OhioNET: State of Ohio’s Response to Induced Seismicity

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Ohio Department of Natural Resources: Division of Oil & Gas Resources Management
Overview

I. State of the Ohio Utica Play
   • Latest Utica Shale
   • Latest Class II Brine Disposal

II. OhioNET Seismic Monitoring System

III. Induced Events
   • Northstar #1 Injection Well
   • Poland Township Hydraulic Fracturing
   • Harrison County Hydraulic Fracturing

IV. Regulation & Mitigation Techniques

V. Interstate Collaboration

VI. Public Awareness & Educational Outreach
Latest Utica Shale
(as of 04/01/2017)

<table>
<thead>
<tr>
<th></th>
<th>Utica</th>
<th>Marcellus</th>
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<tbody>
<tr>
<td>Permits</td>
<td>2,452</td>
<td>46</td>
</tr>
<tr>
<td>Drilled</td>
<td>1,950</td>
<td>28</td>
</tr>
<tr>
<td>Producing</td>
<td>1,528</td>
<td>20</td>
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Recent Per Year Totals

2014 Totals
Oil: 10,999,162 barrels
Gas: 452,866,564 Mcf

2015 Totals
Oil: 21,985,351 barrels
Gas: 954,748,118 Mcf

2016 Totals
Oil: 17,949,097 barrels
Gas: 1,370,220,834 Mcf

Annual Production Percent Change

<table>
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<tr>
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<th>2014 to 2015</th>
<th>2015 to 2016</th>
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<tr>
<td>Oil</td>
<td>99.90%</td>
<td>-22.14%</td>
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<tr>
<td>Gas</td>
<td>110.60%</td>
<td>43.39%</td>
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Latest Class II Brine Disposal Numbers
(as of 03/18/2017)

Active Injection
217

Drilled
11

Drilling
1

Shut In
2

Newly Permitted
8
Recent Per Year Totals

2012 Totals
Brine: 14,157,885 barrels
Active Wells: 146

2013 Totals
Brine: 16,383,043 barrels
Active Wells: 164

2014 Totals
Brine: 24,704,481 barrels
Active Wells: 185

2015 Totals
Brine: 32,023,496 barrels
Active Wells: 212
OhioNET Seismic Monitoring System

- 24/7, 365 real-time continuous seismic monitoring
- OhioNET receives data from almost 45 seismic stations from a combination of sources including ODNR, Operator, TA, and CEUSN seismic stations
  - 12 additional stations are planned to be deployed this year, including ground motion sensors

### Current Configuration
- 19 ODNR owned stations
- 10 operator leased stations
- 15 TA/N4 stations, USGS & CEUSN
- **Total: 44 High quality 3-component stations**
OhioNET Seismic Monitoring System (continued)

Earthworm Seismic Processing Software

• Earthworm is an open source auto-picking earthquake processing software by ISTI
• Earthworm is custom built based on the end users specifications
• Provides automated email alerts to specific administrators and seismic staff of potential seismic events for further analysis within minutes of the event
• Emails contain important preliminary information including an auto-picked location, magnitude, depth, and error values
• Always someone on staff to answer alert and offer interpretation of data
Induced Seismic Events

Northstar #1
Youngstown, OH
December 31, 2011
M4.0

Poland Township
Poland, OH
March 10-11, 2014
M3.0

Harrison County
Freeport, OH
September 2015
M3.1
Induced Seismic Events (continued)

Plot of Induced Seismicity Events at Hamilton Pad

Source: Paul Friberg, ISTI

Magntitude (ML)

Hamilton Pad Active Fracking

Typical sensing threshold

Source: Paul Friberg, ISTI
Induced Seismic Events (continued)

Depth View of Hypocenters

Source: Paul Friberg, ISTI

Approximate depth of Precambrian Basement

Source: Paul Friberg, ISTI
Induced Seismic Events (continued)

Map View of Hypocenters

Source: Paul Friberg, ISTI
Regulation Techniques

Current Seismic Permit Conditions for Injection Wells
Ohio Revised Code Chapter 1501:0-3-06

The chief may require the following tests or evaluations of a proposed brine injection well, in any combination that the chief deems necessary:
Geological investigation of potential faulting within the immediate vicinity of the proposed injection well location, which may include seismic surveys or other methods determined by the chief to assist analysis.
Permit conditions may include seismic monitoring, pressure fall-off tests, spinner tests, radioactive tracer, geophysical and electrical logs and downhole pressure monitoring.

Current Seismic Permits Conditions for Horizontal Wells
Restrictions may be placed on wells drilled near faults or areas of known seismic activity, in which seismic monitors must be installed for a specified time period prior to completion operations.

ML $\geq$ 1.5 – Direct communication starts between operator and Division
ML = 2.0-2.4 – Work with operator to proposed or modify operation
ML $\geq$ 2.5 – Temporary halt completions on lateral
ML= 3.0+ – Completion on pad suspended until an approved plan is submitted by operator

Ground Motion
In the future, the Division will include ground motion as an additional way to monitor induced events. Provides ‘ground truth’ of shaking and allows for a better understanding of how induced events affects the surface and whether damage to a structure is possible or likely. Values based on the particle velocity and frequency of the seismic event, which are held to the same motion limitations as blasting operations.
Mitigation Techniques

Key Points

• Direct communication with the operator is essential
• Discussion of seismic events and stages of the operation in real-time
• Spatial analysis and time correlation with completion data during the operation

Mitigation techniques when induced seismicity occurs during hydraulic fracturing:

• Change from zipper fracking to stack fracking
• At least 20% reduction in volume and/or pressure
• Skipping stages may be necessary, especially if seismic events indicate a lineament or fault structure near a lateral of the operation
• Switch to smaller sieve sizes for proppant, full effect still unsure
Interstate Collaboration

• Ohio is a national leader and participant in the Interstate Oil and Gas Compact Commission and the Ground Water Protection Council

• ODNR continues to prioritize rule development that protects our citizens, the environment and our natural resources
Public Awareness & Educational Outreach

Display station at Ohio State Fair in 2016

OOGEEP Education and Training Sessions in Marietta, OH
Summary

• Shale Oil and Gas development, along with brine disposal in Ohio, will continue to rise for the foreseeable future

• Real-time continuous monitoring is mandatory when trying to mitigate the risk of induced seismicity

• Having an aggressive stance and staying proactive has helped decrease induced seismicity occurrences in Ohio

• Proper policies and regulation have helped guarantee safe and proper extraction of oil & gas while offering less shutdown times for operators

• In the event of induced seismicity, direct communication with operators is essential for mitigation, along with modifying pad operations

• Sharing information with other states and the local community helps assist in tackling the problem of induced seismicity and aids in public confidence of their states regulatory agency
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