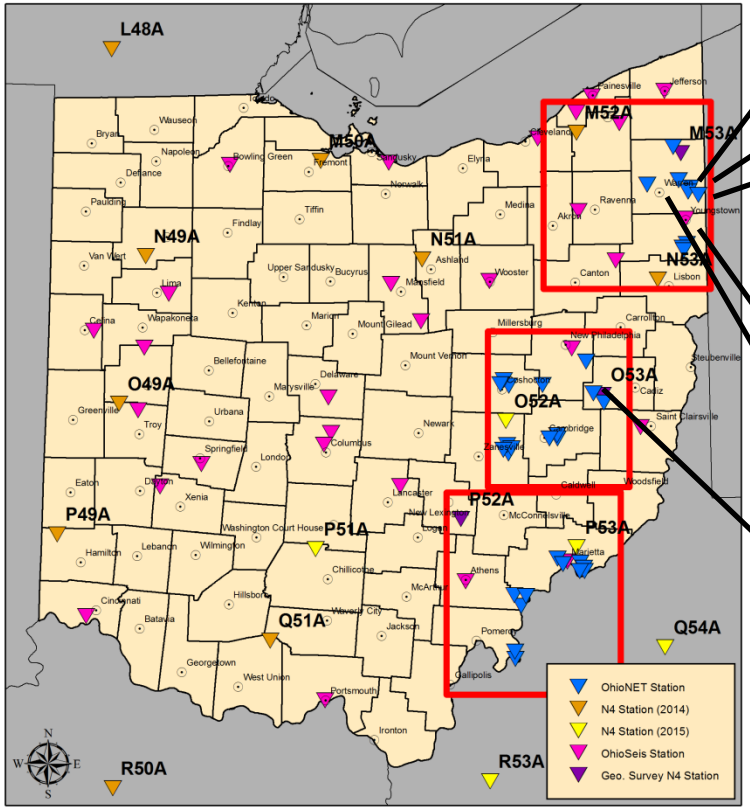
Regulatory Approaches for Induced Seismicity

Richard Simmers
Chief, Division of Oil & Gas Resources Management
Ohio Department of Natural Resources

Ohio Department of Natural Resources: Division of Oil & Gas Resources Management OhioNET Seismic Network



Date	Event	Action
2011	Earthquakes detected in the Youngstown area	In November, the Division detailed seismic monitoring began. Sensors received and deployed December 1, 2011
December 23, 2011	2.7 Magnitude	Division ordered well shut down 12/30/2011
December 31, 2011	4.0 Magnitude	All 3 wells in the immediate area shut down with a moratorium on all new well permits
June 11, 2012	New statute for injection wells	Senate Bill 315 signed into law
2012	Begin deployment of 3-component stations to monitor seismicity in Eastern Ohio	
March 14, 2014	Events associated with well completion	Operator required to deploy 8 sensors; alerts sent to ODNR in real time
August 31, 2014	2.1 Magnitude associated with injection well	Well shut down by Chief's Order
September 10, 2015	Numerous micro-seismic events magnitude -1.5 to 3.1; ODNR established time coincidence between pumping and events	Operator modified well completions procedures; no zipper completions; cut volumes by 20%; skipped stages; reduced pressures; joint operator-Division monitoring; successful completion

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 in identifying potential faulting within the immediate vicinity of the proposed injection well.

Permit conditions may include seismic monitoring, pressure fall-off tests, spinner tests, radiative tracer, geophysical and electrical logs, and downhole pressure monitoring,

Current Seismic Permit Conditions for Horizontal wells drilled near faults or areas of known seismic activity

Seismic monitors must be installed for a specified time period prior to completion operations

M≥1.5 – Direct communication starts between operator and Division

M=2.0-2.5 – Modify completion operations (e.g. no zipper completions, skip stages, cut volumes and pressures)

M≥2.5 – Halt completions on certain portions of the pad

Earthworm Alert – Harrison County during Hydraulic Fracturing Operation

Ohio DNR EW Automated Preliminary Earthquake Location: Please note that earthquake data may be preliminary and subject to change. - EW Event ID: 7298

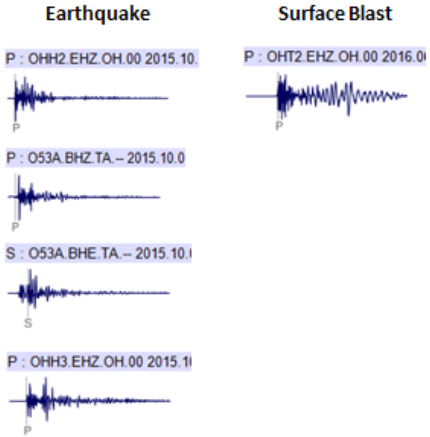
OhioNET@dnr.state.oh.us

Sent: Thu 10/1/2015 3:29 AM

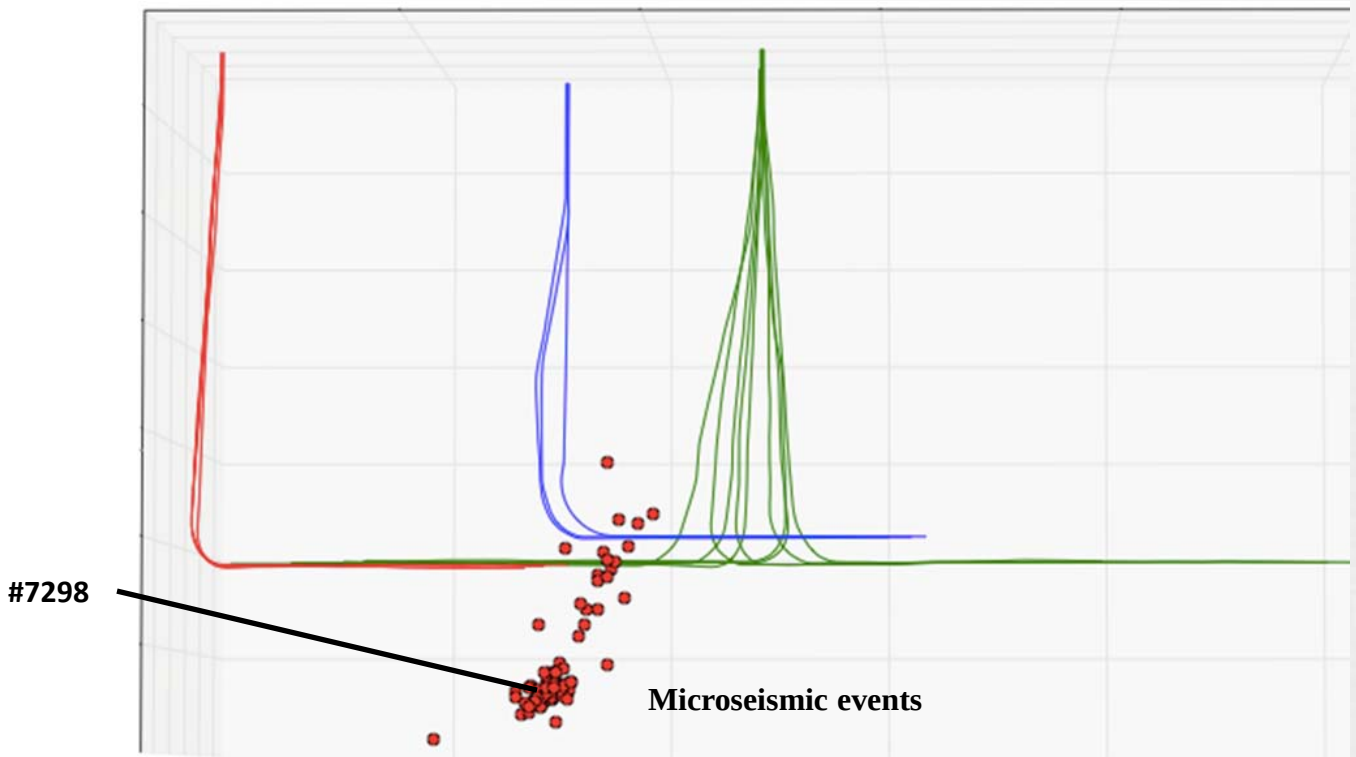
To: Rush, David

Recalculated depth places event at top of basement

EW Event ID: 7298	
Origin time:	2015.10.01 08:25:33 !!
Latitude:	40.2270
Longitude:	-81.1902
Depth:	0.8 km 2.7 km (8860')
Coda Magnitude:	1.5 Md nobs=5
Local Magnitude:	1.7 ±0.6 ML nobs=68
RMS Error:	0.08 s
Horizontal Error:	0.48 km
Depth Error:	0.22 km
Azimuthal Gap:	130 Degrees
Total Phases:	26
Total Phases Used:	13
Num S Phases Used:	4
Quality:	B

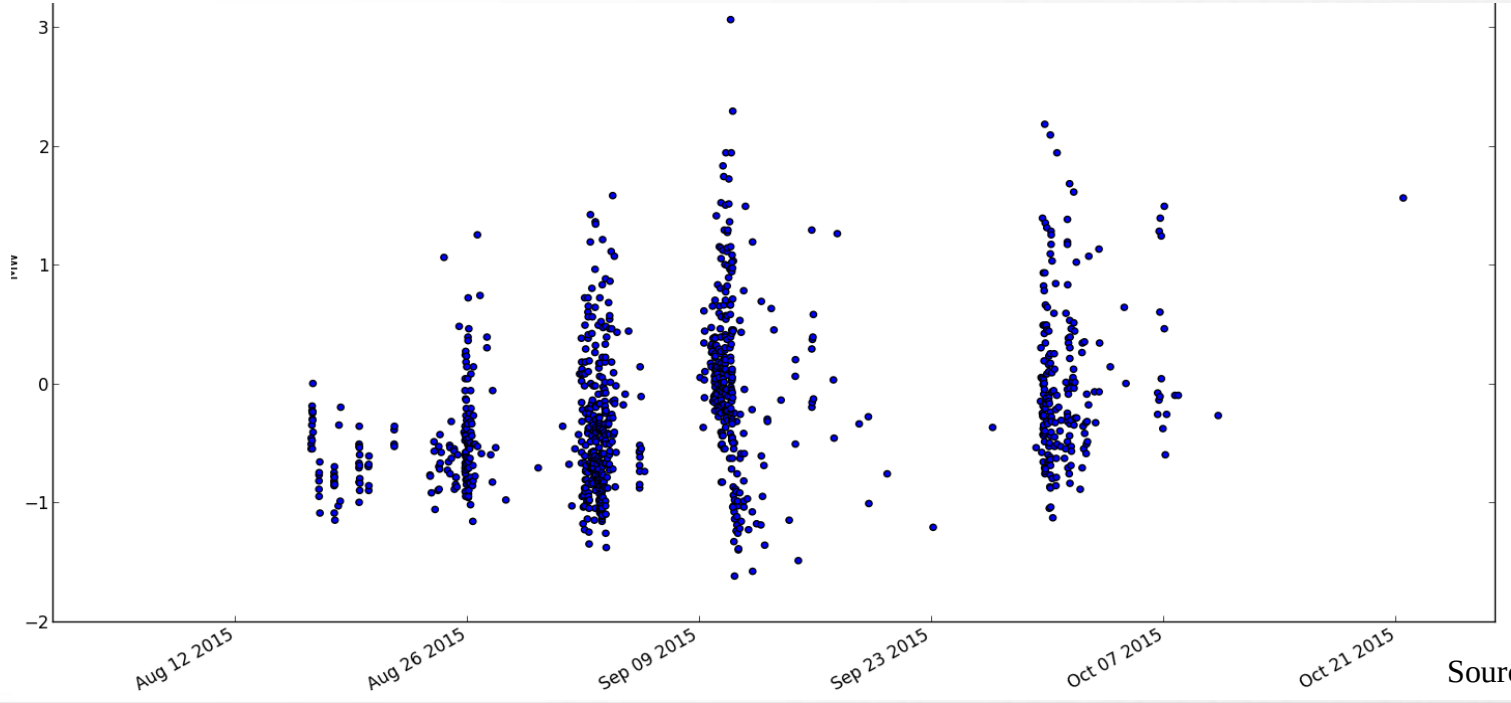


Depth View of Hypocenters



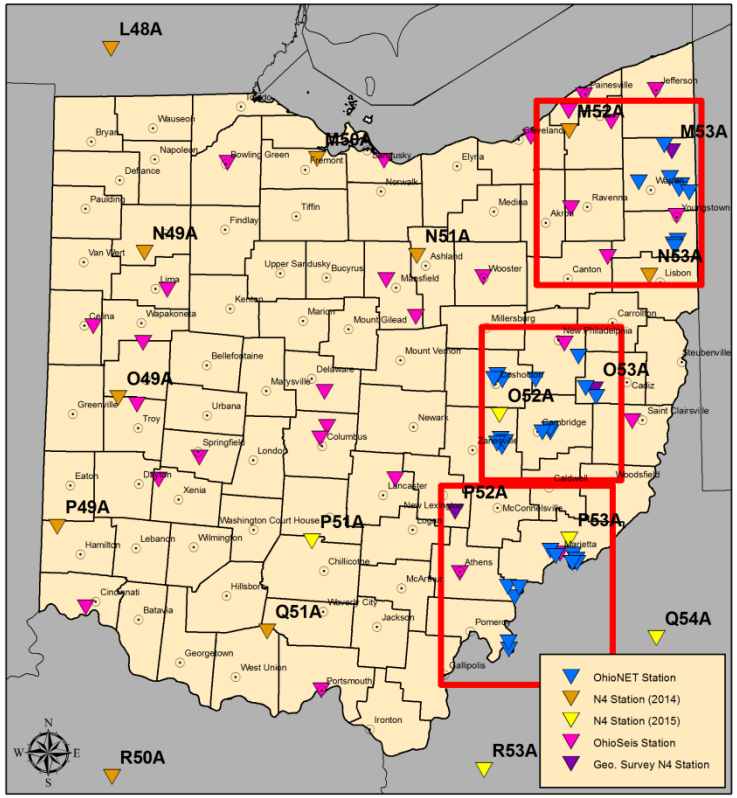
Source: Paul Friberg

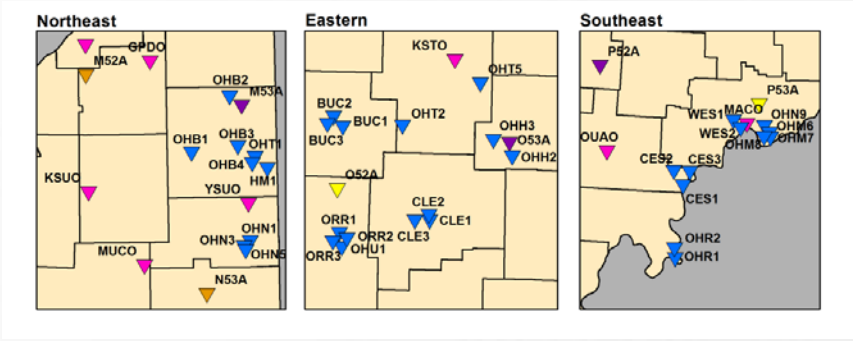
Plot of Microseismic Events at Well Completion Pad, Harrison County



Source: Paul Friberg

Ohio Department of Natural Resources: Division of Oil & Gas
Resources Management OhioNET Seismic Network





OhioNET Seismic Network

- 21 ODNR owned stations
- 12 Operator leased stations
- 13 operator stations
  (ODNR receives alerts and data as needed)

Total: 61 3-component stations

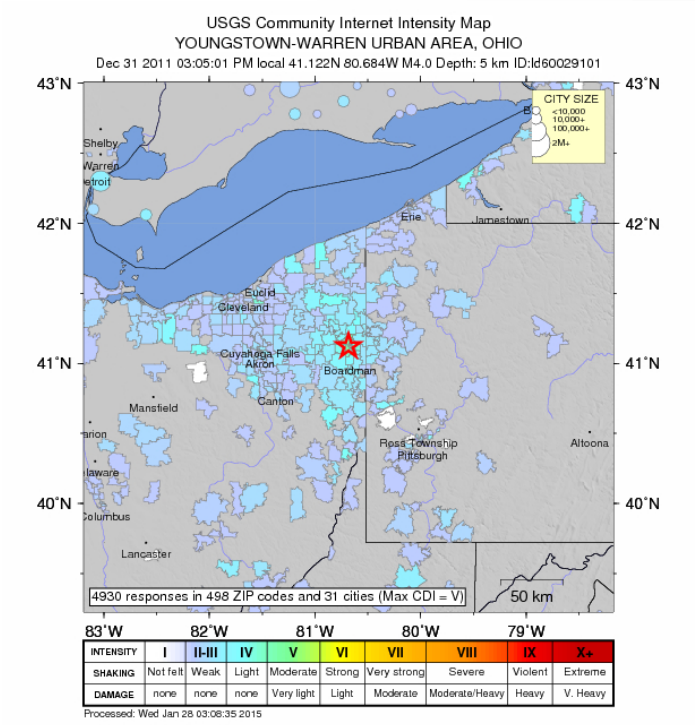
Adding staff and stations in summer of 2016, including surface accelerometers to measure particle velocity

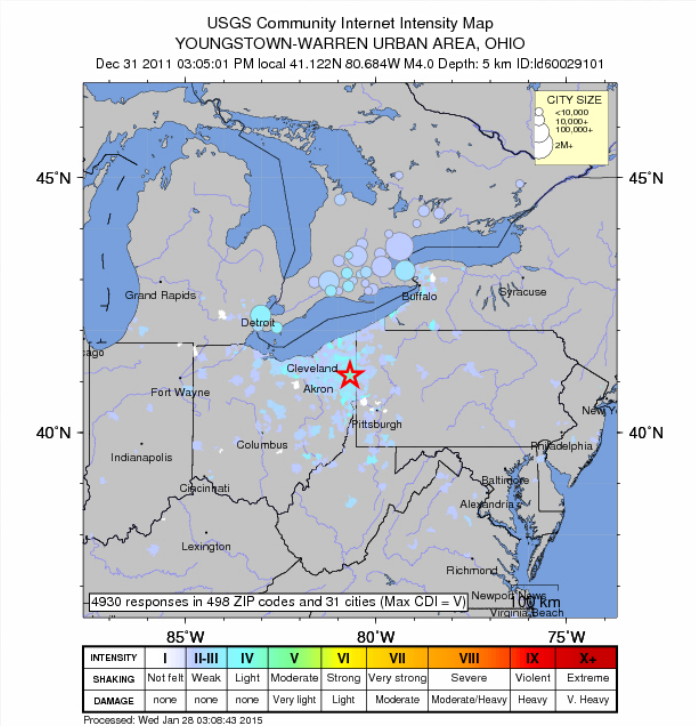
Ohio Department of
NATURAL RESOURCES

Ref Tek Real Time System

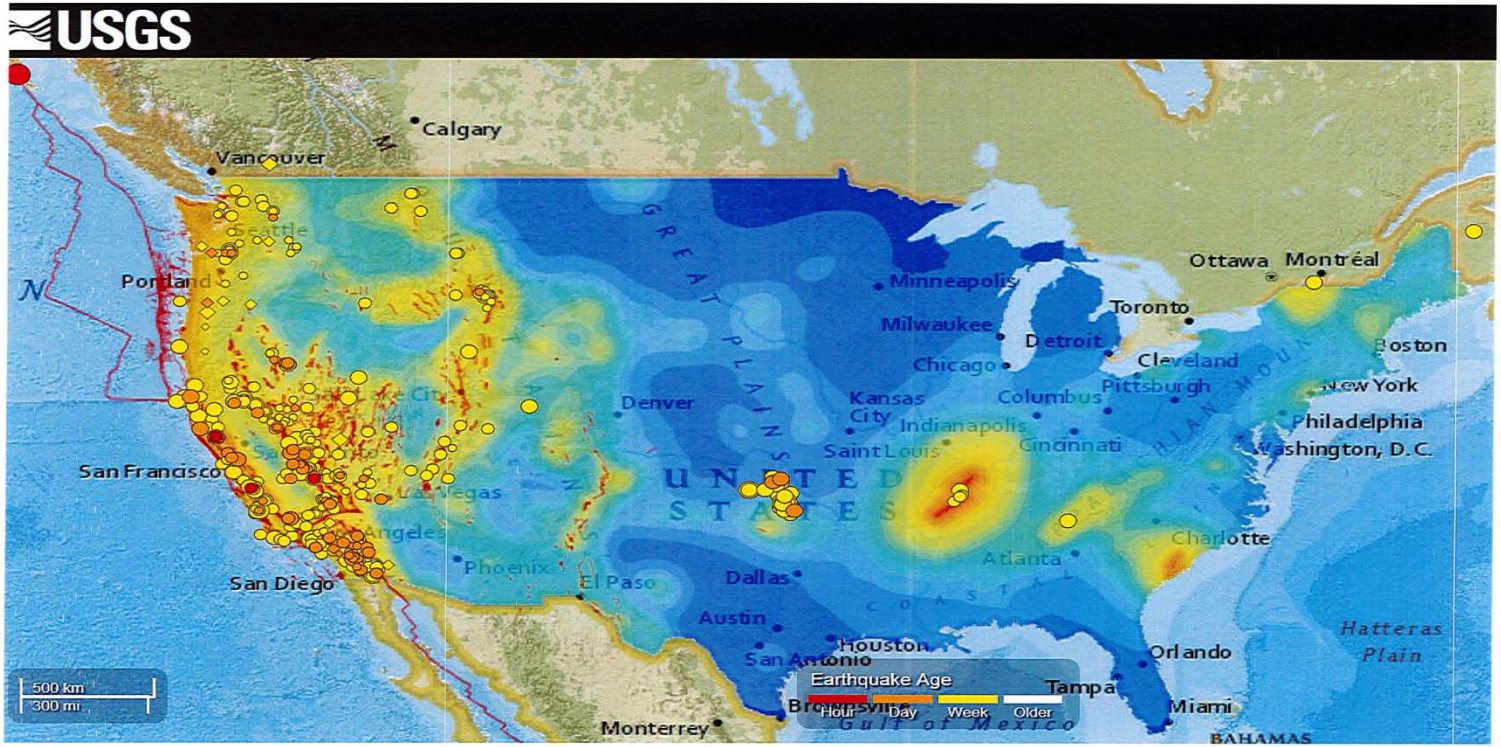
Station	Unit ID	Acquisition	Temp.	Input	Backup	Delay(s)	RAM(Kb)
CES1	BD89	Start On	22.5°C	13.3V	3.3V	2	0%(6400)
CES2	BD13	Start On	25.9°C	12.9V	3.3V	2	0%(6400)
CES3	BDB1	Start On	23.5°C	13.4V	3.3V	2	0%(6400)
CLE1	BEE6	Start On	24.8°C	12.9V	3.3V	2	0%(14592)
CLE2	BEFB	Start On	22°C	12.6V	3.3V	2	0%(14592)
CLE3	BD10	Start On	23.3°C	12.7V	3.3V	2	0%(6400)
CLE4	B2B8	Start On	24.9°C	12.9V	3.3V	2	13%(6400)
CLE5	B50B	Start On	21.5°C	12.6V	3.3V	8492	7%(6400)
HHE1	BF08	Start On	25.5°C	12.7V	3.3V	2	0%(14592)
OHB1	BCAE	Start On	23.4°C	13.2V	3.3V	994	18%(6400)
OHB2	BD0C	Start On	24.8°C	13.4V	3.3V	994	24%(6400)
OHB3	BC25	Start On	24.4°C	13.6V	3.3V	1	0%(6400)
OHB4	BD00	Start On	27.5°C	14V	3.3V	1	0%(6400)
OHH2	B983	Start On	25.9°C	12.9V	0.4V	1	12%(6400)
OHH3	BC99	Start On	27.5°C	13.2V	3.3V	1	0%(6400)
OHM6	B654	Start On	29.4°C	14.1V	0.4V	1	11%(6400)
OHM7	B808	Start On	22.3°C	12.8V	0.4V	3	21%(6400)
OHM8	B95C	Start On	23.8°C	13.1V	0.4V	1	15%(6400)
OHN1	B3E8	Start On	26.4°C	12.7V	0.4V	2	11%(6400)
OHN3	B42F	Start On	28.9°C	13.6V	3.3V	1	4%(6400)
OHN5	BB16	Start On	23°C	12.7V	3.3V	1	0%(6400)
OHN9	B597	Start On	22.5°C	12.7V	0.4V	5994	8%(6400)
OHR1	BCFF	Start On	24.4°C	13.4V	3.3V	1	13%(6400)
OHR2	BD06	Start On	21.4°C	13.6V	3.3V	2244	0%(6400)
OHT1	B948	Start On	19°C	12.7V	3.3V	5994	8%(6400)
OHT2	BD0D	Start On	24.9°C	14V	3.3V	1	13%(6400)
OHT5	BCFE	Start On	23°C	12.5V	3.3V	8494	0%(6400)
OHU1	B980	Start On	21.9°C	12.7V	3.3V	1	20%(6400)
ORR1	BD14	Start On	23°C	12.6V	3.3V	1	0%(6400)
ORR2	BEFF	Start On	23.5°C	12.7V	3.3V	1	0%(14592)
ORR3	BD7C	Start On	23.8°C	12.8V	3.3V	2	0%(6400)
WES1	BCDE	Start On	24°C	13.4V	3.3V	1	6%(6400)
WES2	B548	Start On	23°C	12.4V	2.8V	5369	18%(6400)

Injection Well Earthquake: December 31, 2011





Seismic Risk Assessment



Acknowledgements and Contacts

Bob Worstall
Deputy Chief
ODNR Division of Oil & Gas

Dave Rush
Seismic Manager,
OhioNet Seismic Network
ODNR Division of Oil & Gas
David.Rush@dnr.state.oh.us
614-265-6916

Steven Dade
Geological Technician,
OhioNet Seismic Network
ODNR Division of Oil & Gas
Steven.Dade@dnr.state.oh.us
614-265-6946