UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

STATEMENT OF BASIS

FOR

U.S. EPA'S UNDERGROUND INJECTION CONTROL (UIC) PROGRAM
DRAFT CLASS IID PERMIT NUMBER VAS2D950BBUC

TO BE ISSUED TO

EnerVest Operating, LLC
809 Happy Valley Drive
Clintwood, Virginia 24228

FOR

A project consisting of one Class II-D (produced fluid disposal) injection well that will be used for the continued disposal of fluids produced in association with coal bed methane and conventional natural gas production operations, specifically EnerVest Injection Well No. BU-1614 (hereinafter, "EnerVest Injection Well No. BU-1614" or "the Facility"). The proposed well to be covered by this permit is located in the following location:

Nora and Haysi Fields
Buchanan County, Virginia (Prater District)
Latitude - 37° 12' 21"N; Longitude - 82° 12' 15"W

Background: EnerVest Injection Well No. BU-1614 was drilled by Columbia Natural Resources in August 1999 to a depth of 6,155 feet to produce natural gas from the Devonian Shale and Berea Formations. Pine Mountain purchased the Facility in September 2005 for the purpose of evaluating potential gas production from the Weir Formation. After determining that the Weir Formation had insufficient gas reserves, Pine Mountain converted the Facility to an injection well. The original injection permit was issued on April 10, 2007 and injection began in September 2007. In April 2008, Pine Mountain changed its name to Range Resources and on January 14, 2016, the permit was transferred to EnerVest Operating. LLC ("Permittee")

EnerVest Operating, LLC applied for permit renewal in December 2016. Following its initial review of the December 2016 permit renewal application, EPA sent a Notice of Deficiency ("NOD") dated July 19, 2017 to Permittee requesting additional information. In response to the NOD, the Permittee submitted additional information in October 2017. The Permittee's submittals dated

December 2016 and October 2017 are collectively referred to in this Statement of Basis as the "renewal permit application". EPA has determined that the renewal permit application is complete.

EPA has reviewed the renewal permit application and determined that no impacts to Underground Sources of Drinking Water ("USDWs") are expected to result from the continued operation of EnerVest Injection Well No. BU-1614. Accordingly, EPA intends to reissue a UIC permit for EnerVest Injection Well No. BU-1614, with conditions and terms as stated in the accompanying draft permit, unless information is received during the public comment period indicating that modifications are warranted. Pursuant to 40 C.F.R. Parts 144 and 146, the draft permit specifies conditions for construction, operation, monitoring, reporting, and plugging and abandonment of the EnerVest Injection Well No. BU-1614 in order to prevent the movement of fluids into any USDW. The Facility and the applicable draft permit conditions are further described below.

Area of Review: Pursuant to the applicable regulations, the Area of Review ("AOR") is "the area surrounding an injection well described according to the criteria set forth in §146.06…" 40 C.F.R. §144.3. Section 146.06 provides that the area of review for each injection well shall be determined according to either the zone of endangering influence ("ZEI") or by a fixed radius. Permittee has proposed a one-quarter mile fixed-radius as the AOR around EnerVest Injection Well No. BU-1614. Based on the chemistry of the fluid to be injected, hydrogeology, population (including four surface owners within the AOR) and ground water use and dependence, as well as historical practices in the area (including the injection well's history of operation), EPA has determined that the one-quarter mile AOR is sufficient. The permit requires Permittee to perform corrective action on any unplugged or abandoned wells that penetrate the AOR if they are identified at a future date.

Underground Sources of Drinking Water (USDW): A USDW is defined by the UIC regulations as "an aquifer or its portion" which, among other things, "contains a sufficient quantity of ground water to supply a public water system" and which also "[c]ontains fewer than 10,000 mg/l [milligrams per liter] total dissolved solids", and which is also "not an exempted aquifer" 40 C.F.R. §144.3. The driller's log for this well reported no occurrence of fresh groundwater when the well was drilled. A review of completion reports for coal bed methane wells within the one-quarter mile AOR identified the following: fresh groundwater was encountered at 70 feet below ground surface at BU-3046 and at 194 feet below ground surface at BU-4800. The $9^{5/8}$ inch surface casing is installed at a depth of 395 feet below surface level, which is more than 50 feet from the encountered fresh water found at BU-4800.

Injection and Confining Zone: The Enervest Injection Well No. BU-1614 was drilled to a total depth of 6,155 feet. Injection of fluids for disposal is limited by the permit to the Weir Formation at a depth of 4,354 to 4,464 feet. The Weir Formation is composed of fine-grained siltstone, which is favorable for injection due to its highly permeable, porous structure that allows for the storage and accumulation of fluids under adequate confining conditions. This layer has been depleted of fluid and pressure via oil and gas production, adding to its capacity to store fluid.

According to the applicant, the driller's log shows that the confining zone located immediately above the injection zone, the Big Lime formation, is comprised of approximately 199 feet of dense carbonate (limestone). Multiple additional confining units of shale and other dense rock exist between the injection zone and the surface and include the Mauch Chunk Formation, a formation comprised of over 1,000 feet of low permeability, tight sands, siltstones and limestones. Above the Mauch Chunk is another large interval of siltstone, tight sands, and coal beds that provide additional inhibition of the migration of injected fluid.

The Weir Formation consists of oil and gas reservoir rock with sufficient porosity and permeability to allow fluids to pass through them; a significant hydrocarbon accumulation; and an impermeable cap rock or geologic structure which impedes further hydrocarbon migration. Depleted oil and gas reservoirs (geologic formations which have produced substantial volumes of hydrocarbons and the associated brine water over many years) are desirable brine disposal formations. These formations are desirable disposal targets because the injected fluid is compatible chemically with the fluid remaining in the reservoirs, the reservoir pressure has been significantly reduced, and the presence of multiple confining zones above the Weir Formation present a barrier to upward fluid migration.

Well Construction: This well has $9^{5/8}$ inch surface casing installed from ground level to a depth of 395 feet and cemented back to the surface. This well construction exceeds the technical and generally-accepted criteria of surface casing placement at no less than 50 feet below the lowermost USDW. *See* EPA, "Cementing Records Requirements in Direct Implementation Programs to Achieve Part II of Mechanical Integrity in Class II Injection Wells" (Jan 27, 1999).

(https://www.epa.gov/sites/production/files/2015-08/documents/cementing_records_requirements_in_direct_implementation_programs_to_achieve_part_ii_of_mechanical_integrity_in_class_ii_injection_wells.pdf)

In addition, the renewal permit application indicates that $4^{1/2}$ inch long string casing was placed to a depth of 6,099 feet and initially cemented back to a depth of 4,852 feet. Pine Mountain added additional cement to a depth of 2,570 feet. This exceeds the standard practice of cementing long string casing back to no less than 100 feet above the injection zone. A bridge plug and 50 feet of cement have been placed in the $4^{1/2}$ inch casing at a depth of 4,438 feet to isolate the injection formations from the lower formations, which EPA finds to be consistent with the practice in other states. *See* 40 C.F.R. §§ 147.2104(b)(2) (South Dakota); 147.1655(b)(5) (New York); 147.1154(b)(2) (Michigan); 147.904(b)(2) (Kentucky); and 147.1955(b)(5) (Pennsylvania). The EnerVest Injection Well is located in the Appalachian Plateau Geologic Province, which bears similar geology to that of Kentucky and New York state; therefore, Kentucky and New York UIC regulations are particularly relevant to this analysis. According to the renewal permit application, injection will continue to occur according to the method currently used at the Facility, which is that fluid is injected via a $2^{3/8}$ inch tubing string installed to a depth of approximately 4,376 feet.

Maximum Injection Pressure: The maximum allowable surface injection pressure for the permitted operation has been limited to 1,040 pounds/square inch (psi) at the surface which equates to a pressure of 3,095 psi at a depth of 4,354 feet, where the top of the injection zone meets the bottom of the confining zone. This represents 90% of the calculated pressure that could potentially initiate fractures in the overlying confining formation. A specific gravity for the injection fluid of 1.09 was used in the calculation. This value is based on the maximum specific gravity of fluid EnerVest has been injecting into EnerVest Injection Well No. BU-1614 at the time of permit reapplication. If the specific gravity of the injection fluid is determined to be greater than 1.09, the Permittee must notify EPA. To inject such fluid, the Permittee must either lower the surface injection pressure so that the bottomhole pressure of 3,095 psi is not exceeded, or dilute the fluid so that its specific gravity is no greater than 1.09. The permit requires both injection pressure and annular pressure to be continuously monitored.

The draft permit imposes a lower maximum injection pressure than the injection pressure allowed by the 2007 permit, based on a reevaluation of the maximum injection pressure calculation utilizing the

fracture gradient value of 0.79 psi/ft. This fracture gradient value represents an average fracture gradient value of wells that penetrate the Big Lime within a one-mile radius of EnerVest Injection Well No. BU-1614. EnerVest Injection Well No. BU-1614 and many other wells in the surrounding area were fracked using nitrogen foam. EPA evaluated the consistency of the nitrogen foam used in the fracking by combining fracture gradient values for wells within a one-mile radius of the EnerVest Injection Well No. BU-1614 with a table EnerVest provided EPA with to evaluate foam density.

The pressure limitation imposed by the draft permit is more stringent than the regulatory criteria of 40 C.F.R. §146.23(a) which limits the injection pressure to a level which would "assure that the pressure during injection does not initiate new fractures or propagate existing fractures in the confining zone adjacent to the USDWs" during operation of the Injection Well. Limiting the maximum injection pressure to 90% of the level which would initiate fractures in the confining formation (Big Lime Formation) is more protective than what the regulations require.

Geologic and Seismic Review: The UIC regulations for Class II wells do not require consideration of seismicity, unlike the UIC regulations for Class I wells used for the injection of hazardous waste. Nevertheless, EPA has evaluated factors relevant to seismic activity such as the existence of any known faults and/or fractures and any history of, or potential for, seismic events in the area of the EnerVest Injection Well as discussed below. See also "*Region 3 framework for evaluating seismic potential associated with UIC Class II permits, September, 2013*." The maximum injection pressure in the draft permit is also designed to limit the potential for seismic events.

The region in which the Facility is located consists of an extensive, thick, sedimentary sequence with numerous confining strata between the surface and the existing injection zone. Deep below the sedimentary layers lies the Precambrian, crystalline, igneous/metamorphic bedrock, commonly referred to as "basement rock." Basement rock in the area of the proposed permit is located at depths approximating 16,000 feet, about 11,500 feet below the proposed injection zone.

The permit provides that the Permittee shall inject through the EnerVest Injection Well No. BU-1614 only into a formation which is overlain by a confining zone free of known open faults or fractures within the Area of Review as required in 40 C.F.R. § 146.22(a). The Permittee has indicated that there are no identified faults within the AOR and that the entire Appalachian Plateau, where the Facility is located, is considered geologically stable with no active faults since Virginia lies on a passive continental margin. The Permittee submitted various historical geologic information including a website on Earthquakes from the Virginia Department of Mines, Minerals and Energy, Division of Geology and Minerals (http://www.dmme.virginia.gov/dgmr/earthquakes.shtml).

The available geophysical and seismic information researched by the Permittee, as well as through EPA's review of published information of seismicity in Virginia (refer to information referenced below), shows no evidence of faults that reach the land surface from basement rock. The geologic information does identify the presence of the Russell Fork Fault, which is a right-lateral fault located more than four miles east of the Injection Well, forming the eastern boundary of the Pine Mountain Thrust Block with as much as six miles of lateral displacement. Movement along this fault occurred several million years ago and was due to regional compression (sediment deposition). This fault is a shallow sealing or non-transmissive fault. This geologic information also includes geophysical well logs from wells which penetrate the injection zone and which are located on either side of the suspected surficial fault. This geologic information documents that there has been minimal relative displacement or movement of the deeper injection and confining zones across the fault area.

The geological information shows that Appalachian Basin, including southwestern Virginia which lies on the passive continental margin, is not currently seismically active because insufficient pressure exists to cause movement along ancient faults and fractures. These faults and fractures are closed and non-transmissive due in large measure to the tremendous downward pressure exerted by thousands of feet of overlying sediment deposited since their creation. Further, removal of oil, natural gas and brine from deep formations reduces the reservoir pressure and results in increased fault and fracture-sealing downward stresses.

The United States Geologic Survey (USGS) has not recorded any seismic activity that originated in Buchanan County, Virginia from 1900 through present day - Source: USGS: "Information by Region-Virginia – All Earthquakes 1900-Present": (http://earthquake.usgs.gov/earthquakes/byregion/virginia.php). Virginia is located near the center of the North American Plate and, thus, experiences a much lower rate of seismicity in comparison with an area like California, which is located closer to a plate boundary and experiences shallower, more energetic seismic events due in part to less coherency in the basement rock. Another difference between the states is that California earthquakes often break the ground surface, while earthquakes in Virginia usually occur on faults at depths of from three to fifteen miles. The rare earthquakes felt in Virginia today generally have no relationship with faults seen at the surface. Residual stresses from the formation of the Appalachian Range and the Piedmont province hundreds of millions of years ago appears to be the mechanism for Virginia's earthquakes. Earthquake activity in Virginia has been associated with basement rock, either from basement faulting or faulting at a shallower depth caused by tectonic stresses that originated from the basement rock.

The National Academy of Sciences report, "Induced Seismicity Potential in Energy Technologies", National Academy Press (2013), indicates that oil and gas production in a reservoir can assist in preventing future impacts from seismicity due to injection because of the reduction in reservoir pore pressure during the years of gas production. In the renewal permit application, the Permittee documented significant gas production in the vicinity of the proposed Injection Well (gas pays at depths similar to the proposed injection zone). EnerVest Injection Well No. BU-1614 has been used to dispose of large quantities of produced fluid since 2007 when it was converted from its former status as a production well. The well's track record of successful use as an injection well combined with the reasons described above make the risk of seismic activity in Buchanan County resulting from operation of the EnerVest Injection Well No. BU-1614 very low. The maximum pressure and injection rate allowable under this permit will not result in an appreciable pressure increase in the injection formation.

Finally, a number of factors help to prevent injection wells from failing in a seismic event and contributing to the contamination of a USDW. First, most Class I or Class II deep injection wells (including the Enervest Injection Well No. BU-1614), are constructed to withstand significant amounts of pressure. The ongoing injection will occur into an injection well that has been constructed with multiple steel strings of casing that are cemented in place. Furthermore, both the existing and the draft permits require Permittee to mechanically test the EnerVest Injection Well No. BU-1614 to ensure structural integrity before operations begin and to continuously monitor the Injection Well during operations to detect any potential mechanical integrity concerns. The EnerVest Injection Well No. BU-1614 is also designed to automatically shut in and cease operation in the event that the mechanical integrity of the well is compromised, including by a seismic event.

Injection Fluid: The permit limits the EnerVest Injection Well No. BU-1614 to disposal of produced fluids associated with EnerVest oil and gas production activities. The maximum volume EnerVest Injection Well No. BU-1614 will be permitted to dispose of is 56,000 barrels per month (where a barrel consists of 42 gallons). By limiting disposal to this volume, fluid is expected to be contained within the AOR during the ten-year timespan during which the permit is in effect. Fluid dispersal is modeled, in part, by the ZEI calculation, which is performed by EPA UIC staff and included as part of the Administrative Record. The sources of the disposal fluids are limited to oil and gas production wells owned and operated by the Permittee. Analyses of injection fluid will be conducted as stated in Part II, paragraph B.3 of the draft permit. The parameters chosen for sampling reflect the typical constituents found in Class II injection fluid. Should a ground water contamination incident occur during the operation of the EnerVest Injection Well, EPA will be able to compare samples collected from ground water with the injection fluid analysis to help determine whether operation of the Injection Well may be the cause for the contamination. The Permit also includes a provision requiring the Permittee to ensure the security of the Injection Well in order to prevent unauthorized fluid discharge due to vandalism or other third-party actions.

Testing, Monitoring, and Reporting Requirements: The Permittee is required to conduct a two-part mechanical integrity test (MIT) at least once every five years. The Permittee must conduct MIT within five years from its last test, which was on February 2, 2014. The two-part MIT consists of a pressure test to make sure the casing, tubing and packer in the well do not leak and a fluid movement test to ensure that any movement of fluid does not occur outside the injection zone. Additional pressure testing of the casing, tubing and packer is required to occur whenever a rework on the well requires the tubing and packer to be released and reset. The Permittee will continue to be responsible for monitoring injection pressure, annular pressure, flow rate and cumulative volume on a continuous basis, and reporting this data to EPA on an annual basis. The purpose of these tests, as well as the monitoring requirements, is to corroborate the absence of fluid movement into or between USDWs and flow conditions that exist in the injection zones during operation, thus helping assure that USDWs are protected.

Plugging and Abandonment: The Permittee has submitted a plugging and abandonment plan that is expected to result in an environmentally protective well closure at the time of cessation of operations. The Permittee has also made a demonstration of financial responsibility that verifies that adequate financial resources will be maintained for well closure. The Permittee has submitted surety bond that covers the estimated cost to close, plug and abandon the Injection Well in in the amount of at least $35,000. This figure represents an estimate obtained by the Permittee that budgets out the cost of plugging and abandonment at current Industry costs.

Expiration Date: A final permit, when issued, will be in effect for ten years from the date of permit issuance, unless it is modified, revoked and reissued, or terminated during that time-frame. During the life of the permit, EPA may conduct an annual review of the Permittee's operation at the Facility. At a minimum EPA will review the permit every 5 years. The final permit will contain the same conditions as the draft permit, and would only be changed if information is supplied to EPA which would warrant alternative conditions or actions on this renewal permit application.

Additional Information: Questions, comments, and request for additional information may be directed to:

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A public hearing has been tentatively scheduled for June 28, 2018 at 5:00 PM, at the Dickenson County Judicial Center in Clintwood, Virginia. Requests to hold a public hearing must be received in the office listed above by June 15, 2018. When requesting a public hearing, please state the nature of issues you propose to raise. EPA expressly reserves the right to cancel this hearing unless a significant degree of public interest, specific to the proposed UIC brine disposal injection operation, is evidenced by the above date. The Administrative Record for this action will remain open for public comment until June 15, 2018.

The Index to the Administrative Record is attached hereto, and the actual Administrative Record for this draft permit is available for public inspection during normal business hours at the offices of U.S. EPA Region III, at the address shown above. Links to those online publications that partially compose the Administrative Record are also available via EPA's online public notice located at the web address https://www.epa.gov/va/epa-public-notices-virginia.