Attachment B-15

To: West Bay #22 Administrative Index
From: Jeffrey Wawczak, Permit Writer
Date: October 2014
Re: West Bay #22 Induced Seismicity Report

Seismicity induced by human activity related to energy technologies is caused by changes in pore pressure and/or changes in stress taking place in the presence of 1) faults with specific properties and orientation, and 2) a critical state of stress in the rocks[1]. Human-induced seismicity, associated with disposal of fluid though injection, is possible but is very uncommon due to the specific and necessary conditions that would need to be present. Seismic activity induced by fluid disposal is likely to occur only when the following conditions are present; 1) stressed faults, 2) pressure build up due to disposal activities, and 3) a pathway for increased pressure to communicate with the fault[2]. While reviewing the application for the West Bay #22 injection well, EPA considered all three of these components. As explained further below, EPA found no evidence of conditions that would lead to a seismic event due to disposal of fluid though injection.

Region 5's UIC Branch utilized several sources of geologic and seismic data during its evaluation of the West Bay #22 permit application, and determined that the geologic siting of the well is suitable for underground injection. Stress faults are one of the key components to induced seismicity. Michigan Geology has been well documented in the Michigan Hydrogeologic Atlas[3] and the proposed injection zone (the Niagara Group) is not known to have fractures or other faults. In addition, members of EPA staff, including Tim Elkins (Environmental Scientist), Ross Micham (Geologist), and Jeffrey Wawczak (Environmental Scientist) analyzed seismic data[4] and geophysical profiles[5] submitted by the permit applicant, West Bay Exploration Company (West Bay). The seismic data and geophysical profiles submitted demonstrates that there are no known fractures or faults present in the Niagara injection zone within the vicinity of the proposed site of the West Bay #22.

Furthermore, the UIC Branch used USGS on-line tools to evaluate both the seismic history and probability of earthquakes within the region of the proposed well location. More specifically, a search of historic seismic activity of the region using USGS's global Earthquake Search Application[5] revealed no observed earthquakes within 80 km (approximately 50 miles) of the proposed West Bay #22 site during the last 200 years. Knowledge of seismic events that originated near the proposed well is informative about whether faults exist in that location. The USGS data referenced above indicates that the proposed West Bay #22 site is not seismically active. Recorded earthquakes serve as a general indicator of seismic activity and the potential existence of a stressed fault. A record of past earthquakes would be evidence of the presence of stressed faults in the area, a common criteria taken under consideration when evaluating the

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[1] A White Paper Summarizing a Special Session on Induced Seismicity, Ground Water Research & Education Foundation, February 2013
[2] Minimizing and Managing Potential Impacts of Induced-Seismicity form Class II Disposal Wells, UIC National Technical Workgroup, (Draft) November 2012
[3] Michigan Hydrogeologic Atlas
[4] Seismic cross section entitled "Perspective Salt Water Disposal Wells, Napoleon Field, Jackson County, Michigan" in West Bay #22 Admin. Record
[5] Document ID WB-151 in West Bay #22 Administrative Record

potential for seismic activity and induced seismicity. The lack of seismic activity is evidence that the geologic siting is appropriate for injection, and indicates that there are no active faults in a stressed state in the area.

UIC staff also utilized the USGS's Earthquake Probability Mapping Application[6] to map the probability of an earthquake within 50 km (31.06 miles) of the proposed West Bay #22 well location. The results of this query indicate that there is a less than 3% chance of a 5.0 magnitude earthquake or greater occurring within 50 km of the proposed well during the next 250 years. Based on the absence of faults and fractures under stress in the injection zone, review of site-specific seismic data, small earthquake probability and a history of low seismic activity, it is very unlikely that a seismic event would occur related to this disposal well.

Pressure build-up in the formations due to disposal activities is also an important factor when considering the potential to induce seismicity. EPA limits maximum injection pressure (MIP) by calculating[7] MIP with conservative values (Attachment A of EPA permit# MI-075-2D-0009). In particular, EPA added a safety factor of 0.05 to the Specific Gravity of West Bay's representative brine analysis, when calculating MIP. This not only prevents formations from fracturing and creating migratory pathways but also generally minimizes injection pressure.

The proposed West Bay #22 well is expected to require very little pressure to operate because the Niagara has been well documented in the Michigan Hydrogeologic Atlas[3] to be permeable and very capable of accepting fluid. EPA also requires injection pressure monitoring and reporting in all Class II permits. West Bay will be required to submit monthly monitoring reports, recorded weekly, that include: injection pressure, annulus pressure, flow rate, and cumulative volume.

The last condition needed for induced seismicity is a pathway for increased pressure to communicate with the fault. Faults that commonly cause earthquakes are often in crystalline formations, or basement rock. Basement rocks are igneous or metamorphic rocks that underlie the sedimentary rocks of continents. Basement rocks usually have no effective primary permeability or porosity[8]. The proposed injection zone is much shallower than the basement rock and is not in a crystalline formation.

While reviewing the West Bay #22 application, EPA also reviewed completion reports found on the Michigan Department of Environmental Equality's (MDEQ) website[9]. These completion reports were for production wells (MDEQ permit #59996, #60010, #60011, and #60094[10]) located in close proximity to the proposed site of the West Bay #22. These completion reports showed EPA which layers of rock were near the proposed wells, as well as helped EPA gain knowledge of the approximate depths and thicknesses of each formation. With no stressed faults near the proposed well site and with limitations to prevent pressure build-up or fracturing the

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[6] Document ID WB-149 In West Bay #22 Administrative Record

[7] MIP calculation formula; [{0.08psi/ft – (0.433psi/ft)(Specific Gravity + 0.05)} x Depth] -14.7psi

[8] Minimizing and Managing Potential Impacts of Induced-Seismicity form Class II Disposal Wells, UIC National Technical Workgroup, (Draft) November 2012, pg. 8

[9] Document ID WB-150 West Bay #22 Administrative Record

[10] Document ID WB-155, WB-156, WB-157 and WB-158 in the West Bay #22 Administrative Record

formation, the proposed West Bay #22 will not build up pressure that can communicate with any faults or fractures.

After significant review, EPA concludes that the proposed site for the West Bay #22 well lacks all the conditions that can lead to induced seismicity. The geology of the proposed site is clear of any known faults or fractures that are in such a state of stress as to potentially cause an earthquake. There is no history of seismic activity in the area of the proposed well, indicating that the area is not seismically active. Limitations will also be in place to prevent any pressure building up in the injection zone. In conclusion, EPA determines that the proposed West Bay #22 should not cause a seismic event.