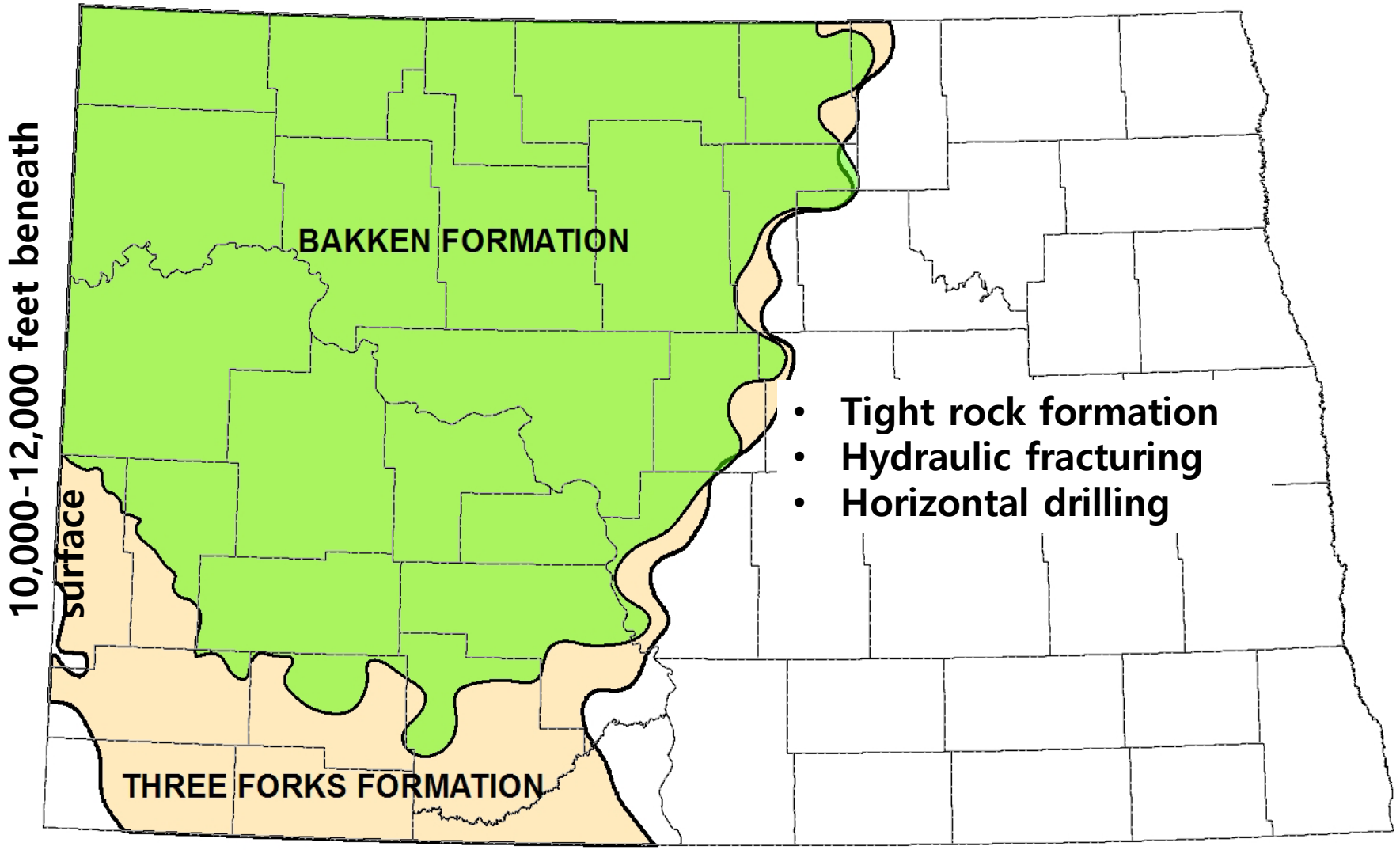
NDSU UPPER GREAT PLAINS TRANSPORTATION INSTITUTE

Energy Transportation & Logistics: Case Study of the Bakken Shale

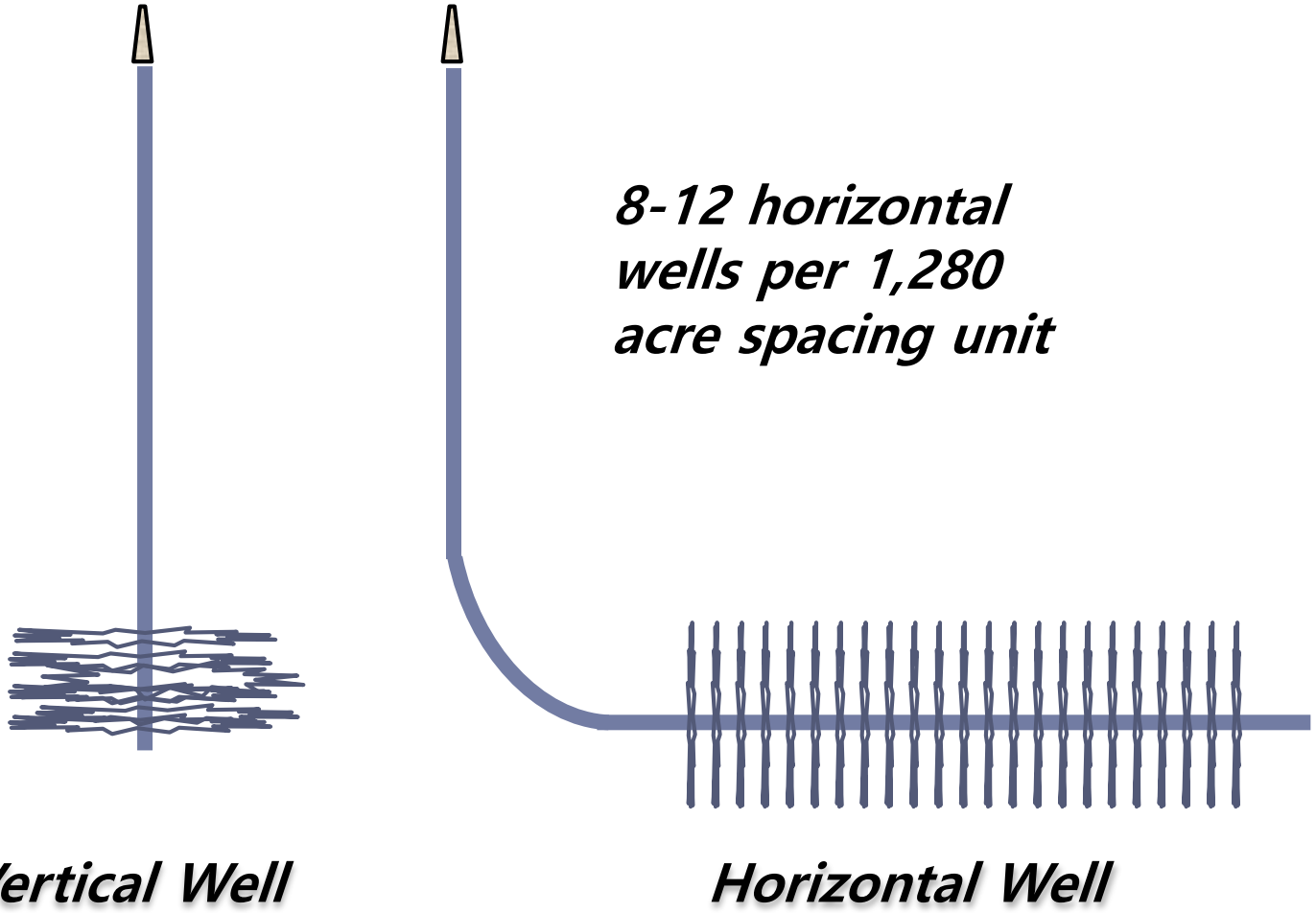
Annual Meeting of the
Transportation Research Forum
Denver Tolliver
March, 2014

Shale Oil Formations in North Dakota



North Dakota Oil and Gas Division

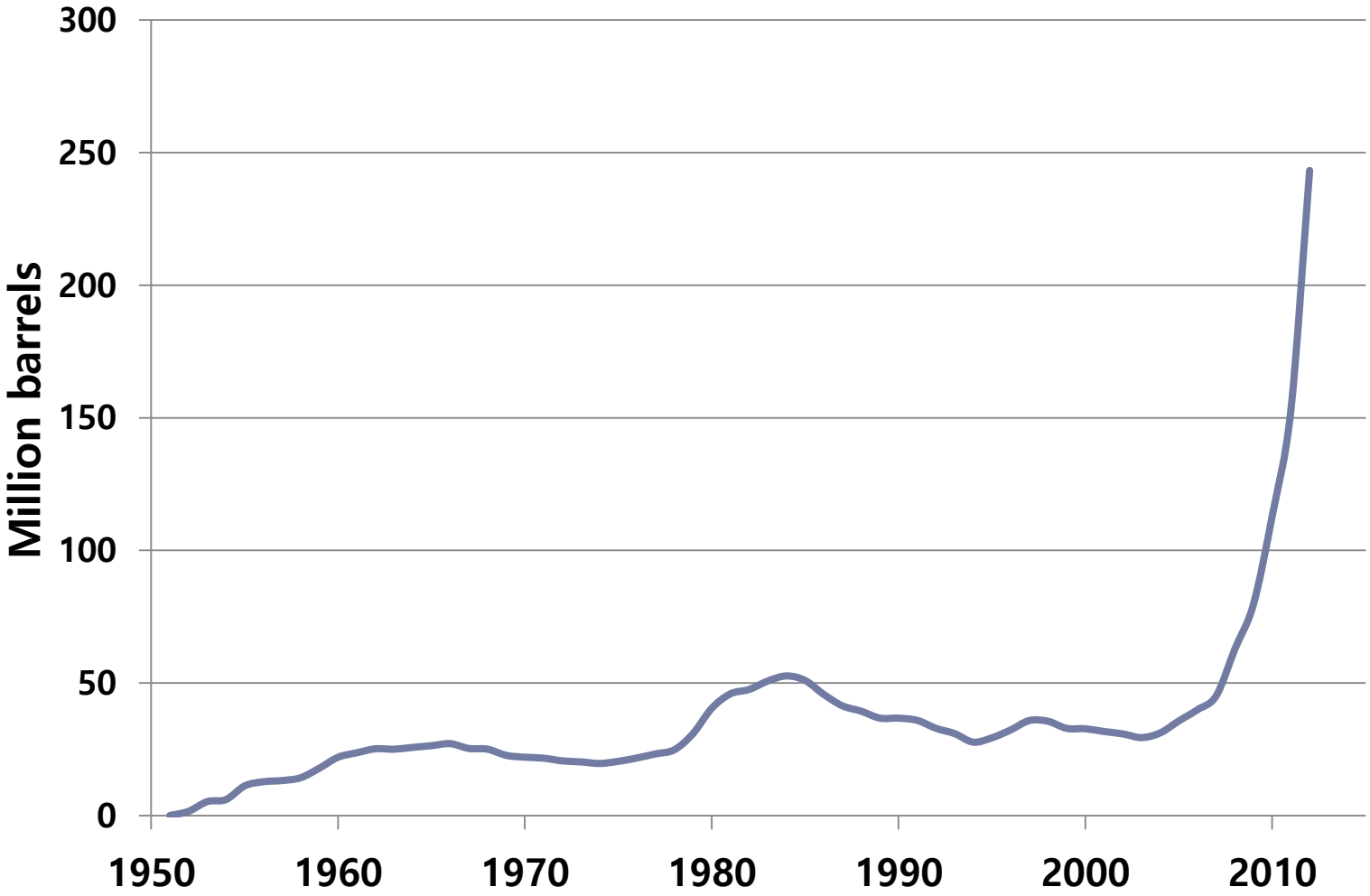
Horizontal versus Vertical Wells



Production Trends and Potential

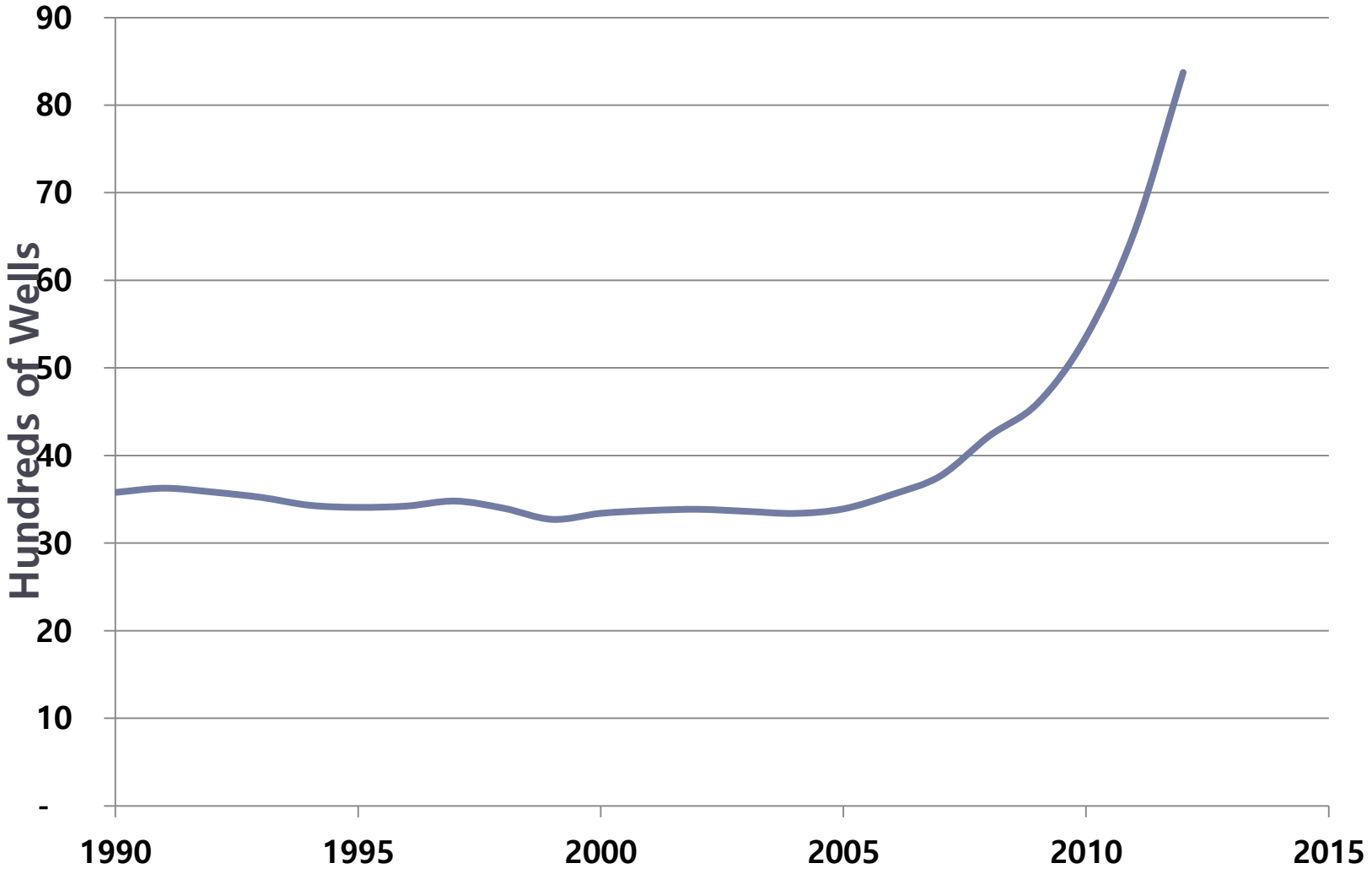
- ND is producing roughly 1 million barrels of oil per day (BOPD)
- Production may increase to 1.6 million BOPD
- Dept. of Mineral Resources projects 10-14 billion barrels of ***technically recoverable reserves***
- Industry projections (e.g., Continental Resources) are much higher—e.g., 20+ billion barrels
- Continental Resources estimates in-place oil reserves of 900 billion barrels
- 60,000 new wells will be drilled over next 20-30 years
- See following production charts

Annual Oil Production: North Dakota



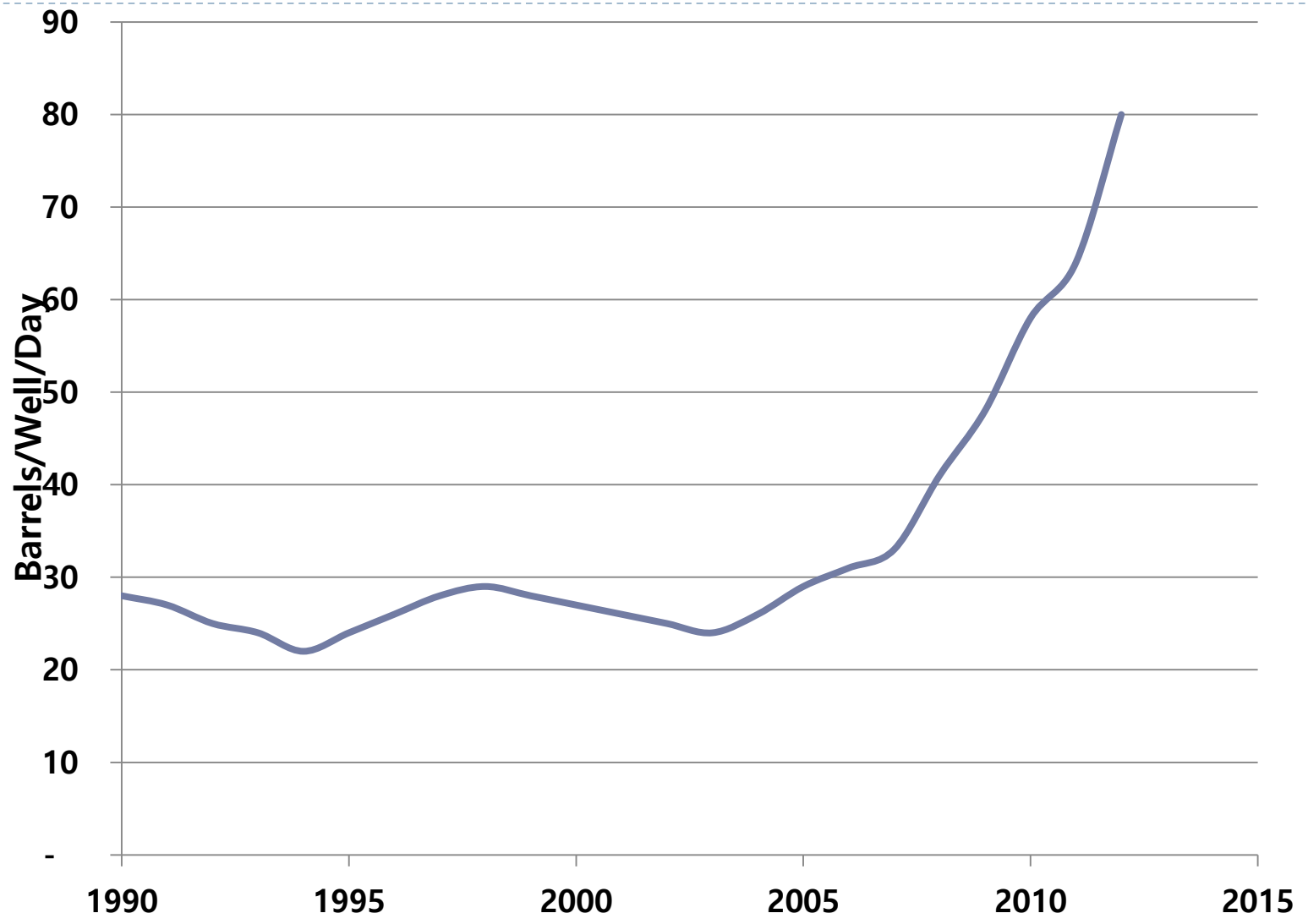
North Dakota is second leading state in oil production

Number of Oil Wells: North Dakota



Currently: 10,000+ producing wells

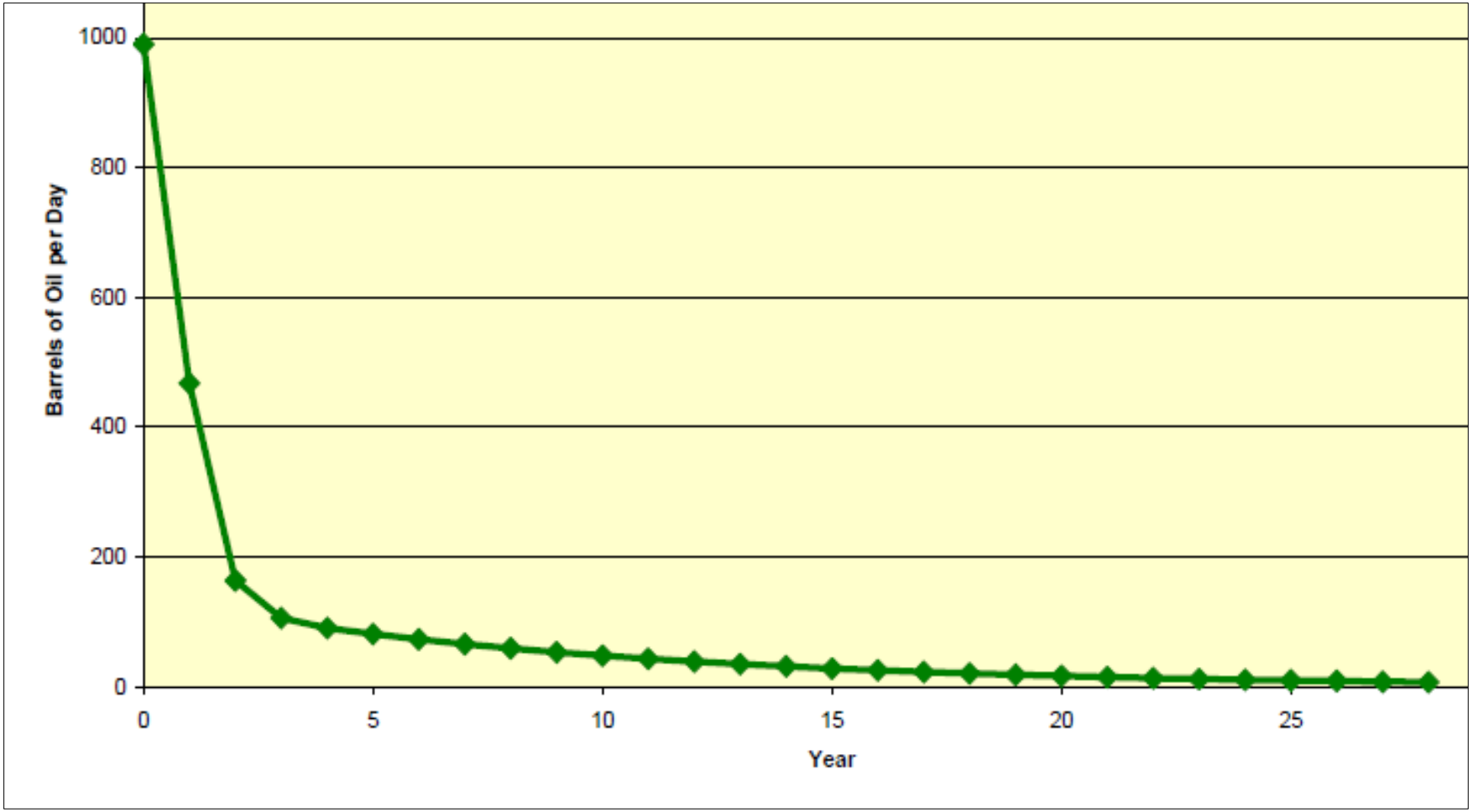
Daily Output per Well: North Dakota



Oil Production Specifics

- Bakken output per well: 140 barrels/day
- Average Initial Production as much as1,700 barrels/day with sharp decline following, statewide average 1,200
- Projected Bakken/Three Forks development
- 1,100 to 2,700 wells per year
  - Expected value (2,000 new wells per year)
- Projected new wells: 40,000 – 70,000 next 30 years
- Daily production may exceed 1.5 million barrels

Bakken Well Production Curve



North Dakota Industrial Commission, Oil and Gas Division, 2012 (Figure 10: *Typical Bakken Well Production Curve*)

Materials and Product Flows

- Inputs to well site for hydraulic fracturing and production; often railed in to transload site
- Specialized equipment to and from well site
- Roughly 2,300 drilling-related truck trips per well
- Outbound crude oil
  - By truck to pipeline or rail transfer location
  - By small diameter pipeline to trunk line connection
- Natural gas: by gathering pipeline to trunk connection
- Outbound byproducts

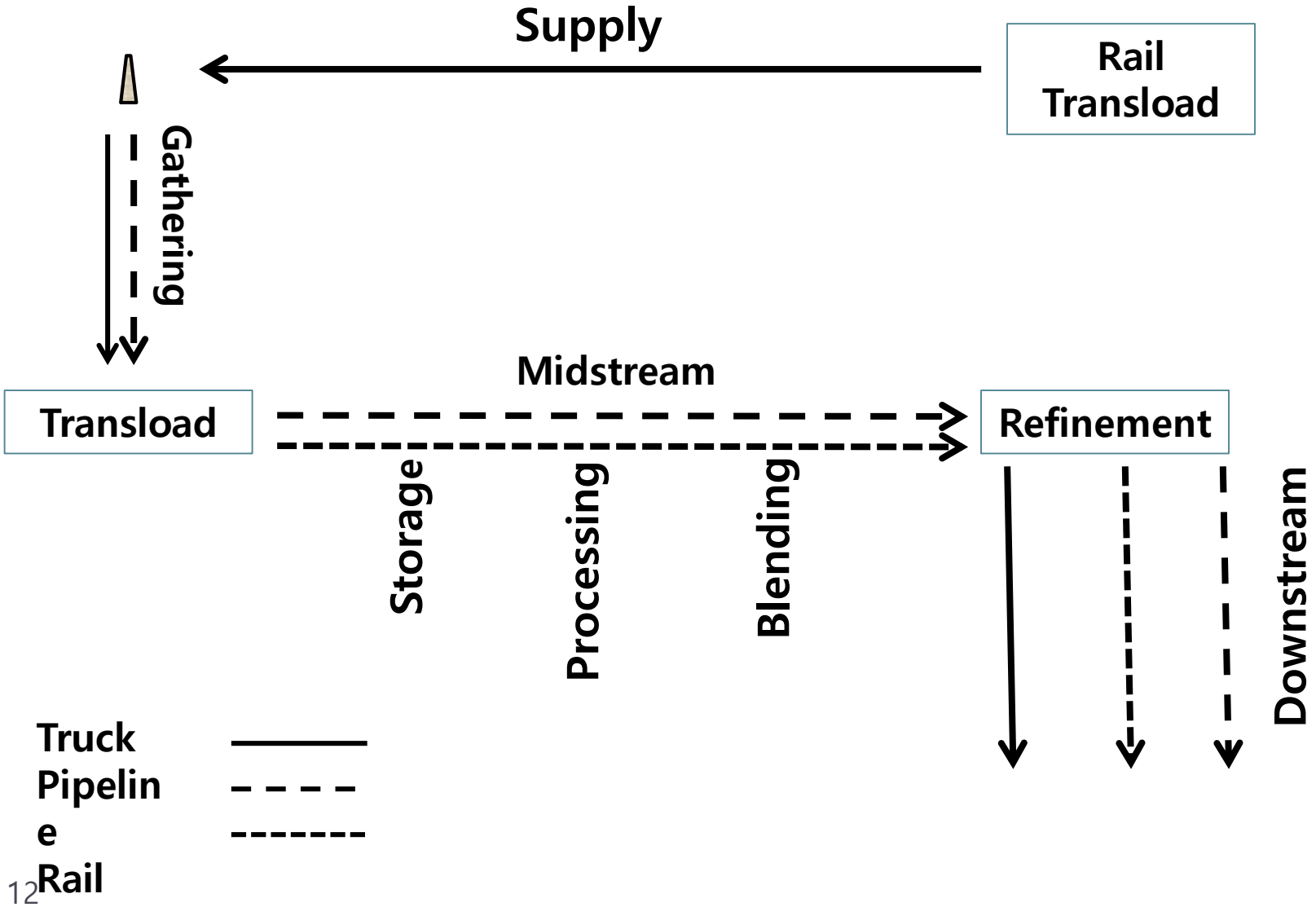
Drilling Related Truck Movements per Bakken Well

Input or Product	Loaded Trucks
Water (Fresh)	450
Water (Waste)	225
Frac Tanks	115
Sand	100
Scoria/Gravel	80
Rig Equipment	65
Drilling Mud	50
Cement	20
Pipe	15
Other	30

1,150 Loaded Trucks

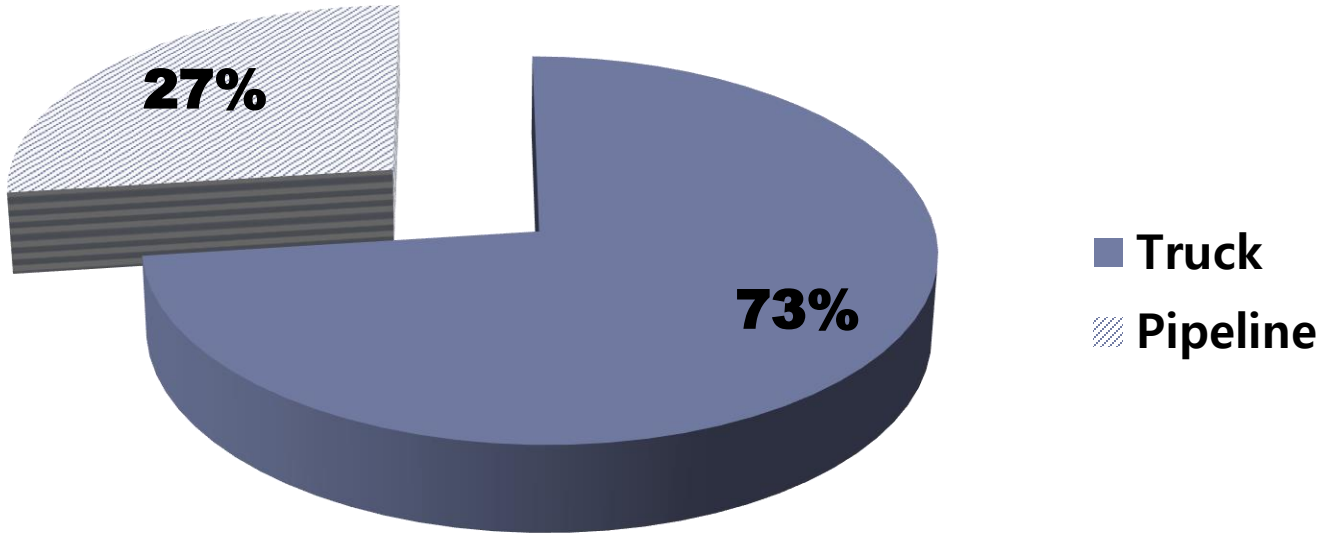
2,300 Loaded & Empty Trucks

Oil Logistics Network



Current Mode Share Crude Oil:
Gathering Movement

Movements from Wells to Transfer Locations

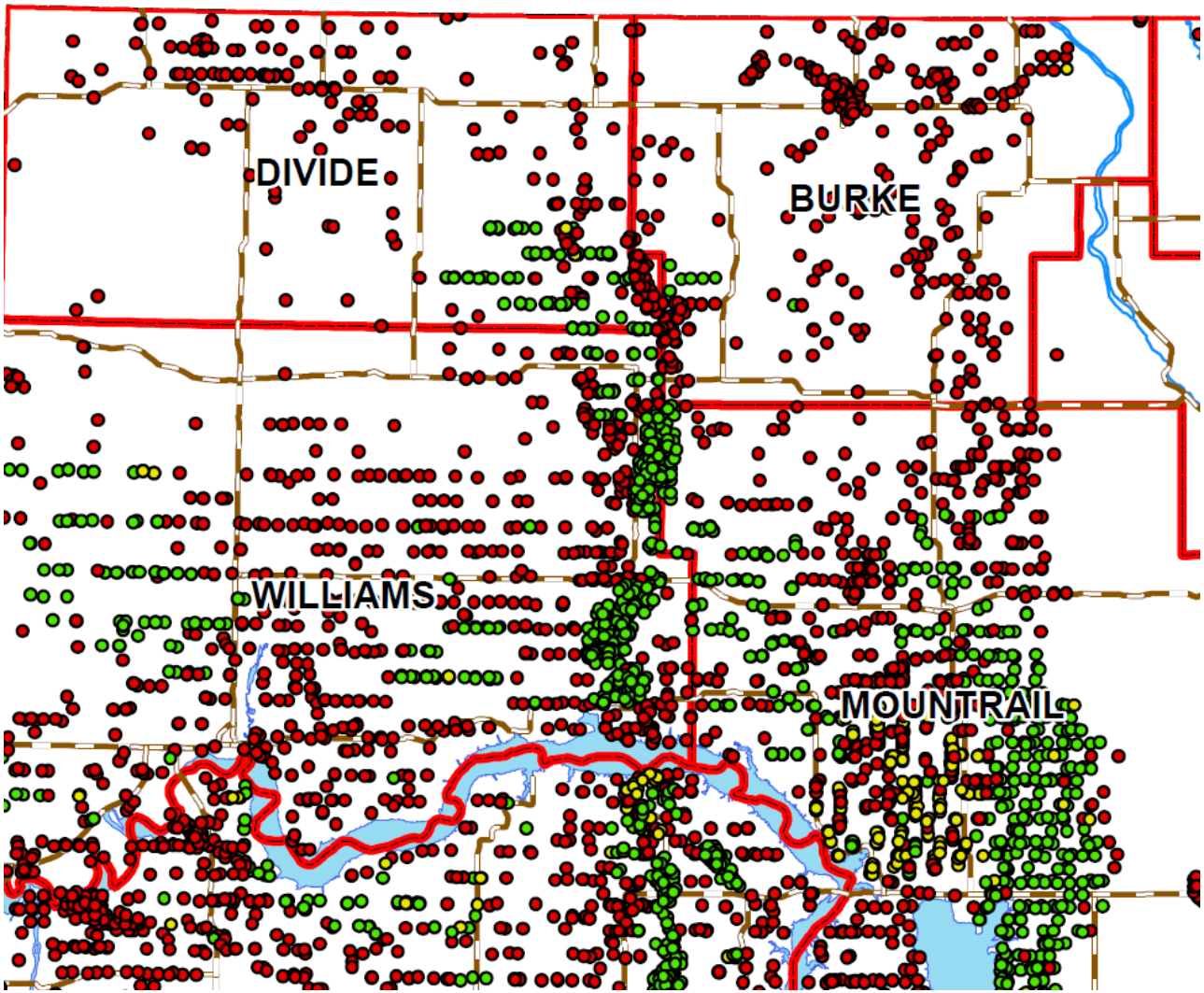


Pipeline Network in North Dakota

Category	*Miles*
Oil gathering pipeline	10,800
Crude oil (transmission) pipeline	3,100
Oil product pipeline	1,070
All oil pipelines	14,970

Estimates from North Dakota Pipeline Authority. No historical requirement for reporting of gathering pipelines. Thus, gathering pipeline miles estimated from multiple sources.

ND Oil Gathering Network:
Northern Bakken Region



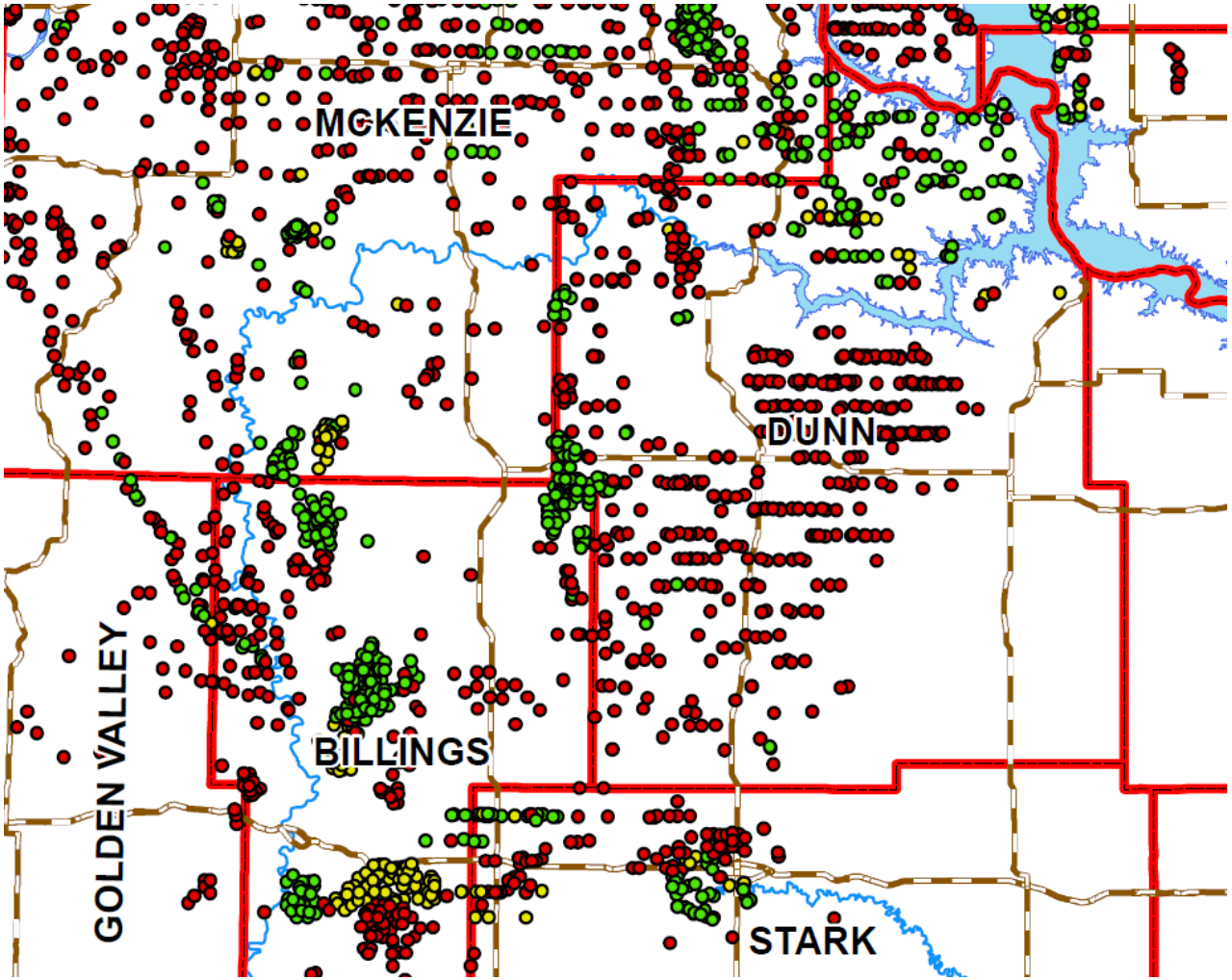
Truck
Pipeline
Both

Note: mature area (green dots) in center

Parshall gathering pipeline network

ND Gathering Oil Network:

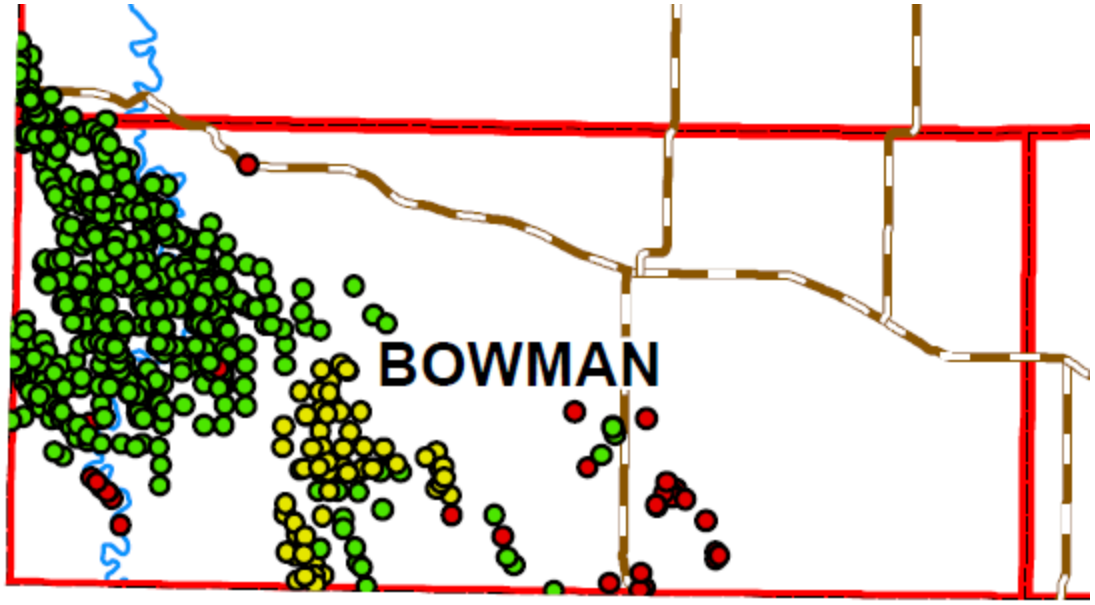
Southern Bakken Region



Truck
Pipeline
Both

ND Oil Gathering Network:
Pre-Boom Legacy Pool

- Mature producing region developed in 1970s
- Most wells have gathering pipeline access
- Compare to recent Bakken development, where trucking dominates



Truck
Pipeline
Both

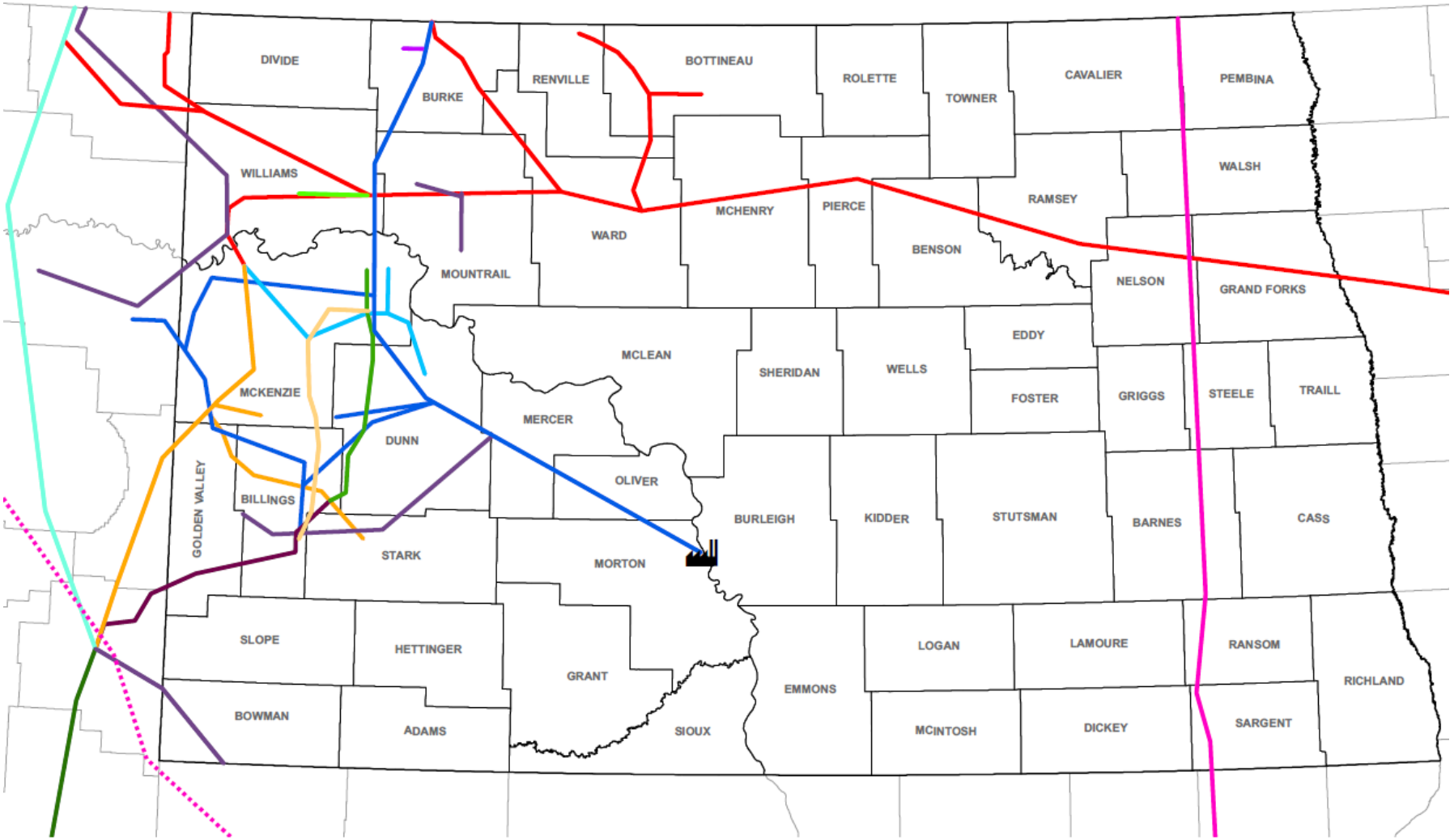
Gathering Mode Distribution Over Time

- Initially, all crude oil is transported by truck to rail or pipeline transfer locations
- When more wells are added to a spacing unit, small diameter gathering pipeline may be built to trunk pipeline network
- Projected distribution: ≥ two-thirds of crude oil outbound by gathering pipeline in mature system
- Depends on many factors: added trunk line capacity, rail improvements and capacity, highway improvements and restrictions

Crude Oil Mode Shares: Line Haul

- Current: 69% rail
- Near-term projection: 90% rail
- Reasons for rail dominance
  - Limited pipeline capacity (sized to historical production: next slide)
  - Challenges/length of time in siting and constructing new pipelines
  - Greater ease in capacity expansion of railroads
  - Lower cost of rail expansion
  - Rail access to a wider variety of markets → premium prices

ND Crude Oil Pipelines



North Dakota Pipeline Authority – Feb., 2013

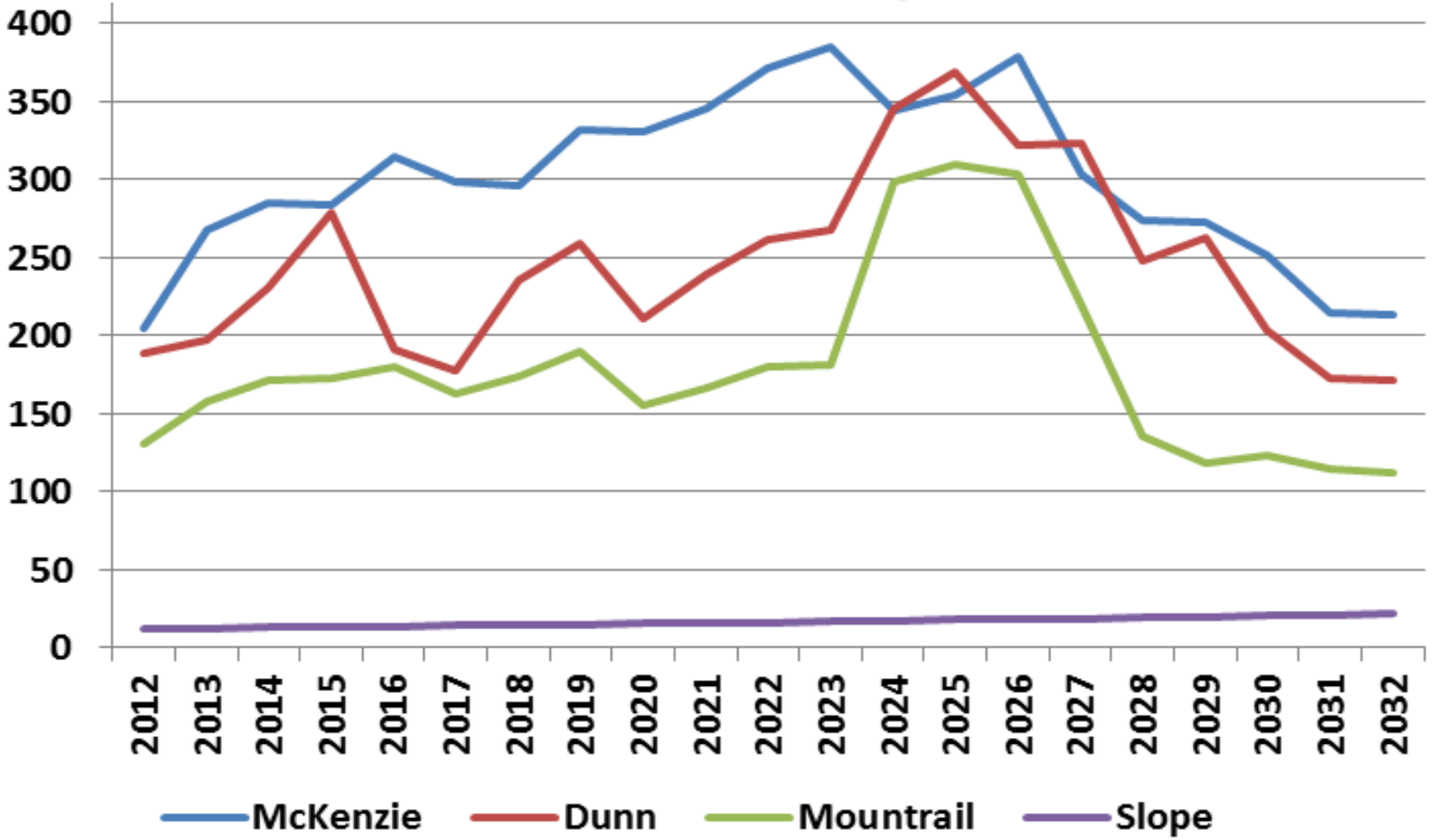
Rail Movement Specifics

- Shipments in multicar units or trainloads (e.g., 100+ cars)
- Current share in ND ≈ 1,000 railcars per day
- Equivalent to 10 100-car trains/day
- If railroads maintain 70%+ share, could have 16-20 trainloads per day of crude oil at peak
- ***Questions/potential issues***
  - Line capacity: other goods
  - Transload capacity
  - Service levels and priorities
  - Classification/placarding
  - Tankcar standards
  - Accident exposure (train-miles)
  - Grade crossings
  - Risk assessment/routing

Road System Impacts

- Studies for ND legislature
  - Detailed forecasts of traffic to/from individual spacing units
  - Truck traffic estimated annually for next 20 years
  - Models calibrated against observed traffic data for base year
  - Estimated truck ADT converted to equivalent single axle loads
  - Paved road condition forecasted year-by-year
  - Improvements identified: reconstruction, widening, resurfacing
  - Unpaved roads analysis based on increasing frequencies of blading/graveling, increased gravel

Avg. Projected Truck ADT on County Roads for Three Heavily Impacted Oil Counties (with Control Case)



Slope County (not impacted by oil production) illustrates traditional truck traffic levels

Damage to ND Highway 68 Resulting from Oil-Related Traffic

NDDOT. *Impact of Oil Development on State Highways*, May, 2006.

Oilfield Access Roads

- Large-scale investment program
  - $2.5 billion state highway program: 2013-2015 biennium
  - Roughly $930 million for county and township roads
  - Current studies include bridge investment needs
- Other critical issues
  - Enforcement resources
  - Safety (including heavy vehicles)
  - Grade crossings
  - Two-lane capacity
  - Hazmat/emergency response

Hazmat Concerns

- Bakken light crude: volatility and precise chemical composition
- Disposal of saltwater fracing mix
- Reduction in flaring: leads to more natural gas processing (LNG of CNG transport)
  - Fractionation: (NGLs)
    - Ethane (C_2), Propane (C_3), and Butane (C_4)
- Grade crossings: increasing truck and train traffic at traditional low-volume crossings
- Emergency preparedness and response
  - Pipeline spills
  - Train and truck movements through cities

Conclusions

- Oil-related traffic patterns are dynamic
- Vary spatially and temporally
- A multimodal transportation system is needed
- Different modes may be utilized more/less intensively in different stages of development
- Rural collector/local road system may be heavily impacted
- Road infrastructure may be entirely inadequate and require substantial upfront investment
- Caution must be exercised not to overbuild the road system

Conclusions (cont.)

- Gathering pipeline network may be added over time
- Crude transmission capacity may also be expanded
- New pipeline construction poses challenges
- Rail can be expanded more quickly at less cost, mostly within existing footprint
- Pipeline transport cost are likely to be lower than rail costs in the long run