

**Merry Christmas Brookfield  
Here's Five Salt Water Injection Wells**

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Trumbull County in northeastern Ohio already has 21 injection wells to dispose of oil and gas wastewater by pumping it under pressure into the earth. Only eight are currently operational. Two were shut down in 2014 after one of them triggered 108 earthquakes. Five were shut down in 2015 after a leaking tank contaminated a small wetland and two private ponds, killing everything. One well was drilled in Brookfield Township through an abandoned coal mine and has yet to inject waste. Five new injection wells are planned adjacent to a mobile home community, with two already permitted by the Ohio Department of Natural Resources (ODNR.) Local residents are opposed to the wells. The company posted notice in the newspaper timed so that they have until Christmas Day 2017 to provide public comment to ODNR. I'll leave it to you to decide if the timing was just a coincidence.

Prior to shale gas development the state of Ohio had suffered slightly over 200 felt earthquakes since 1776. Many of them were near Anna, Ohio that sits in an extension of Illinois' New Madrid and Wabash Valley seismic zones. Anna, The Former Earthquake Capital of Ohio, had damaging earthquakes in 1930, 1931 and twice in 1937. It also suffered swarms of aftershocks, a qualitative indication of human caused earthquake triggering. Based on local newspaper accounts John Armbruster, (Seismologist at Columbia University's Lamont-Doherty Earth Observatory) confirmed that there were oil and gas wells operating in that area at the time of the quakes. Because of the Anna's seismic swarms and prolonged series of earthquakes, he considers it a candidate for human triggering, but without more detailed knowledge it is difficult to make a strong case. A Class One Injection Well triggered earthquakes in 1987 and 2001 on two different faults near Ashtabula , Ohio. The 2001 tremors occurred seven years after the well was closed in 1994.

Since 2011 five Ohio counties, all aseismic, have suffered over 1,100 positive magnitude earthquakes (Table One.) All of the earthquakes were human induced due to fracking for shale gas or injection of liquid fracking waste. The quakes are restricted to six locations, two injection wells and four fracking wells. The policy for posting a seismic event on the ODNR website is that the earthquake was felt or it was magnitude 2.0 or greater. Some earthquakes in Mahoning and Harrison counties that met that criteria have not been posted.

Table One: Induced seismicity since 2011 in five previously aseismic Ohio counties.

Locality	County	Year	Induced Cause	Recorded Quakes	Reference
Youngstown	Mahoning	2011-14	Injection	566	Kim, 2013 Skoumal, 2014, Skoumal, et al 2014a
Freeport	Harrison	2013	Fracking	400	Friberg et al, 2014
Poland	Mahoning	2014	Fracking	77	Skoumal, et al 2015a
Niles	Trumbull	2014	Injection	108	Skoumal, et al 2015b
Mahoning Township, PA		2016	Fracking		
Graysville	Monroe	2016-	Fracking	5	Kowalski, 2017

		17			
Batesville	Noble	2017	Fracking (proposed)	1	Lowe, 2017
TOTALS				1157	

The Northstar 1 well in Youngstown was shut down on December 30, 2011 and was followed by a Magnitude 4.0 earthquake the next day, which caused damage to peoples' homes. In his report, Dr. Kim of Columbia University (Kim, 2013) concluded, "that continued injection of fluid at Northstar 1 well could have triggered potentially large and damaging earthquakes."

Injection of fluids underneath Brookfield Township will subject the community to seismic risks comparable to the damaging earthquakes in Oklahoma and Arkansas. According to U.S. Geological Survey seismologists, McGarr and Barbour (2017), cumulative seismic moment, or energy, correlates as a function of total injected volume. This relationship is based on data from 13 fluid injection-induced earthquake sequences including the Northstar One well in Youngstown (YOH.) Their results and the proposed Brookfield injection volumes are shown in Figure One.

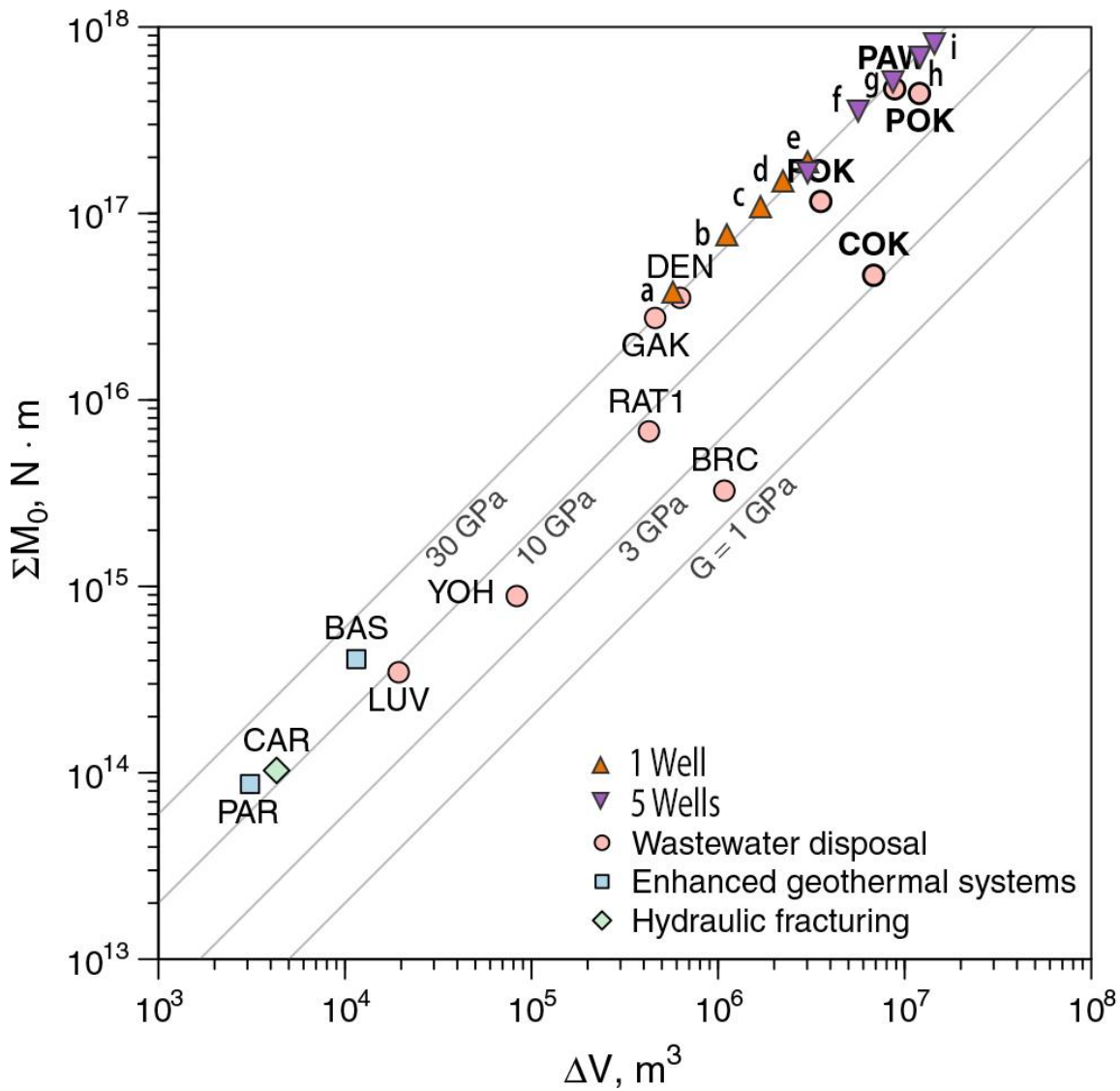


Figure One: Modified from McGarr and Barbour, 2017. Cumulative seismic moment as a function of total injected volume from 13 fluid injection-induced earthquake sequences. Triangles represent proposed injection volume (10,000 bbls/day) of one well (a= 1 year, b = 2 years, c = 3 years, d = 4 years, e = 5 years) and five wells (e= 1 year, f = 2 years, g = 3 years, h = 4 years, i = 5 years.)

The calculations of total injected volume by McGarr and Barbour (2017) include all injection volumes within 10 kilometers (6 miles) of the main shocks. Adopting a six mile radius for the proposed Brookfield Salt Water Injection Wells (SWIW) will include the cumulative volumes of five Kleese SWIW (3,739,022 bbl) that have been shut down since April of 2015 (approximately 4 miles away) and the KTCA Holdings SWIW (233,561 bbl) near the Youngstown Warren Regional Airport, (approximately 5 miles away) all in Vienna Township. This adds the equivalent of slightly over a year’s worth of proposed maximum injection volume for one of the wells and increases the magnitude of a potential earthquake as shown in Table Two.

Table Two: Calculated seismic moments based on the formula of McGarr and Barbour, 2017, based on the proposed injection volumes (10,000 bbls/day) of each well and assuming the approximate upper limit of brittle rock (G = 30 GPa.) Letters a. through j. correspond with the symbols in Figure One.

	Well(s)	Years	Seismic Moment Release	Seismic Moment Release (including Vienna Township Injection volumes)
a.	1	1	5.03	5.24
b.	1	2	5.23	5.35
c.	1	3	5.35	5.44
d.	1	4	5.43	5.50
e.	1	5	5.49	5.55
f.	5	1	5.49	5.55
g.	5	2	5.69	5.72
h.	5	3	5.81	5.83
i.	5	4	5.90	5.91
j.	5	5	5.96	5.97

The calculated potential Seismic Moment Release, shown in Table Two, represents the cumulative magnitude of all induced earthquakes. If there was a single temblor, the Seismic Moment Release values represent the potential magnitude in the range of 5 to 6, considered a moderate earthquake, with damaged chimneys and fallen plaster. Since the largest earthquake in recorded history in Ohio is the March 9, 1937 temblor in western Ohio that was estimated to have had a magnitude of 5.4, the seismic moment based on the proposed injection volumes, could easily top that. Accordingly, the ODNR and the operator must establish beyond a reasonable doubt that there are no faults, especially east-west trending, steeply-dipping, strike-slip faults in the pre-Cambrian basement. To do otherwise will subject the citizens of Brookfield and surrounding communities to some sort of perverse science experiment with potential devastating consequences.

The numerous mines located in the southeastern quadrant of the township (Figure Two) also compound the potential damage due to the seismic risk. These mines have recently had another SWIW drilled through one of them and have also recently shown evidence of collapse. During the question and answer session of his recent lecture at Youngstown State University (November 15, 2017) Dr. Andrew Barbour, a research geophysicist in the Induced Seismicity group at the U.S. Geological Survey’s Earthquake Science Center in Menlo Park, California, stated that the presence of these mines is a “Red Flag” that is

very concerning for public health and safety. I believe that the presence of these mines should prevent the permitting of any SWIW within ten kilometers (6 miles) of these mines. At a bare minimum, these mines need to be reclaimed and properly sealed before any attempts at injection within ten kilometers should proceed.

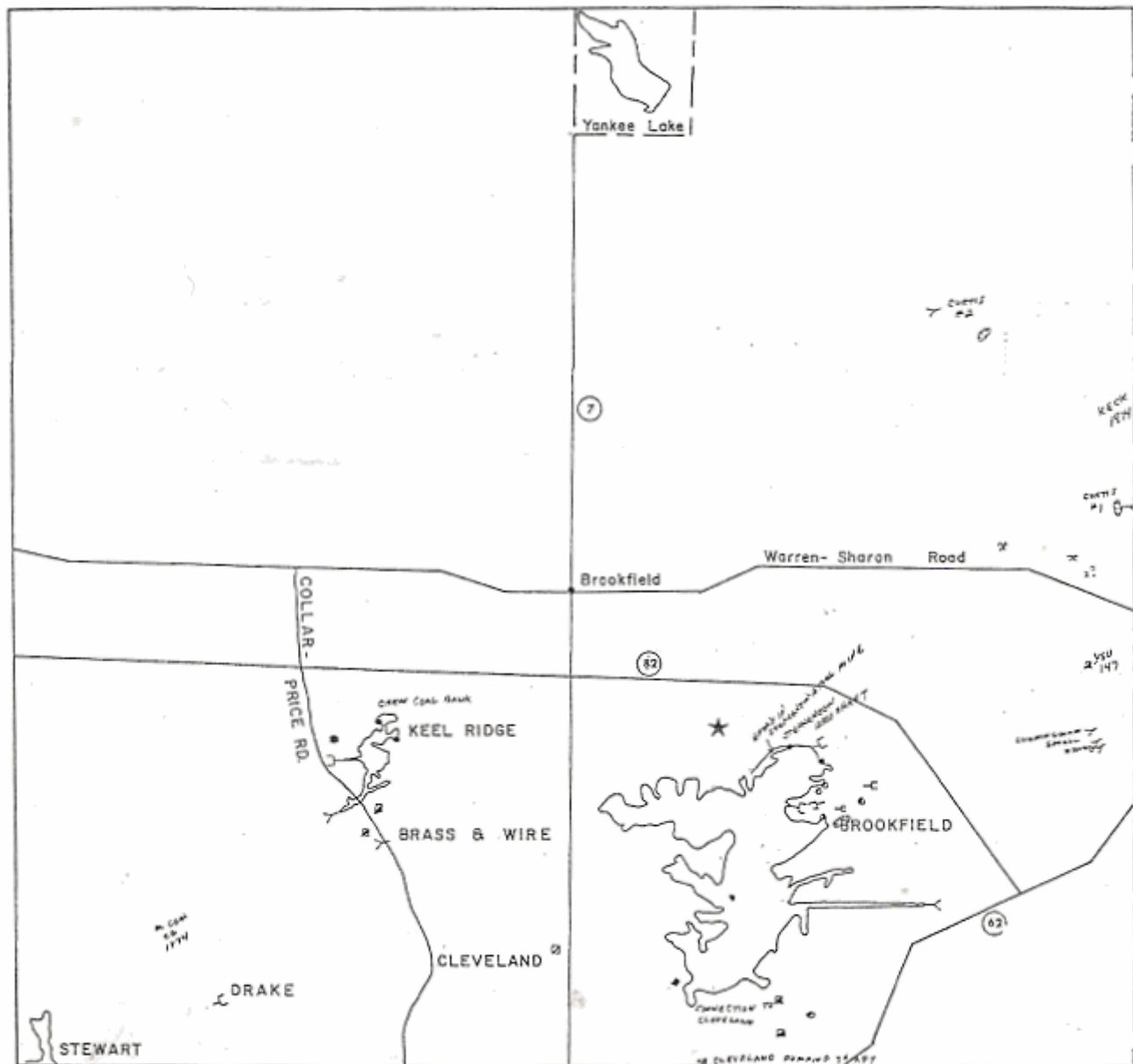


Figure Two: Locations of abandoned underground coal mines in Brookfield Township (from YSU Emeritus Professor Ann Harris' website, [www.ysu.edu/mines](http://www.ysu.edu/mines))

In conclusion, eastern Ohio is now known to have numerous strike-slip faults in the pre-Cambrian basement that have been reactivated by both brine-injection and fracking (Kowzłowska, et al., 2017.) The scientifically established relationship between injection volumes and cumulative seismic moment indicates that the proposed volumes for Brookfield are capable of triggering a magnitude 5 or greater earthquake. Consequently, this permit application, as well as the other two concurrent applications, should be denied and the two already permitted should be revoked. The ODNR wisely revoked the Khalil SWIW

permit in Youngstown due to the seismic risk and the same principle must be applied here. The ODNR is not only tasked with permitting and regulating wells, but also with protecting the natural resources of Ohio and the communities that depend on them.

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