Bakken Production Optimization Program

Energy Development and Transmission Committee
Grand Forks, ND
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Pre-Bakken North Dakota Traffic Jam

Bakken Boom Traffic

The Brave New World – Unconventional Reservoirs

Bakken Production Optimization Program Goals

- Maximize oil production from Bakken and Three Forks wells by employing an “all-of-the-above” approach
  - Advanced reservoir characterization
  - Improve drilling/stimulation/completion/production techniques and sequences
  - Optimize wellsite surface operations
    - ♦ Reduce costs
    - ♦ Reduce development and operation impacts to surrounding landowners
    - ♦ Reduce demands on surrounding infrastructure and water sources

Program Description

$112M

- *Pilot hole logs, core data, other data gathering from multiple wells to create a 3-D picture of what happens during and after the hydraulic fracture treatments in a multistage horizontal well. Continental will analyze this data set to:*
  - *Assess total resource available in the second and third benches of the Three Forks Formation (separate and unique?).*
  - *Confirm whether these benches are distinct and independent of the existing Middle Bakken.*
  - *Predict areas of future sweet spots.*

- Phase I – Drilling 11 New Wells
- Phase II – Completions
- Phase III – Reservoir Engineering
- Phase IV – Expansion Applications via 3-D Seismic

$8M

- *On-site hydrocarbon utilization, waste management, water management, site logistics, process optimization and systems failure analysis, spill remediation, and land reclamation with an eye on decreased environmental impact.*

- Phase V – Optimization of Wellsite Operations

Bakken Production Optimization Program Membership

Continental Resources

Marathon Oil

Whiting

North Dakota oil & gas research program

ConocoPhillips

Nuverra Environmental Solutions

Hitachi Inspire the Next

Hess

Oasis Petroleum

SM Energy

XTO Energy

Phase V – Optimization of Wellsite Operations

- Consortium-driven to help industry partners optimize oil and gas production activities
- Program scope of work:
  1. Hydrocarbon utilization (flare mitigation, crude volatility, enhanced oil recovery)
  2. Waste management (drill cuttings, solid waste, and NORM)
  3. Water management
  4. Site logistics
  5. Process optimization and systems analysis
  6. Waste Minimization & Utilization
  7. Spill remediation (including liquid leak detection)
  8. Land reclamation

2015 Headlines Predictions – Program Addresses Most

- Harvest phase well density and EOR
- Waste management and minimization
  - Produced and flow-back water
  - Drill cuttings
  - Filter socks
  - TENORM
  - Illegal dumping
- Spill reclamation
- Pipeline and PA reclamation
- Flaring reduction
- Pipeline Regulation
  - DMR > gathering
  - PSC > transmission
  - Operators > right of way

Lynn Helms,
Director of Mineral Resources,
North Dakota

Phase 3 "Harvest"

6-28 or more wells per spacing unit

Vern Whitten Photography

6 wells producing - drilling 7-12 - and 11-18 coming soon

Well Density Is the Big Question

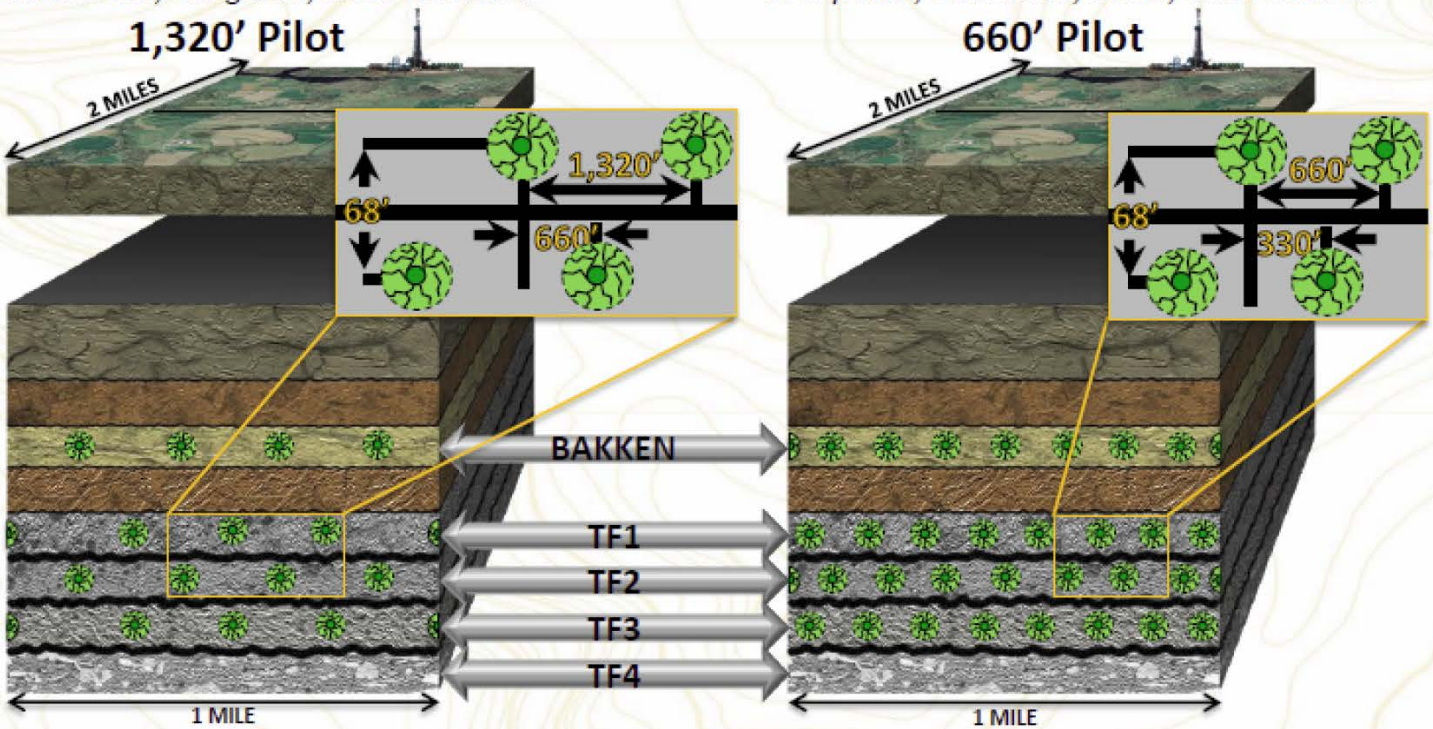
1,320' & 660' Pilot Density Projects: 2013-14

Hawkinson, Tangsrud, and Rollefstad

1,320' Pilot

Wahpeton, Lawrence, Mack, and Hartman

660' Pilot



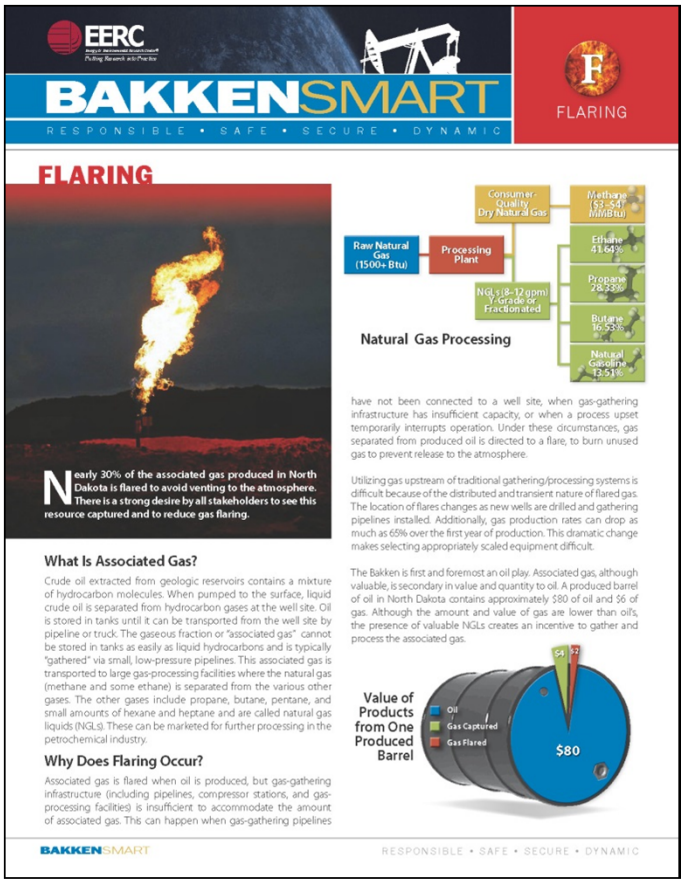
- 3 project areas
- 1,320 ft. same-zone spacing
- 34 new wells (gross)

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

Source: Continental Resources

Task 1 – Hydrocarbon Utilization Remote Capture

BakkenSmart Series – Flaring Fact Sheet



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FLARING

FLARING

Nearly 30% of the associated gas produced in North Dakota is flared to avoid venting to the atmosphere. There is a strong desire by all stakeholders to see this resource captured and to reduce gas flaring.

What Is Associated Gas?

Crude oil extracted from geologic reservoirs contains a mixture of hydrocarbon molecules. When pumped to the surface, liquid crude oil is separated from hydrocarbon gases at the well site. Oil is stored in tanks until it can be transported from the well site by pipeline or truck. The gaseous fraction or "associated gas" cannot be stored in tanks as easily as liquid hydrocarbons and is typically "gathered" via small, low-pressure pipelines. This associated gas is transported to large gas-processing facilities where the natural gas (methane and some ethane) is separated from the various other gases. The other gases include propane, butane, pentane, and small amounts of hexane and heptane and are called natural gas liquids (NGLs). These can be marketed for further processing in the petrochemical industry.

Why Does Flaring Occur?

Associated gas is flared when oil is produced, but gas-gathering infrastructure (including pipelines, compressor stations, and gas-processing facilities) is insufficient to accommodate the amount of associated gas. This can happen when gas-gathering pipelines

Natural Gas Processing

have not been connected to a well site, when gas-gathering infrastructure has insufficient capacity, or when a process upset temporarily interrupts operation. Under these circumstances, gas separated from produced oil is directed to a flare, to burn unused gas to prevent release to the atmosphere.

Utilizing gas upstream of traditional gathering/processing systems is difficult because of the distributed and transient nature of flared gas. The location of flares changes as new wells are drilled and gathering pipelines installed. Additionally, gas production rates can drop as much as 65% over the first year of production. This dramatic change makes selecting appropriately scaled equipment difficult.

The Bakken is first and foremost an oil play. Associated gas, although valuable, is secondary in value and quantity to oil. A produced barrel of oil in North Dakota contains approximately $80 of oil and $6 of gas. Although the amount and value of gas are lower than oil's, the presence of valuable NGLs creates an incentive to gather and process the associated gas.

Value of Products from One Produced Barrel

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In North Dakota, 29% of associated gas produced is flared (as of March 2013). Analysis conducted by the North Dakota Pipeline Authority suggests that nearly one-half of the flared gas is a result of capacity constraints within existing gathering systems. The remainder is flared at wells without pipelines. The flaring rate is down from a peak of 36% in September 2011 and is expected to continue to decrease as more infrastructure is installed. Nearly $4 billion has been spent to expand associated gas-related infrastructure in North Dakota, increasing gas-processing capacity 389% from 2006 to 2012. Today, North Dakota has sufficient gas-processing plant capacity to meet the nearly 900,000 Mcfd of gas production. Additionally, planned expansion will exceed expected gas production over the next several years.

Gas Production, Captured and Flared

There is a desire by all parties to see all associated gas captured and marketed: maximizing profits ensuring efficient use and minimizing environmental impacts. As the Bakken play matures, it is expected that nearly all produced gas will be captured.

How Is Flaring Regulated?

The North Dakota Industrial Commission Oil and Gas Division implements and enforces oil- and gas-related regulations. Typically, state law allows oil production to occur at varying rates during the first several months of operations to determine production rates. Gas can be flared while data are collected to assess the viability and determine gas-gathering capacity requirements. After 12 months of production, the well must be capped, connected to a gas-gathering system, equipped with a value-added process, granted an exemption from the Industrial Commission Oil and Gas Division or must pay taxes and royalties on the flared gas (Section 38-08-06.4 of the North Dakota Century Code, http://northdakotapipelines.com/natgasfacts/).

What Is Being Done to Reduce Flaring in North Dakota?

Rapid Infrastructure Buildout by Industry. As activities in the Bakken continue transitioning from single well pads to in-fill drilling (in which additional wells are drilled at already-producing well sites), gathering infrastructure should be more readily available and reduce the necessity for flaring.

New Technology Investigations. The Energy & Environmental Research Center (EERC) conducted an assessment of alternative gas uses upstream of traditional gas-processing plants. The study investigated using associated gas for power production, transportation fuel, and chemical production, as well as analyzed small-scale gas processing to recover NGLs. Although intriguing, the economic viability of these alternatives was complicated by the distributed and transient nature of flared gas, requiring innovative approaches to effective implementation.

Another project completed by the EERC demonstrated the use of wellhead gas as a fuel for the diesel generators powering drilling rigs. Results from the project indicated that 1.8 billion cubic feet of gas could be used annually to power 200 drilling rigs in North Dakota, saving over $72 million in fuel cost.

Currently, the EERC, Continental Resources, Whiting Petroleum, Marathon Oil, and others are working collaboratively to further improve the efficiency of wellsite operations, including gas use and flaring.

What Should the Public Know about Bakken Flaring?

- Of all gas produced, 29% is flared. Nearly 50% of that gas is from wells already connected to gas-gathering networks.
- Utilizing gas upstream of traditional gathering/processing systems is difficult because of the distributed and transient nature of flared gas.
- The Bakken is first and foremost an oil play. Associated gas, although valuable, is secondary in value and quantity to oil.
- North Dakota and oil producers are involved in concerted efforts to reduce the amount of flared gas.

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North Dakota oil & gas research program

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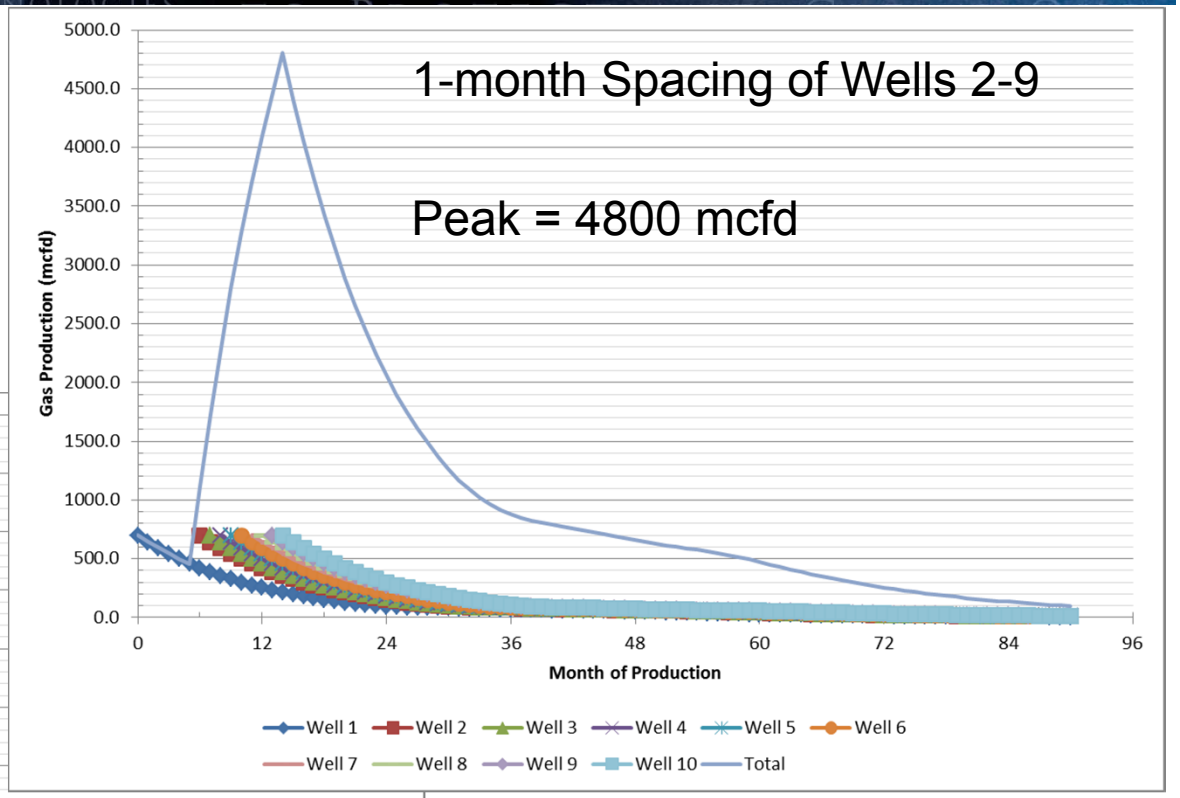
Summary of Flared Gas Statistics

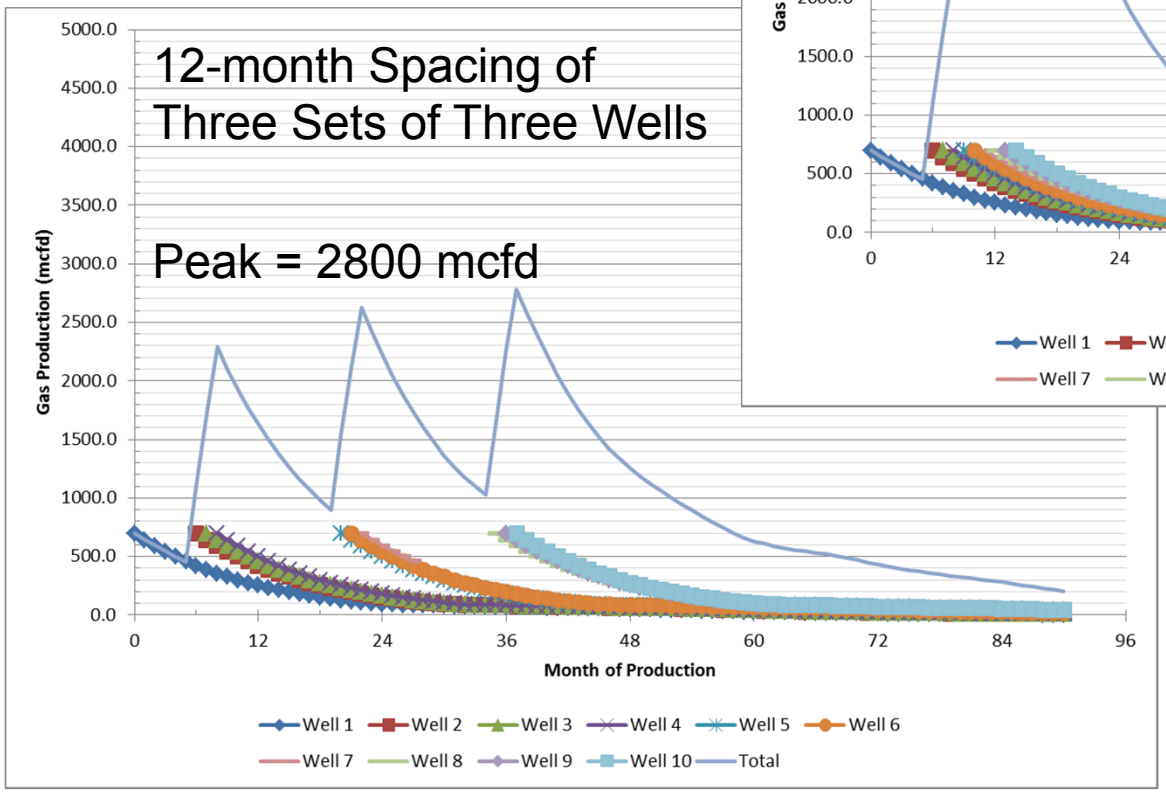
May 2014 Nonconfidential Locations

	<1 mcfd	1–299 mcfd	300–599 mcfd	600–1199 mcfd	1200+ mcfd
TOTAL LOCATIONS					
Locations	2248 (45%)	2491 (50%)	123 (3%)	64 (1%)	51 (1%)
Monthly Gas Flared, mcf	4963 (<1%)	3,338,685 (40%)	1,303,579 (16%)	1,307,353 (16%)	2,318,676 (28%)

238 locations flaring 60% of total flared gas at rates >300 mcfd.

Flowback Strategy and Production Decline from 10-Well Pad





Flaring Rule Update
Industrial Commission Order 24665

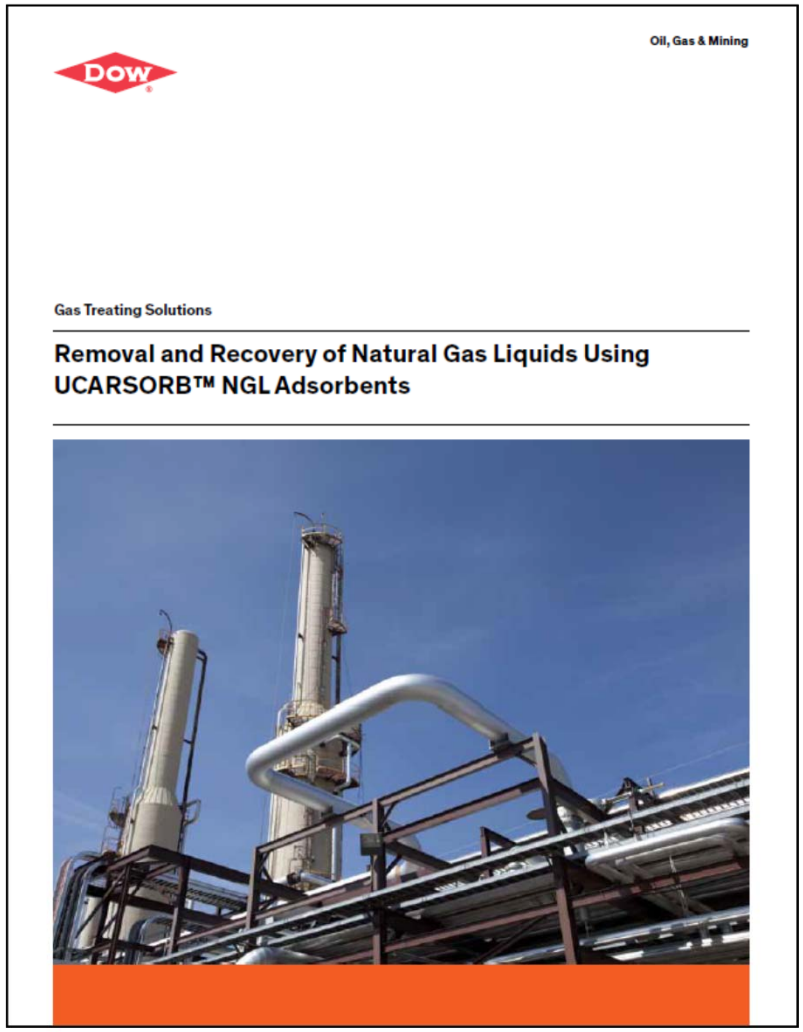
- Flare capture targets:
  - October 1, 2014: 74% capture (26% flaring)
  - January 1, 2015: 77% capture (23% flaring)
  - January 1, 2016: 85% capture (15% flaring)
  - October 1, 2020: 90% capture (10% flaring)
- Gas Capture Plan required with APD June 1, 2014
- All infill wells may produce at MER for 90-days
- If capture targets are not met, production restrictions:
  - 200 bpd provided 60% of monthly produced gas is captured
  - 100 bpd if capture is below 60% of monthly produced gas
- Compliance based on state, county, field, or well
- Flowback testing (14 days) excluded from calculation

Achieving Capture Targets

- How does industry achieve these targets:
  - Gathering pipeline installation
    - ♦ Winter installation
    - ♦ Incentivize excess capacity
  - Additional compression
  - Production planning – drilling, completion, and flowback strategy
  - Gas reinjection
  - Remote capture
    - ♦ Peak shaving initial production 2–24 months
    - ♦ Constrained gathering locations

A Promising Technology…

- Dow UCARSORB™ NGL Adsorbent technology
  - Adsorbent-based system with integrated regeneration
  - Tunable for target NGL recovery
  - Small footprint, low capital and operating cost
  - Potentially lower energy input relative to traditional NGL recovery platforms
  - Needs to be tested in relevant environment


Oil, Gas & Mining

DOW

Gas Treating Solutions

Removal and Recovery of Natural Gas Liquids Using UCARSORB™ NGL Adsorbents

Other Technologies

- Gas to Liquids
  - Clean Global Energy
  - CRNG Energy
  - Element 1
  - Gas Technologies LLC
  - Green Recycling Technologies Inc.
  - GTL Partners
  - ME Resource Corporation
  - Perfect Circle Energy, LLC
  - Portable GTL Systems, LLC
  - Primus Green Energy, Inc.
  - Siluria Technologies
  - Velocys
- Relatively more complex process
- Larger footprint may require separate surface lease
- Operational and environmental permitting requirements to be identified
- Operability with variable-feed quantity/quality to be demonstrated

Role for Remote Capture

- Flare reduction at electrically stranded locations
  - Often small-volume flares, appropriate for NGL recovery and gas-powered electrical generation
- Flare volume “peak shaving” during initial year of multiwell production
  - Larger scale, improved economics
  - NGL recovery followed by lean gas utilization
    - ♦ Grid support power
    - ♦ LNG for bifuel engines
  - Multiwell production can reduce variability of supply gas to remote capture
  - Gas volume in excess of gathering capacity can be reduced
  - Duration of 6–36 months possible, reducing mobilization costs
- Intermediate gathering location

Task 2 – Waste Management

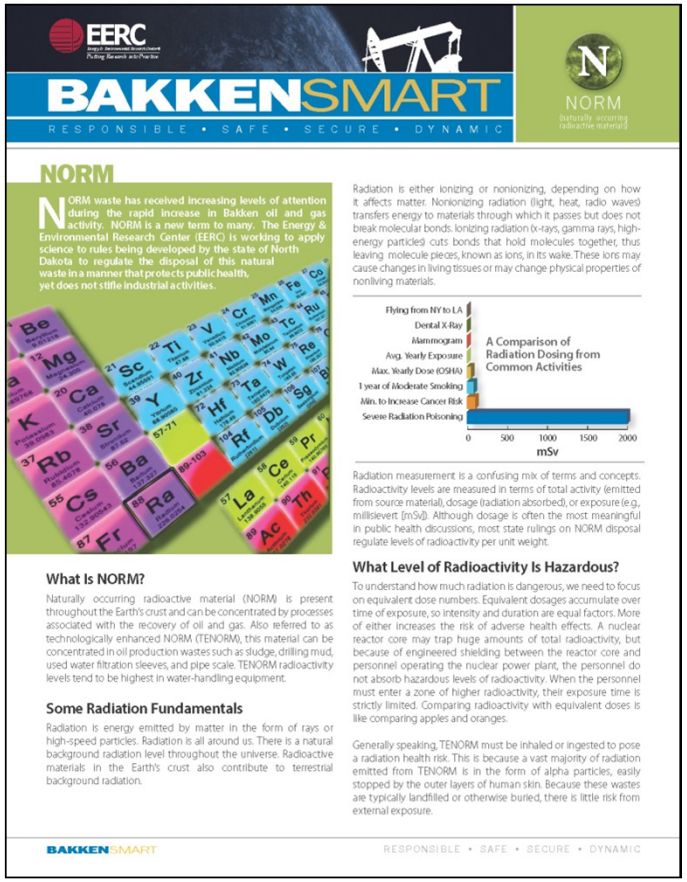
Task Scope

- The waste management area of work is focused on developing improved means of handling drilling and production wastes.
  - Focus on drill cuttings recycling
  - Focus on NORM

Task Accomplishments

- Created a well-received NORM fact sheet as part of a suite for public education
- Serving as consultant for members of this program and the NDPC NORM Task Force regarding the ND Department of Health / Argonne National Laboratory NORM study and recommendations for industry action.
- Coordinated a sampling effort to quantify NORM content in 50 samples of Bakken produced water, frac flowback water, and drill cuttings.
- Shared results of sampling effort with North Dakota Department of Health, at the request of the Task Force.
- Prepared an *industry edition* of the NORM Primer.
- Working with NDPC Communications Committee on a *public edition* of the NORM Primer.
- Drafted a wellsite waste survey for dissemination among industry members.

BakkenSmart Series – NORM Fact Sheet



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NORM
(Naturally occurring radioactive material)

NORM

NORM waste has received increasing levels of attention during the rapid increase in Bakken oil and gas activity. NORM is a new term to many. The Energy & Environmental Research Center (EERC) is working to apply science to rules being developed by the state of North Dakota to regulate the disposal of this natural waste in a manner that protects public health, yet does not stifle industrial activities.

What Is NORM?

Naturally occurring radioactive material (NORM) is present throughout the Earth's crust and can be concentrated by processes associated with the recovery of oil and gas. Also referred to as technologically enhanced NORM (TENORM), this material can be concentrated in oil production wastes such as sludge, drilling mud, used water filtration sleeves, and pipe scale. TENORM radioactivity levels tend to be highest in water-handling equipment.

Some Radiation Fundamentals

Radiation is energy emitted by matter in the form of rays or high-speed particles. Radiation is all around us. There is a natural background radiation level throughout the universe. Radioactive materials in the Earth's crust also contribute to terrestrial background radiation.

Radiation is either ionizing or nonionizing, depending on how it affects matter. Nonionizing radiation (light, heat, radio waves) transfers energy to materials through which it passes but does not break molecular bonds. Ionizing radiation (x-rays, gamma rays, high-energy particles) cuts bonds that hold molecules together, thus leaving molecule pieces, known as ions, in its wake. These ions may cause changes in living tissues or may change physical properties of nonliving materials.

A Comparison of Radiation Dosing from Common Activities

Flying from NY to LA
Dental X-Ray
Mammogram
Avg. Yearly Exposure
Max. Yearly Dose (OSHA)
1 year of Moderate Smoking
Min. to Increase Cancer Risk
Severe Radiation Poisoning

0 500 1000 1500 2000
mSv

Radiation measurement is a confusing mix of terms and concepts. Radioactivity levels are measured in terms of total activity (emitted from source material), dosage (radiation absorbed), or exposure (e.g., millisievert [mSv]). Although dosage is often the most meaningful in public health discussions, most state rulings on NORM disposal regulate levels of radioactivity per unit weight.

What Level of Radioactivity Is Hazardous?

To understand how much radiation is dangerous, we need to focus on equivalent dose numbers. Equivalent dosages accumulate over time of exposure, so intensity and duration are equal factors. More of either increases the risk of adverse health effects. A nuclear reactor core may trap huge amounts of total radioactivity, but because of engineered shielding between the reactor core and personnel operating the nuclear power plant, the personnel do not absorb hazardous levels of radioactivity. When the personnel must enter a zone of higher radioactivity, their exposure time is strictly limited. Comparing radioactivity with equivalent doses is like comparing apples and oranges.

Generally speaking, TENORM must be inhaled or ingested to pose a radiation health risk. This is because a vast majority of radiation emitted from TENORM is in the form of alpha particles, easily stopped by the outer layers of human skin. Because these wastes are typically landfilled or otherwise buried, there is little risk from external exposure.

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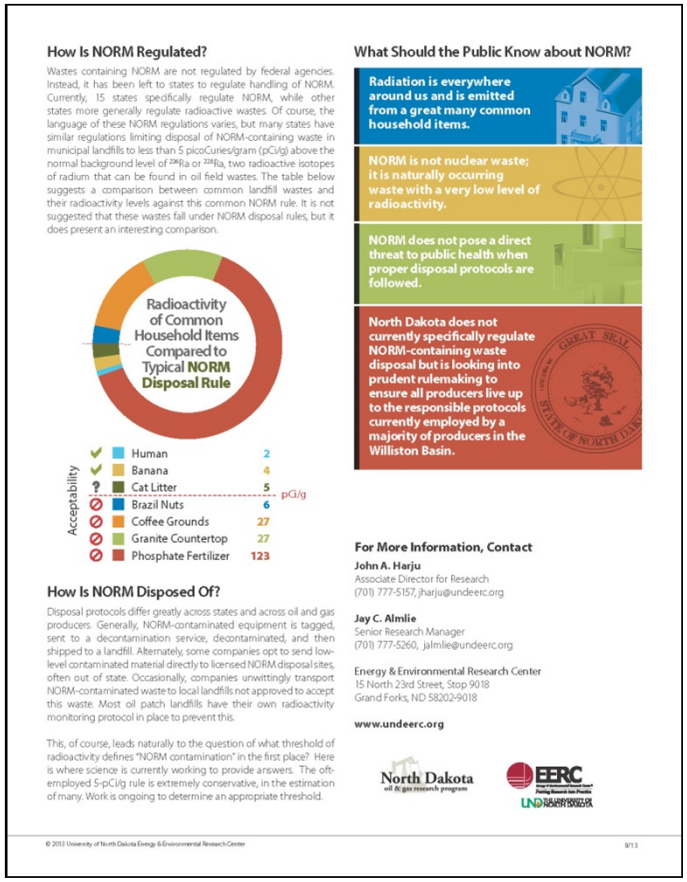

How Is NORM Regulated?

Wastes containing NORM are not regulated by federal agencies. Instead, it has been left to states to regulate handling of NORM. Currently, 15 states specifically regulate NORM, while other states more generally regulate radioactive wastes. Of course, the language of these NORM regulations varies, but many states have similar regulations limiting disposal of NORM-containing waste in municipal landfills to less than 5 picoCuries/gram (pCi/g) above the normal background level of ^{226}Ra or ^{228}Ra, two radioactive isotopes of radium that can be found in oil field wastes. The table below suggests a comparison between common landfill wastes and their radioactivity levels against this common NORM rule. It is not suggested that these wastes fall under NORM disposal rules, but it does present an interesting comparison.

Radioactivity of Common Household Items Compared to Typical NORM Disposal Rule

Acceptability		pCi/g
✔	Human	2
✔	Banana	4
?	Cat Litter	5
⊘	Brazil Nuts	6
⊘	Coffee Grounds	27
⊘	Granite Countertop	27
⊘	Phosphate Fertilizer	123

How Is NORM Disposed Of?

Disposal protocols differ greatly across states and across oil and gas producers. Generally, NORM-contaminated equipment is tagged, sent to a decontamination service, decontaminated, and then shipped to a landfill. Alternately, some companies opt to send low-level contaminated material directly to licensed NORM disposal sites, often out of state. Occasionally, companies unwittingly transport NORM-contaminated waste to local landfills not approved to accept this waste. Most oil patch landfills have their own radioactivity monitoring protocol in place to prevent this.

This, of course, leads naturally to the question of what threshold of radioactivity defines "NORM contamination" in the first place? Here is where science is currently working to provide answers. The oft-employed 5-pCi/g rule is extremely conservative, in the estimation of many. Work is ongoing to determine an appropriate threshold.

What Should the Public Know about NORM?

Radiation is everywhere around us and is emitted from a great many common household items.

NORM is not nuclear waste; it is naturally occurring waste with a very low level of radioactivity.

NORM does not pose a direct threat to public health when proper disposal protocols are followed.

North Dakota does not currently specifically regulate NORM-containing waste disposal but is looking into prudent rulemaking to ensure all producers live up to the responsible protocols currently employed by a majority of producers in the Williston Basin.

For More Information, Contact

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Program Focus on Improved Methods of Drill Cuttings Disposal and Recycling

Key Questions on Drill Cuttings

KEY QUESTIONS

- How much water and total hydrocarbon content can be extracted economically from wet drill cuttings?
- What products can be derived from individual lithofacial zones?
- What are the regulatory concerns?
- What impacts from local winter climate can be expected on recycling processes?

KEY CONCERNS

- NORM
- Salt
- Biological
- Fugitive dust

KEY OPPORTUNITIES

- Decreased pressures on landfills
- Conversion of disposal cost into new revenue stream
- Resolution of liability issues
- Public opinion
- Economic impact

Program Progress on Drill Cuttings

- The Program is currently assessing available recycling technology options for use in the Bakken:
  - Dryvac™ (DCDC)
  - Cuttings reinjection (various)
  - Terrafficient^{SM} (Nuverra)
  - Others
- White paper summary will be available 4th Quarter 2014.
- Nuverra is developing deep science in association with the Program.
- We are currently in discussions with individual producers to focus solutions on specific local needs.

A Promising Drill Cuttings Recycling Option for the Bakken….

- Nuverra Environmental Solutions, a Program partner, is now offering a turnkey approach to drill cuttings disposal:
  - Collect
  - Transport
  - Process
  - Recover
  - Recycle and reuse

Includes field coordination, special collection, minimizing solids control equipment and man power, transport, documentation, advanced treatment, and beneficial reuse.

Overview

Introducing Terrafficient℠

An environmentally sensitive and sustainable solution that is cost-effective and reliable:

- Advanced process that will significantly reduce environmental exposure
- Recovers 99.9% of hydrocarbons and produces materials that can be reused
- Technology has been verified by third-party science
- Managed to the highest regulatory and safety standards

Nuverra Environmental Solutions™

Turning Waste into Resources

Beneficial Reuse Applications

Extensive third-party research determined Terrafficient℠ produces material that can be safely reused for a variety of industrial purposes

- Flowable fill/controlled low-strength material (CLSM)
  - Used for drilling pads, temporary roads, road base
  - Trench filling for pipelines and utilities
- Fill material, either stand-alone or blended with commercially available fill
- Road salt
- Road base additive

Nuverra Environmental Solutions™

Task 3 – Water Management

Task Scope

- The water management area of work is focused on technologies to limit demand for freshwater, decrease wastewater production, and reduce water/wastewater trucking to and from the wellsite.

BakkenSmart Series – Water Fact Sheets

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WATER

WATER

Water is a critical ingredient for oil and gas development within the unconventional oil reservoirs of western North Dakota. Because of the current high costs for acquisition, disposal, and transportation of existing potable water resources in the region, treatment and/or use of nontraditional water supplies may be an economically viable alternative. The Energy & Environmental Research Center (EERC) is currently engaged in a project to investigate and accelerate development of new options to reduce fresh water consumption in Bakken production operations and decrease water costs to production operations.

How Is Water Used in Oil and Gas Production?

Development of one of the largest unconventional oil and gas plays in North America is occurring in North Dakota and Montana, with oil from the Bakken and Three Forks Formations being produced at over 800,000 barrels a day. It is estimated that there are hundreds of billions of barrels of oil in these formations. Robust development is expected to continue for at least another decade. While development of these resources clearly enhances the nation's energy security, a number of challenges are associated with that development, including the need for substantial volumes of water for hydraulic fracturing operations.

How Much Water Are We Talking?

Hydraulic fracturing is a process that injects a blend of mostly water with minor amounts of various additives at high pressure into these deep formations to create fractures and flow paths necessary for oil and gas extraction from rocks with very low permeability. A Bakken well requires 1 million to 5 million gallons of water for hydraulic fracturing. The North Dakota Department of Mineral Resources estimates that 20 million to 30 million gallons of water a day, or 7.3 billion to 11 billion gallons of water a year, will be needed over the next few decades.

Center pivot irrigation in North Dakota requires about 4 million gallons of water a day for a 1-square-mile section of land.

Where Do Producers Get the Water?

While the volumes of water used for hydraulic fracturing are not especially high when compared to those needed for municipal and agricultural use within western North Dakota, in some areas there is a high degree of competition among various users for limited freshwater supplies. As shown below, there are a limited number of locations from which to obtain freshwater. Many such water depots and municipalities have a limited supply. The Missouri River system has an abundant supply of water, but federal concerns over suitable access points have delayed and/or limited access. Most other surface water bodies in the region are small and do not provide a reliable supply of water because of seasonal flow variations.

For water haulers, the limited number of water supply locations translates to long transportation distances and excessive amounts of time spent waiting in lines at water depots, resulting in high water acquisition (and wastewater disposal) costs for Bakken oil producers. Given the current demand for water resources and the high costs of transportation, the oil and gas industry is motivated to explore options for water reuse and/or recycling.

Operating Water Depots (as of September 11, 2012)

Crosby, Grenora, Powers Lake, Kenmare, Tioga, Stanley, Williston, Alnsor, New Town, Parshall, Watford City, Killdeer, Medora, Dickinson

Developed
Municipal Permit
Low gpm
Temporary Irrigation to Industrial
Bakken Development
Glacial Aquifers

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WATER-HANDLING COSTS

ACQUISITION COSTS

	Cost, $/bbl	Cost, $/1000 gal
Raw Water	$0.25–$1.05	$5.95–$25.00
Transportation	$0.63–$5.00	$15.00–$119.05

DISPOSAL COSTS

	Cost, $/bbl	Cost, $/1000 gal
Transportation	$0.63–$9.00	$15.00–$214.29
Deep Well Injection	$0.50–$1.75	$11.90–$41.66
Total Costs	$2–$17	$47–$400

Source: Energy & Environmental Research Center Report on Bakken Water Opportunities – Phase II

What Options Do We Have?

As treatment technologies and fracturing fluid systems advance, there may be potential options for treatment, reuse, and/or recycling of nontraditional water supply sources for use in Bakken development, such as:

- Treatment and reuse of the water used for hydraulic fracturing after it returns to the surface (referred to as flowback).
- Treatment and use of wastewater from other nontraditional sources, such as saline groundwater and municipal wastewater.
- Use of hydraulic fracturing fluid systems that work with saline water rather than high-quality water.

The above approaches are not without challenges. For example, Bakken flowback tends to be very salty, and only a portion of it returns to the surface (typically about 25% or less), making treatment difficult and limiting the amount available for reuse. Treatment of other nontraditional water sources may be easier, but transportation costs may be too high. The use of salt-tolerant fracturing fluids may hold promise, but these formulations are just beginning to be developed. While industry recognizes the benefits of water recycling and reuse for Bakken development, these challenges have prevented widespread implementation to date.

How Will Development of New Water Options Benefit North Dakota?

Industry development of new technologies to recycle or otherwise utilize flowback, produced water, or saline groundwater would provide multiple benefits to the state and industry and improve the quality of life for residents impacted by truck traffic and associated dust and road maintenance issues. Some of the key benefits include the following:

- Decreased demand on freshwater resources
- Decreased wastewater disposal costs and associated costs for industry
- Fewer issues associated with the heavy volume of truck traffic in the region, such as road maintenance, dust control, and air emissions
- Increased versatility in water supply options, resulting in decreased production costs
- Decreased environmental footprint for Bakken development

What Does the Public Need to Know about Water Use in Oil Production?

A typical Bakken well requires 1 million to 5 million gallons of high-quality water for hydraulic fracturing.

Locations to obtain freshwater are limited, and many have a limited supply, resulting in high water acquisition (and wastewater disposal) costs.

Potential options for water treatment are being developed to minimize demands on freshwater supply sources.

The use of salt-tolerant fracturing fluids may hold promise, but these formulations are just beginning to be developed.

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North Dakota oil & gas research program

EERC

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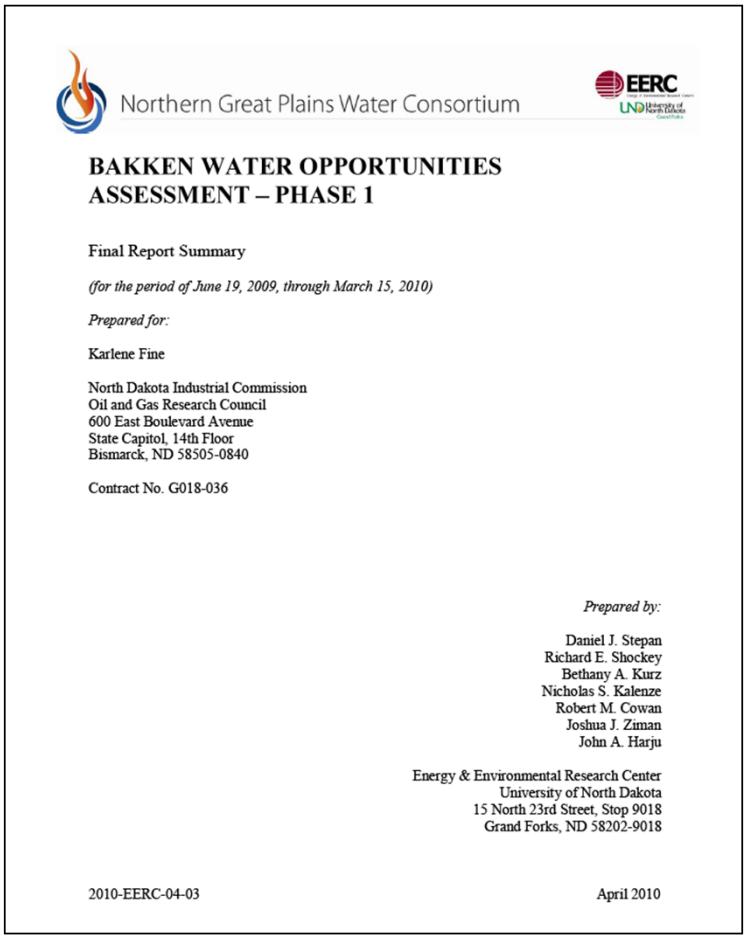
Bakken Water Optimization Activities

- Updating data and information on Bakken water use and handling:
  - Fresh water use
  - Flowback and produced water generation
  - Well maintenance water requirements
- Preliminary microbiological assessment and contamination risk:
  - Risk based on water source and/or handling
  - Microbiologically influenced corrosion
- Updated reports and fact sheets



Northern Great Plains Water Consortium

BAKKEN WATER OPPORTUNITIES ASSESSMENT – PHASE 1

Final Report Summary

(for the period of June 19, 2009, through March 15, 2010)

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Current Trends in Bakken Fracturing

Slickwater fracturing

- Low viscosity, high rate fracturing
  - ♦ Pumped at 60 to 80 bpm, compared 30 to 40 bpm for conventional gel fracturing.
- Requires more water (160,000 – 200,000 bbls)
- Slickwater fracturing can utilize 100 percent produced water (with minimal treatment – i.e., filtering), reducing the demand for fresh water.

ND State Water Commission Factoids

- The average fracturing process in North Dakota requires about 54,000 bbls (7 acre-ft of water)
- In 2012, records indicate that 98 million bbls (12,629 acre-ft) of surface and groundwater were used for fracturing. That amounts to 4% of North Dakota's 2012 consumptive use.
- One day of the average daily flow in the Missouri River at Bismarck is 353 million bbls (45,480 acre-ft) is enough to fracture 6497 wells.
- Evaporation from Lake Sakakawea is 19 million bbls/day (2472 acre-ft/day).

Photo credit: ND Tourism

Task 7 – Spill Remediation
&
Task 8 – Land Reclamation

Task Scope

- The spill remediation and land reclamation areas of work are focused on developing improved methods of returning lands affected by oil exploration and production activities to productive and natural states in a more timely manner

Ongoing Activities

Spill Remediation

- Fact sheets
- Best practices guide

Land Reclamation

- Fact sheets
- Best practices guide

- Site-Specific Demonstration(s)

BakkenSmart Series – Spills and Reclamation Fact Sheets

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SPILLS

SPILLS

As oil and gas production in North Dakota has increased, so has the number of spills associated with that production. Occasional spills are an unavoidable consequence of oil and gas production. To minimize the impact of these spills, an understanding of the size and nature of spills is needed. With that knowledge, appropriate remediation and reclamation techniques can be used to return impacted soils to productive use. The Energy & Environmental Research Center (EERC) is working to understand the magnitude of the issue and provide a science-based resource for the remediation and reclamation of these spills.

What Types of Spills Are Associated with Oil and Gas Production?

In North Dakota, oil- and gas-related spills are reported in three categories: hydrocarbon, saline, and other (in some cases spills are a combination of these categories). Hydrocarbon spills are typically crude oil; saline spills are primarily produced water; and fluids reported under the other category include drilling muds, fracture gels, and non-crude-oil fluids such as diesel fuel and hydraulic fluid.

In addition, spills are reported as either "contained" or "not contained." "Contained" spills occurr within an existing barrier such as at the oil and gas location, while not-contained spills extend beyond an existing barrier and impact the natural environment.

Putting Spills into Perspective

Based on a review of the North Dakota Department of Health Oilfield Environmental Incidents database (2001–2014), total oil- and gas-related spills have increased from 190 incidences in 2001 to 1904 incidences in 2013, and total spill volume has increased from 8550 barrels in 2001 to 162,889 barrels in 2013. Although the number of spills and spill volume have increased, the number of spills and the total spill volume as a function of oil production has remained unchanged since 2001 and have actually gone down since development of the Bakken Formation.

What Happens When a Spill Occurs?

The state of North Dakota requires immediate reporting of any spill or other incident that could adversely affect human health or the environment. The wellsite operator is responsible for making proper notifications to the state, but suspected leaks or observed spills needing immediate attention may also be reported by the public. Depending on the spill or incident, one of the following agencies would be notified and provided with relevant information:

- North Dakota Department of Emergency Services
  1 (800) 472-2121 (24-hour hotline)
- North Dakota Oil and Gas Division
  1 (701) 328-8020
- North Dakota Department of Health
  1 (701) 328-5210 or 1 (701) 328-5166

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RECLAMATION

RECLAMATION

Reclamation of land affected by oil and gas production is an integral part of the cradle-to-grave oil and gas production process. The Energy & Environmental Research Center (EERC) and North Dakota State University (NDSU) are working to improve the understanding of the reclamation process and the practice of reclamation actions, as well as to provide all those involved in the process with resources to maximize the potential for successful reclamation.

Understanding the Reclamation Process

The goal for any reclamation project is to restore the pre-disturbance ecological functions of a site disturbed during the construction activities associated with oil and gas production.

Oil and gas companies deploy reclamation activities for two distinct reasons: 1) as the final step of the remediation process after a spill and 2) as the final step after disturbance of native land from construction of a pipeline, production site, or other infrastructure.

This fact sheet discusses reclamation of privately owned lands. Reclamation of state and federally owned lands will most likely involve the same process but will be overseen and directed by the state or federal agency charged with its care.

Who Is Involved in a Reclamation Project?

Oil and Gas Production Company. The company is responsible for the reclamation project, including the execution of the reclamation and its final success. Producers either perform the reclamation operations themselves or hire contractors to perform the reclamation.

Reclamation Contractors. Contractors have expertise in reclamation and are often hired by oil and gas companies to perform reclamation operations.

North Dakota Department of Health (NDDH). NDDH is responsible for supervision of the overall reclamation project and regulates the oil and gas company regarding the successful completion of the reclamation. Generally, NDDH regulatory jurisdiction is for remediation and reclamation outside of the oil and gas production pad.

North Dakota Oil and Gas Division. Like NDDH, the North Dakota Oil and Gas Division is responsible for the supervision of the overall reclamation projects and regulates the oil and gas company regarding the successful completion of the reclamation. Generally, the North Dakota Oil and Gas Division's regulatory jurisdiction is for remediation and reclamation on the oil and gas production pad and, in some cases, gathering pipeline networks.

How Are Spills Reclaimed?

Spill cleanup has two distinct phases: remediation and reclamation. The reclamation phase is focused on returning the impacted area back to original conditions and reestablishing vegetation.

Once the impacted soils have been sufficiently remediated, reclamation typically involves the following steps:

- Perform a thorough inventory of the surrounding area to document site-specific information and ecosystem functions that need to be restored.
- Replace soil appropriately (i.e., subsoil, then topsoil). This will most likely require bringing subsoil and topsoil from an off-site source to replace the excavated soils during the remediation.
- Apply soil amendments as needed.
- Prepare seedbed for seeding.

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Please visit:

www.undeerc.org/Bakken/

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