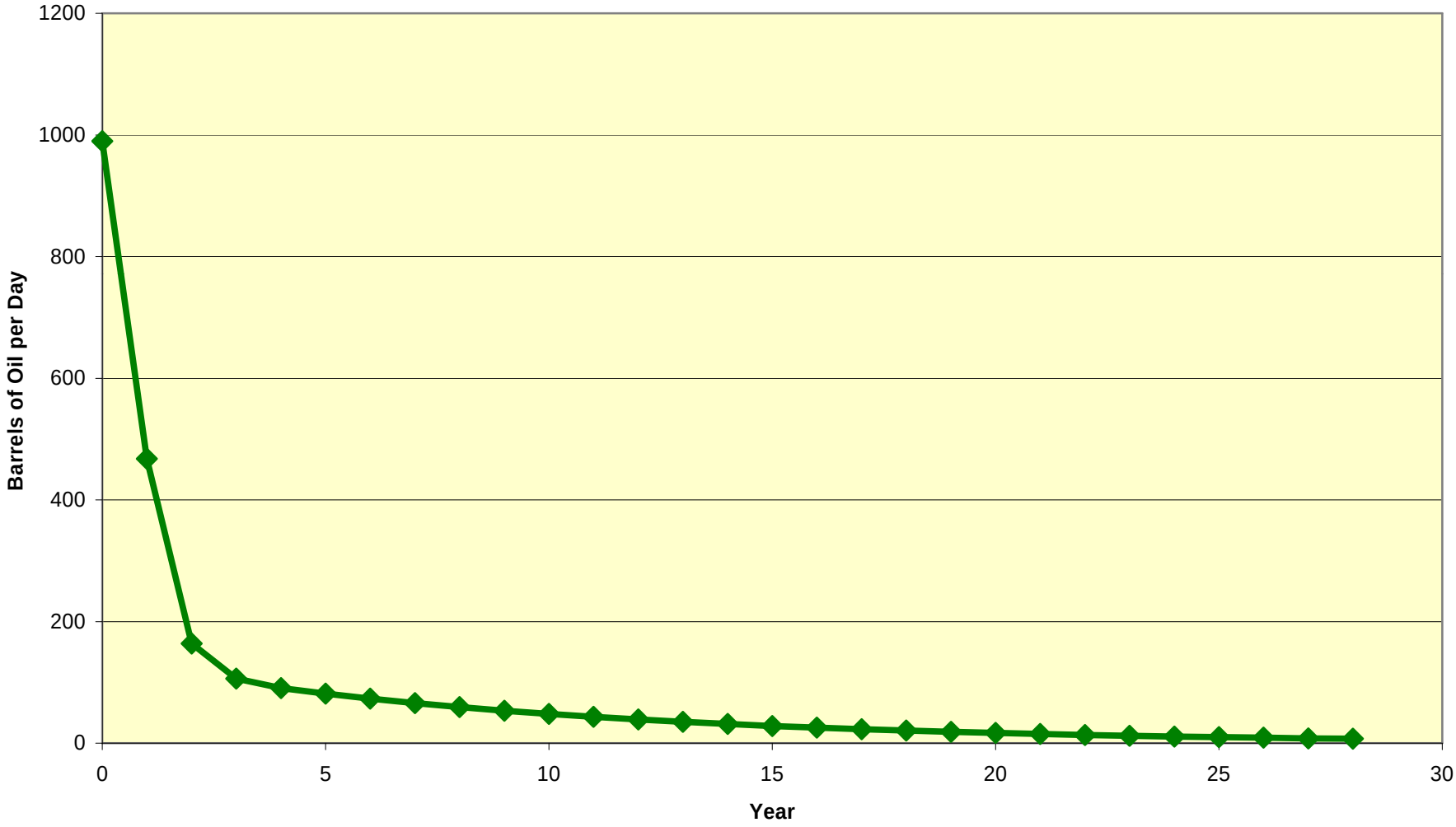
Vern Whitten Photography

Typical Bakken Well Production



What Does Every New Bakken Well Mean to North Dakota

A typical 2010 North Dakota Bakken well will produce for 28 years

If economic, enhanced oil recovery efforts can extend the life of the well

In those 28 years the average Bakken well:

Produces more than 575,000 barrels of oil

Generates over $20 million net profit

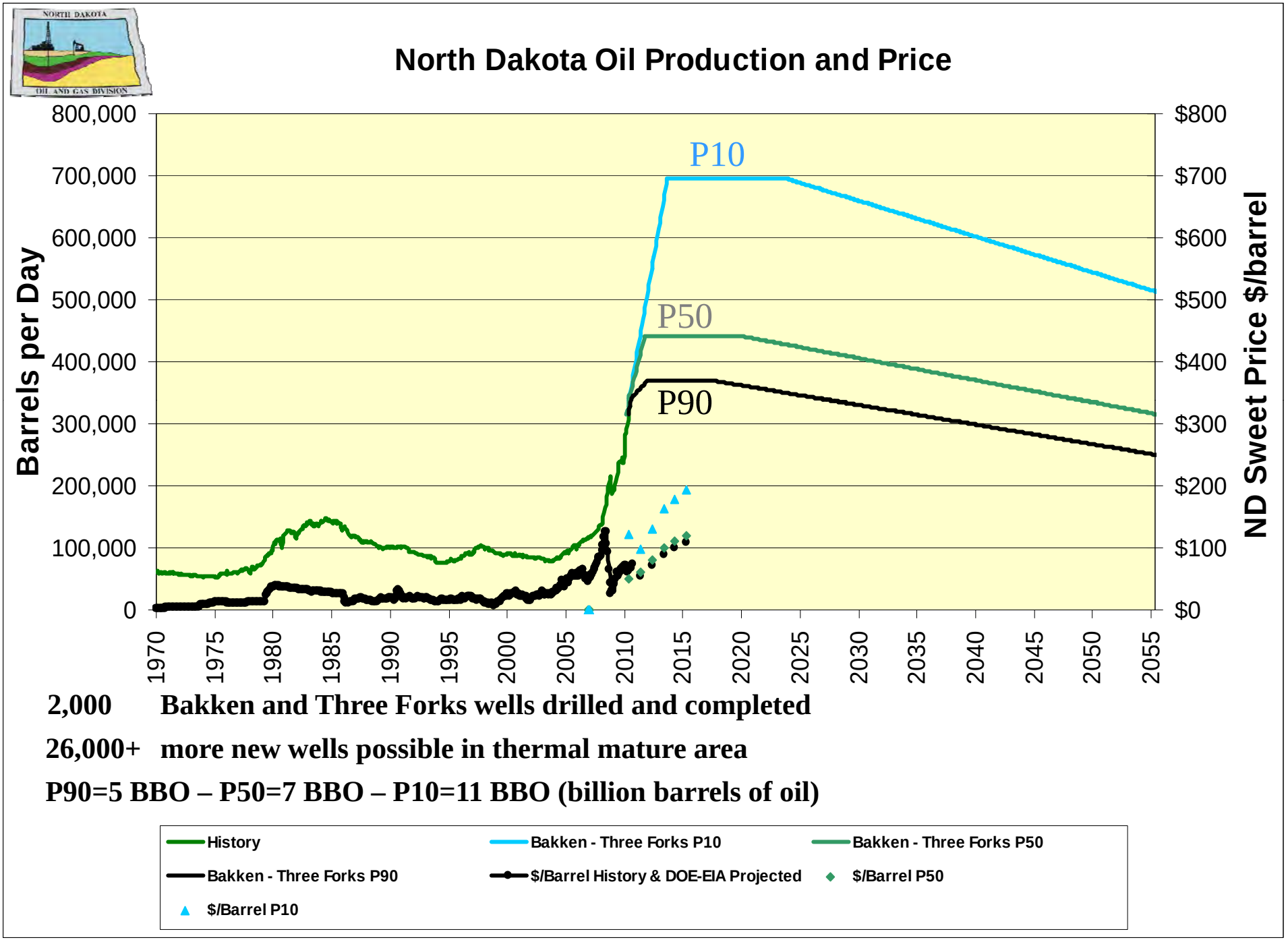
Pays approximately $4,250,000 in taxes
- $1,930,000 gross production taxes
- $2,000,000 extraction tax
- $320,000 sales tax

Pays royalties of $6,900,000 to mineral owners

Pays salaries and wages of $1,550,000

Pays operating expenses of $1,900,000

Costs $6,600,000 to drill and complete


North Dakota Oil Production and Price
Barrels per Day
ND Sweet Price $/barrel
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
$800
$700
$600
$500
$400
$300
$200
$100
$0
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
P10
P50
P90
2,000 Bakken and Three Forks wells drilled and completed
26,000+ more new wells possible in thermal mature area
P90=5 BBO – P50=7 BBO – P10=11 BBO (billion barrels of oil)
History
Bakken - Three Forks P10
Bakken - Three Forks P50
Bakken - Three Forks P90
$/Barrel History & DOE-EIA Projected
$/Barrel P50
$/Barrel P10

North Dakota Geological Survey
Geologic Investigations No. 127

RESOURCE POTENTIAL OF THE TYLER FORMATION

Stephan H. Nordeng and Timothy O. Nesheim

Edward C. Murphy, State Geologist
Lynn D. Helms, Director Dept. of Mineral Resources
2015

Figure 1. Horner plot of pressures measured during the shut-in periods of an open hole drill stem test (DST) of the Tyler Formation (8580-8292 ft. M.D.) in Pennzoil Co. & Depco's BNRR15-44 (Figure 5, #6848). The extrapolated shut-in pressures (Horner, 1951) from the 2nd and 3rd shut-in periods of the DST indicate that the Tyler Formation fluid pressure is ~4575 psi at a depth of 8730 ft., which yields a pressure gradient (0.55 psi/ft.) above the expected hydrostatic pressure range (0.43-0.46 psi/ft.). The 1st shut-in period did not reach "steady-state" conditions and therefore does not yield a reliable extrapolated formation pressure. The fluid recovered in this test was 354' of gas cut mud. This well was spudded on February 2nd, 1979 (DST run on March 18th, 1979) in the Flat Top Butte field, where only one well produced just 446 bbls of oil from the Tyler-Heath Formation over a four month period in 1960 (Texaco Inc.'s Mary Pace #1; API: 33-053-00461-00-00; NDIC: 2667; Sec. 13, T146N, R101W). There is no record of injection within the Flat Top Butte field.

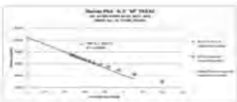


Figure 2. Horner plot of pressures measured during the shut-in period of an open hole drill stem test (DST) of the Tyler Formation (7743-7776 ft. M.D.) in Amerada Petroleum Corp.'s N.P. "M" 198 #2, shown on Figure 5 by #3867. Both the maximum pressure recorded (4039 psi = 0.52 psi/ft.) and the extrapolated formation pressure (4112.7 psi = 0.53 psi/ft.) are above the hydrostatic pressure range expected for the depth tested (3300-3560 psi = 0.43-0.46 psi/ft.). The DST fluid recovery was 2.3 BBLS oil, reversed out 69.34 BBLS oil. Cumulative production for this well was 1,440,113 BBLS of oil. This well was spudded on May 2nd, 1965 (DST run on May 15th, 1965) in the Medora field, where initial production began in June, 1964 and initial injection in February, 1970.

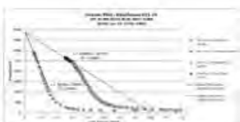


Figure 3. Horner plot of pressures measured during the shut-in periods of a conventional bottom hole drill stem test (DST) on the Tyler Formation (7540-7556 ft. M.D.) in Milestone Petroleum's Kirschman #21-24, shown on Figure 5 by #11484. The calculated fluid pressure of the Tyler Formation (the average of the extrapolated pressures from the two DST shut-in periods) is ~3883 psi at a depth of 7545 ft., which yields a pressure gradient (0.51 psi/ft.) above the hydrostatic pressure expected for this depth (0.43-0.46 psi/ft.). The DST fluid recovered was 0.03 bbls of oil and 0.48 bbls of water. Kirschman #21-24 was a wildcat well drilled outside areas of production and injection for the Tyler Formation.

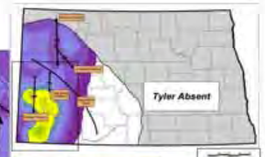


Figure 6. Time-Temperature Index map of the Pennsylvanian Tyler Formation in the Williston Basin of North Dakota. The color-filled contours represent the Time Temperature Index of the Tyler Formation. Areas in which the Tyler is absent are in gray (modified from Anderson, 1974).

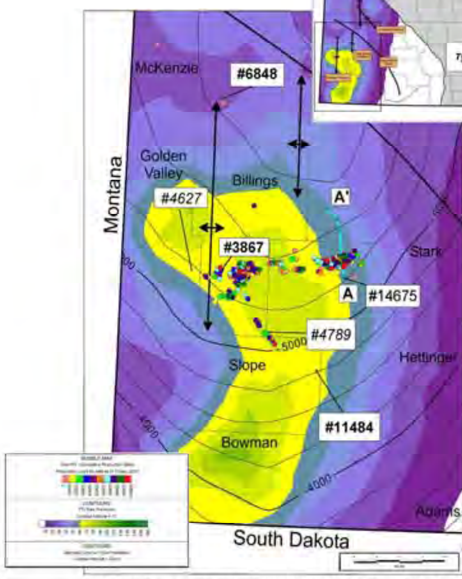


Figure 5. Detail map showing the distribution of Tyler production (total Bbls) in North Dakota together with Time-Temperature contours and the location of wells from which pressure gradients (#6848, #3867, #11484) and Rock Eval data (#4627, #4789) were obtained. The color-filled contours represent the Time-Temperature Index of the Tyler Formation and are keyed to the color bar located in the lower left corner. Shades of yellow and green (~65) represent the TTIs that correspond with the oil window. TTIs less than 65 and above 15 are in shades of blue and purple and represent conditions that could generate oil. This map lies within the black outline on Figure 6. Cumulative production from the Tyler Formation (barrels oil) is represented by the color of the circles centered on the wells that have and/or are producing oil from the Tyler Formation. The solid contour lines on the detail map represent the minus sea level elevation of the top of the Tyler Formation.

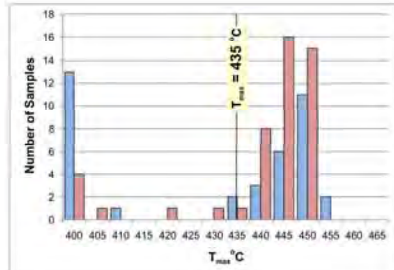


Figure 7. A frequency diagram showing that most of the samples of the Tyler Formation collected from the Government Taylor A-1 (#4627) in red, and the State of North Dakota #41-36 (#4789) in blue, have been thermally matured beyond the threshold that marks the onset of oil generation (Tmax ~435oC).

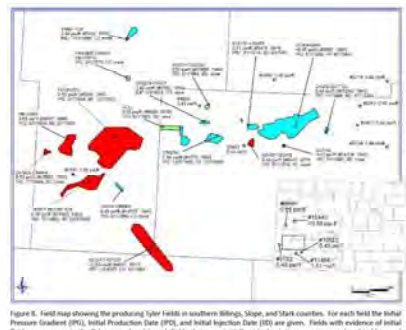


Figure 8. Field map showing the producing Tyler Fields in southern Billings, Slope, and Stark counties. For each field the Initial Pressure Gradient (IPG), Initial Production Date (IPD), and Initial Injection Date (IID) are given. Fields with evidence of initial fluid overpressure in the Tyler are colored in red, fields that were initially at hydrostatic pressure are colored in blue, and fields that were underpressured prior to production are colored green. Most of the western Tyler fields all contain evidence of overpressuring prior to injection with the exception of Davis Creek. The eastern Tyler fields were at or below hydrostatic pressure, with the exception of the Heart River and Eland fields. Field boundaries are approximate. In the bottom right corner is an index map of North Dakota showing the Tyler DST's of interest with their NDIC well numbers that are located outside the main area of Tyler production. DST results indicate that the Tyler Formation is over-pressured in three wells and at hydrostatic pressure within two wells outside the area of main production.

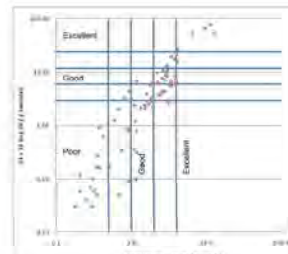


Figure 9. A kerogen quality diagram (Dembicki, 2009) constructed from the Total Organic Carbon (TOC) versus the mass of existing (S1) and potential (S2) hydrocarbons contained in samples of the Tyler Formation. The samples are from the Government Taylor A-1 (green circles) and the State of North Dakota #41-36 (red squares).

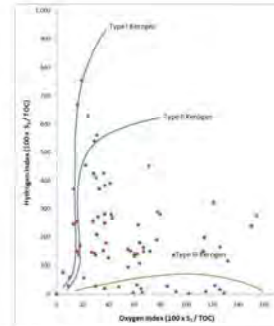


Figure 10. A modified van Krevelen diagram that classifies kerogen on the basis of the Hydrogen Index (HI) and Oxygen Index (OI) derived from Rock Eval pyrolysis data. The blue diamonds represent the data from the Government Taylor A-1 (NDIC # 4627, SESE, Sec. 9, T139N, R103W) and the red squares refer to data from the State of North Dakota #41-36 (NDIC #: 4789, NE NE, Sec. 36, T137N, R100W). The data suggest that kerogen within the Tyler Formation includes oil prone Type I and Type II, gas prone Type III as well as mixtures of both oil and gas prone kerogen.

Discussion

The purpose of this study is to examine the pressures within the Pennsylvanian aged Tyler Formation with the intent of determining whether or not the formation exhibits pressure-depth relationships consistent with a source system that is hydraulically isolated from the over and underlying formations. Hydraulic isolation is one of the key elements that Schmoker (1996) used to define a basin-centered petroleum accumulation. Meissner (1978) recognized several of these elements in the Bakken Formation in the Williston basin. In these accumulations, the source rock and reservoir rock are either one and the same or lie in very close proximity to one another. This occurs because the rocks that encase the source beds lack sufficient permeability to allow petroleum generated within the source beds to escape and migrate away. As a result, pressures within the source beds and associated reservoir rocks typically exhibit abnormally high or low formation fluid pressures relative to the pressure expected in a reservoir that is in hydraulic communication with the overlying rocks. The "expected" pressure in this study assumes hydrostatic conditions so that the expected pressure would be consistent with a hydrostatic gradient of between 0.43 and 0.49 psi/ft. Therefore, abnormally low or high pressure would yield hydraulic gradients (pressure/depth) that lie outside the range of gradients that correspond with fresh water (0.43 psi/ft) or saltwater (0.49 psi/ft).

The Tyler Formation is a regionally extensive, organically-rich, Pennsylvanian unit deposited during the earliest stages of the Absaroka Sequence. Terrestrial sediments derived from source areas south of the Williston basin are interbedded with near-shore, marine limestone and shale (Gerhard and Anderson, 1988). The Tyler Formation is bounded below by an erosional surface developed on Mississippian aged rocks formed during tectonic uplift in the Late Mississippian and Early Pennsylvanian. A variety of lithologies consistent with progradation of sediments into the basin overly the Tyler except along the eastern margin of the basin where these rocks have been truncated by the erosional surface that marks the Absaroka – Zuni sequence boundary (Anderson, 1974; Gerhard and Anderson, 1988).

Pressure gradients were obtained from pressure build up curves and pressure recorder depths used during drill stem tests of the Tyler Formation. Estimates of formation pressures are obtained by constructing Horner plots in which formation pressures are plotted against the logarithm of Horner time (Horner Time = (Total Flow Time + Δ(Shut-in time))/Δ(Shut-in time)). The formation pressure is determined from the Horner plot by finding the y-intercept of the best-fit line that passes through the pressures recorded during the last part of the shut-in periods (See Figures 1-3).

The range of initial pressure gradients present in the Tyler Formation suggest that the formation is frequently over-pressured and in a few cases under-pressured. Several fields were initially over-pressured and prior to injection: Dance Creek, Eland, Flat Top Butte, Fryburg, Heart River, Medora, Rocky Ridge, and Round Top Butte (Figure 8). Most of these over-pressured fields are located on the western side of the producing Tyler fields. Two fields may have been under-pressured prior to production, Bell and North Creek, which are located in the central area of most of the producing Tyler fields (Figure 8). These results lead to the conclusion that the Tyler Formation is not always in hydraulic communication with the units above or below it and thus suggests that the Tyler may be sufficiently isolated so as prevent the petroleum generated within the Tyler Formation to escape.

The Time-Temperature Index (TTI) map of the Tyler Formation, constructed from modern geothermal heat flow measurements (SMU Geothermal Lab, 2010) and stratigraphic interval thickness data shows that oil production from the Tyler Formation is from rocks that are mature enough to generate oil. Rock Eval data also indicates that at least some of the organic-rich rocks within the Tyler are good to excellent source rocks even though there is probably more than one type of kerogen present. The available Rock Eval data also confirms the presence of thermally mature shales in vicinity of current Tyler production (Figures 5 & 7).

The limited data available today suggest the Tyler Formation is a regionally extensive unit that may contain good to excellent quantities of oil prone kerogen (Figures 9 & 10) that is sufficiently mature (Figure 7) to generate oil within a hydraulically compartmentalized environment (Figure 8). If so, then the Tyler Formation possesses the elements needed to qualify as a basin centered petroleum accumulation.

References

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Dembicki, H., 2009, Three common source rock evaluation errors made by geologists during prospect or play appraisals. American Association of Petroleum Geologists Bulletin, v. 93, p. 341-356.

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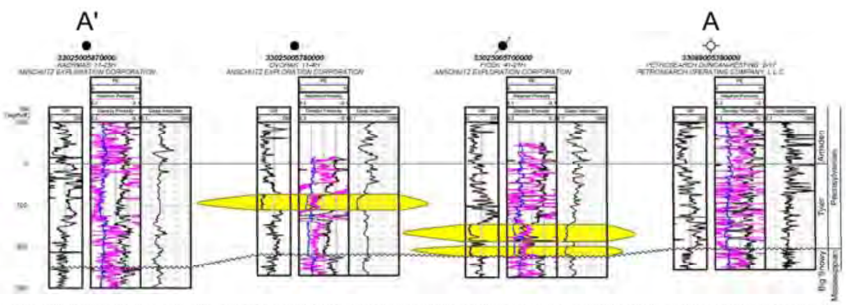


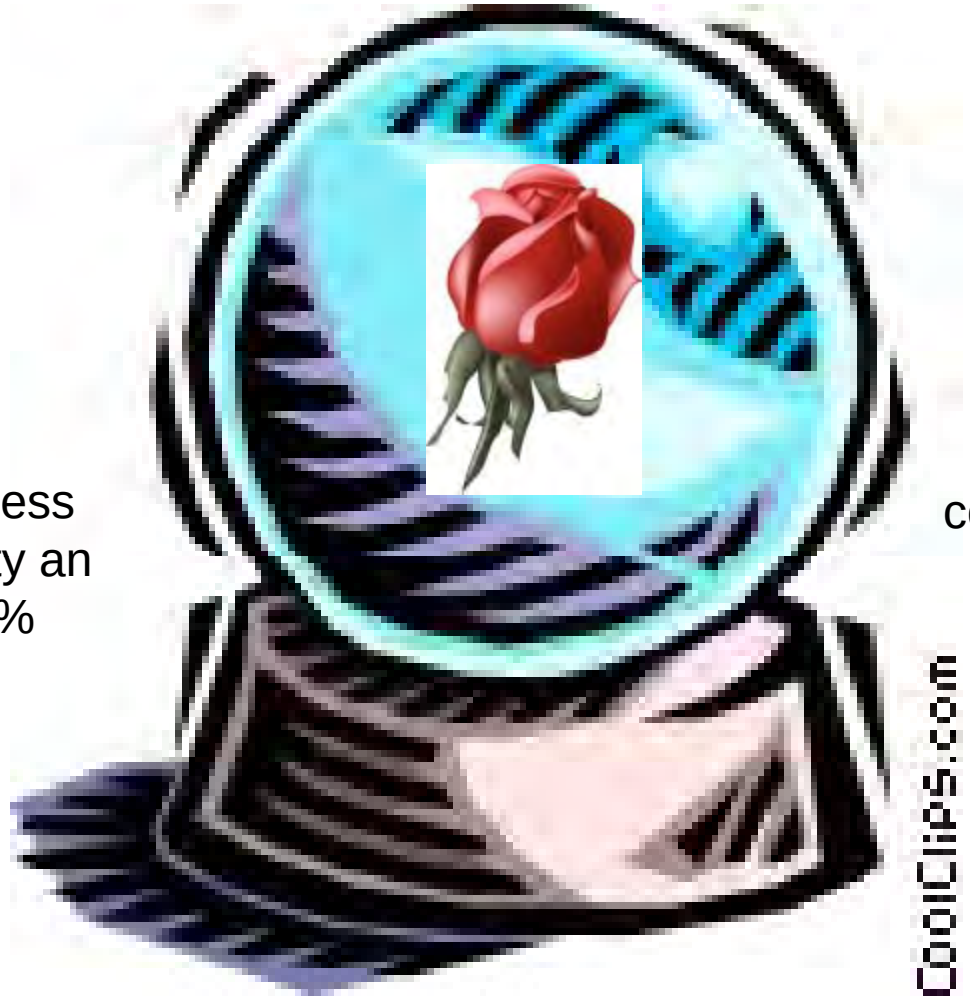
Figure 4. Cross-section extending from A to A' along the light blue line in Figure 5. The Testing 2-17 (#14675 on Figure 5) corresponds to the point labeled A. Conventional sandstone reservoirs are shown in yellow. The section illustrates the discontinuous nature of the conventional sandstone reservoirs of the Tyler Formation.

Western North Dakota

- 1,100 to 2,700 wells/year = 2,100 expected
  - 100-225 rigs = 12,000 – 27,000 jobs = 21,000 expected
- 15 - 30 million gallons frac water/day
- 10 to 20 years
  - 26,000 new wells = long term jobs

Cap and trade proposals in congress could reduce activity an estimated 35-40%

Current administration budget contains tax rule changes that could reduce activity an estimated 35-50%



The future looks promising for sustained Bakken/Three Forks development

EPA regulation of hydraulic fracturing could halt drilling activity for 18-24 months production decline of 25-30%

Federal regulations require 6 -12 months longer for drilling and surface use approval