An Analysis and Recommendation to Address the Technical Feasibility, Practicality, Reasonableness, and Potential Adverse Impacts of Attempting to Alleviate Potential Gas Pressure and Volume in the Vicinity of the Plugged Gesford 3S and Gesford 9 Gas Wells Within the Dimock/Carter Road Area

Respectfully Submitted by:

Dan A. Billman, CPG, PG

May 24, 2023

I, Dan Billman of Billman Geologic Consultants, Inc., was asked by Coterra Energy Inc. (Coterra)[1] to conduct an analysis and recommendation to address the technical feasibility, practicality, reasonableness, and potential adverse impacts of attempting to alleviate potential gas pressure and volume in the vicinity of the plugged Gesford 3S and Gesford 9 gas wells (Gesford Pad), including but not limited to, potential impacts to residents of Carter Road (Dimock/Carter Road Area, Figure 1) in accordance with its obligation pursuant to the November 29, 2022 Consent Order and Agreement (COA). Coterra provided technical data, maps, literature, previous internal studies/evaluations, and published technical papers and documents. Based on my review of this information, together with my own professional expertise and research of technical papers, I provide the following analysis and recommendation based on a reasonable degree of geologic certainty.

"Dimock/Carter Road Area"

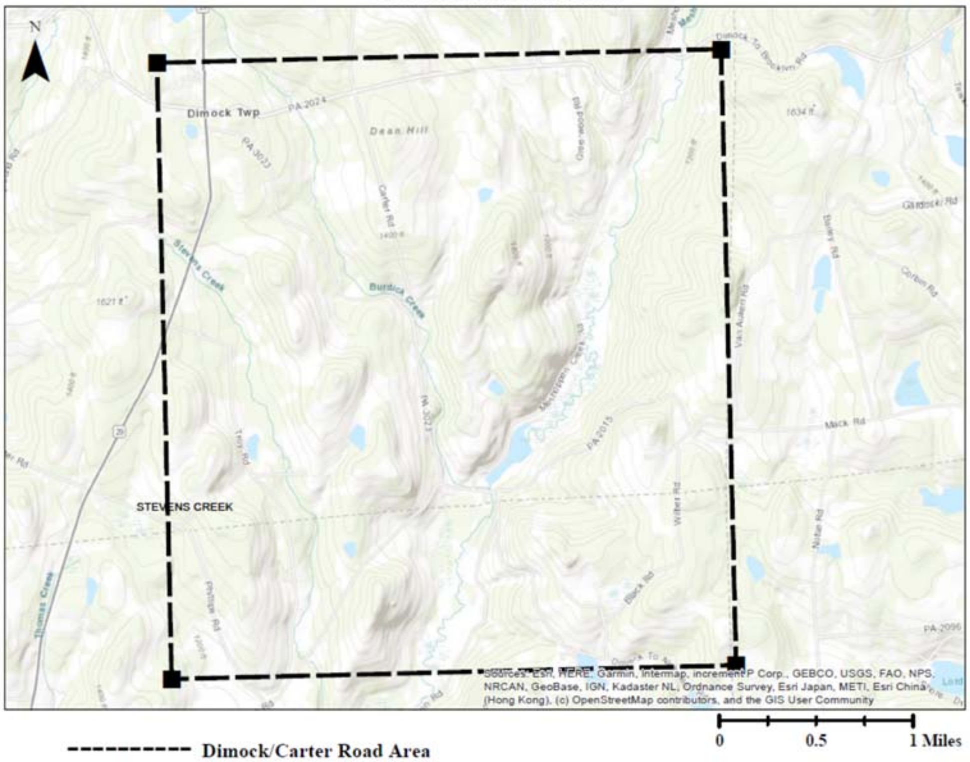

Figure 1: Outline of the Dimock/Carter Road Area, Dimock Township, Susquehanna County, Pennsylvania.

My qualifications include:

> I have over thirty-four years of experience in the Appalachian Basin, primarily as a consulting geologist and President of Billman Geologic Consultants, Inc. Prior to independent consulting, I worked as an exploration and development geologist for Mark Resources Corporation and Eastern States Exploration Company. I am a registered Professional Geologist (PG) in the state of Pennsylvania and a Certified Petroleum Geologist (CPG) through the American Association of Petroleum Geologists.

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[1] Cabot Oil & Gas Corporation changed its name in October 2021 to Coterra Energy Inc. after a merger with Cimarex Energy Co. For clarity, this report uses the name Coterra.

I have extensive development and exploration experience in both unconventional plays (shales and tight gas sandstones), legacy conventional plays, and reservoirs in the Appalachian Basin. I have performed numerous geologic reviews of natural gas and oil exploration prospects throughout the Appalachian Basin, as well as geologic studies related to gas migration investigations, gas storage, and saltwater disposal wells. I have also written and co-authored numerous published papers and technical presentations on the petroleum geology of the Appalachian Basin.

I received a Bachelor of Science degree in Geology from the University of Toledo and a Master of Science degree in Geology from West Virginia University, with an emphasis on structural geology. I am a member of the American Association of Petroleum Geologists (AAPG) and currently the AAPG Delegate representing the Pittsburgh Geological Society and AAPG Advisory Council member, representing the Eastern Section AAPG. I am a past board member of the Pennsylvania Council of Professional Geologists (PCPG) from 2010 through 2016 and President of PCPG 2017 and 2018. A full resume is attached under Attachment 1.

I. Gesford Pad Operational History

A. Location of the Gesford Pad

The Gesford Pad is in Dimock Twp., Susquehanna County. A map of the pad, as designed, is included as Figure 2. Note the Gesford Pad has since been reclaimed and the erosion and sediment control permit has been terminated; however, final, end-of-life pad reclamation has yet to be performed.

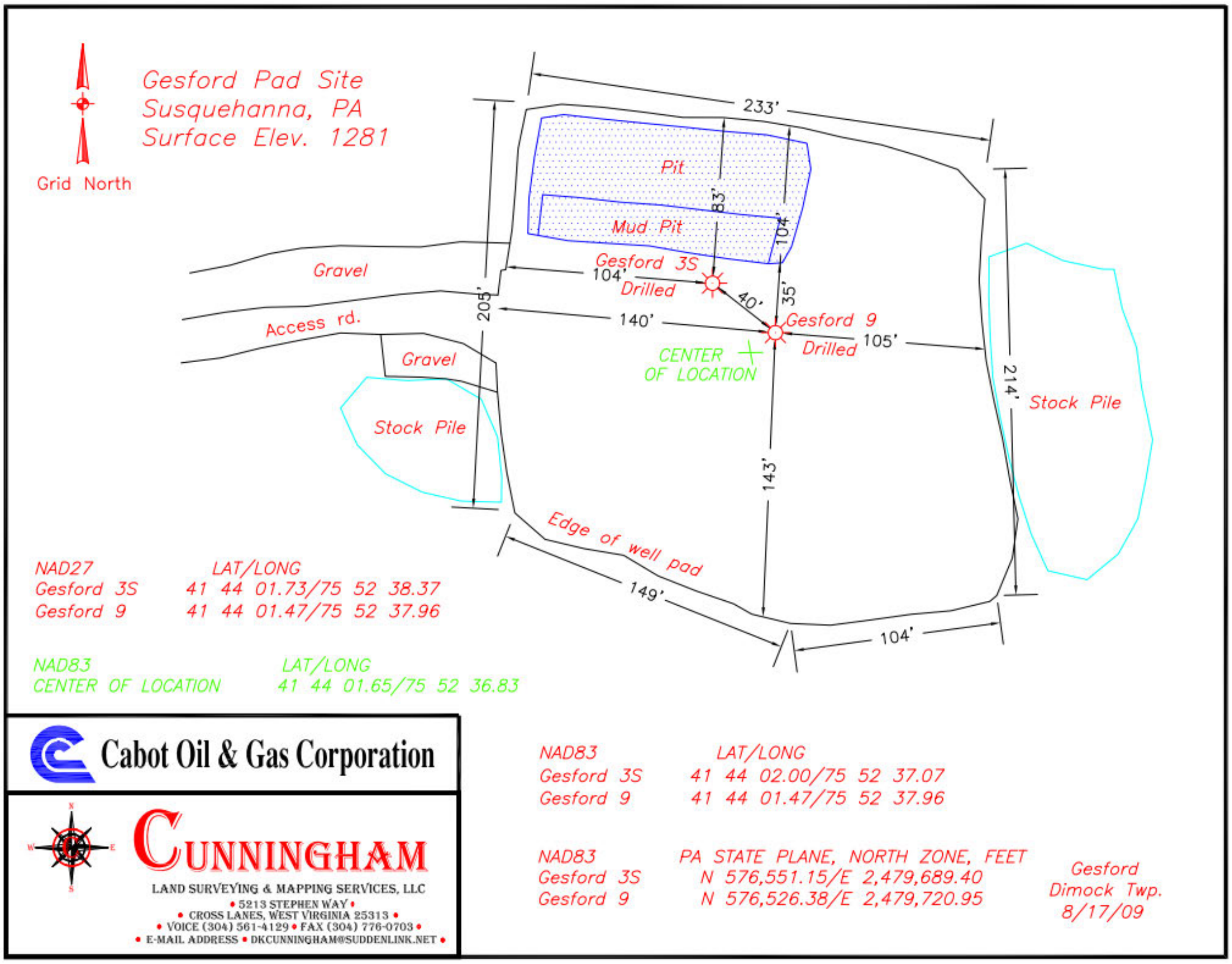

Figure 2: Map of the Gesford Pad, Dimock Township, Susquehanna County, Pennsylvania.

B. <u>Review of the Gesford 3S (API # 37-015-20019) and Gesford 9 (API # 37-015-20187)</u>

Table 1 depicts a timeline of initial operations of the Gesford 3S and the Gesford 9 wells.

Date From	Date To	Gesford 3S	Gesford 9V (originally drilled as the Gesford 3)
9/26/2008	10/5/2008		Spud well and set 13 3/8" Conductor at 30', grouted with cement. Drilled 12 1/4" hole to 888' and attempted to run 9 5/8" casing. Had to deepen 13 3/8" casing to 190' and re-cement.
10/5/2008	10/8/2008		Drilled out cement and continued drilling to 595' before becoming stuck. Drill pipe was cut at 528' leaving the drilling BHA in the hole, fishing was unsuccesful.
10/9/2008	10/9/2008		Hole was abandoned with Class A cement plugs from 360' to 180' and 180' to surface.
10/13/2008	11/3/2008	Spud well and set 20" conductor at 47', issues with mud circulating behind conductor, cemented 20" conductor and drilled 17 1/2" hole and ran 280' of 13 3/8" surface casing and cemented to surface.	
11/3/2008	11/6/2008	Began drilling 12 1/4" hole and 515' the 13x20 annulus began circulating mud to surface. Re-cemented the 13 3/8" casing.	
11/7/2008	11/11/2008	Returned to drilling 12 1/4" hole, at 553' lost circulation. Ran 1 1/2" tubing down drill string to clear bridge. Tripped drill string out and set cement plug from 553' to 265' to help with lost circulation. Tripped in hole and drilled new hole to 913' and ran 9 5/8" casing to 892' and cement to surface.	
11/11/2008	11/15/2008	**Drilled 8 3/4" hole to 1,560' and hit gas show of 900 mcf/d. Ran log showing gas entry from 1,459'-1,503'**. Ran 7" casing to 1,673' and cemented to surface. 7x9 annulus built to 90 psig. Squeezed 1 bbl of 16.3 ppg cement into 7x9 annulus eliminating pressure.	
11/16/2008	1/3/2009	Drilled well to TD at 7,058' and ran 4 1/2" production and cemented. Ran CBL with TOC estimated at 5,293'.	
1/22/2009	3/19/2009		Return to well and drilled out cement, attempting sidetrack, but ended up drilling into former wellbore and encountered fish, and recovered fish. Drilled 12 1/4" hole to 890' and ran 857' of 9 5/8" casing and cemented in with no returns. Grouted 9x13 annulus to surface. Ran CBL on 9 5/8" which showed cement to surface.
3/20/2009	3/31/2009	Completed 2 stages in well and flowed back well then performed PBUT on production casing, final pressure 2,680 psig on 4 1/2" casing.	
4/3/2009	4/28/2009	Set plug to squeeze cement in 4x7 annulus. Perforated at 5,150'-5,152' and squeezed 85 bbls of cement. Ran CBL which estimated the TOC at 880'. Milled out cement in casing and cleaned out to 6,947' and installed tubing and turned well into sales.	
5/28/2009	6/30/2009	Gas identified in cellar, which was investigated. Cellar was dugout to inspect and a vent pipe was installed and a cement pad was poured around conductor casing. Small bubbles observed on 13x20 annulus.	
8/20/2009	9/2/2009		Resumed drilling. **Drilled 8 3/4" hole to 1,911' before well kicked blowing mud from the hole**. Tripped out of hole and had to fish a twisted off bit. Ran 1,435' of 7" casing and cemented to surface. Installed 2 3/8" tubing to 1,415' and swabbed well. Pulled tubing, SICP at 500 psig.
9/5/2009	10/8/2009		Returned with drilling rig and drilled out cement and back to 1,911'. Installed 2 3/8" tubing to 1,541' and turned well into sales.
1/29/2010	1/31/2010		Pulled 2 3/8" tubing, set RBP and ran CBL and tested casing to 1,000 psig, good test. Re-installed 2 3/8" tubing and returned to production at 500 mcf/d.
4/6/2010	4/8/2010	Mobilized into to begin well plugging.	Mobilized into to begin well plugging.
4/22/2010	4/23/2010	Ran Temperature/Audio Log.	Ran Temperature/Audio Log.
4/24/2010	4/25/2010		Well was being plugged.
4/26/2010	5/16/2010	Well was being plugged.	
5/17/2010	5/24/2010	Well was being plugged. Vent pipe and monument installed.	Well was being plugged. Vent pipe and monument installed.

Table 1: Timeline of operations on the Gesford 3S and 9 wells.

1. Gesford 9 (API # 37-015-20187)

The Gesford 9 was originally drilled as the Gesford 3 in late September through early October 2008, but due to the drilling assembly becoming stuck, the original Gesford 3 well was abandoned and a second well on the Gesford Pad, the Gesford 3S, was started. After completion of the drilling operations on the Gesford 3S, Coterra re-permitted the original Gesford 3 to the Gesford 9 and the well was re-entered.

In January 2009, Coterra recommenced operations on the well, drilling out the cement plug. After drilling out the plug and recovering the fish, Coterra resumed drilling, but experienced a gas kick at 1,911 feet and halted drilling. Coterra then installed tubing and brought the well into sales. The Gesford 9 was selected for plugging at the direction of the Pennsylvania Department of Environmental Protection (PADEP). The Gesford 9 was plugged and abandoned on 5/23/2010 pursuant to a plugging plan that was approved by the PADEP.

Figure 3 is a schematic diagram of the pre and post plugging and abandonment of the Gesford 9 wellbore.

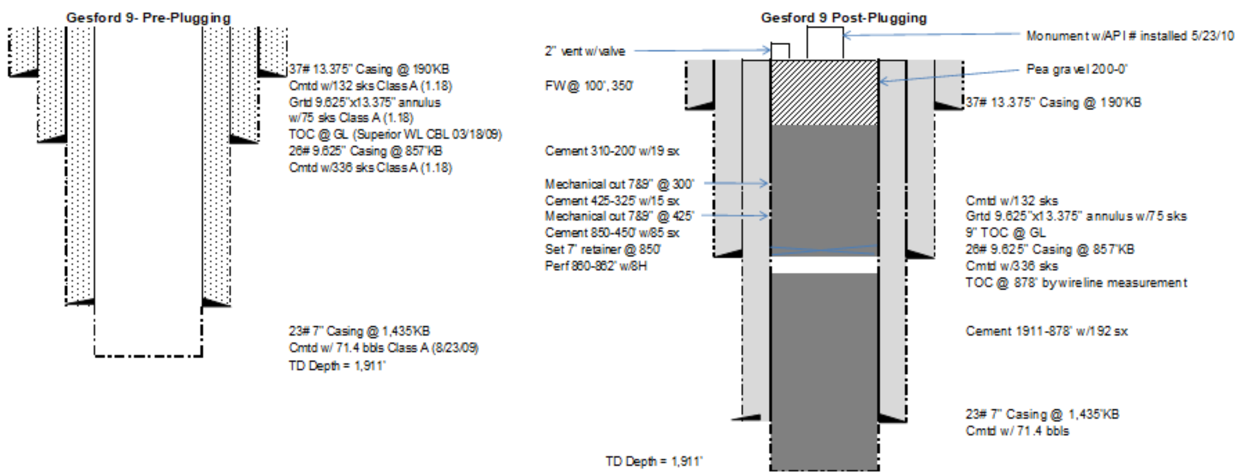

Figure 3: Pre and Post Gesford 9 abandonment diagram.

2. Gesford 3S (API # 37-015-20019)

In October to November 2008, Coterra drilled the Gesford 3S well. During drilling operations, circulation was lost at approximately 553 feet and a cement plug had to be set to help with circulation returns. Afterwards, drilling continued and a natural gas show of 900 mcf/d occurred at 1,560 feet. Coterra logged the wellbore, and gas entry was recorded at 1,459 feet through 1,503 feet.

Eventually drilling resumed and by January 2009, a 6 1/4" hole was drilled to a total depth of 7,058 feet and 4 1/2" production casing was set and cemented in place to 6,974 feet. A cement bond log was acquired, and the cement top was estimated at 5,293 feet.

In March 2009, the Gesford 3S was hydraulically fractured in two stages from 6,640 to 6,950 feet. After the completion operations finished squeeze work was performed on the 4 ½" x 7" annulus. A cement bond log was used to evaluate the squeeze work, which showed a new estimated top of cement on the production casing at 880 feet. Once the squeeze work was completed, production tubing was installed and the well was turned into sales in April 2009.

The Gesford 3S was plugged and abandoned on 5/23/2010 pursuant to a plugging plan that was approved by the PADEP. The Gesford 3S was also selected for plugging at the direction of the PADEP.

Figures 4a and 4b are schematics of the pre and post plugging and abandonment of the Gesford 3S wellbore.

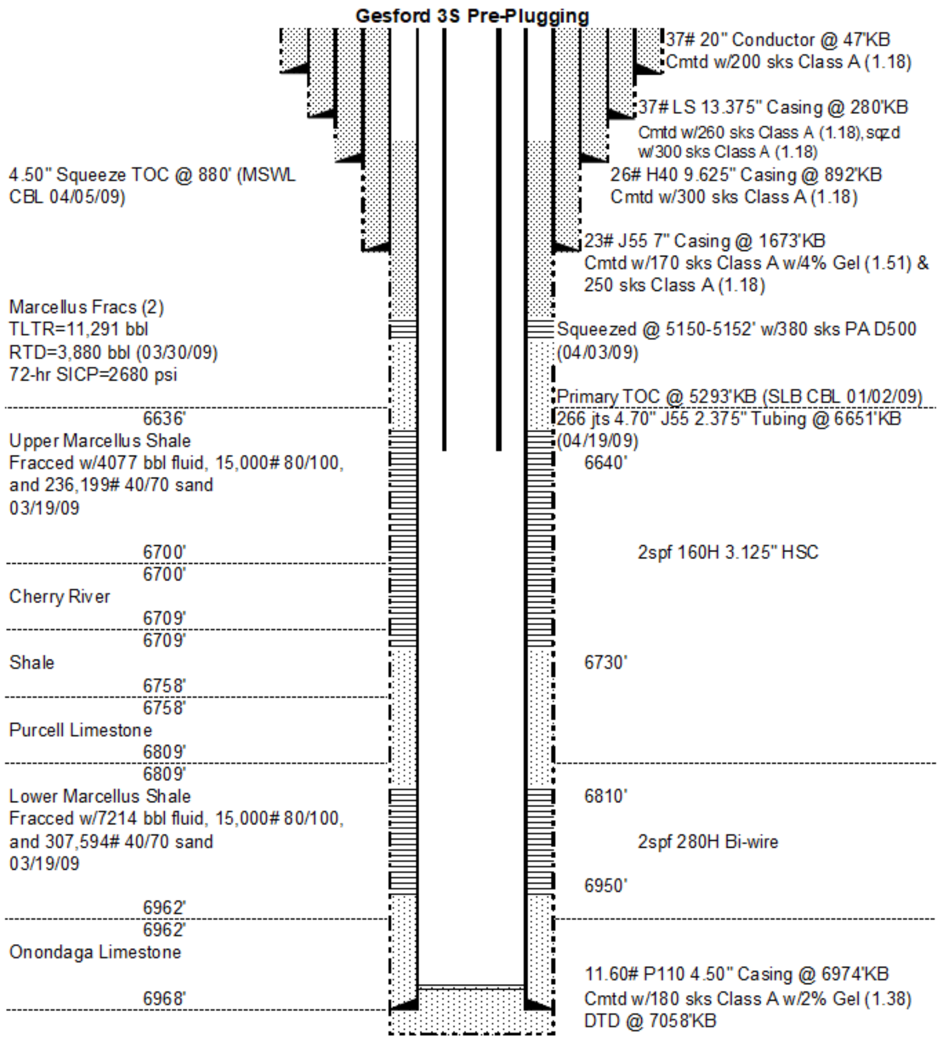

Figure 4a: Pre-Plugging Gesford 3S abandonment diagram.

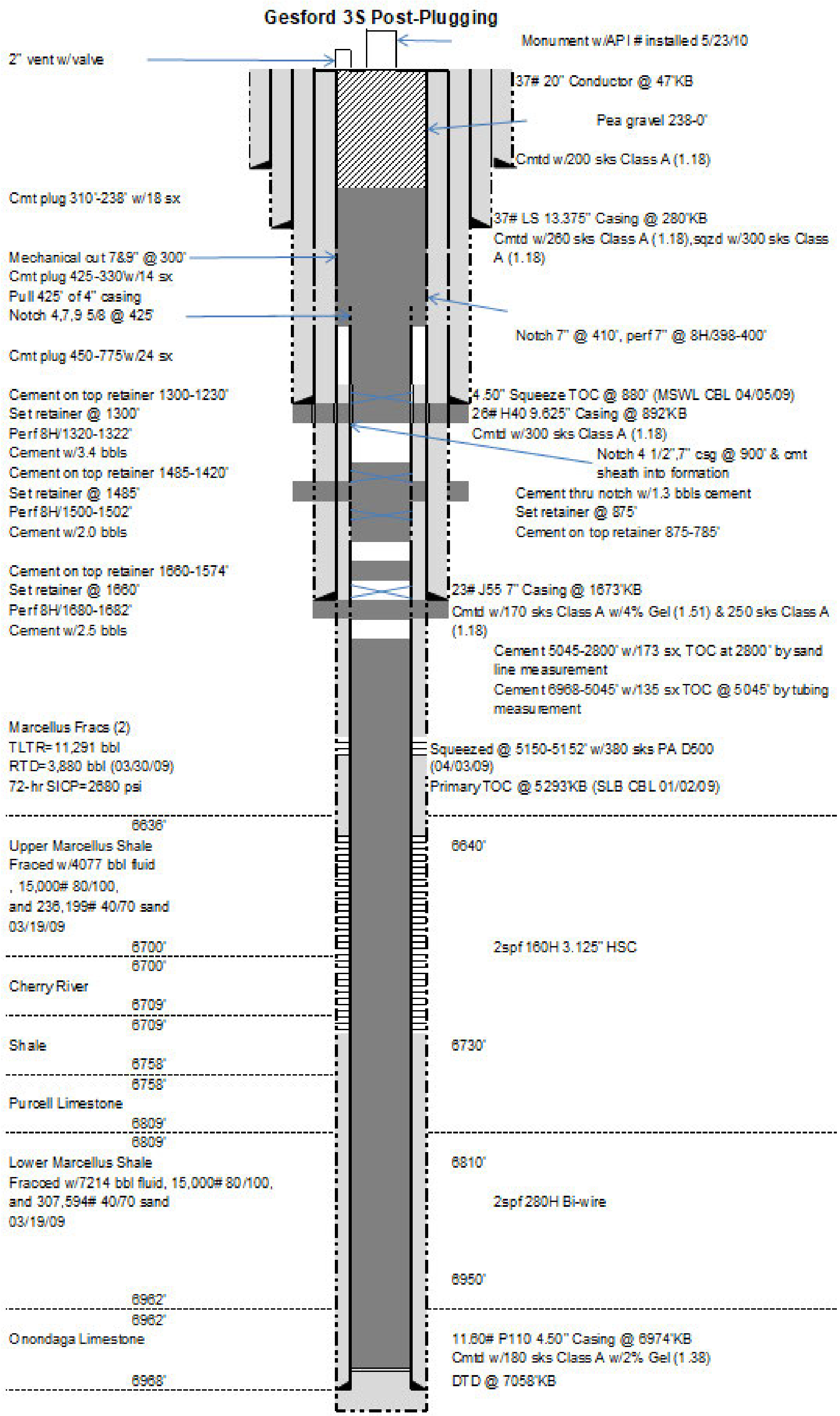

Figure 4b: Post-Plugging Gesford 3S abandonment diagram.

II. Discussion of Regional Geology and Hydrology

A. Near-Surface Geologic Discussion of Susquehanna County, PA

The Dimock/Carter Road Area is within the "Glaciated Low Plateau" physiographic province of Pennsylvania (PA Geologic Survey, Map 13, included as Attachment 2 to this report). The Glaciated Low Plateau is characterized by low to moderate rounded hills and valleys, sandstones, siltstones, and shale rocks at the surface and low-amplitude folds in the subsurface.

Bedrock at the surface is predominately Upper Devonian Catskill Formation which includes interbedded deltaic sediments; sandstones (often red), siltstones, shales, mudrocks, and locally minor conglomerates (Figure 5). The Catskill Formation clastic wedge lies conformably above the Lock Haven Formation (historically referred to as the Chemung Formation), which is also composed of sandstone, siltstones, and shales. Both the Catskill and Lock Haven Formations contain sandstones of reservoir quality west of Susquehanna County, in Western and Central Pennsylvania and these reservoirs have been producing oil and natural gas in Pennsylvania for over one hundred years. Both are also utilized as aquifers, located at suitable depths, throughout Pennsylvania, including Susquehanna County.

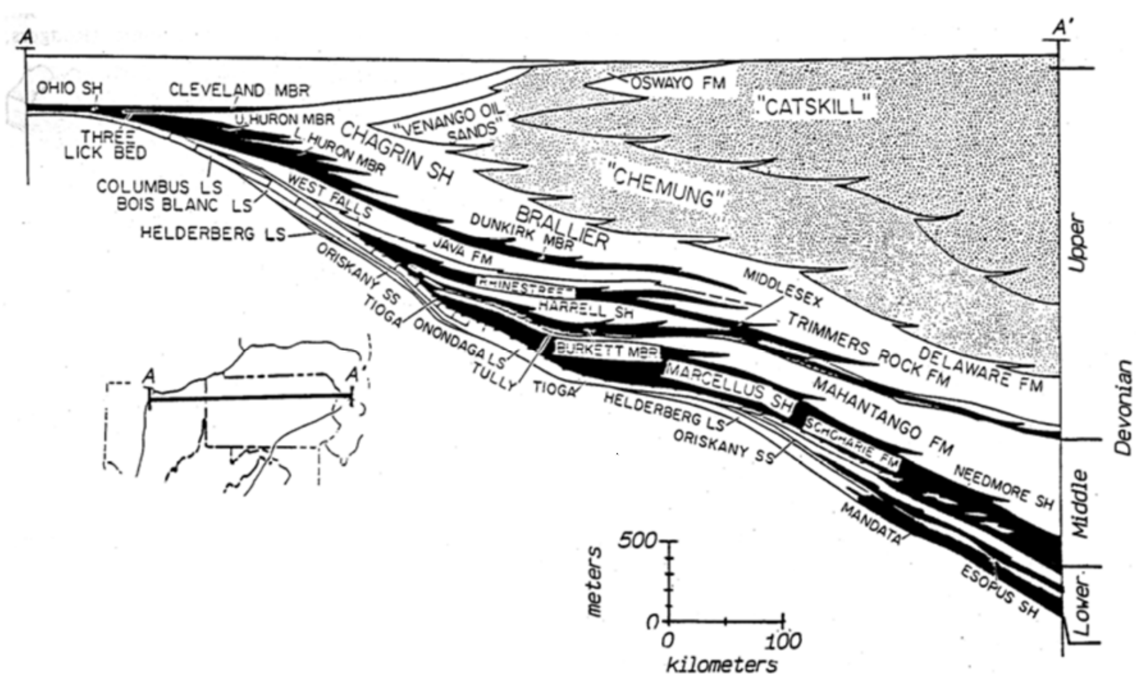

Figure 5: Stratigraphic cross-section depicting the Catskill Clastic Wedge (Delta). From Facies and Sedimentary Environments of the Catskill Systems Tract in Central Pennsylvania, 2009, Rudy Slingerland, Mark Patzkowski and Dan Peterson, Penn State University.

The bedrock of Susquehanna County exhibits numerous features owing to a complex history; from burial, diagenetic processes, faulting, fracturing and mountain building events. Sediment sources for these rocks were derived from the Appalachian Mountains to the east during the Acadian Orogeny. During burial these sediments were lithified into the Catskill and Lock Haven

Formations. Later, during the Alleghenian Orogeny the Catskill Formation was broadly folded and fractured.

Erosional processes after the Alleghenian Orogeny removed much of the overburden exposing these rocks at the surface that are found throughout much of Susquehanna County. More recently, glacial processes carved out valleys exploiting natural weaknesses in the exposed bedrock and deposited glacial till and outwash across Susquehanna County (Sevon, W.D. and Braun, D.D., 2000). Glacial loading and unloading associated with this event also created sub-horizontal joints (roughly parallel to bedding planes).

In the area of the Gesford Pad, the Catskill Formation is often utilized as an aquifer. Most of the water supplies in the area are located within the Catskill Formation. Aquifers can occur in both fractured rock and in porous rock, such as sandstone, where water resides between sand grains. Due to burial history of these specific rocks, diagenetic alteration and compaction has largely limited any primary porosity/intergranular porosity and porosity in the aquifers is fracture dominated.

B. Natural fracturing in the near-surface of Susquehanna County

Tectonic fractures are pervasive throughout the Appalachian Basin and are in a semi-predictable orientation as seen in Figure 6 and Figure 7 below.

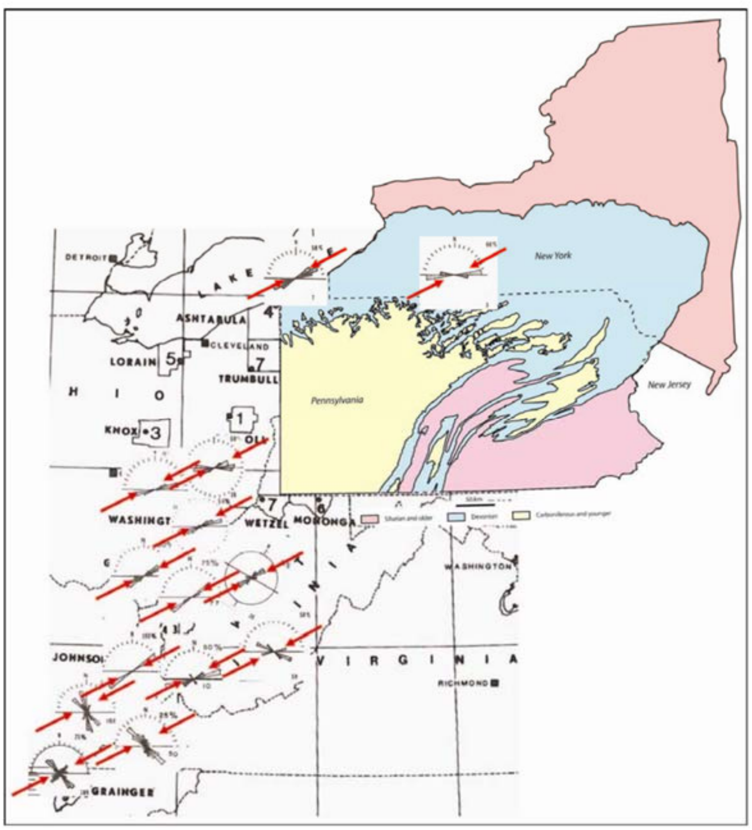

Figure 6: Rose diagrams depicting the J1 joint set orientation (in red) across the northern Appalachian Basin states of Pennsylvania, New York, Ohio and West Virginia. From: Structural Geology of the Marcellus and other Devonian Gas Shales, AAPG-SEG Eastern Section Meeting Fieldtrip Guide, Oct. 11-12, 2008.

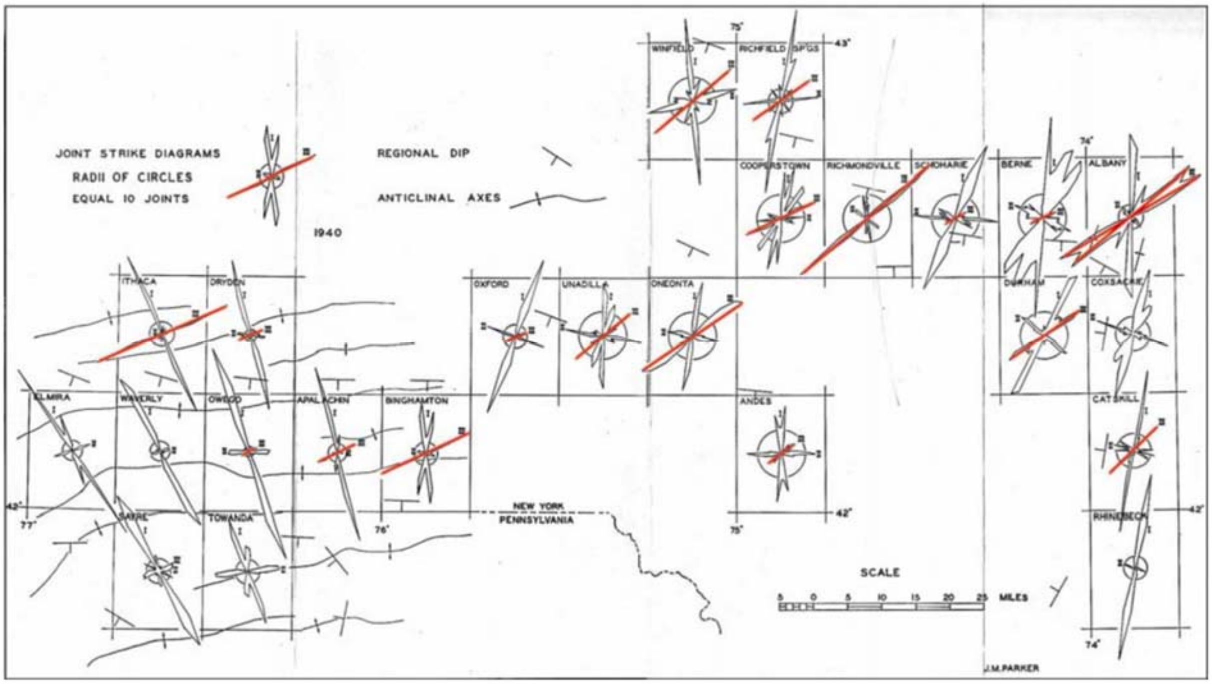

Figure 7: Depiction of the J1 (in red) and J2 joint sets in northern Pennsylvania and the southern tier of New York. From: Structural Geology of the Marcellus and other Devonian Gas Shales, AAPG-SEG Eastern Section Meeting Fieldtrip Guide, Oct. 11-12, 2008.

The through-going, pervasive joints (known as J1 Joints) have a general northeast-southwest orientation, as seen in Figure 6 and Figure 7, while the less pervasive joints (known as J2 Joints) have a general northwest – southeast orientation, as seen in Figure 7. These joint sets have been documented throughout the northern and central Appalachian Basin. These J1 and J2 joint sets are pervasive through the entire Paleozoic rock column, which includes the Devonian Catskill formation.

The J1 and J2 joint sets were created through tectonism during the Alleghenian Orogeny and further enhanced, near-surface, during the glacial periods of northern Pennsylvania.

Although the J1 and J2 joint sets are in a predictable orientation across the basin, what is not predictable is whether the joints are "open" allowing for fluid flow (water or natural gas). Also, not predictable is the spacing of the fractures. Spacing is often related to rock bed mechanics (strength or ductility) and thickness. Also, as discussed previously, shallow, sub-horizontal bed parallel fractures are also intersecting the J1 and J2 joint sets.

Extensive observations and research have been completed by Coterra over the past years in the flagstone quarries of Susquehanna County, to observe and better understand the near-surface natural fractures. Both the J1 and J2 joint sets are observed throughout the flagstone quarries in the area. Included as Figures 8 through 14 are numerous flagstone quarry photos from across Susquehanna County, PA. Some examples of joints and rock interaction are depicted below. Of note, numerous pictures depict iron and manganese staining within fractures and along the exposed quarry faces. The staining is due to water movement through the conductive (open) fractures. Staining is specific to the fracture sets within the flagstones that received mineral laden waters and dissipates away from those fractures.

Figure 8: Meshoppen Elk Lake Quarry: Looking north/northeast at J1 joints spaced ~30-50 feet apart. The J2 joints would be running roughly parallel with the outcrop face. Upper weathered bedrock transitions from fractured to coherent with depth as does the unweathered bedrock. Bedding plane fractures are localized and run between thin shale layers.

Figure 9: Meshoppen Elk Lake Quarry Note the heavy calcite (white to buff colored mineralization) along the J2 joint on the right of the photo. A person, wearing a red coat, is standing on the outcrop for scale.

Figure 10: Meshoppen Elk Lake Quarry Looking northeast. Notice the fractures subparallel to bedding running along the wall to the right of the person (for scale). Note the staining as water flows along these fractures and not through the entire sandstone body.

Figure 11: Powers Stone Quarry 1: Looking south. View of J1 joint spacing in weathered bedrock above, at far end of quarry. Note mining equipment for scale.

Figure 12: Powers Stone Quarry 2: Depiction of the glacial till (light brown colored and on top, below the vegetation line), red shale (waxy texture and burrowed), and bedrock, (flagstone), in part iron stained due to water flow through fractured flagstone.

Figure 13: Powers Stone Quarry 3: View looking west/southwest across J2 joint in foreground. Rock hammer for scale. Notice the iron and manganese staining from water movement is highly contained in bands of jointing, both in the foreground and background outcrops. This quarry is two townships northwest from the other quarries that were in the Dimock area.

Figure 14: Robert Stankiewicz Quarry: Note the iron staining and the currently wet areas both vertically segmented as they are associated with the joint sets in the flagstones. Not all joints/fractures are stained and not all joints/fractures are currently transmitting water. It appears to be unpredictable and related to the timing of the opening of the joints/fractures.

As noted in the numerous pictures of flagstone quarries (Figures 8 through 14) mineral staining is associated with certain vertical joints/fractures throughout the area. This staining indicates a period of fluid flow through open vertical fractures or joints, through geologic time. Not all joints/fractures are necessarily open and transmit fluid through the joints/fractures at any given time. Figure 14 is a perfect example of this, depicting numerous joints/fractures through the outcrop. Some joints/fractures are mineral stained; some are not. Some joints/fractures are currently transmitting water; some are not.

It is important to remember that many of the J1 and J2 joints sets were enhanced +/- 20,000 years ago after the melting of glacial ice and the crustal uplifting related to isostatic rebound. The melting of glacial ice and the removal of that great weight, allowed for the J1, J2 and bedding parallel joint/fracture sets to "relax and rebound". This could result in changes of the conductivity (transmissivity) of the shallow fracture sets through time.

In summary, joint sets and fractures are common in the shallow Catskill and Lock Haven Formations of Susquehanna County, PA. Although the joints/fracture sets are pervasive, review of the rocks in the flagstone quarries show that while some joint/fracture sets are currently open (transmitting water) some joint/fracture sets are not. And, while some joint/fracture sets show mineral staining from past water movements, other joint/fracture sets are less stained. In the subsurface, predicting which joint/fracture sets are open and transmitting fluids versus which joint/fracture sets are tight and not transmitting fluids is extremely difficult to impossible.

C. Methane found in groundwater

Methane (natural gas) is a common component or constituent of groundwater in Susquehanna County, PA. Most of the groundwater wells in Susquehanna County are completed and produced from the Catskill or Lock Haven Formations. As previously discussed, the Catskill Formation is natural gas prone in much of the Appalachian Basin and contains thousands of economically productive natural gas wells completed in the sandstones of the Catskill Formation, west of Susquehanna County. These hydrocarbons are thermogenic gases, associated with organic matter entrained in the rock during deposition. Therefore, finding thermogenic natural gas trapped in the Catskill Formation sandstones and siltstones is a common and natural occurrence.

Another source of methane in groundwater can be from biogenic sources. Likewise, finding biogenic natural gas trapped in the Catskill Formation sandstones and siltstones is a common and natural occurrence.

The Catskill Formation contains significant amounts of disseminated organic material that has undergone sufficient thermal maturity and is the source of shallow, naturally-occurring methane (Figure 15) (Wilson, 2014). Coal like stringers are observable on both a macro and micro scale throughout the Catskill Formation (Wilson, 2014).

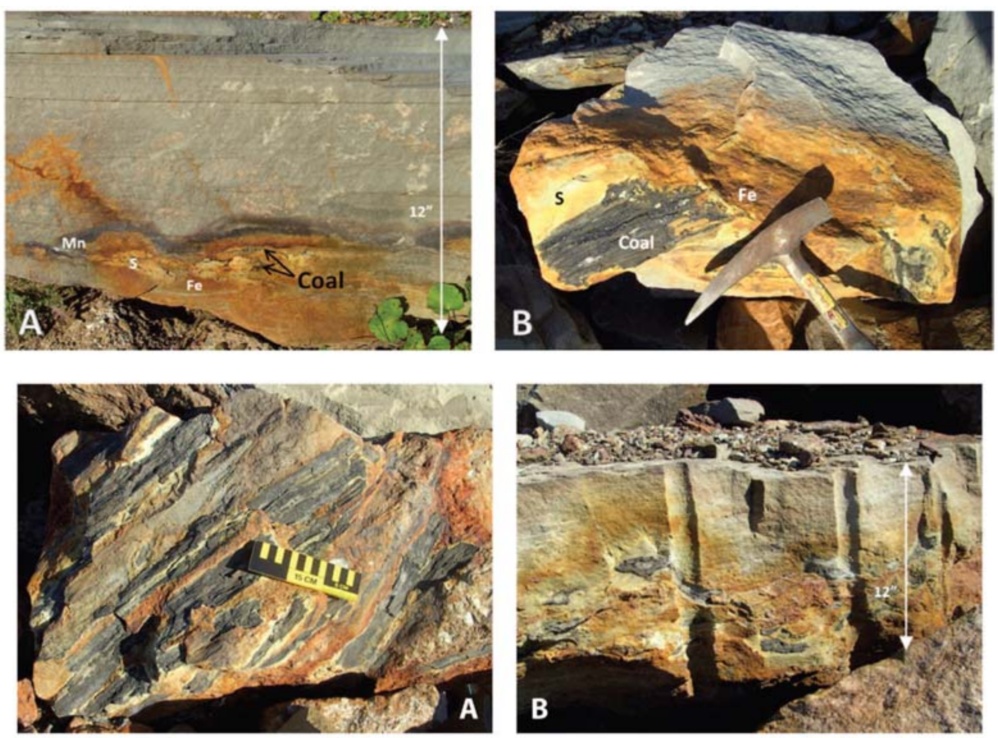

Figure 15: Coals and organic fossils from the Catskill Formation. Mineral staining is related to water flowing through the rocks. From: Wilson, B., Geologic and baseline groundwater evidence for naturally occurring, shallowly sourced, thermogenic gas in northeastern Pennsylvania. AAPG Bulletin, v. 98, no.2, February 2014, pp. 373 – 394.

Significant research completed by GSI Environmental and Coterra found methane to be ubiquitous in shallow groundwater as measured in approximately 1,700 pre-drill water wells in Susquehanna County, PA (Molofsky, et al., 2011). The study found higher dissolved natural gas concentrations in water wells that were in lowland valleys versus wells that were in the highlands or hill tops, prior to Marcellus Shale activities occurring in the area. This relationship is depicted on the map included as Figure 16. Hence, the higher dissolved methane levels pre-existed Marcellus Shale well development.

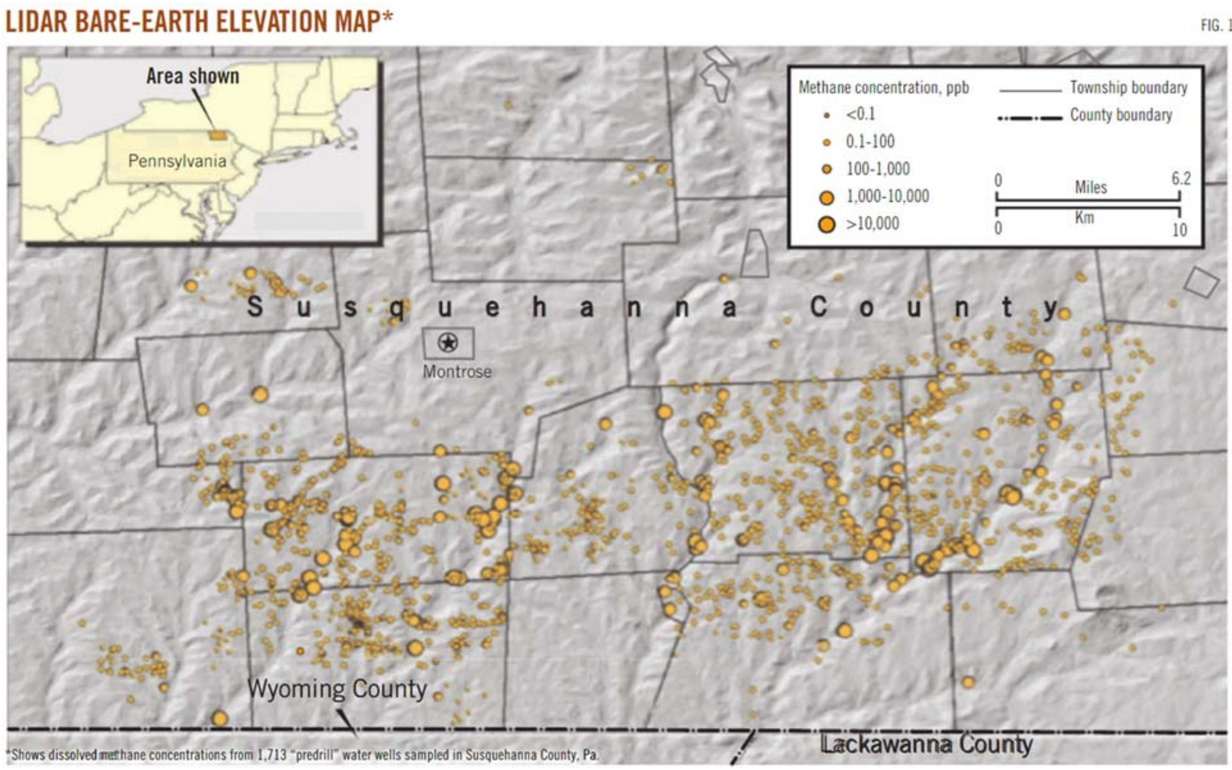

Figure 16: Map depicting the relationship between higher methane concentrations in water wells and lowlands or valleys. Data was collected pre-drill and prior to extensive and proximal Marcellus Shale activity. From L.J. Molofsky, J.A. Connor, S.K. Farhat, A.S. Wylie and T. Wagner, 2011, "Methane in Pennsylvania water wells unrelated to Marcellus shale fracturing", Oil & Gas Journal, pg. 54 – 67.

Historically, water wells and shallow gas wells have existed in the greater Susquehanna County area for almost two hundred years (Molofsky, et al., 2011). Table 2, below, from Molofsky, et al., 2011, lists numerous gas shows and gas wells in the Greater Susquehanna County area.

LIST OF HISTORIC GAS SHOWS AND GAS FIELDS IN THE CATSKILL AND LOCK HAVEN FORMATIONS

Table 1

Date	Location	Description of gas show	Total depth, ft	Formation
1825	Susquehanna County, Pa.	Bubbles of gas observed in Salt Spring with flash-like powder if touched with fire.	n/a	Catskill
1881	Susquehanna County, Pa.	"Plenty of gas was found."	680	Catskill
1882	Wyoming County, Pa.	Flow of gas heard from some distance.	n/a	Catskill
1882	Wyoming County, Pa.	Flow of gas.	2,089	Catskill
1873	Susquehanna County, Pa.	Inflammable gas encountered at 525 ft. Inflammable gas observed coming from bed of creek.	780	Catskill
1903	Susquehanna County, Pa.	Gas seep at surface.	n/a	Catskill
1908	Susquehanna County, Pa.	Gas encountered.	400	Catskill
1922	Narrowsburg County, NY	Gas encountered.	800	Upper Devonian
1939	Bradford County, Pa.	Water contains natural gas.	300	Lock Haven
1939	Bradford County, Pa.	Natural gas bearing water.	412	Lock Haven
1939	Bradford County, Pa.	Reported to contain flammable gas.	600	Lock Haven
1939	Bradford County, Pa.	Water contains flammable gas.	138	Lock Haven
1939	Tioga County, Pa.	Well yields natural gas.	411	Lock Haven
1956	Harveys Lake field, Pa.	Methane gas.	2,800-2,900	Lock Haven/Trimmers Rock
1957	Susquehanna County, Pa.	Methane gas reported at 522 ft.	1,075	Catskill
1959	Chemung County, NY	Contains natural gas.	172	Upper Devonian
1959	Chemung County, NY	Well yielded natural gas.	128	Upper Devonian
1959	Chemung County, NY	Water contains natural gas.	80	Upper Devonian
1959	Chemung County, NY	Water contains natural gas.	100	Upper Devonian
1959	Chemung County, NY	Water contains natural gas.	80	Upper Devonian
1959	Chemung County, NY	Quicksand ignited during drilling.	96	Upper Devonian
1961	Sullivan County, NY	Methane gas reported at 460 ft. Two gas explosions during drilling.	492	Catskill
1961	Sullivan County, NY	Well reportedly penetrated pocket of natural gas.	208	Catskill
1963	Delaware County, NY	Water contains flammable gas.	505	Catskill
1963	Delaware County, NY	Well penetrated pocket of flammable gas when drilled.	420	Catskill
1963	Delaware County, NY	Water contains flammable gas.	296	Catskill
1965	Wyoming County, Pa.	Natural gas.	~2,600	Lock Haven
1966	Lackawanna County, Pa.	Methane gas encountered.	n/a	Catskill
1969	Lycoming County, Pa.	Natural gas.	~2,700	Lock Haven
1975	Lackawanna County, Pa.	Methane found in flowing water well.	175	Catskill
1975	Lackawanna County, Pa.	Well has gas. Well shown on figure in reference not identified.	250	Catskill
1975	Lackawanna County, Pa.	Well has gas. Well shown on figure in reference not identified.	320	Catskill
1975	Lackawanna County, Pa.	Water well contains methane.	198	Catskill
2007	Tioga County, Pa.	Combustible gas present.	220	Lock Haven
2007	Tioga County, Pa.	Combustible gas present.	135	Lock Haven
2007	Lawrence, Tioga counties, Pa.	Combustible gas present.	83	Lock Haven
2010	Chemung, Tioga, Broome counties, NY	Gas reported in more than 10 water wells.	various	Lock Haven

Table 2: From L.J. Molofsky, J.A. Connor, S.K. Farhat, A.S. Wylie and T. Wagner, 2011, "Methane in Pennsylvania water wells unrelated to Marcellus shale fracturing", Oil & Gas Journal, pg. 54 – 67.

As seen in both the previous map and table, natural gas is pervasive throughout the Catskill and Lock Haven Formations in Susquehanna County, as found in both water wells and historic attempts at producing shallow natural gas in northeastern Pennsylvania.

Wilson (2014) completed significant work in quantifying the weight percent of Total Organic Carbon (TOC) in the Catskill and Lock Haven Formations across Susquehanna and surrounding Counties (Figure 17). Also, it is observed that the rocks are in the natural gas generation window based on Vitrinite Reflectance (Ro) values (a measure of thermal maturity) from 1.25 to 3.0 Ro (Figure 17).

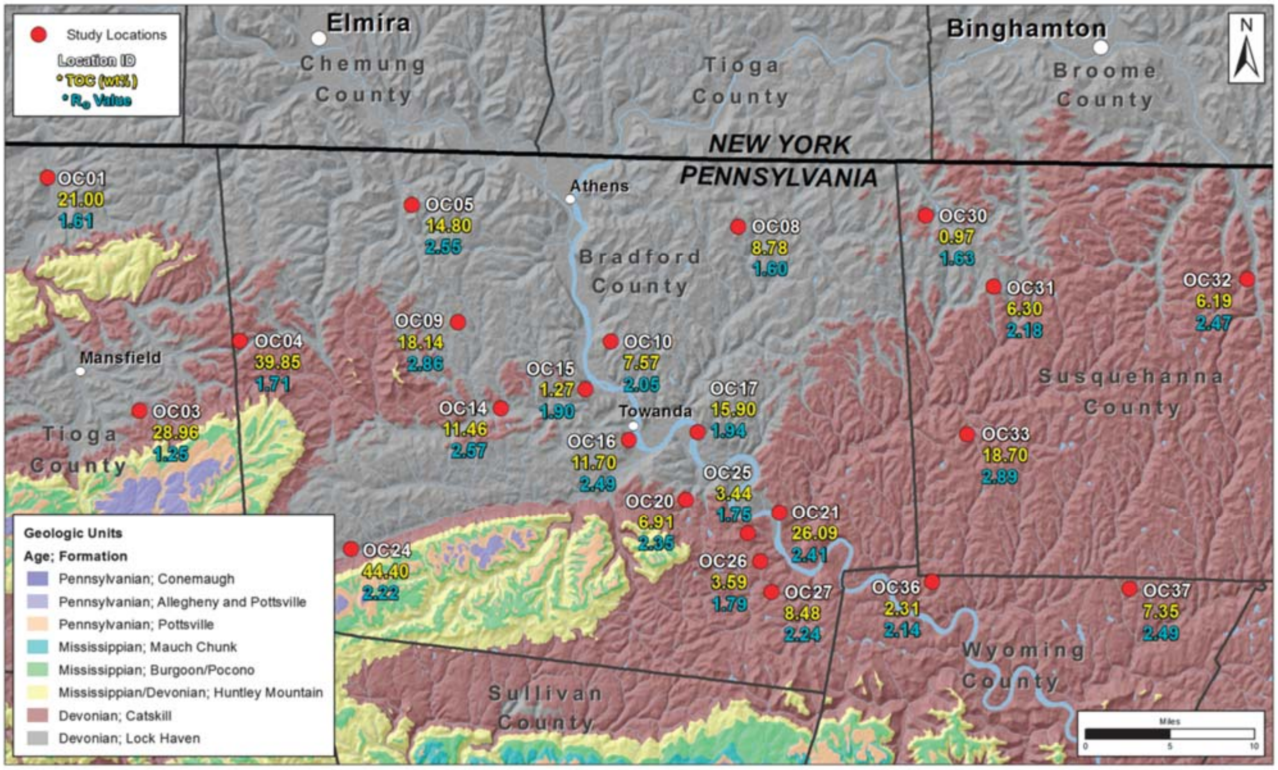

Figure 17: TOC and Ro, a measure of thermal maturity (Ro >1.25 indicates rocks in the natural gas generation window), from samples across Susquehanna and surrounding counties. TOC values can be very high (15%+ weight percentage) from the Catskill and Lock Haven Formations. Thermal maturities indicate conditions that put the rocks in the "natural gas generation window". From: Wilson, B., 2014, Geologic and baseline groundwater evidence for naturally occurring, shallowly sourced, thermogenic gas in northeastern Pennsylvania. AAPG Bulletin, v. 98, no.2, February 2014, pp. 373 – 394.

Given the amount of organic matter in the Catskill and Lock Haven Formations and that the rocks are in the natural gas generation window (Wilson, 2014), it is logical and expected to find natural gas in the shallow subsurface when drilling water wells. As outlined throughout this report, this is also supported by historical and anecdotal observations.

Historic geologic publications have found similar natural gas in ground water at shallow depths. Stanley W. Lohman of the U.S. Geological Survey published "Ground Water in Northeastern Pennsylvania" (1937) and an excerpt is included as Figure 18. Natural gas was encountered in a spring near Franklin Forks, Susquehanna County and a nearby historic shallow gas well located within the Chemung Formation (now referred to as the Lock Haven Formation). A similar well was only drilled to a depth of 680 feet and encountered natural gas and saltwater.

A spring on the bank of a small stream about 1 mile west of Franklin Forks yields about 10 gallons a minute from thin-bedded sandstone in the Chemung formation. The water is very salty and deposits iron at the overflow. Bubbles of inflammable gas rise to the surface and can be ignited with a match, and a gas well about 200 feet from the spring supplies a farm house with gas for cooking. It seems probable that the gas is methane (CH_4), as this gas is known to come from gas wells in the Chemung formation in several of the counties in the north-central part of Pennsylvania. Near the center of Middleton Township a test hole for oil was drilled to a depth of 680 feet[23]. No oil was obtained, but gas and salt water were found in the Chemung formation at a depth of 300 feet. A nearby well 300 feet deep supplied brine for the manufacture of salt. The old county reports mention salt springs in Apolacon, Auburn and Franklin Townships that were used by early settiers as sources of salt.

Except for these occurrences of salt water in beds of the Chemung formation, the ground waters of Susquehanna County are entirely satisfactory for most purposes.

Figure 18: An excerpt from Lohman, S.W., Ground Water in Northeastern Pennsylvania, 1937, Pennsylvania Geological Survey, Fourth Series, W4, Pg. 263.

Numerous researchers have shown that natural gas is naturally occurring in the Catskill and Lock Haven Formations. Natural gas shows in shallow springs, wells and aquifers have been documented since the early 1800’s. Natural gas is shown to be sourced within the Catskill Formation. The Catskill Formation includes entrained organic matter that was further moved through the proper temperature and pressure to allow for generation of natural gas.

D. <u>Review of the shallow geology as seen in the Gesford “deep” wells</u>

The Gesford 3S ultimately reached a total depth of 7,058 feet. The Gesford 3S encountered a gas show at approximately 1,459 to 1,503 feet, while drilling. The Schlumberger “Platform Express” log (density, neutron, caliper gamma ray, temperature, audio) from that portion of the Gesford 3S is included as Figure 19. In reviewing the electric log, no obvious reservoir with primary porosity is present in the interval. Based on my experience, the gas show is from fractures, encountered while drilling, from approximately 1,459 to 1,503 feet, as there is no evidence in the log of a reservoir sandstone/siltstone with primary or secondary granular porosity.

Similarly, the Gesford 9 had an initial mudlog gas show at approximately 1,500 feet, in what was described as grey to dark grey shale. Later, while drilling, the well “kicked” at 1,911 feet, although no obvious mudlog show was logged, this may have been attributed to a second set of fractures, again while drilling grey to dark grey shale.

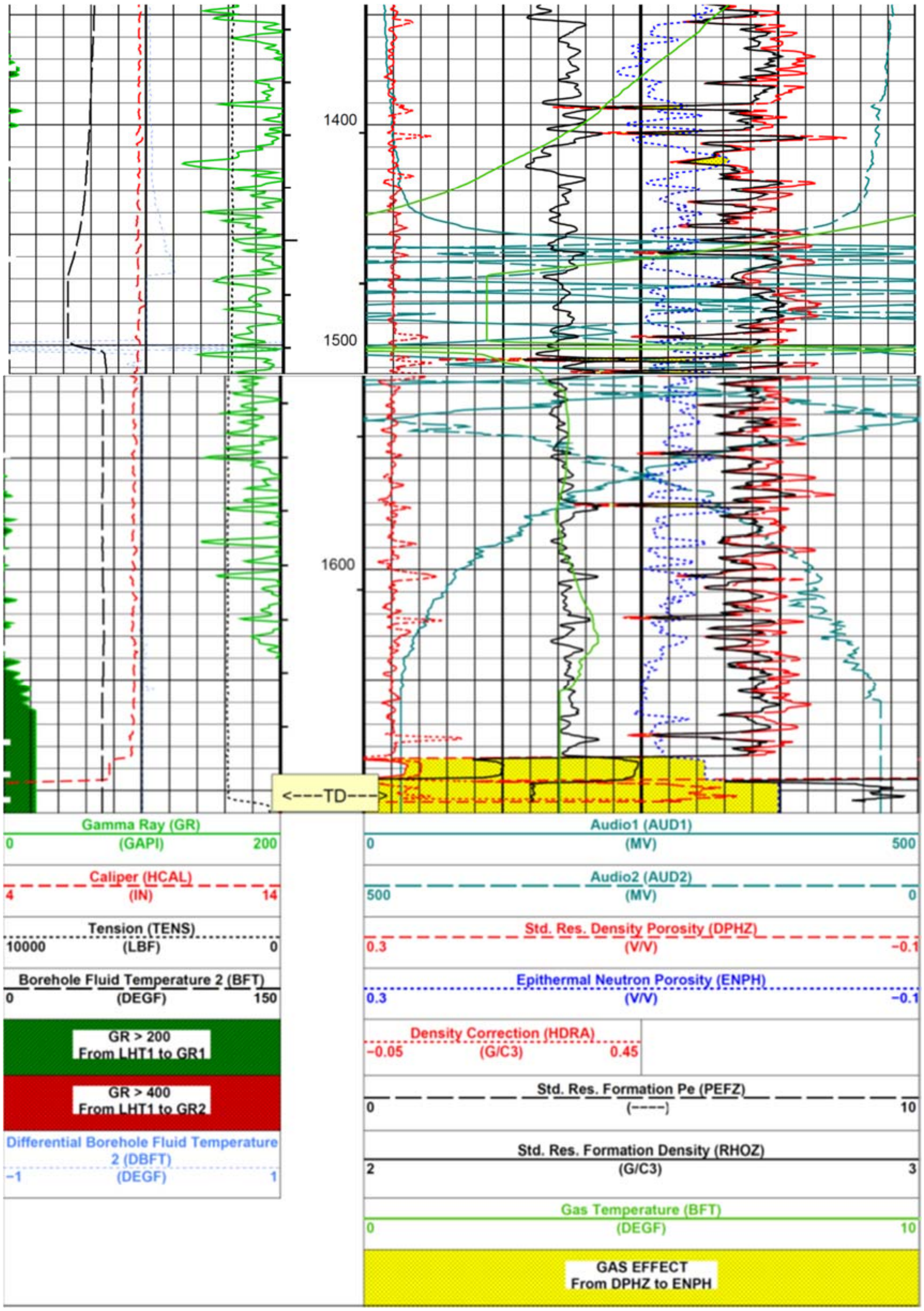

Figure 19: Schlumberger "Platform Express" log (density, neutron, caliper gamma ray, temperature, audio) from the Gesford 3S (API# 37-015-20019). Note significant gas show entering the borehole from approximately 1,459 to 1,503 feet. Also, note that no formation with obvious primary porosity is providing this gas show. This is a gas show from fractures encountered while drilling.

E. Compartmentalized and unpredictable water flow along fractures

As previously discussed, the flagstone outcrops and quarries contain joints and fractures that indicate different joint/fracture sets have been open in the past, while still other fracture sets are currently open and transmitting water. Figure 14 in the Robert Stankiewicz Quarry depicts numerous joints/fracture sets, some with staining, some without, and some currently transmitting water and some not. It should be noted that these are in a very unpredictable pattern. Mapping these joint/fracture sets with water well data, or shallow logging from natural gas wells would not yield a method to predict open joints or fractures on a meso-scale (or outcrop scale).

Figure 20 depicts Liesegang Banding along fracture sets due to water movement through the rocks. Of note is that not all fractures have a similar banded nature around them, indicating the unpredictable nature of water movement through the Catskill Formation.

Figure 20: Meshoppen Elk Lake Quarry. Liesegang Banding along fractures due to differing water flow timing along different fractures in the Catskill Formation.

It is true that natural gas concentrations in water wells in Susquehanna County increases in the valleys and lowlands (Molofsky, 2011), as depicted on Figure 16, however, that is at a macroscale. At a "wellbore" scale (measured in inches across), prediction of fractures encountered, whether those fractures are open or closed and whether those open fractures are transmitting water and/or natural gas is difficult to impossible to predict.

F. Methane concentrations observed in shallow groundwater wells

Methane has long been present in unpredictable concentrations throughout Susquehanna County. Included as Attachment 3 to this report are cross-sections of water wells along the Dimock/Carter Road Area and a map depicting cross-section locations. Methane concentrations vary across the area from as low as 0.005 mg/l to 67 mg/l. Interestingly, the two extreme values are approximately 1,500 feet from one another, validating the complexities of predicting methane concentrations across small distances in Susquehanna County. The three larger methane concentrations (34 mg/l, 63 mg/l and 67 mg/l) are indeed concentrated in the valleys as has been observed by other researchers (Molofsky, 2011). However, within the valley there are numerous lower concentrations, including aquifers with concentrations of 0.043 mg/l, 2 mg/l, 0.012 mg/l and 0.46 mg/l (listed from north to south, down the valley).

Similarly, the people of Susquehanna County have acknowledged natural gas in water wells for many years. Anecdotal information concerning historic natural gas found in water wells in Susquehanna County includes:

> Martha Locey, who has lived in the Dimock area all her life, since 1932. "My father dug our well in 1945, and we knew it had lots of iron in it, and we thought it had something else, but we weren't sure, because it had lots of bubbles in it," Ms. Locey said. "So my nephew took it to school in the '60s, and the science teacher lit it, and it burned, so he said, 'It's methane.' The truth is, our well has been that way since 1945," added Ms. Locey. From: https://www.nytimes.com/2010/11/07/business/energy-environment/07frack.html and testimony from the case Nolen Scott Ely, Et Al v. Cabot Oil & Gas Corp. Case# 09-CV-2284.
>
> Ms. Locey worked at a nursing home on Carter Road in the 1964 to 1966 timeframe. As a cook, she was very familiar with the water. She stated that the water had "lots of bubbles" (methane) and was worse than her home's water a few miles to the north. She also stated that the water "really smelled bad". Lastly, she agreed that this occurred in the mid 1960's prior to natural gas drilling in the area. From: testimony from the case Nolen Scott Ely, Et Al v. Cabot Oil & Gas Corp. Case# 09-CV-2284.
>
> Another such story is that of Mildred Green and her husband, who drilled a new water well in 1984. It is her experience that the back of the toilet would "…blow some of the stuff off…" the back of the toilet, if left not flushed for four or five days. Also, her husband had a jug in the kitchen, that he would fill the jug, shake it and light the gas after opening. She referred to it as a "…fun thing to do." From: https://naturalgasnow.org/dimock-firewater-show-takes-center-stage/

Apart from historical and anecdotal information, Coterra has been sampling water wells, pre and post drilling, for years in Susquehanna County. Methane concentrations vary greatly, as is expected based on previous observations discussed in this section. Included with this document as Attachment 4 are Coterra's plots of methane concentrations for water wells in the vicinity of the Dimock/Carter Road Area. The data shows that over time, methane concentrations have mostly decreased or stabilized.[2]

Within the immediate vicinity of the Gesford Pad along in the Dimock/Carter Road Area, Coterra and the PADEP have extensively sampled several water supplies. Specifically, within 2,500 feet of the Gesford Pad, these water supplies include:

- [redacted]
- [redacted]

[2] The data reflects the best-available data, dependent upon landowner permission for Coterra and its contractors to conduct water sampling. For example, Coterra has had limited access to the [redacted] water supplies.

- [redacted]
- [redacted]
- [redacted]
- [redacted]

Of these, only the [redacted] wells continue to consistently exhibit dissolved methane concentrations above the PADEP Recommended Action Level of 7 mg/l. In the case of the original [redacted] well, concentrations appear to be stable over time. At the former [redacted] well, concentrations were also stable for an extended period of time, from 2013 to 2021. Most recently, a change in water supply usage occurred with the property being re-occupied and has likely contributed to apparent increases observed. This increase is a recent phenomenon, and there is no indication that it is related to the Gesford Pad due to lack of activity. The remaining water supplies have generally decreased over time. It should be noted that within this 2,500 foot radius of the well pad, multiple additional water supplies are also present that have never exhibited the presence of dissolved methane beyond trace amounts.

In summary, natural gas in the joint/fracture systems within the Catskill and Lock Haven Formations of Susquehanna County is fully expected and has been historically documented. The rocks of the Catskill Formation have entrained organic matter that would have been able to generate natural gas as the rocks moved through the natural gas generation window, at depth. Work by Wilson (2014) shows that the rocks of the Catskill and Lock Haven indeed did have the proper thermal maturity to generate natural gas. Natural gas has been documented in shallow rocks/aquifers in Susquehanna County since the mid-1800s, long before Coterra or any other operator conducted hydraulic fracturing operations and continues to be observed today. Higher concentrations of methane can be observed in valleys throughout Susquehanna County, PA. This relationship may be due to open fractures related to geomorphology (drainage systems, glacial erosion, and isostatic rebound), but it does not appear to be related to Marcellus shale pad locations (Molofsky, 2011). Coterra has been sampling water wells in the Dimock/Carter Road Area for many years and the data shows that for most wells, the methane concentrations have been decreasing and stabilizing across the area.

III. Remediation Assumptions and Challenges

As part of the COA, I conducted an analysis of the technical feasibility, practicality, reasonableness, and potential adverse impacts of attempting to alleviate potential gas pressure and volume in the vicinity of the Gesford 3S and Gesford 9 gas wells (Gesford Pad), including but not limited to, potential impacts to residents of the Dimock/Carter Road Area. This analysis, detailed below, demonstrates numerous challenges and practical considerations that would make any remedial efforts either unsuccessful, impractical, or potentially counter-productive.

A. Shallow natural gas is naturally occurring in this area.

As discussed in Section II above, natural gas has been documented in the aquifers of Susquehanna County for tens (hundreds) of years prior to Coterra's entrance into the region. Natural gas has been documented by researchers (Molofsky, 2011, Molofsky, 2013, Wilson, 2014) as well as anecdotally discussed by residents of the area in question. Given the organic matter documented in the Catskill Formation in Susquehanna County and the fact that this rock existed within the natural gas generation window (Wilson, 2014) one should not be surprised by naturally occurring natural gas in portions of the Catskill Formation. Therefore, it is unclear what a reasonable and expected homeostasis would be or how nature (natural fractures, aquifer development, etc.) impacts those levels.

B. Natural fracturing in the shallow rocks of Susquehanna County.

The shallow rocks of Susquehanna County have had an interesting and complex path to get to the point that the rocks are at today. The Catskill Formation and deeper Lock Haven Formation (previously referred to as the Chemung Formation) are Upper Devonian in age and approximately 360 to 380 million years old. After burial and initial diagenesis, the rocks were folded, fractured, and faulted during the Alleghenian Orogeny approximately 250 to 300 million years ago. Since the end of the Alleghenian Orogeny, the rocks of the Catskill and Lock Haven Formations have been slowly exhumed, as the Allegheny Mountains eroded over time. Further diagenesis assuredly occurred, often precluding any primary porosity (grain-to-grain porosity) in the sandstones and siltstones. Lastly, approximately 20,000 years ago, after the last ice age, which covered portions of northern Pennsylvania, shallow formations were further fractured, or existing fractures altered, as tons of ice were removed (melted) from their position in Susquehanna County.

All the described processes resulted in systematic fracturing across the northern Appalachians. As discussed previously, these fractures are found in three prevailing orientations and referred to as J1 and J2 joint sets and the bedding parallel fracture sets. The J1 joints are roughly parallel with the strike of the basin, in a northeast – southwest orientation, while the J2 joint sets are in a dip of the basin orientation, roughly northwest – southeast. Also, pervasive are bedding parallel fractures, often common at the surface and often common along bedding planes or partings where different rock types meet.

Although the deep, tectonic fracture orientation in the basin is predictable, fracture openings, connectivity and transmissivity/conductivity are not. As seen in the flagstone quarry examples, certain fracture/joint sets are open, appearing wet, while others appear closed, not transmitting groundwater and still other joint/fracture sets show evidence of past water movement. There is no indication of predictable shallow, open fractures as observed in the numerous pictures of flagstone quarries in Susquehanna County. Therefore, the impact of any potential remedial efforts is similarly unpredictable.

C. Drainage patterns of aquifers.

As seen in the flagstone quarries of Susquehanna County, water movement in the shallow subsurface occurs along fractures and joints. Often when one envisions an aquifer, its drainage appears as a "Cone of depression". Although this type of drainage is common in unconsolidated materials or porous medium, it is less common in fractured rocks. So, drainage around any remedial efforts at the Gesford Pad would not necessarily be symmetrical. If a well were to be drilled, drainage would occur along open fractures and would continue where the borehole encountered intersection with the open fractures (assuming that indeed open fractures are encountered in a shallow borehole). If a well were to be drilled, the drainage pattern from such a well would be unpredictable and may not lend itself to the intended purpose.

D. Natural gas encountered in water wells in the Dimock/Carter Road Area.

As stated above, shallow natural gas has been documented in Susquehanna County for decades (Molofsky, 2011, Wilson, 2014). Coterra has been monitoring groundwater wells in the Dimock/Carter Road Area for years and has an extensive database of water testing data (Attachment 4). The data shows that most of the wells have been decreasing in methane concentrations over time, a very positive trend for the residents of the Dimock/Carter Road Area. Most wells' methane concentrations are trending below the PADEP Methane Action Level of 7.0 mg/l and are significantly below the Methane Saturation Limit of 28.0 mg/l.

With methane levels diminishing or stabilizing in the Dimock/Carter Road Area, it seems prudent to not conduct any remedial efforts that could cause the methane levels to trend in an adverse direction, particularly where there is no identifiable residual gas reservoir (as discussed above and below) and considering that an interim water treatment/permanent water supply replacement solution is available.

E. No identifiable residual gas target.

During drilling operations on the Gesford Pad, Coterra experienced gas shows on the Gesford 3S (from 1,459 to 1,503 feet) and Gesford 9 (at 1,502 feet and again at 1,911 feet) (Table 1). However, the associated log data for these wells failed to reveal an obvious natural gas reservoir (for example, a sandstone with obvious porosity) at those depths and there is no data to indicate, to the extent that there was natural gas in a fracture system, that the fracture system remains natural gas charged today. From a technological perspective, without an identifiable gas reservoir, there is no defined target for remedial efforts. Further exploratory operations to determine whether a natural gas charged fracture system exists could negatively impact the current homeostasis of the area. Considering (a) the unpredictable nature of natural fracturing in this area, (b) homeostasis of the area is occurring, and (c) the lack of an identifiable gas reservoir, it does not seem prudent to attempt any remediation efforts.

F. Drilling of a relief well in the Dimock/Carter Road Area.

I have also investigated the feasibility of success regarding a potential relief well on the Gesford Pad. For the reasons set forth herein and below, it is inadvisable to drill a relief well on the Gesford Pad. Over an extended period of time, natural gas levels in water supplies have decreased or stabilized, indicating the Gesford 3S and 9 wells have mechanical integrity and a state of homeostasis for natural gas in the area. The complicated natural fracturing, operational concerns (e.g., reclaimed well pad, anti-collision, etc.), and lack of an identifiable target further undermine this proposal.

To date, no definitions of success have been established for a possible relief well or any other remediation procedure. If natural gas flow is established in a shallow relief well, how is success determined? Is it by initial flow rate? A specific volume over time? Only if changes occur to nearby water wells? Over what time-period is a relief well or remediation well to be produced? There is also the significant question as to what Coterra should do with small amounts of natural gas that it might be able to isolate; most likely, it would need to be flared at the well pad.

G. Risks associated with renewed operations on the Gesford Pad.

As explained in the timeline and review of the Gesford 3S and Gesford 9, Coterra conducted extensive work on these wells. Because of the extensive remedial work, it is not a viable option to resume operations in these two wells. For example, in the Gesford 3S, there is cement all the way down to 6,968 feet and the Gesford 9 has cement to 1,911 feet. Moreover, based on the decreasing or stabilizing natural gas levels in the surrounding water wells, it is not advisable to attempt reentry of these wells and potentially jeopardize the mechanical integrity of these plugged wells. Without a clearly identifiable residual natural gas reservoir or measure of success , and in light of the apparent homeostasis for natural gas in the area and stabilized methane levels in nearby water wells, the risks associated with such activity must be considered.

H. Additional considerations.

In addition to the reasons outlined above, there are additional considerations that weigh against remedial operations on the Gesford Pad:

- Notably, the Gesford Pad is a reclaimed pad and all existing permits have been terminated. Any remedial operations will require Coterra to re-permit the site and construct a new pad. Further, any such remedial operations may be outside the scope of Coterra's existing rights with the landowner. For example, natural gas, to the extent any exists, may not exist in paying quantities.
- With past remediation efforts discussed above proving successful given the improvement to water quality, even if Coterra were to reenter an existing well or drill a new well, such remedial efforts may not successfully find the same fractured interval.
- To the extent Coterra is able to isolate and produce any shallow natural gas, it would likely be in small volumes at low pressures, necessitating a separate gas supply line to operate compression or well pad flaring. There could be a negative perception of a visible flare and/or compression from Dimock/Carter Road Area residents.
- Currently the COA does not allow for drilling on surface locations within the Dimock/Carter Road Area.

IV. Conclusions

Following this review, it is my opinion within a reasonable degree of geologic certainty that remedial efforts at the Gesford Pad are not advisable and would not likely achieve the desired effect of alleviating potential gas pressure and volume in the vicinity of the Gesford 3S and Gesford 9 plugged and abandoned wells, to the extent it still exists, or reducing shallow subsurface gas in the immediate Dimock/Carter Road Area. Further, as the levels of dissolved gas in the residential water wells have either remained stable over an extended period of time (indicating that they are at background state) or have decreased, this is indicative that Coterra's prior gas well plugging efforts were successful and any gas that may have been introduced during prior drilling of the Gesford 3S and Gesford 9 wells has naturally attenuated. Therefore, it is surmised that further work would likely yield no positive benefit and could, in effect, jeopardize the current homeostatic conditions.

Respectfully submitted by:

Dan A. Billman, PG, CPG

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ATTACHMENT 1

DAN A. BILLMAN, P.G.
PRESIDENT / GEOLOGIST

SUMMARY OF QUALIFICATIONS

- Geologic, technical, and economic reviews of natural gas and oil exploration prospects and properties (both Conventional and Unconventional) in the Appalachian Basin, as well as the Black Warrior Basin, Anadarko Basin, Delaware/Permian Basin, Fort Worth Basin, East Texas Basin, and Illinois Basin.

- Over twenty-five years of geologic and drilling experience including: geologic mapping, drilling/siting geologic recommendations, rock/core analysis, electric log analysis and reserves calculations, well completion/frac treatment recommendations and decisions, property valuations.

PROFESSIONAL HISTORY

March 1993 to present	**PRESIDENT/GEOLOGIST** Billman Geologic Consultants, Inc., Houston, PA
January 2015 to July 2016	**VISITING GEOLOGY INSTRUCTOR** University of Tulsa, Continuing Engineering and Science Education Department
October 1992 to March 1993	**ASSISTANT GEOLOGIST II** Michael Baker Jr., Inc., Beaver, PA
June 1990 to July 1992	**PROJECT GEOLOGIST** Eastern States Exploration Co., Snow Shoe, PA
May 1989 to June 1990	**GEOLOGIST** Mark Resources Corporation, Pittsburgh, PA

EDUCATION AND TRAINING

Master of Science Degree, Geology, West Virginia University, 1989
Master's Thesis: Microstructural Analysis in the Ordovician-Mississippian Cover above the Alleghenian Thrust System of the Valley and Ridge Province, West Virginia and Virginia
Bachelor of Science Degree, Geology, University of Toledo, 1986

Misc. Training:
First Annual Appalachian Basin Geophysical Symposium, Geophysical Society of Pittsburgh, June 5, 2019
Minerals Appraisal Workshop, International Institute of Minerals Appraisers, October 3, 2018
Variability in the Gas Geochemistry of the Appalachian Basin & Contemporaneous Influences on Fate and Transport, Pennsylvania Council of Petroleum Geologists, September 11, 2017.
Hydraulic Fracturing Geomechanics for Unconventionals: Concepts and Practices, PTTC, December 2, 2014
Paleozoic Organic-rich Mudstones of Ontario: Core Analysis Short Course, ES-AAPG, October 1, 2014
AAPG Geoscience Technology Workshop: Marcellus and Utica Point/Pleasant Shales, June 17 – 19, 2014
Depositional Systems and Hydrocarbon Potential of the Upper Devonian, Ohio Shale, OGS, May 30, 2014
SEC Reserves Rules and Unconventional Resources Workshop, AAPG, November 2013
Reserves and Resources Estimation Forum, AAPG, October 2013
Re-Assessing the Technically Recoverable Undiscovered Hydrocarbon Resources of the Marcellus Shale, PTTC/USGS, March 2011

PROFESSIONAL REGISTRATION AND AFFILIATIONS

Registered Professional Geologist in the Commonwealth of Pennsylvania, #PG-000554-G
Pennsylvania Council of Professional Geologists, Board President, 2017 & 2018, Board Member 2010-2016
American Association of Petroleum Geologists
- AAPG Certified Petroleum Geologist, #5933
- AAPG Advisory Council member representing the Eastern Section, 2019 – present.
- AAPG Delegate representing the Pittsburgh Geological Society, 2002-present, (Secretary/Editor, 2013-14)
- Treasurer of the Division of Professional Affairs (DPA), 2010-2012, Dist. Service Award, 2014
- Member of the Energy Minerals Division and Division of Environmental Geosciences
- Eastern Section President 2007-2008, V.P. 2006-2007, Secretary 2005-2006, Treasurer 2004-2005
- Eastern Section AAPG, Distinguished Service Award 2009, Honorary Member Award 2014

Member of: Pittsburgh Association of Petroleum Geologists (Treasurer 1994-96, President 1997-99, Vice-president 2004-2005) Pittsburgh Geological Society, Ohio Geological Society, Appalachian Geological Society, Buffalo Association of Professional Geologists, Northern Alleghanies Geologic Society, Pennsylvania Independent Oil & Gas Association

BILLMAN GEOLOGIC

REPRESENTATIVE PROJECT EXPERIENCE

Oil and Gas Exploration and Production

- Geologic, technical, and economic review of prospective oil and gas exploration/development acreage and wells: Appalachian, Illinois, East Texas, Fort Worth, Delaware/Permian, Anadarko, and Black Warrior Basins
- Completion decisions and design considerations for reservoirs including Trenton/Black River carbonates, Utica Shale, Marcellus Shale, and Upper Devonian tight gas sand reservoirs.
- Field geologist: drill cutting analysis/mudlogging, well site evaluations/reserves estimates and electric logging (including sonic logging, dip meter oversight and sidewall coring), western and central Pennsylvania, eastern and central Ohio, northern West Virginia, and southern Illinois Basins.
- Research log, drilling, completion, and production data. Creation of well databases.
- Well log interpretation and log-based reserves calculations for newly drilled wells and up-hole/behind pipe potential evaluations.
- Detailed regional mapping, log analysis and reservoir description to delineate drill sites for Devonian through Cambrian targeted acreage positions, Pennsylvania, Ohio, West Virginia, and New York.
- Coordinated onsite/offsite petrographic/geologic analysis for full bore core/sidewall coring projects.
- Geologic and economic evaluation of acquisition submittals from third parties.
- Geologic review of gas storage fields in western Pennsylvania.
- Conducted numerous New York State Energy and Research Development Association (NYSERDA) sponsored projects including Trenton/Black River potential of northeastern New York, hydrocarbon potential of Otsego County, NY and hydrocarbon potential of southwestern Chautauqua Co, NY.

Coal Resource Evaluation

- Geologic and economic review of prospective coal acreage, northwestern PA
- Prepared cross-section and profiles for strip mine reclamation sites, West Virginia
- Logging and coring of test boreholes in coal refuse at reclamation sites, southern West Virginia
- Constructed geologic cross sections and fracture maps for deep mine PADEP Permit Application.

Geotechnical and Hydrogeological Evaluations

- Field geologist for investigative coring/boreholes, road, and bridge design projects (soil and core logging, well installation and sampling)

PUBLICATIONS & PRESENTATIONS

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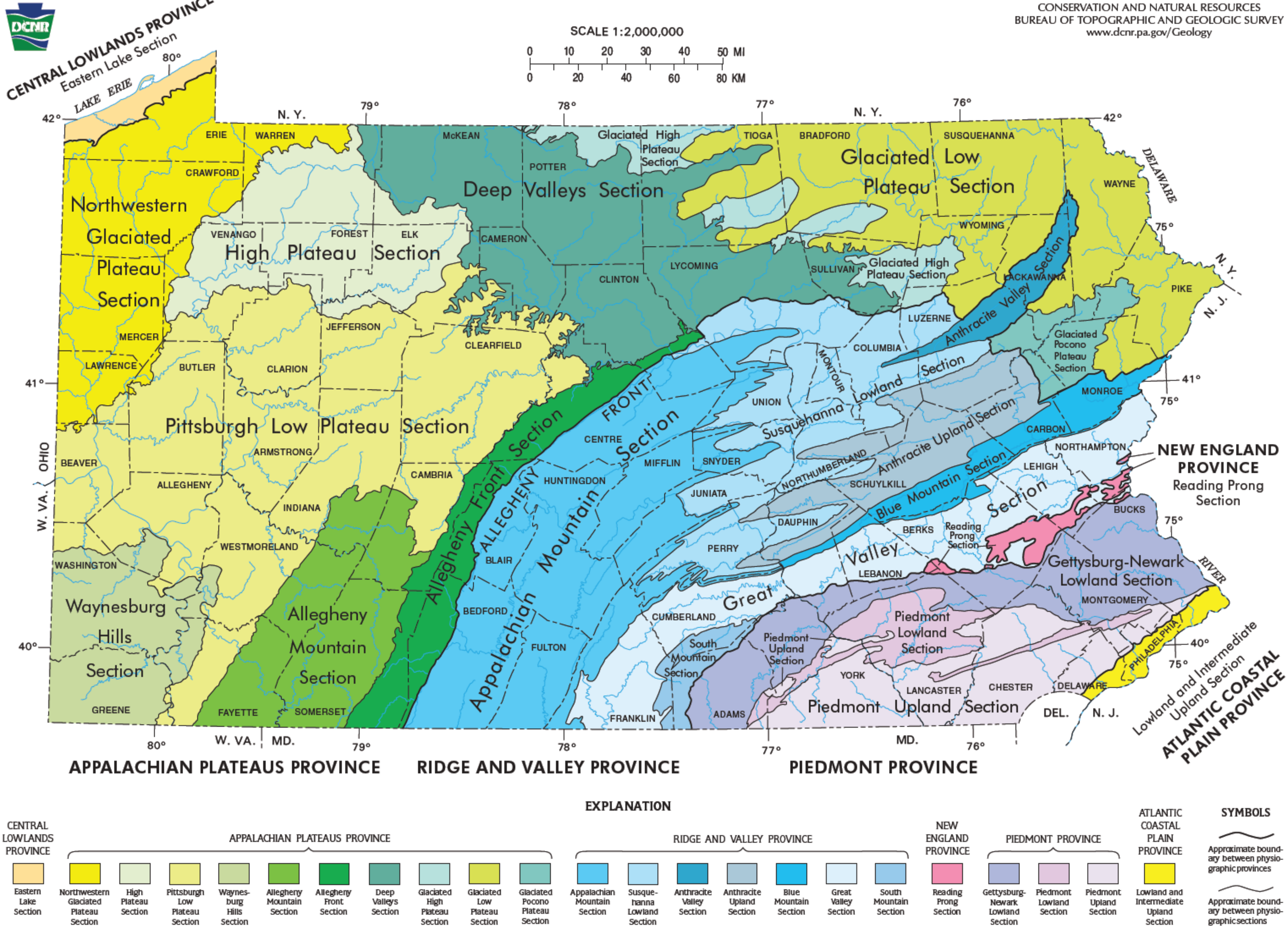
ATTACHMENT 2

MAP 13

PHYSIOGRAPHIC PROVINCES OF PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF
CONSERVATION AND NATURAL RESOURCES
BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY
www.dcnr.pa.gov/Geology



Compiled by W. D. Sevon. Fourth Edition, 2000; Second Printing, 2018.

PHYSIOGRAPHIC PROVINCES OF PENNSYLVANIA

PHYSIOGRAPHIC PROVINCE	PHYSIOGRAPHIC SECTION	DOMINANT TOPOGRAPHIC FORM	LOCAL RELIEF[1]	UNDERLYING ROCK TYPE	GEOLOGIC STRUCTURE	APPROXIMATE ELEVATION[2] Min.	Max.	DRAINAGE PATTERN	BOUNDARIES	ORIGIN
CENTRAL LOWLANDS	Eastern Lake	Northwest-sloping, lake-parallel, low-relief ridges.	Very low to low.	Shale and siltstone.	Beds either horizontal or having low south dip.	570	1,000	Parallel.	*Northwest:* Lake Erie. *Southeast:* Base of escarpment.	Glacial, lake, and fluvial deposition and erosion.
APPALACHIAN PLATEAUS	Northwestern Glaciated Plateau	Broad, rounded upland and deep, steep-sided, linear valleys partly filled with glacial deposits.	Very low to moderate.	Shale, siltstone, and sandstone.	Subhorizontal beds.	900	2,200	Dendritic.	*Northwest:* Base of escarpment. *Southeast:* Glacial border.	Fluvial and glacial erosion; glacial deposition.
	High Plateau	Broad, rounded to flat uplands having deep, angular valleys.	Moderate to high.	Sandstone, siltstone, shale, and conglomerate; some coal.	Low-amplitude, open folds.	980	2,360	Dendritic.	*Northwest:* Glacial border. *Northeast:* Margins of deep valleys. *South:* Arbitrary along drainage divides between coal and noncoal areas.	Fluvial erosion; periglacial mass wasting.
	Pittsburgh Low Plateau	Smooth to irregular, undulating surface; narrow, relatively shallow valleys; strip mines and reclaimed land.	Low to moderate.	Shale, siltstone, sandstone, limestone, and coal.	Moderate- to low-amplitude, open folds, decreasing in occurrence northwestward.	660	2,340	Dendritic.	*Northwest:* Glacial border. *Elsewhere:* Arbitrary at topographic changes with adjacent sections.	Fluvial erosion; periglacial mass wasting; strip mining.
	Waynesburg Hills	Very hilly with narrow hilltops and steep-sloped, narrow valleys.	Moderate.	Sandstone, shale, red beds, and limestone.	Horizontal beds.	848	1,638	Dendritic.	Arbitrary at change of topography.	Fluvial erosion and landslides.
	Allegheny Mountain	Wide ridges separated by broad valleys; ridge elevations decrease to north.	Moderate to high.	Sandstone, siltstone, shale, and conglomerate; some limestone and coal.	Large-amplitude, open folds.	775	3,210	Dendritic.	*East:* Arbitrary between coal and noncoal areas. *West:* Base of west flank of Chestnut Ridge. *North:* Approximates northeast terminus of large-amplitude, open folds.	Fluvial erosion; some periglacial mass wasting.
	Allegheny Front	*East:* Rounded to linear hills rising by steps to an escarpment; hills cut by narrow valleys. *West:* Undulating hills sloping away from escarpment.	Moderate to high.	Shale, siltstone, and sandstone.	*South:* Broad fold. *Elsewhere:* Beds having low northwest dip; some faults.	540	2,980	Parallel and trellis.	*East:* Stream at base of hills below escarpment. *West:* Arbitrary between coal and noncoal areas.	Fluvial erosion; periglacial mass wasting.
	Deep Valleys	Very deep, angular valleys; some broad to narrow uplands.	Moderate to very high.	Sandstone, siltstone, shale, and conglomerate.	Moderate-amplitude, open folds that control valley orientations.	560	2,560	Angulate and rectangular.	Arbitrary at margins of deep valleys, either at top of valley slope or along drainage divide.	Fluvial erosion; periglacial mass wasting.
	Glaciated High Plateau	Broad to narrow, rounded to flat, elongate uplands and shallow valleys.	Low to high.	Sandstone, siltstone, shale, and conglomerate; some coal.	Moderate-amplitude, open folds.	620	2,560	Angulate and dendritic.	*East:* Base of escarpment. *Elsewhere:* Arbitrary with margins of deep valleys.	Fluvial and glacial erosion; glacial deposition.
	Glaciated Low Plateau	Rounded hills and valleys.	Low to moderate.	Sandstone, siltstone, and shale.	Low-amplitude folds.	440	2,690	Dendritic.	Base of escarpments of adjacent uplands; base of Pocono escarpment. *Elsewhere:* Arbitrary.	Fluvial and glacial erosion; glacial deposition.
	Glaciated Pocono Plateau	Broad, undulatory upland surface having dissected margins.	Low to moderate.	Sandstone, siltstone, and shale; some conglomerate.	Beds having low north dip; some small folds.	1,200	2.320	Deranged.	*South and east:* Base of Pocono escarpment. *North:* Crest of drainage divide. *West:* Arbitrary.	Fluvial and glacial erosion; glacial deposition.
RIDGE AND VALLEY	Appalachian Mountain	Long, narrow ridges and broad to narrow valleys; some karst.	Moderate to very high.	Sandstone, siltstone, shale, conglomerate, limestone, and dolomite.	Open and closed plunging folds having narrow hinges and planar limbs; variety of faults.	440	2,775	Trellis, angulate, and some karst.	*Southeast:* Base of slope change on southeast side of Blue Mountain. *West and northwest:* Center of valley bottom west of westernmost linear ridge. *Elsewhere:* Base of slope change of eastern ridges; arbitrary between ridges.	Fluvial erosion; solution of carbonate rocks; periglacial mass wasting.
	Susquehanna Lowland	Low to moderately high, linear ridges; linear valleys; Susquehanna River valley.	Low to moderate.	Sandstone, siltstone, shale, conglomerate, limestone, and dolomite.	Open and closed plunging folds having narrow hinges and planar limbs.	260	1,715	Trellis and angulate.	Base of slope change to higher ridges of all surrounding areas; arbitrary in valley areas.	Fluvial erosion; some glacial erosion and deposition in northeast.
	Anthracite Valley	Narrow to wide, canoe-shaped valley having irregular to linear hills; valley enclosed by steep-sloped mountain rim.	Low to moderate.	Sandstone, siltstone, conglomerate, and anthracite.	Broad, doubly-plunging syncline; faults and smaller folds.	500	2,368	Trellis and parallel.	Outer base of surrounding mountain.	Fluvial and glacial erosion; some glacial deposition.
	Anthracite Upland	Upland surface having low, linear to rounded hills, strip mines, and waste piles; upland surrounded by an escarpment, a valley, and a mountain rim.	Low to high.	Sandstone, shale, conglomerate, and anthracite.	Many narrow folds having steep limbs; many faults.	320	2,094	Trellis.	*Northeast:* Arbitrary between coal and noncoal areas. *Elsewhere:* Outer base of surrounding mountain.	Fluvial erosion; some glacial erosion and periglacial mass wasting.
	Blue Mountain	Linear ridge to south and valley to north; valley widens eastward and includes low linear ridges and shallow valleys.	Moderate to high.	Sandstone, siltstone, and shale; some limestone and conglomerate.	*Southwest:* South limb of broad fold. *Northeast:* Small folds north of Blue Mountain.	300	1,680	Trellis.	*Southeast:* Base of slope change on southeast side of Blue Mountain. *Northwest:* Base of mountain; base of Pocono escarpment. *Northeast:* Arbitrary.	Fluvial erosion; some glacial erosion and deposition in northeast.
	Great Valley	Very broad valley. *Northwest half:* Dissected upland. *Southeast half:* Low karst terrain.	Low to moderate.	*Northwest:* Shale and sandstone; slate at east end. *Southeast:* Limestone and dolomite.	Thrust sheets, nappes, overturned folds, and steep faults; many third- and fourth-order folds.	140	1,100	Dendritic and karst.	*North:* Base of slope change on southeast side of Blue Mountain. *South:* Base of slope change to adjacent uplands.	Fluvial erosion; solution of carbonate rocks; some periglacial mass wasting.
	South Mountain	Linear ridges, deep valleys, and flat uplands.	Moderate to high.	Metavolcanic rocks, quartzite, and some dolomite.	Major anticlinorium having many second- and third-order folds.	450	2,080	Dendritic.	Base of slope change to adjacent lowlands.	Fluvial erosion of highly variable rocks; some periglacial mass wasting.
NEW ENGLAND	Reading Prong	Circular to linear, rounded hills and ridges.	Moderate.	Granitic gneiss, granodiorite, and quartzite.	Multiple nappes.	140	1,364	Dendritic.	Base of slope change to adjacent lowlands.	Fluvial erosion; some periglacial mass wasting.
PIEDMONT	Gettysburg-Newark Lowland	Rolling lowlands, shallow valleys, and isolated hills.	Low to moderate.	Mainly red shale, siltstone, and sandstone; some conglomerate and diabase.	Half-graben having low, monoclinal, northwest-dipping beds.	20	1,355	Dendritic and trellis.	Base of slope changes with adjacent uplands and lowlands. *Elsewhere:* Arbitrary.	Fluvial erosion of rocks of variable resistance.
	Piedmont Lowland	Broad, moderately dissected, karst valleys separated by broad, low hills.	Low.	Dominantly limestone and dolomite; some phyllitic shale and sandstone.	Complexly folded and faulted.	60	700	Dendritic and karst.	*South:* Base of slope change to adjacent upland. *North:* Mesozoic red rocks.	Fluvial erosion; some periglacial mass wasting.
	Piedmont Upland	Broad, rounded to flat-topped hills and shallow valleys.	Low to moderate.	Mainly schist, gneiss, and quartzite; some saprolite.	Extremely complexly folded and faulted.	100	1,220	Dendritic.	*East:* Base of low to vague Fall Line escarpment. *North:* Base of slope change to adjacent lowlands.	Fluvial erosion; some periglacial mass wasting.
ATLANTIC COASTAL PLAIN	Lowland and Intermediate Upland	Flat upper terrace surface cut by shallow valleys; Delaware River floodplain.	Very low.	Unconsolidated to poorly consolidated sand and gravel; underlain by schist, gneiss, and other metamorphic rocks.	Unconsolidated deposits underlain by complexly folded and faulted rocks.	0	200	Dendritic.	*Northwest:* Base of low to vague Fall Line escarpment. *East:* Arbitrary.	Fluvial erosion and deposition.

[1] Local relief: 0 to 100 feet, very low; 101 to 300 feet, low; 301 to 600 feet, moderate; 601 to 1,000 feet, high; >1,000 feet, very high.
(Relief categories listed here for Pennsylvania do not necessarily apply to other states or countries.)
[2] Elevations are in feet.

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ATTACHMENT 3

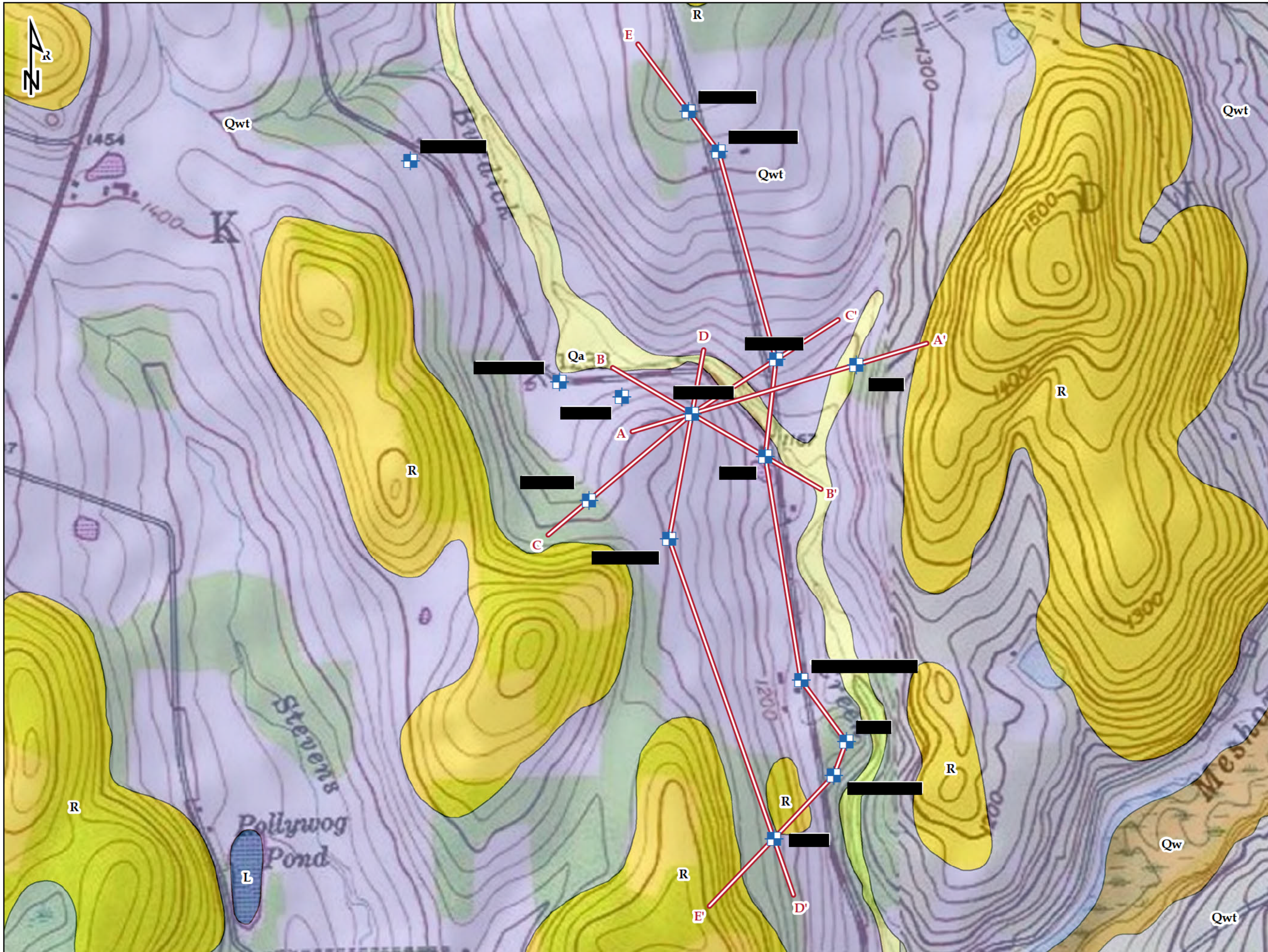

FIGURE 1
Geologic Map

EHS Costello, J. Pad 1

Dimock Township
Susquehanna County
Pennsylvania

Prepared for:
Cabot Oil and Gas

Legend

- Private Water Wells
- Cross Section Lines

Surficial Geology

- L - Lake
- Qa - Alluvium
- Qw - Wetland
- Qwt - Wisconsinan Till
- R - Bedrock

Map Reference:
Copyright:© 2011 National Geographic Society, i-cubed

Scale: 1 in = 750 ft
0 375 750 1,500
Feet

Project #: 11-134-AG

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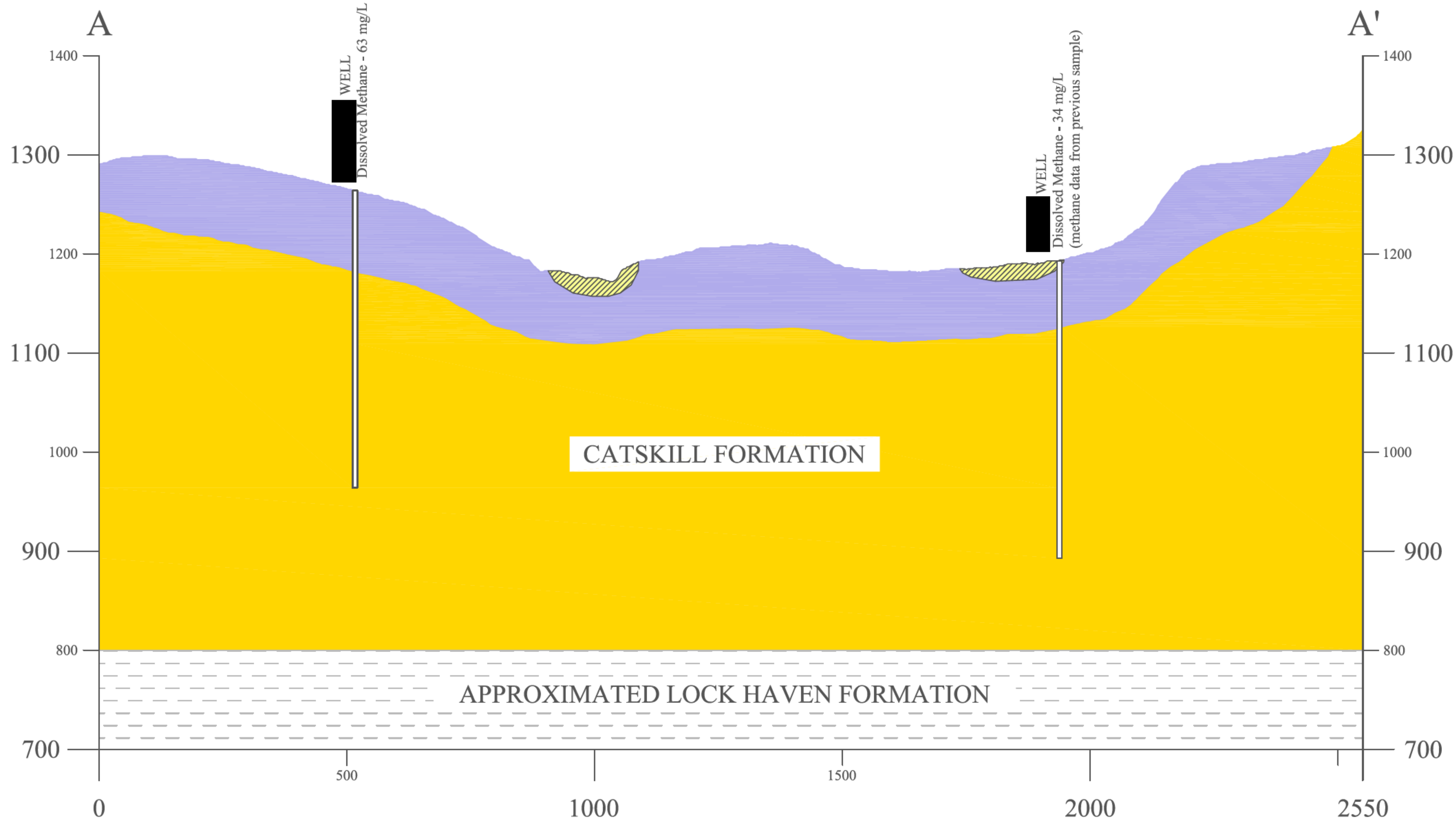
Drawn by	Checked by	Date	Revision
EDC	DPE	2/13/2013	1



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Note:
Surficial geology contacts and depths are estimated from published geologic maps and PAGWIS data. Bedrock geology contacts are estimated from published geologic maps.

Legend:
- Private Water Well
- Alluvium
- Wisconsinan Till
- Catskill Formation
- Approximated Lock Haven Formation

Scale:
Vertical Scale: 2x
1 inch = 200 feet
0 100 200 400 Feet

Prepared for: Cabot Oil and Gas

Drawing References:
- Elevation Data: PAMAP Program, PA Department of Conservation and Natural Resources, Bureau of Topographic and Geologic Survey
- Bedrock Geology of Pennsylvania: PA Bureau of Topographic and Geologic Survey, DCNR.
- Braun, D. D., 2006, Surficial geology of the Springville 7.5-minute quadrangle, Susquehanna and Wyoming Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report OFSM 06-17.0, 13 p., Portable Document Format
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Project #: 11-134-AH

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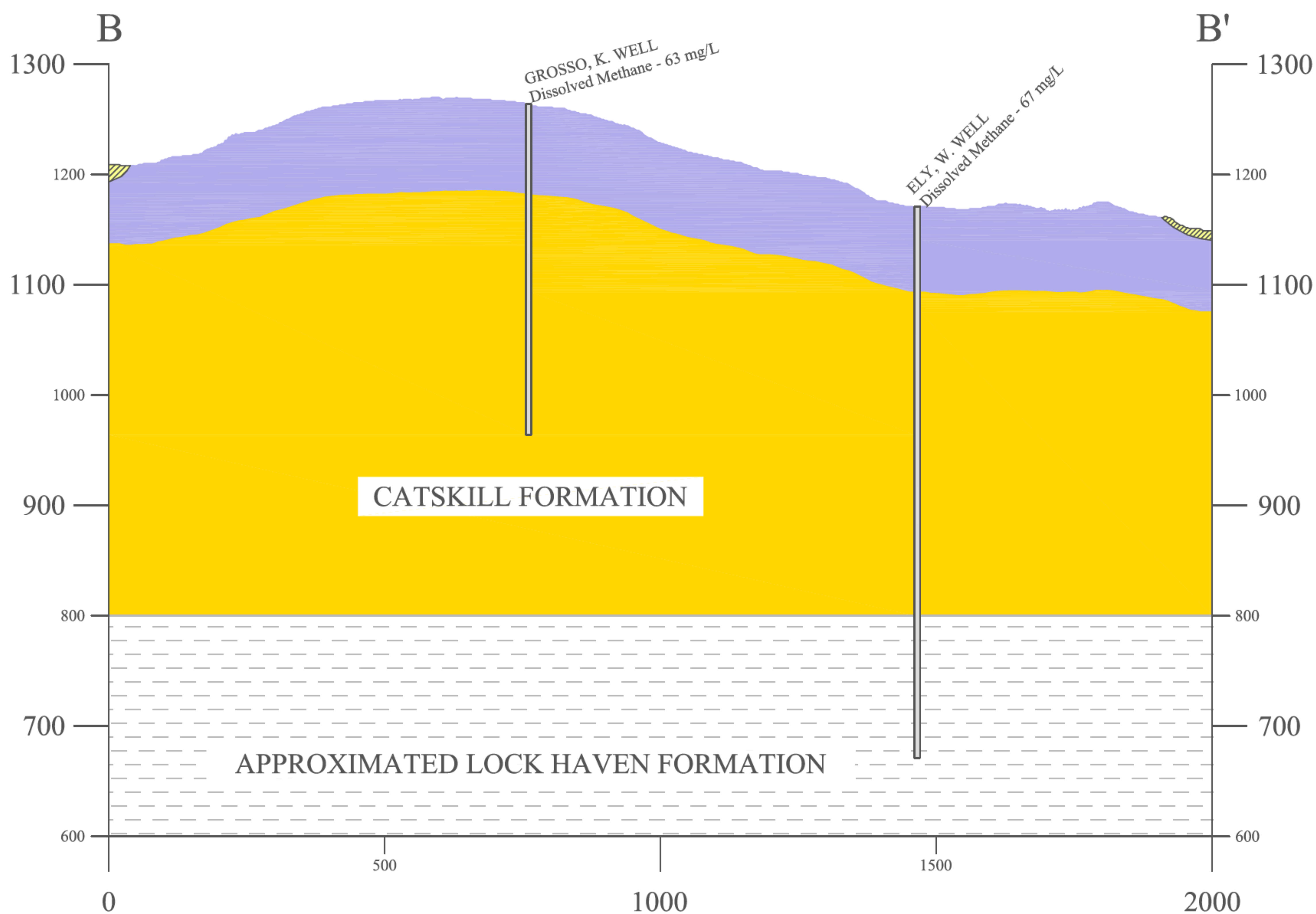
EDC	DPE	2/12/2013	0

FIGURE 2

CROSS-SECTION A-A'

EHS COSTELLO, J. PAD 1
DIMOCK TOWNSHIP
SUSQUEHANNA COUNTY, PENNSYLVANIA



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Legend:
- Private Water Well
- Alluvium
- Wisconsinan Till
- Catskill Formation
- Approximated Lock Haven Formation

Scale:
Vertical Scale: 2x
1 inch = 200 feet
0 100 200 400 Feet

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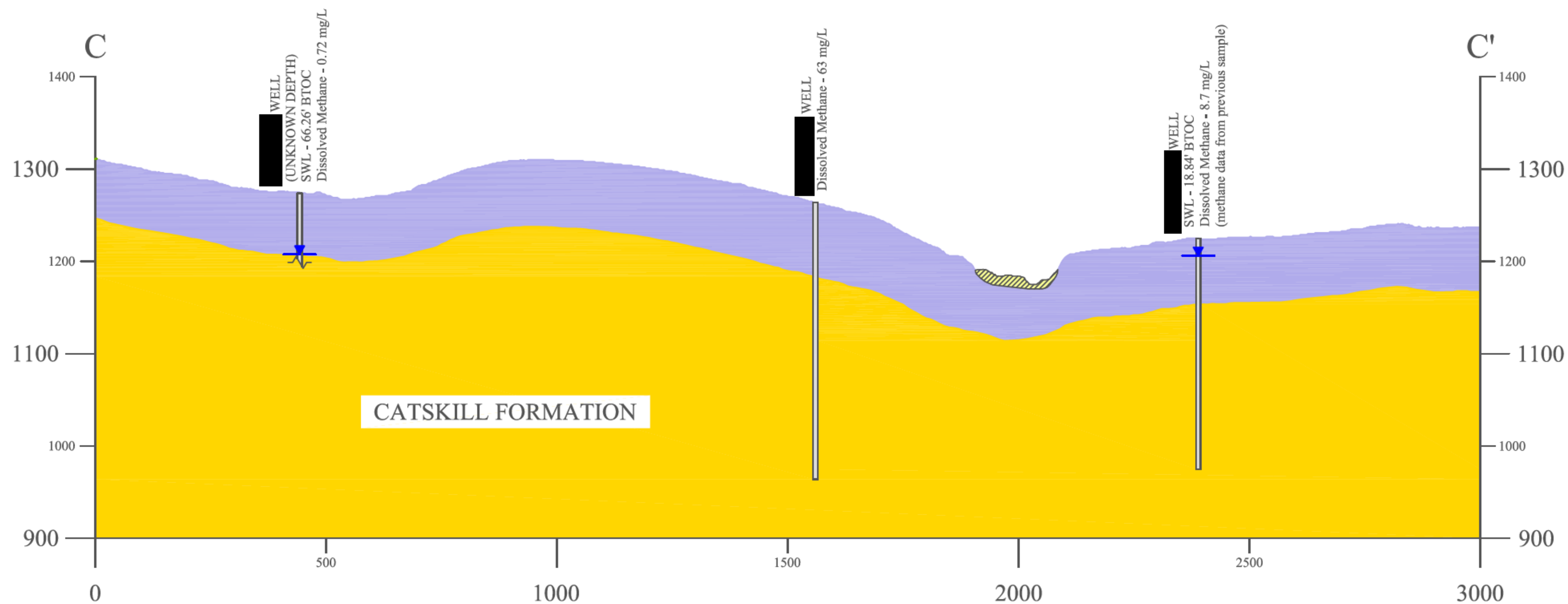
EDC	DPE	2/12/2013	0

FIGURE 3

CROSS-SECTION B-B'

EHS COSTELLO, J. PAD 1
DIMOCK TOWNSHIP
SUSQUEHANNA COUNTY, PENNSYLVANIA



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Note:
Surficial geology contacts and depths are estimated from published geologic maps and PAGWIS data. Bedrock geology contacts are estimated from published geologic maps.

Legend:
- Private Water Well
- Alluvium
- Wisconsinan Till
- Catskill Formation

Scale:
Vertical Scale: 2x
1 inch = 250 feet
0 125 250 500 Feet

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Drawing References:
- Elevation Data: PAMAP Program, PA Department of Conservation and Natural Resources, Bureau of Topographic and Geologic Survey
- Bedrock Geology of Pennsylvania: PA Bureau of Topographic and Geologic Survey, DCNR.
- Braun, D. D., 2006, Surficial geology of the Springville 7.5-minute quadrangle, Susquehanna and Wyoming Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report OFSM 06–17.0, 13 p., Portable Document Format
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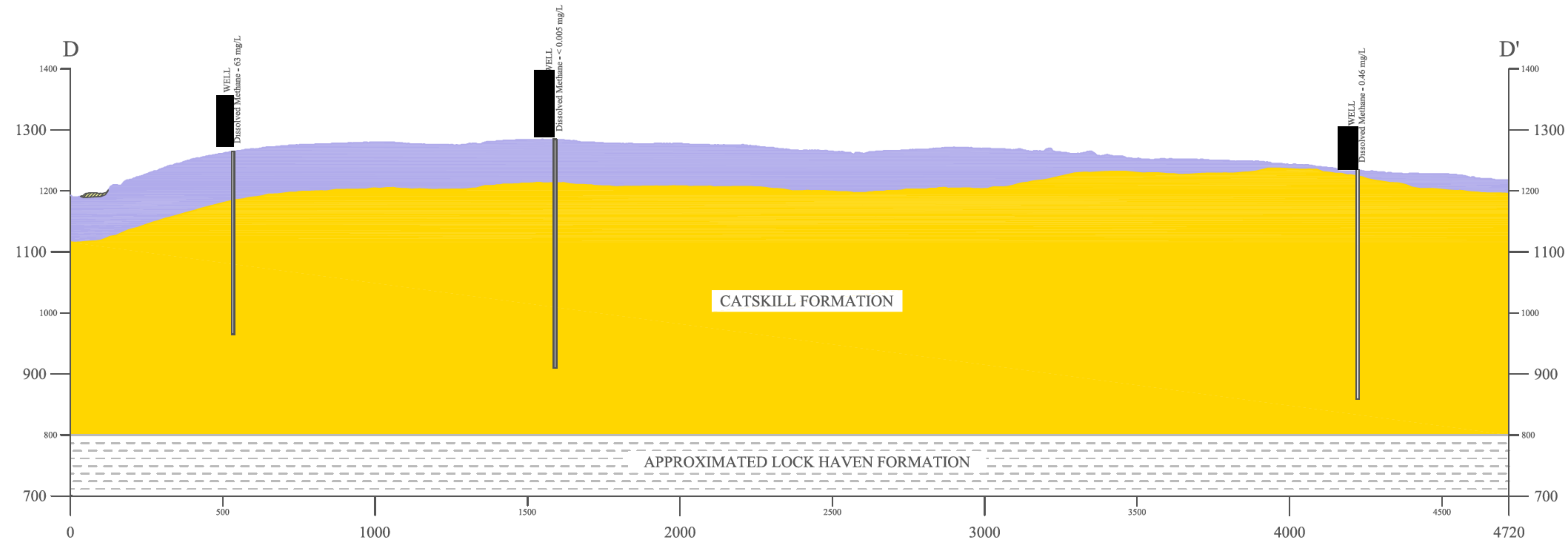
EDC	DPE	2/12/2013	0

FIGURE 4

CROSS-SECTION C-C'

EHS COSTELLO, J. PAD 1
DIMOCK TOWNSHIP
SUSQUEHANNA COUNTY, PENNSYLVANIA



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Note:
Surficial geology contacts and depths are estimated from published geologic maps and PAGWIS data. Bedrock geology contacts are estimated from published geologic maps.

Legend:
- Private Water Well
- Alluvium
- Wisconsinan Till
- Catskill Formation
- Approximated Lock Haven Formation

Scale:
Vertical Scale: 2x
1 inch = 350 feet

0 175 350 700 Feet

Prepared for: Cabot Oil and Gas

Drawing References:
- Elevation Data: PAMAP Program, PA Department of Conservation and Natural Resources, Bureau of Topographic and Geologic Survey
- Bedrock Geology of Pennsylvania: PA Bureau of Topographic and Geologic Survey, DCNR.
- Braun, D. D., 2006, Surficial geology of the Springville 7.5-minute quadrangle, Susquehanna and Wyoming Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report OFSM 06-17.0, 13 p., Portable Document Format
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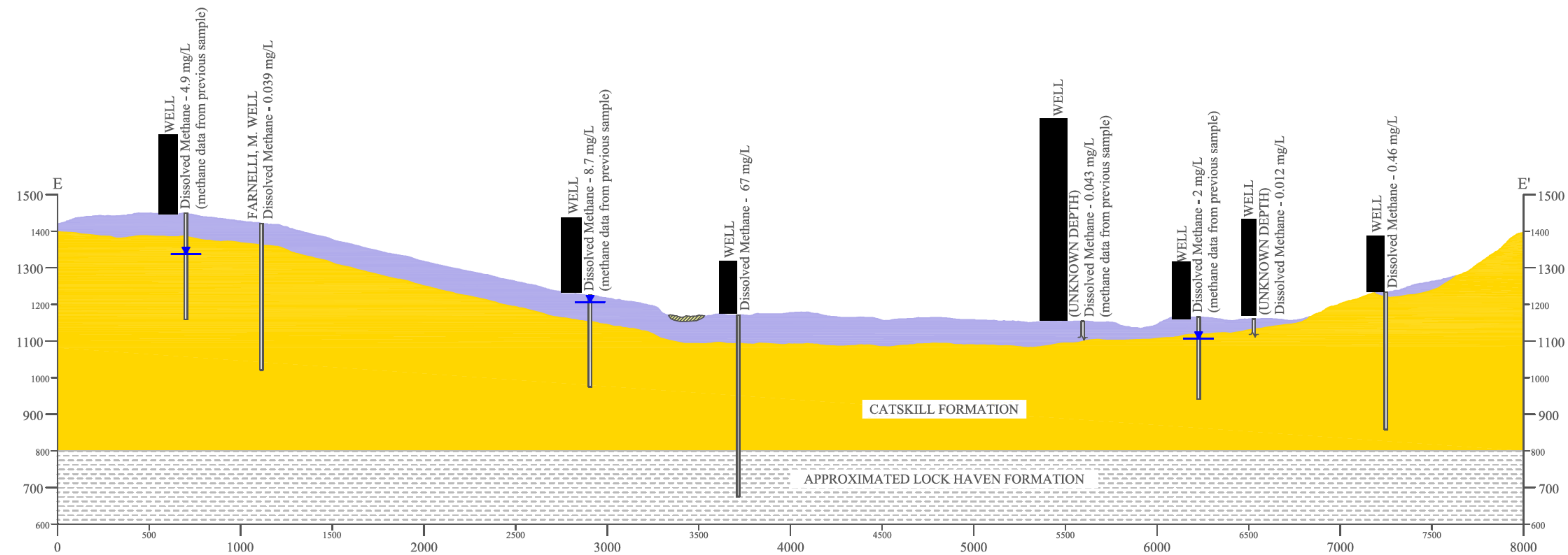
Project #: 11-134-AH

Drawn by:	Reviewed by:	Date:	Revision:
EDC	DPE	2/12/2013	0

FIGURE 5

CROSS-SECTION D-D'

EHS COSTELLO, J. PAD 1
DIMOCK TOWNSHIP
SUSQUEHANNA COUNTY, PENNSYLVANIA



Moody and Associates, Inc.
685 Broad Street Ext.
Suite 1
Waverly, NY 14892
607.565.8800 voice 607.565.8805 fax
www.moody-s.com

Note:
Surficial geology contacts and depths are estimated from published geologic maps and PAGWIS data. Bedrock geology contacts are estimated from published geologic maps.

Legend:
- Private Water Well
- Alluvium
- Wisconsinan Till
- Catskill Formation
- Approximated Lock Haven Formation

Scale:
Vertical Scale: 2x
1 inch = 550 feet
0 275 550 1100 Feet

Prepared for: Cabot Oil and Gas

Drawing References:
- Elevation Data: PAMAP Program, PA Department of Conservation and Natural Resources, Bureau of Topographic and Geologic Survey
- Bedrock Geology of Pennsylvania: PA Bureau of Topographic and Geologic Survey, DCNR.
- Braun, D. D., 2006, Surficial geology of the Springville 7.5-minute quadrangle, Susquehanna and Wyoming Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Open-File Report OFSM 06-17.0, 13 p., Portable Document Format
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Project #: 11-134-AH

Drawn by:	Reviewed by:	Date:	Revision:
EDC	DPE	2/12/2013	0

FIGURE 6

CROSS-SECTION E-E'

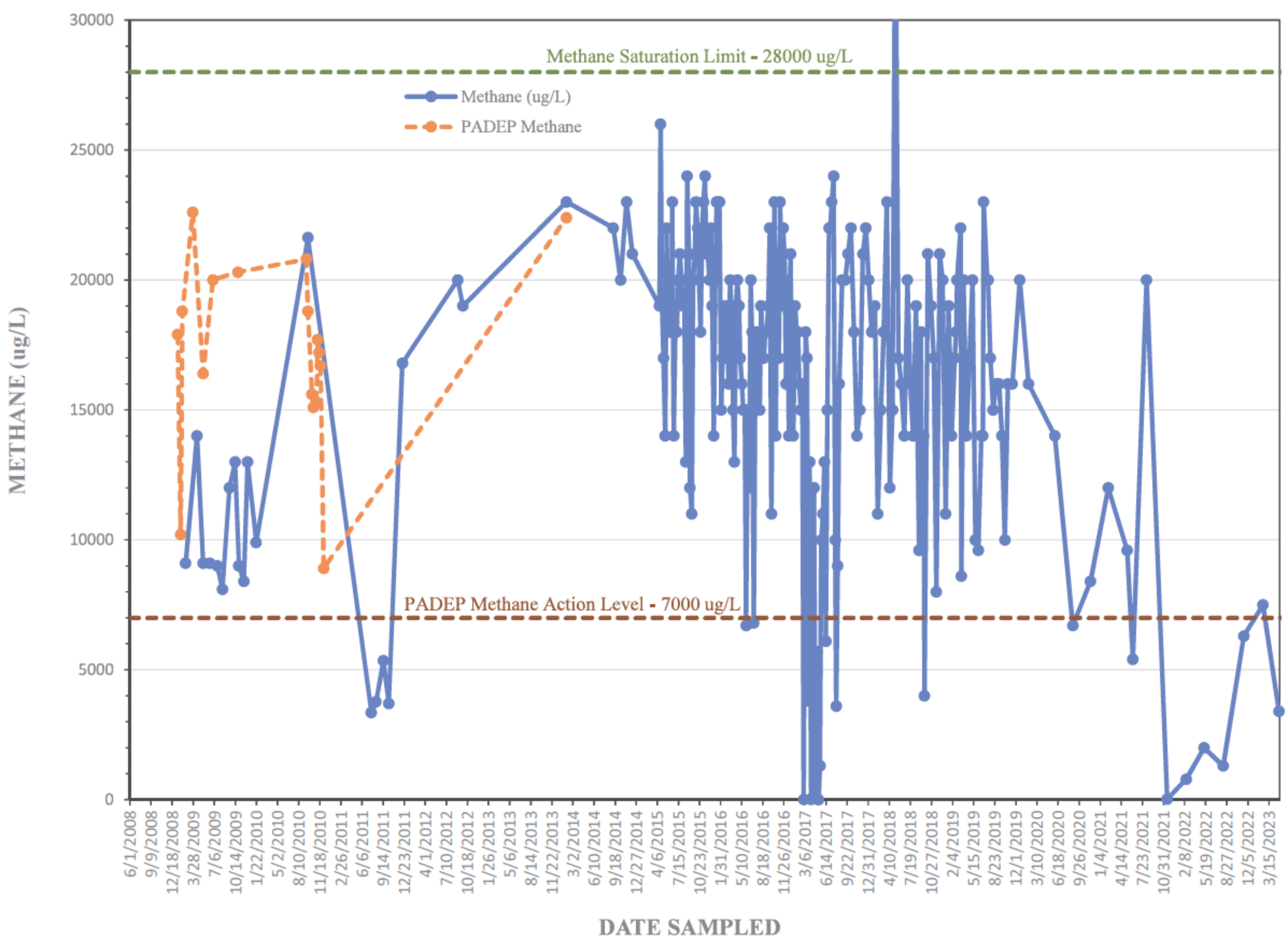
EHS COSTELLO, J. PAD 1
DIMOCK TOWNSHIP
SUSQUEHANNA COUNTY, PENNSYLVANIA

ATTACHMENT 4

COTERRA

[redacted]

DISSOLVED METHANE CONCENTRATION

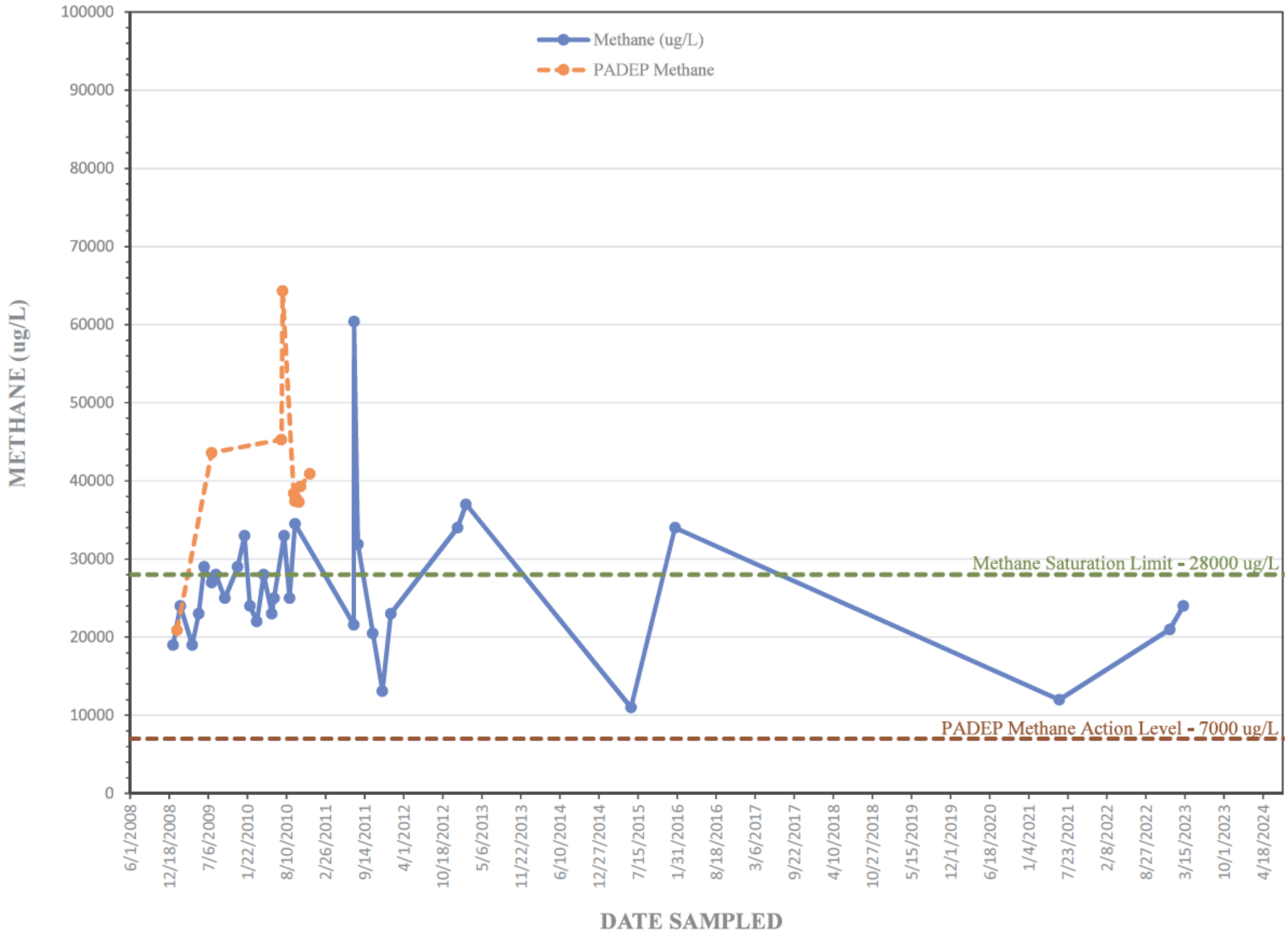


Prepared by: Moody and Associates Inc.

COTERRA

[redacted]

DISSOLVED METHANE CONCENTRATION



Prepared by: Moody

COTERRA

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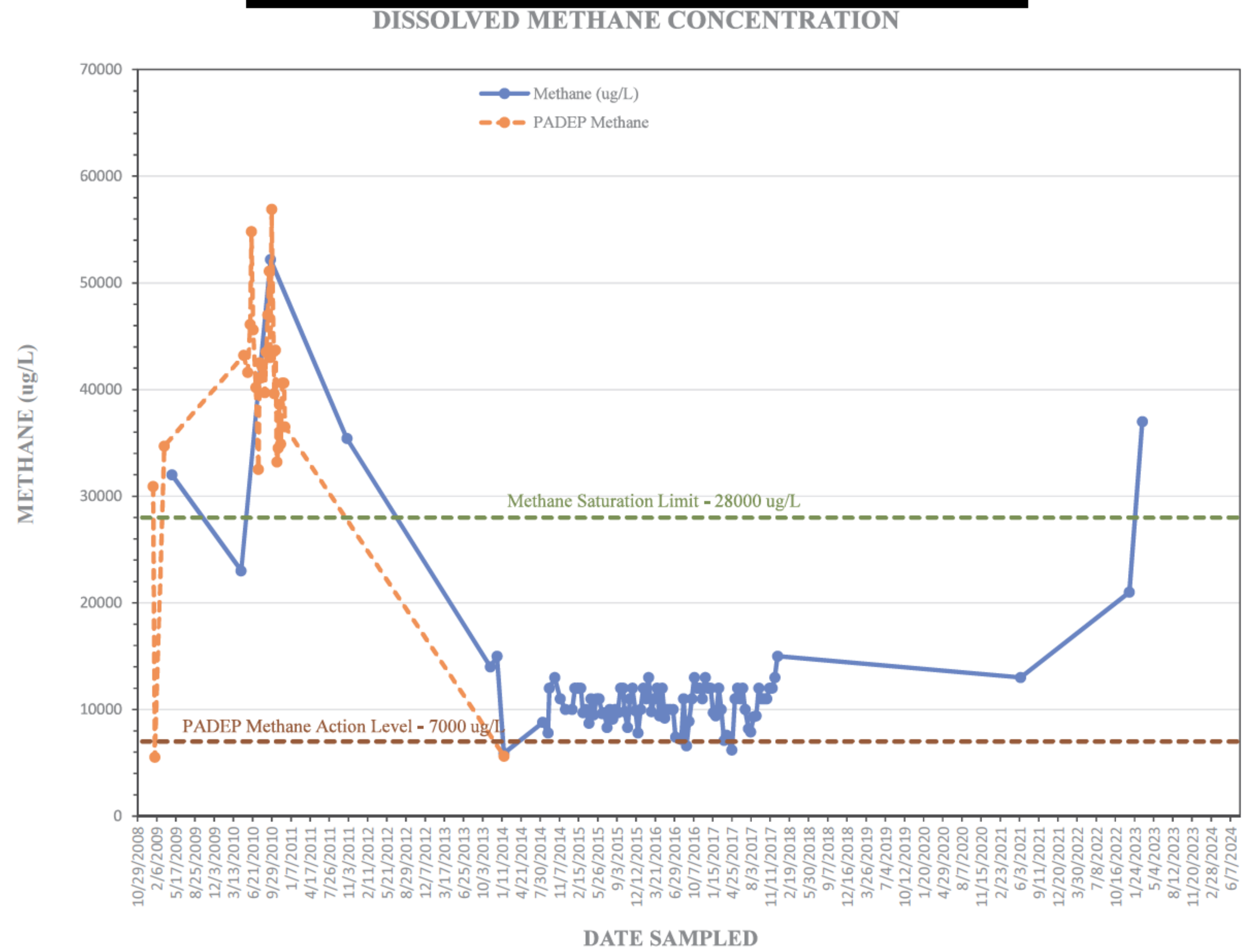

Prepared by: Moody

COTERRA

[redacted]

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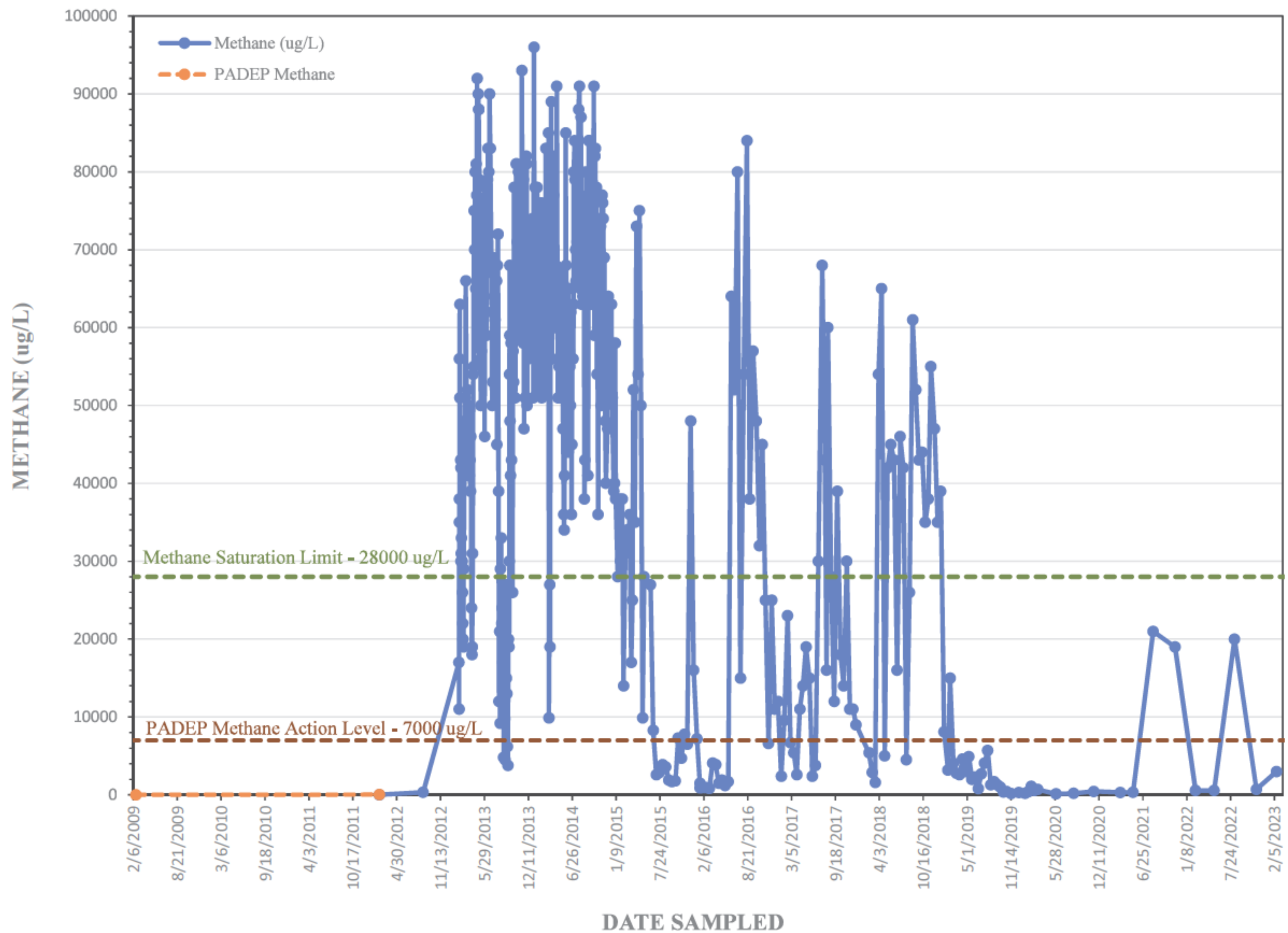

Prepared by: Moody and Associates Inc.

COTERRA

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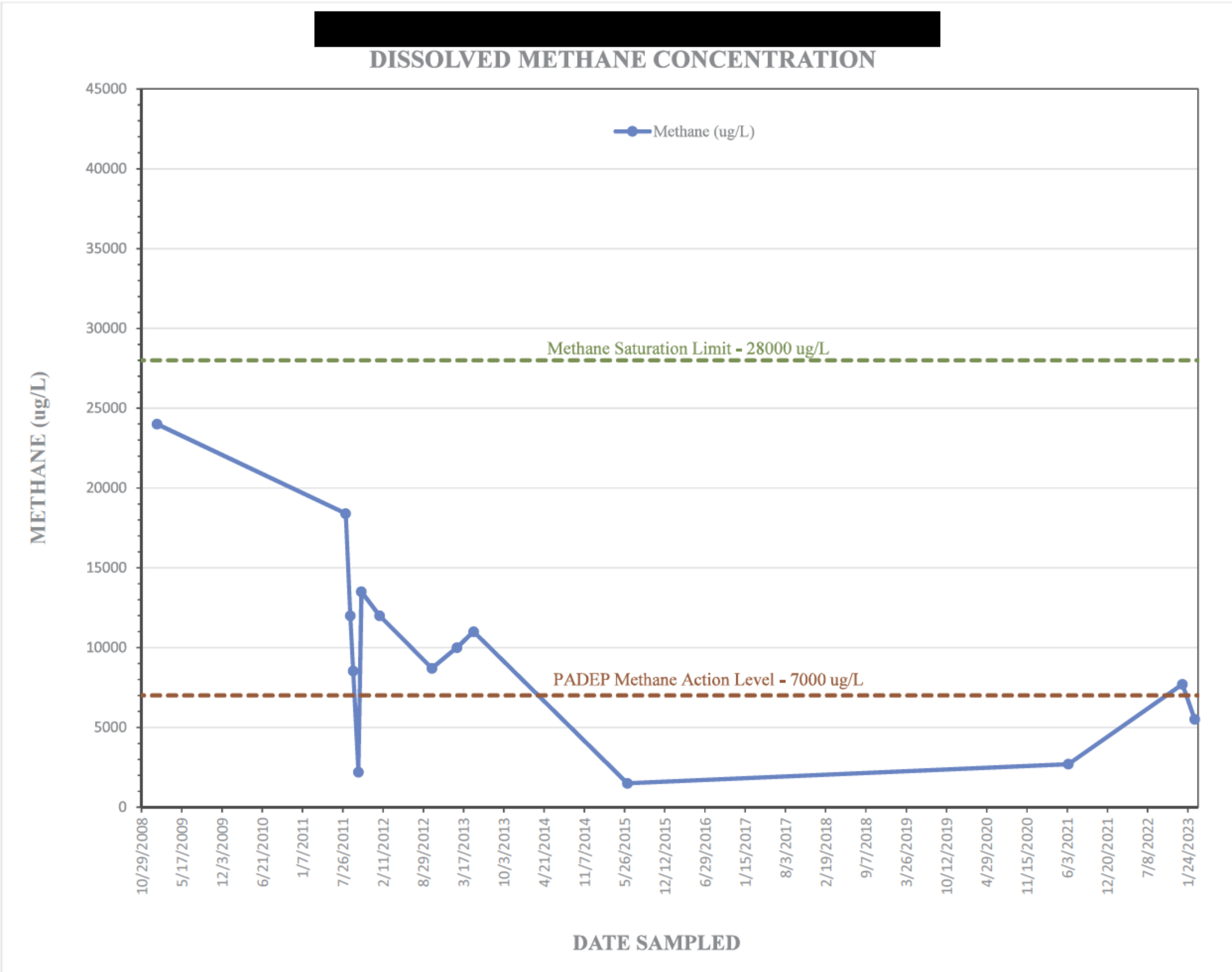

Prepared by: Moody

COTERRA

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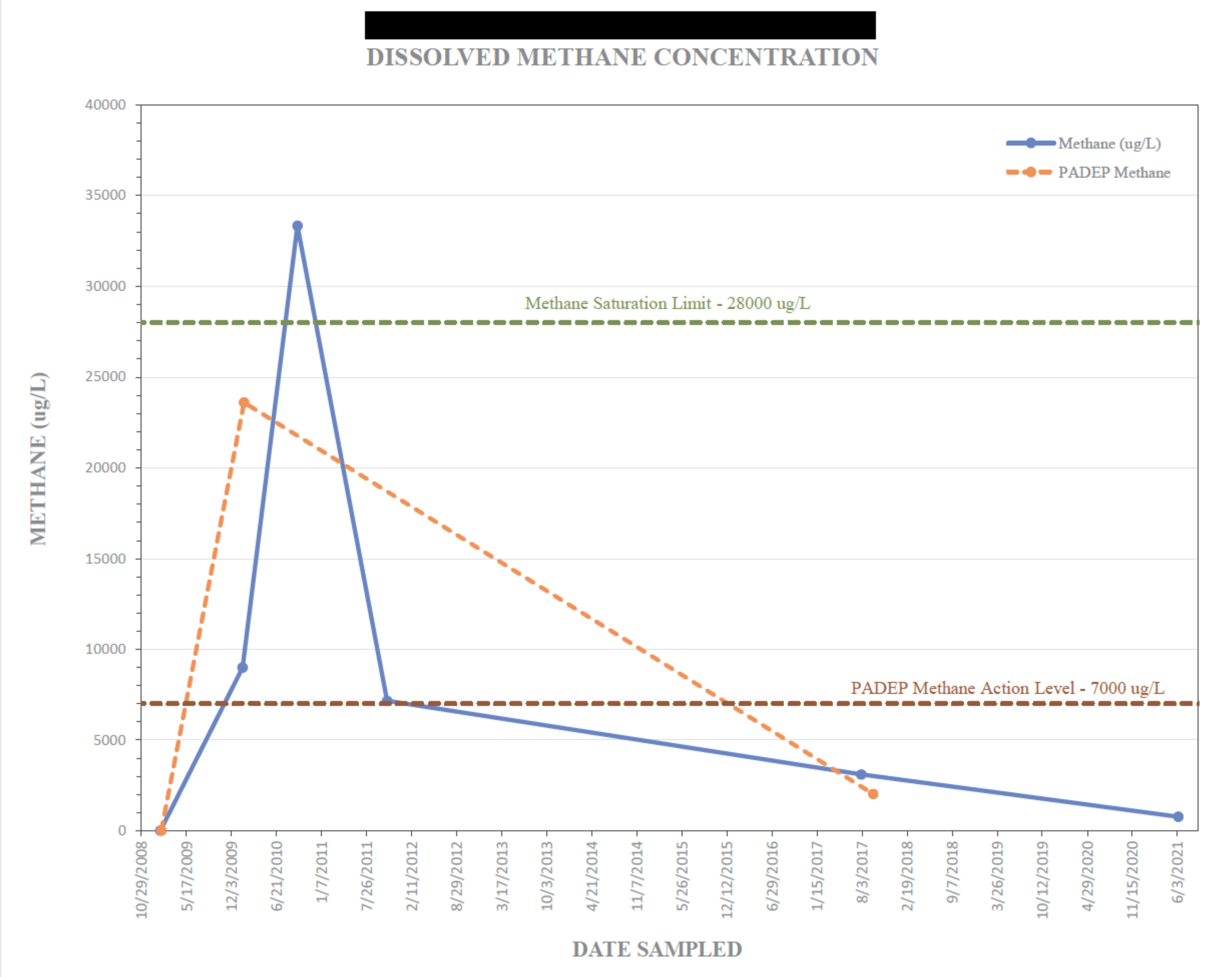

Prepared by: Moody