



MEMO

TO Eric A. Gustafson *GAJ 3/16/17*
FROM Harry C. Wise, P.G. *HCW*
DATE March 16, 2017
RE PGE – Indiana County Yanity Well #1025
Geological Review
EPA UIC Application Documents

MESSAGE:

Analysis

This technical review is in response to a request from John Ryder to assess the suitability of the geologic structure and setting for waste disposal via injection in the vicinity of the Pennsylvania General Energy Company L.L.C (PGE)'s existing Yanity Well #1025 gas well in Grant Township, Indiana County, Pennsylvania, API # 37-063-31807-00. The well formerly served as a production well and is a candidate for conversion to an underground injection control (UIC) well.

I reviewed all the documents that were submitted by PGE under cover letter dated March 30, 2015 to Pennsylvania Department of Environmental Protection Office of Oil and Gas Planning and Program Management's (hereafter the Department) Southwest District Office for a well permit to reclassify the Marjorie C. Yanity Well. The document was titled "Change of Use – Well Permit Application Marjorie C. Yanity #1025, API #37-063-31807-00, Grant Township, Indiana County, PA, dated March 30, 2015". Various documents were identified as having information pertaining to geologic structure and setting.

The discussion that follows is based on my experience as a Professional Geologist and environmental regulator.

The proposed UIC well (Yanity #1025) served as a former gas production well targeting the Huntersville Chert. PGE has indicated that the Marcellus shale, which is situated between 7,430 feet and 7,522 feet below existing site grades, would effectively serve as a stratigraphic seal (confining zone). PGE has also identified a structural anticline/salt dome near the well site. Per PGE's analysis, the anticline introduces difficulties with regard to Marcellus shale development, but serves as a good trap for lower geologic units and creates ideal conditions for fluid storage.

The Department reviewed Alleghanian structures to confirm the presence of a nearby anticline – the Chestnut Ridge Anticline is located along the northwestern edge of the mile-radius area of review (Figure 1). To the north of the site, the Chestnut Ridge Anticline merges with the Grapeville – Kinter Hill Anticline (also known as the Jacksonville Anticline) (Skema et al, 2008, Pennsylvania Department of Conservation and Natural Resource (DCNR) Open File Report OFMR 08-01.0). The merging of the anticlinal forms structurally pinches out the Dixonville Syncline west of the site. This structural complexity is consistent with PGE's discussion

about the geologic structure in their response to United States Environment Protection Agency's (EPA) Notice of Deficiency.

Finally, the Department's review of available petrophysical (gamma ray) and drilling logs corroborates PGE's identification of the injection zone. The log data submitted as required by § 91.51. Potential pollution resulting from underground disposal confirms that the injection zone is sealed by a shaly sequence of rocks, i.e., Marcellus shale; and underlain by a dense carbonate rock formation, providing the desired isolation from shallower hydrostratigraphic intervals saturated with fresh groundwater and deep crystalline basement rock, respectively.

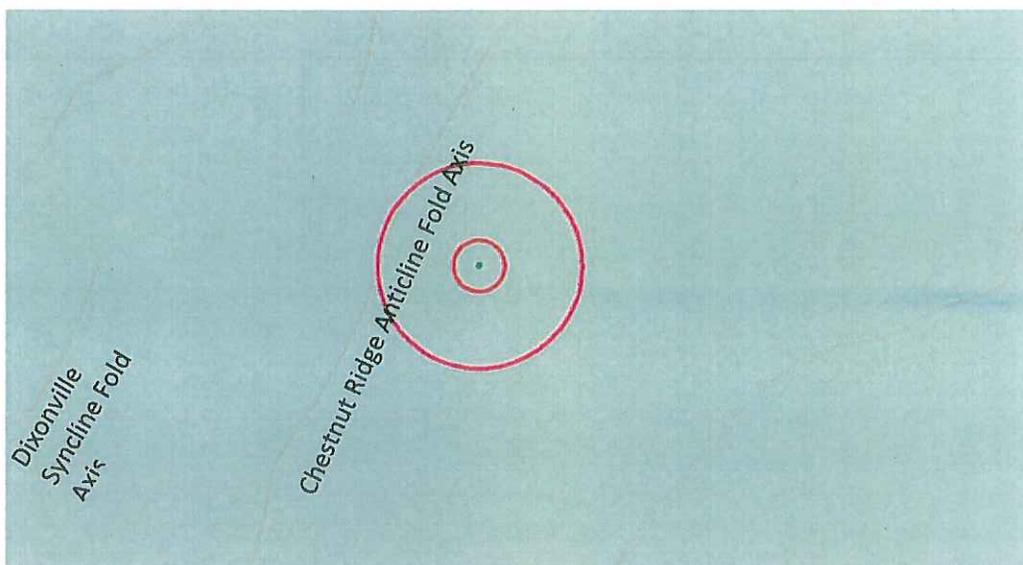


Figure 1. Alleghanian folds near well site. Well surrounded by quarter-mile and one-mile buffers.

It is my professional opinion that the injection horizon and surrounding strata result in suitable geologic structure and stratigraphy for waste disposal via underground injection. There are no suitability concerns related to containment, as explained below. It is recommended that the Department monitor for future Marcellus shale or deeper penetrations in this area.

The Department's review of deep operating wells within quarter- and one-mile radial distances confirmed the information provided by PGE in the application and Notice of Deficiency response. The only operating wells that penetrate the produced horizon are PGE owned and operated wells. These include API# 063-32044, located 0.54 miles west-northwest of the site; API# 063-33809, located 0.71 miles north-northeast of the site; and API# 063-31663, located 0.96 miles northeast of the site. The wells are drilled to total depths of 7,788 feet, 7,794 feet and 7,780 feet, respectively (Figure 2).

One proposed Marcellus well is mapped within the mile-radius area of review along the eastern portion of site. This well is categorized as “proposed but never materialized” (API # 063-36091, by OGO 38602 – MDS Energy LTD) (Figure 2). The Department has field confirmed that this well was proposed but never drilled.

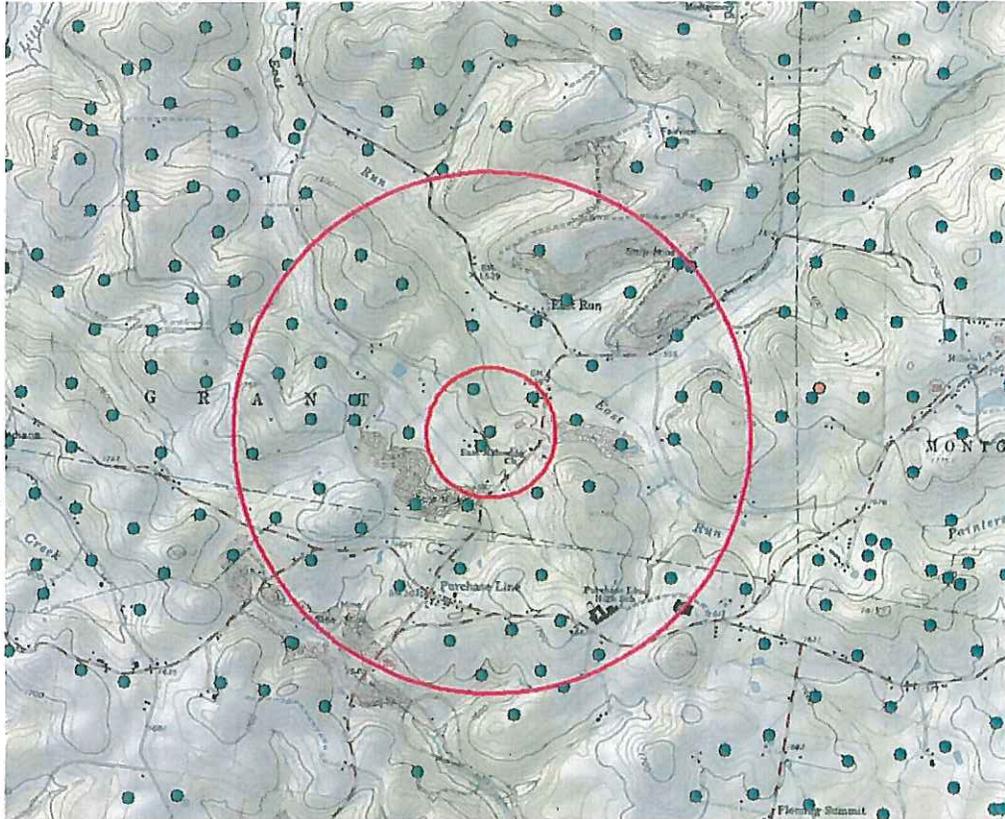


Figure 2. Conventional (green) and unconventional (orange) wells with the quarter-mile and one-mile buffers depicted.

Historic and other well sites were reviewed. No wells exceeding a depth of 3,800 feet below existing site grades are located in the quarter- and one-mile radial distances around the proposed injection site. There are three wells located within the mile-radius buffer that PGE listed as proposed, but the Department’s eFACTS system lists as active. The API numbers of these wells are 063-36066, 063-36067 and 063-36068 (listed to OGO 38602 – MDS Energy LTD). The Department has field confirmed that these wells were proposed but never drilled (Figures 2 and 3).

It is my professional opinion that there are no concerns related to the suitability of the caprock, or seal, created by ongoing and legacy oil and gas production activities in the vicinity of the proposed UIC well location.

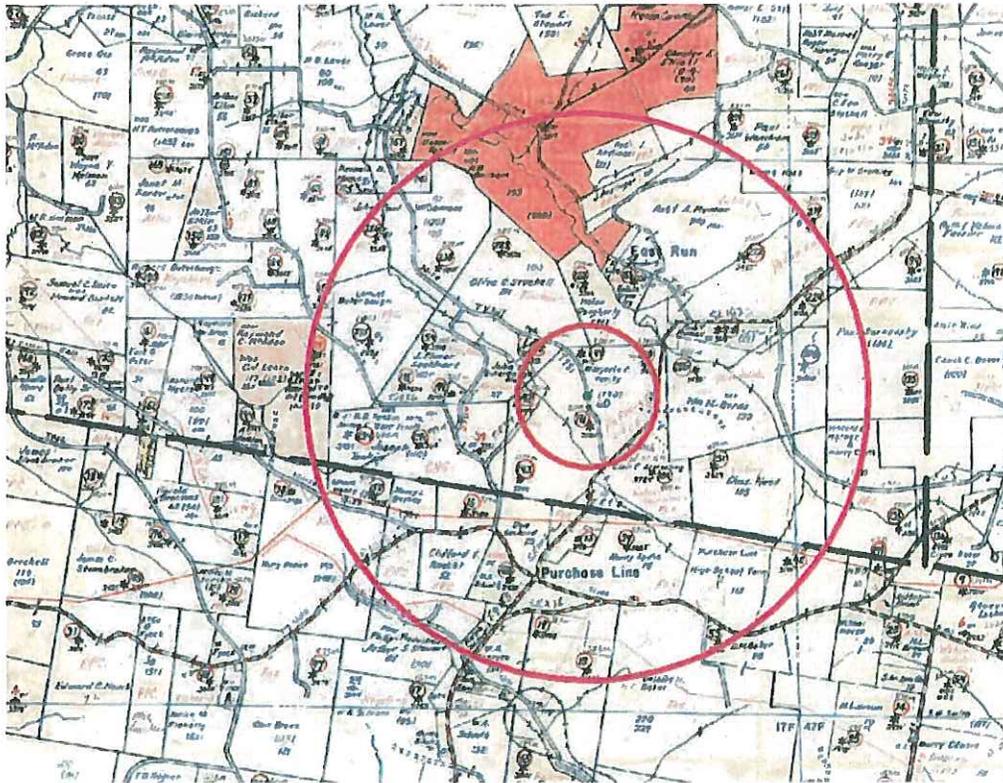


Figure 3. Historical well information with the quarter- and one-mile radius area of review.

The Department's review indicates there are no mapped faults or structural fronts within the quarter- and one-mile radius area of review (Figure 4). This is consistent with EPA's review of the PGE application. The nearest fault is identified as an "unnamed fault" dipping to the northwest and located just northwest of the one-mile area of review. The Home-Gallitzin Lineament is located 3.68 miles southwest of the site. The faulting to the northwest appears to be coincidental with the regional folding structures classified as an anticlinal axis. Faulting is often noted in association with structural deformation features such as the anticline/syncline pairs common throughout the Appalachian fold belt/plateau of Pennsylvania. While these faults were active during the geologic history of the area, they are now considered "inactive" due to the changes in the geologic stress fields that are attributed to their formation.

Another structural geologic anomaly within the area is the upper Middle Jurassic Dixonville-Tanoma kimberlite. This structural geologic feature is located 6.18 miles west-southwest of the site. The kimberlite does not have any surface geologic expression and is only encountered underground in the Barr Slope and Tanoma Coal Mines west of the site. It is reported to be 100 feet long by 45 feet thick in the *Geology of Pennsylvania*, published in 1999 by DNCR. The kimberlite dike intrudes into the Lower Freeport coal bed. Evidence of the kimberlite has not been reported in the Rox Coal North Branch mine that targets the Lower Kittanning coal bed (a coal unit stratigraphically older and located at a greater depth than the Lower Freeport coal bed) and is in closer proximity to the proposed injection well site. The *Geology of Pennsylvania* publication indicates that the Dixonville-Tanoma kimberlitic dike is associated with the Home-Gallitzin

structural lineament. However, it is suggested that this lineament was reactivated during the Mesozoic under tensional stress regimes associated with the crustal rifting during the formation of the Atlantic Ocean. The dike also appears to be truncated by the Dixonville Syncline which is located southwest of the Home-Gallitzen Lineament, indicating the emplacement of the dike occurred prior to the regional structural deformation of the Alleghanian orogeny.

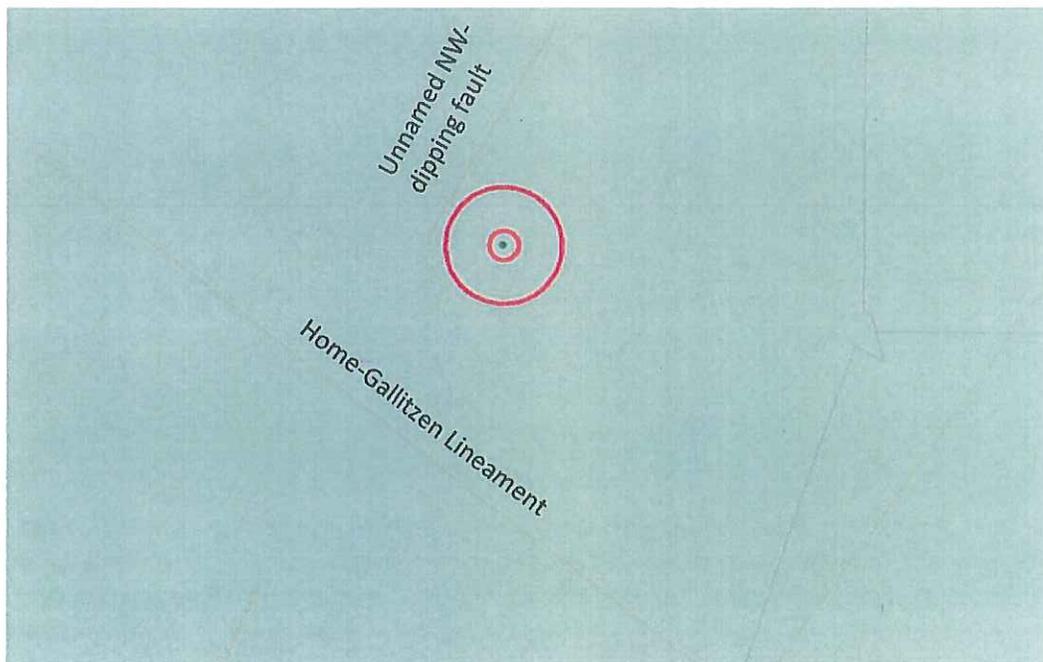


Figure 4. Faults located near the proposed well site.

The Department's review indicates there are no historical seismic events within the quarter- and one-mile radius area of review (Figure 5). There are no earthquakes of magnitude two (2M) or greater within Indiana County.

In EPA's Responsiveness Summary for Public Comments, Question 10 asks "What is the probability of the proposed Yanity Well #1025 injection well causing earthquakes like the ones in Braxton, WV, Youngtown, Ohio and other states?" In this report, EPA discusses how induced seismic events associated with injection wells in Ohio were created by disposal in Precambrian basement rock. These rocks are often cross-cut by blind faults or are crystalline in nature. Additional studies by the State of Oklahoma (<http://earthquakes.ok.gov/>) and within the geologic community appear to corroborate the belief that injecting fluid into brittle, crystalline basement rock can induce seismicity. In PGE's application, it is noted that geophysical investigations estimate the Precambrian basement rock is located approximately 10,000 feet below the injection zone. The Department's review of maps showing the basement rock (depth of approximately 17,000 feet) and the injection zone (depth of 7,532 to 7,622 feet) for this well indicate a separation distance of approximately 9,300 to 9,400 feet (Figure 6).

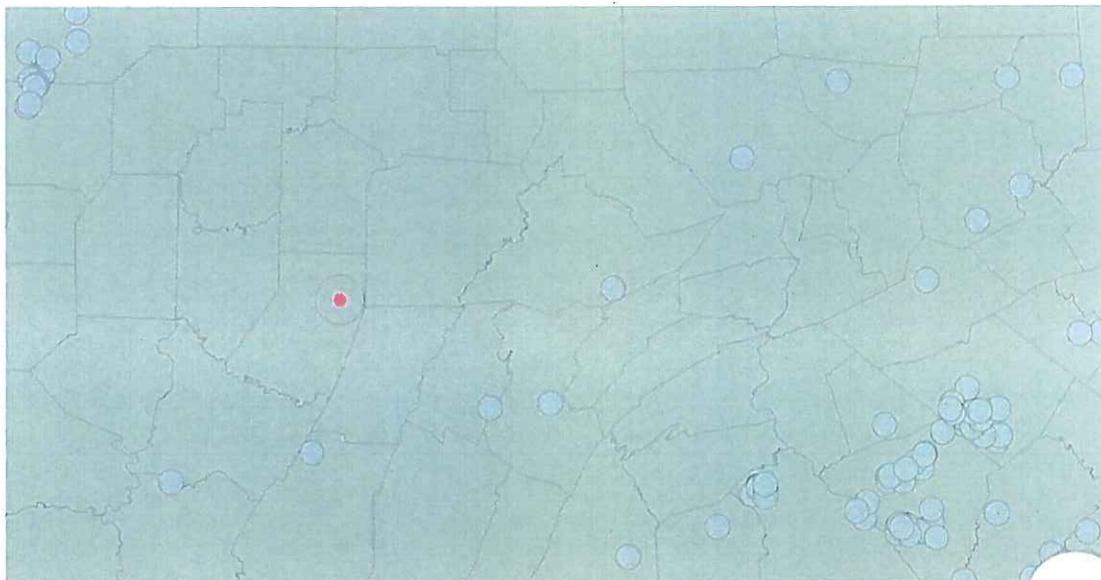


Figure 5. Seismic activity map showing 3-mile buffers around Magnitude 2 or greater earthquakes.

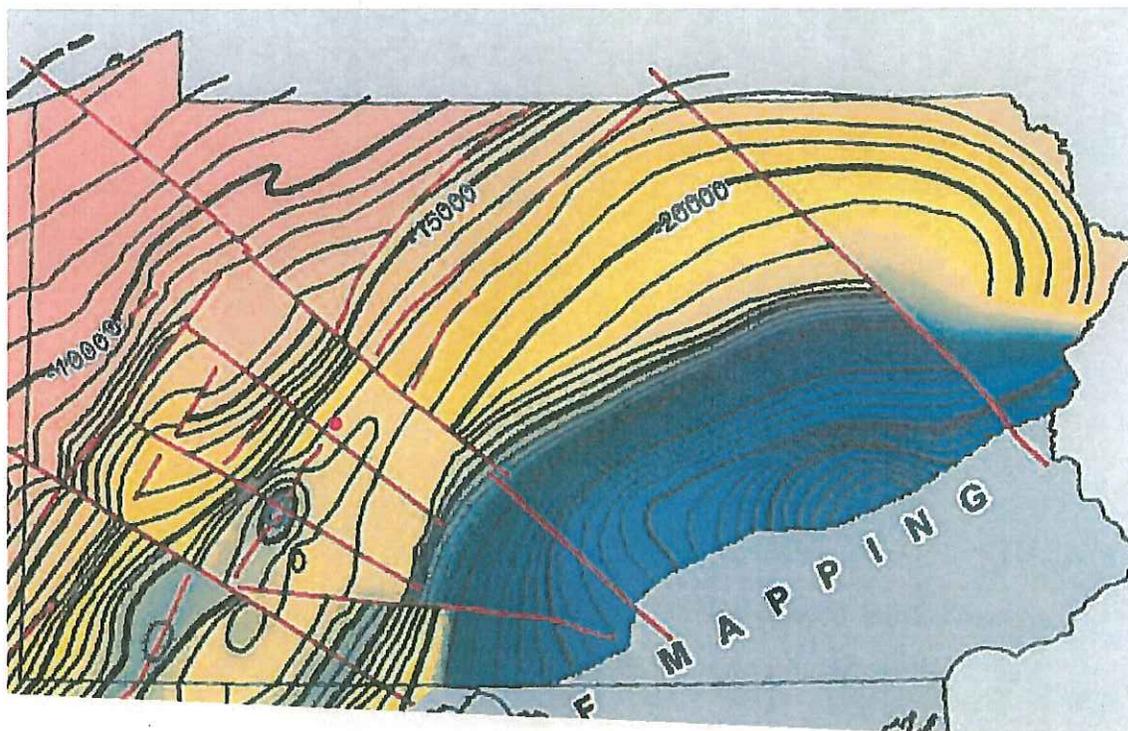


Figure 6. Depth to Precambrian crystalline basement rock. UIC well site (pink circle).

Induced seismicity relating to the operation of injection wells results from the interrelationship of factors such as depth to basement rock, distance to existing faults, fault plane orientation and pore pressure regimes. This geologic analysis has not revealed indicators suggestive of a heightened potential for induced seismicity; however, there are some reported structural geologic anomalies that have been noted within the area surrounding the well. Based upon the review of all available information, it is my professional opinion that injection activities at this well pose a low risk with regards to induced seismicity. It is recommended that this risk be managed through the application of the specific permit conditions addressing seismic monitoring and mitigation listed in Appendix A.

The Department's review indicates the closest storage well is located approximately 4 miles east of the proposed injection well site (API # 063-24564). There is a storage field (Kinter #1) just over 5.5 miles northwest of the site (Figure 7) and this is not expected to pose any concerns related to operation of the injection well.

The Department's review indicates there is surface mining within the quarter- and one-mile radius area of review. However, there is no deep mining within the quarter-mile buffer. There is an active deep mining permit boundary that may encroach on the mile buffer in the future depending on resource development in the area (Figure 8). The mining that was identified appears to be consistent with PGE's application to EPA. There is no deep mining within the quarter-mile area of review, thus the injection well's integrity is not expected to be affected by contact with mine waters or structural deformation. In addition, the distance of this well from any existing or planned mines is great enough that there is no anticipated potential for communication of injected fluids with current, former, or planned mining activities.

The Department's review indicates there are active municipal water wells associated with Purchase Line School District within the 1-mile radius of review. These wells are located southeast of the site (Figure 9). Since the casing and cementing requirements of 25 Pa. Code Chapter 78, Subsection D are satisfied, there is no expected risk to these wells provided injection well integrity is maintained. In PGE's application to EPA, 13 private water wells were identified within a quarter-mile radius area of review and PGE documented the deepest USDW well to penetrate to a depth of 520 feet below existing site grades. The Department concurs with PGE's statement that the well construction details at the proposed UIC well (fully cemented surface casing at 569 feet and fully cemented intermediate casing at 1,539 feet) is adequate to protect groundwater in the area of the proposed injection well. The EPA did not raise any concern with the analysis during their review.

It is my professional opinion that it is improbable that disposal activities would affect these additional site features (including gas storage fields, deep mines and public/private water supplies) due to the construction of the well, the geology, and the distance of these features to the well and its injection horizon.



Figure 7. Map showing storage well locations. Quarter-mile and one-mile buffers depicted.

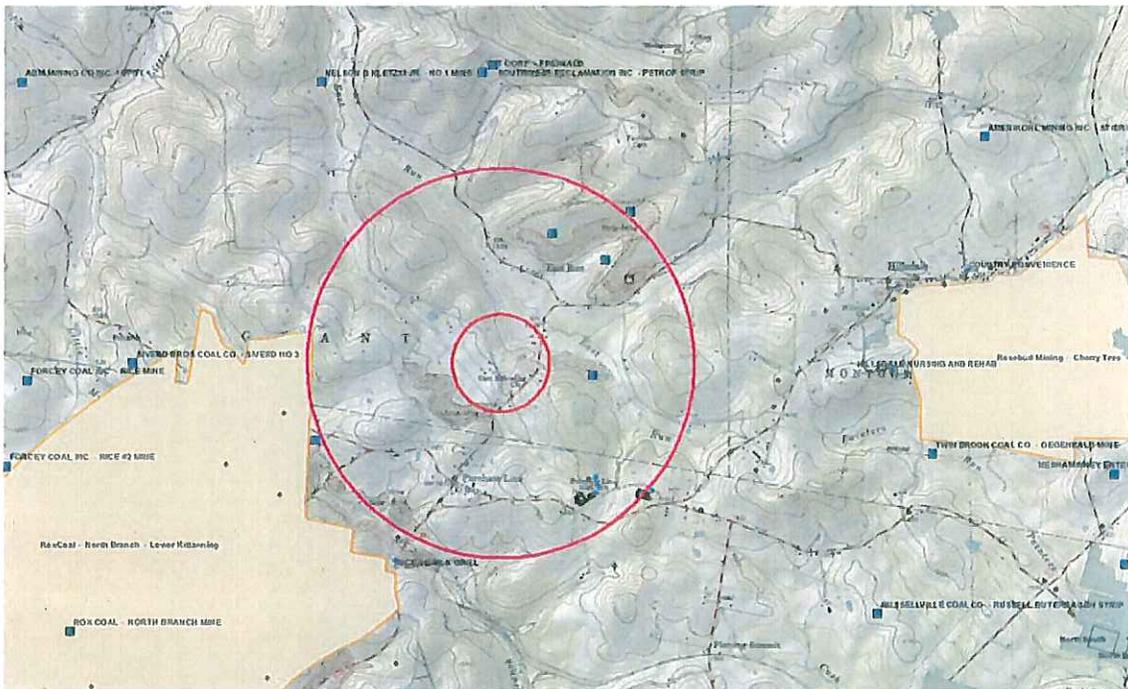


Figure 8. Map showing surface and underground mining activities in the area. Quarter-mile and one-mile buffers depicted.

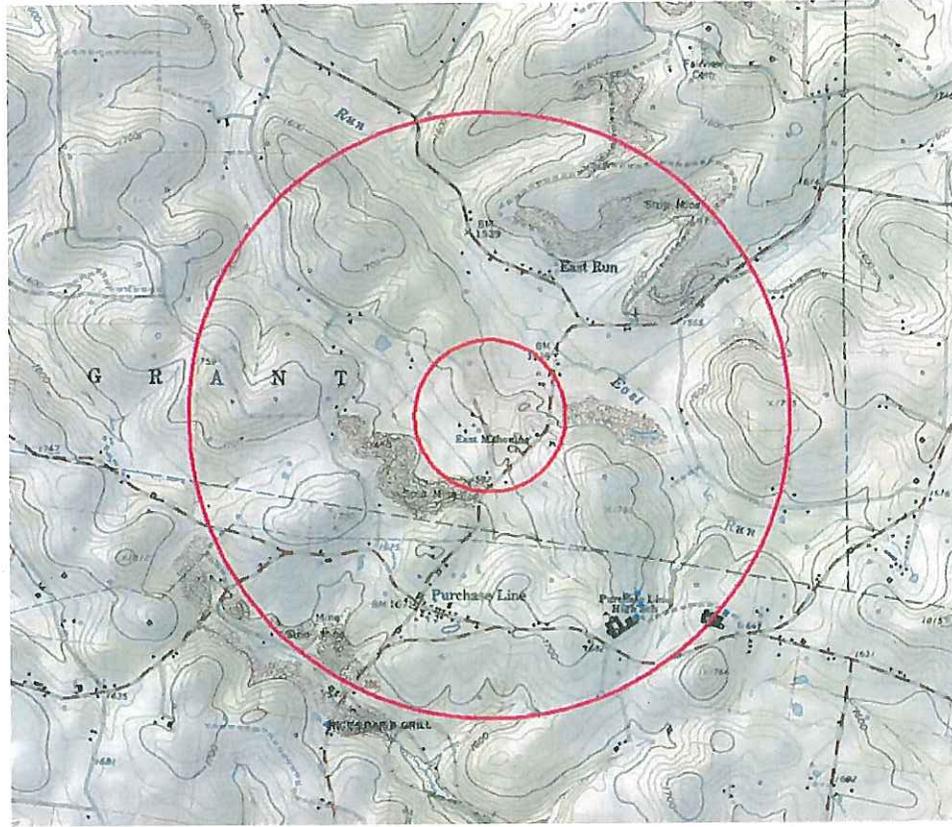


Figure 9. Map showing public water supply wells. Quarter-mile and one-mile buffers depicted.

Summary of Geological Review/Assessment and Recommendations

Geological Assessment for the PGE – Indiana County, Yanity Well #1025 gas well:

In my professional opinion, based on the data reviewed, the geological structure and setting of the PGE – Indiana County, Yanity Well #1025 gas well makes it a suitable candidate for conversion from a production well to an underground injection well.

The following recommendations are noted:

- (1) During the operation of the injection well: It is recommended that the Department monitor for future Marcellus shale or deeper penetrations in this area.

cc: John Ryder
Elizabeth Davis
Rick Watling
Thomas E. Donohue

APPENDIX A

Based on the structural geologic complexities within the area of the site, such as the structural anticline/salt dome which affects Marcellus Shale development, the merging of the Chestnut Ridge Anticline with the Grapeville – Kinter Hill Anticline (also known as the Jacksonville Anticline) to the south of the site, the emplacement of Dixonville-Tanoma kimberlitic dike and the presence of faults within the basement rock including the Home-Gallitzen Lineament, the following permit conditions are recommended as part of a Seismic Monitoring and Mitigation Plan.

- (1) Installation of a seismometer that, at minimum, includes the following:
 - a. One 3-component velocity sensor (X, Y, and Z axes), high-frequency seismometer or a local network consisting of a **minimum** of four high-frequency seismometers that have 3-component velocity sensors.
 - b. For purposes of this seismic Monitoring and Mitigation Plan, a “seismic event” shall mean circumstances which reflect tectonic seismic activity above the thresholds and within the distances set forth in Paragraphs (11) or (12) below.
 - c. For purposes of this seismic Monitoring and Mitigation Plan, an “Injection-Induced Seismic Event” shall mean circumstances which reflect seismic activity that may be directly attributable to the permitted injection activities. Raw seismic data gathered by the seismometer(s) described in (1) a. will be processed to calculate event location (epicenter/hypocenter) and magnitude. Events attributable to surface activities (such as, but not limited to, mining or blasting) or system noise will not be considered potential Injection-Induced Seismic Events.
 - d. If the one sensor option is chosen, and an Injection-Induced Seismic Event occurs at or above the thresholds specified in (11) c and d below, the operator will mobilize a local network consisting of a minimum of four (4) high-frequency seismometers that have 3-component velocity sensors within 48 hours of the event.
 - e. All seismometers shall be installed in accordance with the manufacturer’s instructions prior to operation of the disposal well.
- (2) A description of and specification sheet for the seismometer installed at the disposal well site.
- (3) The installation of a recorder that, at a minimum, continuously records 100 samples per second using a data logger with 24-bit digitizer and Global Positioning System (GPS) timing, in accordance with the manufacturer’s instructions prior to operation of the disposal well.
- (4) A description of and specification sheet for the seismic recorder installed at the disposal well site.
- (5) A description of the protocol for operating and completing calibration of the seismometer and seismic recorder installed at the disposal well site demonstrating that it conforms with the standards employed by the Pennsylvania State Seismic Network (PASEIS) and the manufacturer’s instructions.
- (6) A description of the routine maintenance and service checks that will be implemented to monitor the operability or running condition of the seismometer and seismic recorder installed at the disposal well site. The description should detail how the checks satisfy the manufacturer’s instructions.
- (7) Verification that tectonic seismic event data will be captured at the disposal well site electronically and in a manner that is suitable for tectonic seismic event recordation and analysis.
- (8) Verification that seismic data will be provided to the Incorporated Research Institutions for Seismology (IRIS) Network in real time and that the continuous, real time data conforms to the data format required by IRIS for archiving under PASEIS’ network code (PE) and open distribution. If

data transmission is interrupted, notification will be provided to the Department verbally within 24 hours and in writing within seven (7) days.

- (9) A description of measures that will be taken to install the seismometer in a manner that will minimize interference from background sources and allow for optimal Seismic Event identification and location (epicenter and hypocenter). This shall include a plan view map of proposed seismometer location(s).
- (10) Contact information for the responsible person in charge of conducting seismic monitoring activities at the disposal well site.
- (11) If the one sensor option is chosen, a tectonic seismic event contingency plan that includes monitoring, reporting and mitigation provisions consistent with the following:
 - a. Immediate electronic notification to the Department and the Department of Conservation and Natural Resources' Bureau of Topographic and Geologic Survey (BTGS) of detection of any measurable event, within six (6) miles measured radially from the disposal well.
 - b. Notification within 10 minutes via email to the Department and 1 hour via telephone to the Department's statewide toll-free number in the case of seismic activity referenced in a. above will include filtering/processing of raw seismic data to identify and remove non-tectonic events (e.g. mine blasts or system noise).
 - c. Should an Injection-Induced Seismic Event occur (i.e., not a surface-related event or system noise), the Operator will reduce the well's operating injection rates. Reduction of the disposal well's operating injection rates in use at the time of the Injection-Induced Seismic Event by 50% within 48 hours of the occurrence of 3 or more consecutive Injection-Induced Seismic Events greater than 1.0 and less than 2.0 on the Richter Scale over a seven (7) day period occurring within three (3) miles measured radially from the disposal well. The seven (7) day period is defined as starting with the occurrence of any Injection-Induced Seismic Event of magnitude 1.0 or greater. Reduced operating injection rates shall be maintained until the Department provides written notice addressing injection rates.
 - d. Termination of all injection activities within 48 hours of the occurrence of an Injection-Induced Seismic Event of magnitude 2.0 or greater within three (3) miles measured radially from the disposal well until receipt of a written notice from the Department addressing continued well usage and operating conditions. The assessment of continued usage will include, but not limited to, the following criteria:
 - i. Magnitude and frequency of events detected;
 - ii. Operational history prior to the event and operating conditions at the time of the event (rates, volumes, pressures);
 - iii. Any mitigation/intervention attempts made prior to termination of activities;
 - iv. Ability of permittee to identify another potential source for the event based on data processing and analysis of conditions.
- (12) If the network option is chosen, a tectonic seismic event contingency plan that includes monitoring, reporting and mitigation provisions consistent with the following:
 - a. Immediate electronic notification to the Department and the BTGS of detection of any measurable event, within three (3) miles measured radially from the disposal well.
 - b. Notification within 10 minutes via email to the Department and 1 hour via telephone to the Department's statewide toll-free number in the case of seismic activity referenced in a. above will include filtering/processing of raw seismic data to identify and remove non-tectonic events (e.g. mine blasts or system noise).

- c. Should an Injection-Induced Seismic Event occur (i.e., not a surface-related event or system noise), the Operator will reduce the well's operating injection rates. Reduction of the disposal well's operating injection rates in use at the time of the Injection-Induced Seismic Event by 50% within 48 hours of the occurrence of 3 or more consecutive Injection-Induced Seismic Events greater than 1.0 and less than 2.0 on the Richter Scale over a seven (7) day period occurring within three (3) miles measured radially from the disposal well. The seven (7) day period is defined as starting with the occurrence of any Injection-Induced Seismic Event of magnitude 1.0 or greater. Reduced operating injection rates shall be maintained until the Department provides written notice addressing injection rates.
 - d. Termination of all injection activities within 48 hours of the occurrence of an Injection-Induced Seismic Event of magnitude 2.0 or greater within two (2) miles measured radially from the disposal well until receipt of a written notice from the Department addressing continued well usage and operating conditions. The assessment of continued usage will include, but not limited to, the following criteria:
 - i. Magnitude and frequency of events detected;
 - ii. Operational history prior to the event and operating conditions at the time of the event (rates, volumes, pressures);
 - iii. Any mitigation/intervention attempts made prior to termination of activities;
 - iv. Ability of permittee to identify another potential source for the event based on data processing and analysis of conditions.
- (13) Provisions for submitting an updated seismic Monitoring and Mitigation Plan as needed or as may be required by the Department. Updates may be necessary in cases where the risk profile associated with injection activities changes. A signed and certified statement by a qualified professional person responsible for preparing the seismic Monitoring Plan that the plan is true and accurate and includes the components outlined above. The certification shall provide: "I, (insert name), hereby certify, under penalty of law as provided in 18 Pa.C.S. § 4904 (relating to unsworn falsification to authorities) that I prepared the seismic Monitoring Plan for (insert facility name) and the information provided is true, accurate and complete to the best of my knowledge and belief."
- (14) Upon commencement of disposal activities at the disposal well, the permittee shall record tectonic seismic event data electronically in an appropriate format for analysis (event location and magnitude) and maintain daily records of tectonic seismic event data electronically for review at the request of the Department. Tectonic seismic event records must be maintained for one (1) year.
- (15) The permittee shall maintain all calibration, maintenance and repair records for the seismometer for at least five (5) years.
- (16) The permittee shall maintain all calibration, maintenance and repair records for the seismic recorder for at least five (5) years.
- (17) The operator may submit a summary report and plan for modification or discontinuation of the seismic Monitoring Plan five (5) years after injection activities commence. The Department's review will be completed as soon as practicable after receipt of the summary report and a written response will be provided to the operator. DEP's assessment of the report will be dependent on, but not limited to, the following criteria:
- a. Magnitude and frequency of any events during the monitoring period;
 - b. Operational history during the monitoring period (rates, volumes, pressures);
 - c. Planned operational conditions moving ahead (rates, volumes, pressures);

- d. Demonstration through pressure fall-off that system is at equilibrium and behaving in as a homogenous reservoir;
- e. Need for any mitigation/intervention during the monitoring period.

End