UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
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SUPPLEMENT TO THE STATEMENT OF BASIS

On March 28, 2013, the Environmental Appeals Board (EAB) of the United States Environmental Protection Agency (EPA) remanded to EPA Region III (Region) an Underground Injection Control (UIC) permit which had been issued to Stonehaven Energy Management, LLC (Stonehaven) in Cranberry Township, Venango County, Pennsylvania. See In re Stonehaven Energy Management, LLC, UIC Appeal No. 12-02, (EAB March 28, 2013). This permit authorizes the construction and operation of one Class II-D brine disposal injection well, the Latshaw #9.

The EAB remanded the permit to the Region based on its conclusion that the Region did not provide adequate support in the administrative record for its response to public comments on the geological features of the injection zone and the risk of earthquakes. The EAB indicated that although the Region addressed geology and seismic risk in its response to comments document, the Region's response was conclusory and that the administrative record did not adequately explain and support the Region's rationale. The EAB remanded the permit to the Region to address, based upon evidence on the record, earthquake risk and the existence of faults or fractures in the confining zone. In particular, the EAB indicated that the Region did not identify in the record the basis for its conclusions that there is no evidence of seismic activity in the well area and that there are no transmissive faults that intersect or could be influenced by the intended zone of injection. Here the Region supplements the record to clarify and provide additional evidence to support its determination that there is no evidence of seismic activity or of faults in the well area. The remand was limited to this particular issue.

Pursuant to the EAB March 28, 2013 remand, and to 40 C.F.R 124.14, the Region is issuing a public notice to reopen the public comment period on the information added to the administrative record. The reopening of the public comment period is limited to two issues: (1) the question remanded from EAB on the Region's conclusion regarding the risk of earthquakes from this well; and (2) the addition of a monitoring well. The Region intends to require in the permit one more monitoring well in addition to three monitoring wells already included in the permit. The additional monitoring well would be located northwest of the injection well and, like the other monitoring wells, will be used to monitor changes in fluid level.

Application requirements

EPA regulations specify information that an applicant must submit for a UIC permit. Requirements include, among other things, information pertaining to the siting of a well so that injection will occur into a formation which is separated from an underground source of drinking water (USDW) by a confining zone that is free of **known** open faults or fractures within the area of review, 40 C.F.R. §146.22, and appropriate geological data on the injection zone and confining zone including lithologic description, geological name, thickness and depth. 40 C.F.R §146.24(a)(5). In addition, EPA may request additional information from an applicant to clarify or supplement previously submitted information. 40 C.F.R. § 124.3(c).

The regulations do not specifically require information related to seismic activity or whether an injection operation will cause seismicity. The intent of the regulations is to provide information on known faults or fractures in the geologic confining zone within the area of review so as to evaluate and prevent possible fluid movement through these geologic features into USDWs during the operation of an injection well.

The UIC permit application that Stonehaven submitted to the Region on June 30, 2011 supplied the information requested by the UIC regulations. Attachment G of the permit application provided information on the geology of the injection and confining zones as well as gamma ray logs depicting the geology of the injection and confining zones and fracture stimulation information for wells that had been drilled into the Speechley formation for gas production. Stonehaven also supplemented the geologic information in Attachment G of the permit application on October 10, 2011, by supplying additional information on injection pressure and rate, obtained during the fracture stimulation of the Speechley formation in the Latshaw #9 well, with their response to the Region's request for additional information.

It is incumbent on the permitting authority, in this case the Region, to develop permit conditions to protect USDWs from fluid movement out of the injection zone. Permit conditions in the Stonehanven permit which were developed to prevent fluid movement out of the injection zone, such as the maximum injection pressure and injection fluid volume limitations, and the continuous monitoring requirements, also minimize the risk of induced seismicity.

Injection-induced seismicity

Under certain conditions, disposal of fluids through injection wells has the potential to cause induced seismicity. However, induced seismicity associated with brine injection is uncommon, as conditions necessary to cause seismicity often are not present. Seismic activity induced by Class II wells is likely to occur only where all of the following conditions are present: (1) there is a fault in a near-failure state of stress; (2) the fluid injected has a path of communication to the fault; and (3) the pressure exerted by the fluid is high enough and lasts long enough to cause movement along the fault line. In the United States, EPA Region III is aware of fewer than 10 documented cases of injection well-induced seismicity, in more than 30,000 wastewater disposal injection wells in operation. Induced Seismicity Potential in Energy Technologies, National Academy Press (prepublication draft), 2012, at p. 6.

The presence of a fault in a receiving formation potentially creates a more vulnerable condition for a future seismic event. A fault is a fracture or a crack in the rocks that make up the Earth's crust, along which displacement has occurred. During a seismic event waves of energy are transmitted through bedrock from the origin of the earthquake. The United States Geologic Survey (USGS) tracks, records and maps faults and earthquake epicenters in certain areas throughout the United States. The USGS as well as the Pennsylvania Bureau of Topographic and Geologic Survey, the principal organizations that conduct geologic research in Pennsylvania, have not recorded any seismic activity that has originated in Venango County. Despite statements made by members of the public during the public comment period for the Stonehaven permit, no faults have been identified by the USGS or the Pennsylvania Bureau of Topographic and Geologic Survey in the receiving formation (the Speechley formation) or the confining units adjacent to the Speechley. This does not prove or disprove whether any faults exist, but no such fault is known.

In its remand to the Region, the EAB discussed seismic events that took place near Venango County. In particular, the EAB mentioned a 1998 earthquake centered near the Pymatuning reservoir in

Crawford County, Pennsylvania and a December 2011 earthquake centered outside of Youngstown, Ohio, both which were felt in western Pennsylvania. These seismic events centered elsewhere do not provide information about the geology of Venango County, even if these events were felt there. During an earthquake, energy is radiated away from the area of the fault in the form of seismic waves. This energy causes the ground to move as the seismic waves travel away from the fault. However, the fault where the earthquake originated does not extend to the whole area that felt the earthquake. For this reason, history of seismicity that originates in areas other than the location of the injection well does not provide information about potential faults or formation pressures at the location of the well. For example, in the case of the Northstar 1 injection well in Youngstown, Ohio, the earthquake is believed to have been generated by injection into crystalline bedrock, a deeper receiving formation, with different geology, than in the case of the Stonehaven well. The seismic waves radiating away from this area were felt in locations at significant distances away from Youngstown, including western Pennsylvania, but they have no relevancy to the geologic setting in Venango County or at the Stonehaven location, and do not provide information about faults in the receiving formation at the well location. This is also true for the Pymatuning earthquake, which originated nearly 30 miles from where the injection well is located.

Scientists believe that injection can cause seismicity when the pore pressure (pressure of fluid in the pores of the subsurface rocks) in the formation increases to such levels as to overcome the frictional force that keeps a fault stable. Pore pressure increases with increases in the volume and rate of injected fluid. Thus, the probability of triggering a significant seismic event during injection, where a fault exists in the receiving formation, increases with the volume and the rate of fluid injected. In addition, the larger the volume injected over time (rate of injection), the more likely a fault could be intersected, because the fluid will travel farther within a formation. When injected fluid reaches a fault, frictional forces that have been maintained within that fault can be reduced by the fluid. At high enough pore pressure, the reduction in frictional forces can cause the formation to shift along the fault line, resulting in a seismic event.

Because increases in pore pressure due to the rate and the volume of injected fluid can act on existing faults and provide a mechanism for induced seismicity, most examples of injection-induced seismicity are in cases where the receiving formation has low permeability and/or the pressure or volume of fluid injected over time is quite large. Formations such as crystalline basement rock (deeper geological formations of igneous or metamorphic rock that underlie layers of sedimentary rock) have very low permeability. Permeability is the ease with which a fluid can flow through the pores in a rock layer. Where permeability is low, injected fluid cannot flow easily through the pores in this rock and therefore flow is oriented mainly through existing fractures or faults in the rock. These kinds of rock formations have high transmissivity and low storativity. This means that the formation cannot store a lot of fluid; rather fluid moves farther and faster in these formations than in more porous formations. Because of the high transmissivity and low storativity of these kinds of rocks, the potential exists to induce pore pressure increases at considerable distances away from the injection well.

The seismic event that occurred in Youngstown, Ohio, due to an injection operation is a good example to explain why injection-induced seismic activity is not likely during the operation of the Stonehaven injection well. The Youngstown well was injecting into deep very low permeability crystalline bedrock. At the location of the Stonehaven injection well, the Speechley formation is a sandstone formation. Sandstones have significantly higher porosity and greater permeability than the crystalline bedrock. In the Speechley formation injected fluid will flow more readily through the pores in the rock and will not be oriented directly towards fractures that may exist in the rock.

In addition, the Speechley formation in the vicinity of the Stonehaven injection well has a long history of oil and gas production ("Geology of the Oil and Gas Fields of the Hillands Quadrangle". Commonwealth of Pennsylvania Topographic and Geologic Survey, R.E. Sherill and L.S. Matteson, July 1939). Oil and gas production from the Speechley formation began in the early 1900s and continues today. The production of oil and gas, with the accompanying removal of brine water during such operations, results in the removal of large amounts of fluid from the formation. This means that there has been a corresponding decrease in pore pressure in the formation. If injection occurs into these depleted reservoirs, pore pressure may not reach the original levels, or in some cases, may not increase at all due to the relative volumes of injection versus extraction. Therefore, a more permeable sedimentary formation, as well as a formation that has seen the depletion in pore pressure due to past oil and gas production, can make an excellent disposal zone and is unlikely to induce seismicity.

The EAB also concluded that there appeared to be no basis in the record for the Region to conclude that there is no evidence of non-transmissive faults. The history of oil and gas production from the Speechley formation is relevant for demonstrating the likely absence of a transmissive fault as well as formation confinement. For oil and gas to be produced from a formation, there needs to be a trapping mechanism (i.e., confinement of the fluids), otherwise the oil and gas would move to other formations. If a fault were present in the Speechley formation or in the confining zone above the Speechley, it would have to be a sealing fault (i.e., a non-transmissive fault) or the oil and gas would have migrated out of the Speechley formation through the fault. In addition, the drilling records for the Speechley formation which were submitted in the permit application (for the monitoring wells) do not show evidence of any geologic displacement (movement upwards or downwards) in the formation from seismic activity. Formation displacement would be indicative of past movement along a fault. Drilling records consistently show that the depth to the Speechley formation, taking into account topographic differences, remains consistent no matter the location of where the well is drilled. In contrast, drilling records of nearby wells that, despite their proximity, show the same formation at different depths would suggest the presence of a fault.

As mentioned earlier in this document, the conditions regarding maximum injection pressure and injection fluid volume imposed by this permit not only help to prevent fluid movement out of the injection zone into USDWs but also help to prevent the possibility of a seismic event even if a currently unknown fault were to exist in the Speechley. As discussed above, the rate and the volume of injected fluid can act on existing faults and provide a mechanism for induced seismicity because of an increase in pore pressure. Although there is no evidence of the presence of a fault in the Speechley formation and even though the formation's pore pressure has been reduced by past oil and gas production, the Region chose to limit the injection volume to 4,500 barrels per month. For comparison, permits for injection wells in Texas, where injection-induced seismicity was apparently related to the injection volume and rate of injection, allowed up to 150,000 barrels per month. The Stonehaven permit will also require continuous monitoring of the injection volume and pressure during the operation of the injection well.

In addition to limiting the injection volume, the permit also limits the injection pressure. The maximum injection pressure condition is designed to prevent the initiation of new fractures or the propagation of existing fractures in the injection zone, to prevent contamination of USDWs. By preventing the fracturing in the receiving formation, the permit condition also prevents fractures that could act as conduits through which fluid could flow and intersect with a fault.

Endangerment of USDWs due to earthquakes

Of the hundreds of thousands of injection wells operating in the United States, EPA is not aware of any case where a seismic event caused an injection well to contaminate an USDW. EPA is also unaware of any studies that have been done specifically to determine whether injection wells have caused contamination of an USDW during a seismic event. There have not been any reports of earthquakes affecting the injection wells in the cases of induced-seismicity in Ohio, Texas, West Virginia or Colorado. The Region consulted with other regional personnel in the Agency and found no examples of contamination from injection wells due to an earthquake. A number of factors help to prevent injection wells from failing in a seismic event and contributing to the contamination of an USDW. Most deep injection wells, those that are classified as Class I or Class II injection wells are constructed to withstand significant amounts of pressure. They are typically constructed with multiple steel strings of casing that are cemented in place. The casing in these wells is designed to withstand both significant internal and external pressure. See Halliburton Cementing Tables, Halliburton Services, 1980, for the industry standards in casing and cementing wells. Furthermore, injection wells are required to be mechanically tested to ensure integrity before they are operated and many are continuously monitored after testing to ensure that mechanical integrity is maintained. An injection well can be designed to automatically shut in and cease operation if a seismic event occurs and affects the operation and mechanical integrity of the well.

The Stonehaven injection well will be constructed with multiple steel casing strings which will be cemented. In addition, the Stonehaven injection well will be tested for mechanical integrity prior to commencing operation to ensure that there are no leaks in the casing, tubing and packer and to ensure the prevention of fluid movement out of the injection zone. Once tested, the well will be continuously monitored for injection pressure, annular pressure and flow. If a seismic event were to occur that affected the operation and mechanical integrity of the Stonehaven injection well, the well is designed to automatically detect a failure due to pressure changes in the well and this would cause the well to stop operating (i.e., the well would automatically be "shut-in"). Furthermore, the injection zone which exists at a depth of approximately 1935 feet has multiple confining geological formations that exist from approximately 1700 feet to 1935 feet that would have to be breached, and the injection zone would have to have enough pressure to allow fluid to move out of the injection zone into the lowermost USDW, which is located at approximately 360 feet. Monitoring wells, which the permit requires, will allow the pressure in the formation to be continuously monitored and will ensure, under operating conditions, that the pressure in the injection zone will not be great enough to cause fluid to migrate into USDWs even if a conduit for fluid migration were to exist.

Subject to public comments on the information added to the administrative record to support the Region's findings that there is no evidence that potential seismic activity could affect the well operations and no evidence of transmissive faults that intersect or could be influenced by the injection operation, the Region intends to issue the UIC permit to Stonehaven for the Latshaw #9 injection well, as proposed during the earlier comment period with one change. One additional monitoring well will be installed to the northwest of the injection well location to enable monitoring of the fluid level in the injection zone at that location. This additional monitoring well is necessary because a private landowner would not allow a potential unplugged/abandoned well located on his property to be plugged by the permittee. This will add further protection to USDWs by ensuring that the pressure in the injection zone during operation will not be great enough to allow fluid movement into the USDW through this unplugged/abandoned well or through any unknown unplugged/abandoned well if it were to exist in this location.

For a more extensive discussion on injection-induced seismicity, see the report by the National Academy of Sciences, *Induced Seismicity Potential in Energy Technologies*, National Academy Press (prepublication draft), 2012. See also *A White Paper Summarizing a Special Session on Induced Seismicity*, Ground Water Research & Education Foundation, February 2013; *Preliminary Report on the Northstar 1 Class II Injection Well and the Seismic Events in Youngstown Ohio Area*, Ohio Department of Natural Resources, March 2012; *Final Report and Recommendations*, Workshop on Induced Seismicity Due to Fluid Injection Production From Energy-Related Applications, Lawrence Berkeley National Laboratory, February 4, 2012; and "Managing the Seismic Risk Posed by Wastewater Disposal", Earth, April 17, 2012