MARINO ENGINEERING ASSOCIATES, INC.

January 23, 2017

Ms. Shannon Anderson
Acting Director
Powder River Basin Resource Council
934 Main St.
Sheridan, WY 82801

Exhibit 12

Re: Brook Mine Permit Application

Ms. Anderson,

As you have requested, I have reviewed the mine application for the proposed Brook Mine by Ramaco, LLC. This proposed mining is located about 8.5 miles north of Sheridan, WY (see Figure 1.1). In my evaluation of the Ramaco mine application, I performed a cursory to detailed review of the following documents:

- Mine Plan
    - Addendum MP-1: Alternative Sediment Control Measures
    - Addendum MP-3: Groundwater Model
    - Addendum MP-6: Subsidence Control Plan
    - Addendum MP-7: Blasting Plan Supplemental Materials
- Appendix D2: History
- Appendix D5: Topography, Geology, and Overburden Assessment (Oct. 2014 and Jul. 2015)
    - Addendum D5-1: Drill Hole Tabulations (State Plane Coordinates)
    - Addendum D5-2: Lithologic and Geophysical Logs

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- Addendum D5-3: Geologic Cross-Sections
- Addendum D5-4: Isopach Maps
- Addendum D5-5: Overburden, Roof and Floor Sample Analysis Tables
- Addendum D5-6: WDEQ/LQD Overburden Sampling Frequency Waiver
- Addendum D5-7: Soil Analysis Reports

- Appendix D6: Hydrology
  - Addendum D6-1: HEC-HMS Model
  - Addendum D6-2: Miller Regression Analysis
  - Addendum D6-3: HEC-RAS Model
  - Addendum D6-4: Surface Water Hydrographs
  - Addendum D6-7: Monitor Well Completion Data
  - Addendum D6-8: Pumping Test Report
- Appendix D11: Alluvial Valley Floors
- Bond Estimate
- Reclamation Plan
- Effects of Coal Mine Subsidence in the Sheridan, Wyoming Area, USGS Paper 1164 by C. Dunrud and F. Osterwald, 1980
- Technical Report on the Welch Ranch Coal Fire by E. Heffern, J. Queen, and K. Henke, April 28, 2003
- 2014-2019 Sheridan County, WY Multi-Hazard Mitigation Plan
- USDA Soil Survey of Sheridan County Area, Wyoming

SITE TOPOGRAPHY

The topography of the mine site is shown in Figure 1.2. As seen in Figure 1.2, except for the southeastern "leg" of the application area, the proposed mine site is just north of the meandering east-west Tongue River, with the overall ground surface within this application area draining to the Tongue River. The main drainage features trend NW-SE (e.g. Early Creek, E. Fork Early Creek, Slate Creek, and Hidden Water Creek) approximately conjugate to known fault traces. Between each tributary or drainage incision, the surface elevations reach about 3,840 ft. – 4,100 ft., with relief from the valley of typically 150 ft. to 200 ft. The lowest point is shown at about 1,680 ft. El. at the Tongue River whereas the highest point depicted is centrally located near the north limits of the application area at Elevation about 4,100 ft. In the smaller southeastern "leg" of the application area, the ground basically drains west into Goose Creek or to the north into the Tongue River.

GEOLOGIC CONDITIONS

Within the mine application area, the relevant geologic materials are reported to be weathered to unweathered rock and colluvium from mass wasting. These rock beds belong to the Union Fort Formation of Tertiary age with the coal bearing strata in the lower sequences of the Tongue River Member. See Figure 2.1. Below the Tongue River Member is the Lebo Member which regionally consists of mainly clayey shale.

Mineable heights of the site sub-bituminous coal beds are discontinuous across the site. The main seams that will be mined are the Carney and the lower Masters. The Carney seam splits to the west into the upper and lower Carney benches. This claystone parting is reported to reach a thickness in excess of 30 ft. Where the Carney is vertically continuous, it is stated to be 15 to 20 ft. thick, but when it splits, the upper unit is 2 to 6 ft. thick, and the lower, which typically has better quality, is 4 to 10 ft. thick. The thickness of the underlying Masters, where present, was found to be 4 to 6 ft.

There is also the potential that the overlying Monarch and other more localized coal beds will be mined. It is noted that much of the Monarch seam has been burnt into scoria.

The interburden thickness between the Carney and the Masters has been measured to be from less than 1 ft. at the eastern mine application limit to over 50 ft. As described in the mine application, the vast majority of the coal measures are composed of claystone with fairly localized layers of moderately to well cemented sandstone to siltstone lenses. In other words, the floor of the mineable coal seams is claystone. The Lebo member which underlies the Master Coal measures is described as mudstone.

The application area is known to be faulted. Normal faults are reported which trend NE-SW causing a horst and graben structure across the mine area, the dip of this faulting, or the character of it's broken zone are not known. Based on the surface drainage features conjugate structure may also be present. The dip of the beds in the faulted blocks is reported to be about 2 degrees in the south-southeast direction.

GEOTECHNICAL CONDITIONS

From review of the relevant portions of the permit application, all the reported geotechnical laboratory results for the coal measures in the reserve are summarized in Table 3.1. As can be seen here, there has been scant few rock mechanics testing. And consequently no sense of the important engineering properties and their spatial variations of the relevant coal measures through the reserve can be realistically achieved. The rock mechanics testing should include:

- Moisture content
- Liquid and plastic limits determinations
- Rock durability
- Tensile strength
- Uniaxial compression or Point load strengths
- **Consolidated-drained** triaxial strength
- Swell potential

Furthermore, from a geotechnical engineering standpoint, the rock descriptions for the borings drilled are wholly inadequate. This includes:

- No RQD measurements
- No fracture descriptions – are fissures or slickensides present and at what frequency?
- No to inadequate (uncodified) hardness descriptions
- No codified description of rock classifications

From a geotechnical engineering perspective, there is a severe concern given that the vast majority of the coal measures are described as claystone. Claystone represents very poor mine roof and floor conditions in addition to highwall stability problems. Fine-grained rocks are likely to significantly reduce in strength over time as they swell/soften and deteriorate (Marino and Osouli, 2012). Also, there appears to be mischaracterization as some of the reported claystone as it is described to be fissile, which indicates bedding (not a non-bedded rock).

To properly understand the engineering material nature of fine-grained rocks, sufficient testing of the rock plasticity (Atterberg Limits) and rock durability should be performed (Marino and Osouli, 2012).

MINE PLAN

Ramaco plans to mine with the reserve area mainly in two coal seams. They are the Carney and Masters coals. In the western part of the reserve, the Carney coal seam splits into upper and lower beds. Because these mineable beds are covered, Ramaco plans to create highwalls to expose them by excavating mainly slots or areas by strip mining. Once the mineable seam(s) are exposed, they will be extracted utilizing a remote-controlled continuous miner and conveyor system. An illustration of this proposed highwall operation was provided by Ramaco in Figure 4.1.

The plan showing the areas of proposed mining are depicted in Figure 4.2. This plan shows the blocks of highwall mining and associated strip mining areas. In Figure 4.3, the delineated coal blocks have been numbered for future reference from 1 to 20 east to west. As noted in the application, Ramaco plans to mine essentially from east to west.

The coal blocks will be mined from benches along the highwall by driving parallel entries into the highwall face apparently perpendicular to the highwall. A remote continuous miner system will be utilized to drive the rooms to depths of up to 2,000 ft. The mining equipment that will be used is an ADDCAR highwall mining system with accuracy of 0.1m in 384m of penetration. However, potentially more significant in determining the actually cut pillar widths is the azimuth accuracy which is not discussed. Using this continuous miner, it is noted that typical extraction heights of 30 in. to 28 ft. can be achieved.

The proposed room and pillar configuration is depicted in Figure 4.4. As can be seen in Figure 4.4, there is no definitive geometry stipulated in the application as much of the identified dimensions are qualified. Using the "typical" web pillar widths and room width, the panel extraction ratio would vary from 59% to 70% in the panels.

Ramaco also states that where multiple coal seams will be mined in a block the pillars will be stacked. With apparently the parallel entries of about the same width, this means the pillar width would be the same for all seams of different thickness. Ramaco states the pillar width will be determined by the seam with the greater thicknesses [MP-6-7].

In order to better understand the ground conditions in the areas of proposed mining, the mining layout given in Figure 4.3 has been superimposed over the various isopach exhibits for the Carney and Masters seams provided in the mine application. These drawings are shown in Figures 4.5 to 4.12. Also, the mine block areas had been delineated on the various geologic cross-sections drawn by Ramaco across the site (see Figure 4.3). The modified cross-sections showing the mine block locations are shown in Figures 4.13 to 4.24. From this reported information, the Dietz, Monarch, Carney, and Masters related conditions per block have been summarized in Table 4.1.

Other considerations are noted below.

- There is no discussion that could be found on reclamation of the mine openings in the highwalls which are left after an area is complete. Depending upon the seal (if any) and dip of the coal, groundwater (and runoff if not sealed) can pool in the entry. Also, if any of these areas are contoured, these entries, as a source of water, can have a detrimental effect of the stability of the reclaimed slope.

- The mine application notes oil and gas wells are present. There is no discussion that could be found on how these wells will be addressed during mining, or how they will be handled if the well is mislocated or was unknown when encountered during mining.

- Ramaco has not addressed the potential for the significant portion of the pillar being composed of claystone from mining in the blind where the coal has significantly variable thickness, or clay parting(s).

MINE STABILITY ANALYSIS

An integral part of assessing the subsidence potential for any proposed coal mining is the determination of whether the coal mine structure will be stable in the short and long term. The mine application, however, provides no calculations of the planned and expected roof, pillar, or floor conditions. In fact, the only governing criteria provided is that "support pillars will be designed to have a width equal to or exceeding the maximum extraction thickness" [MP-6-4]. Ramaco states that this is based on the NIOSH pillar stability program and the recommended stability factor (i.e. safety factor) and that "pillar dimension will also be in accordance with Brook Mine's Ground Control Plan approved by MSHA". Contact with MSHA found that no ground control plan has been filed. They stated that such a plan applies to open pit conditions and thus would not address pillar dimensions (although the NIOSH pillar program manual for highwall mining notes it is part of the MSHA ground control plan). Moreover, approval from MSHA (whose responsibility is safety) is irrelevant as the concern here is land subsidence.

In stating the pillar width to height ratio will be one or greater, none of the input assumptions or output for the pillar dimension criteria have been provided to evaluate how this criterion was arrived at. For example, the assumed coal strength for the various subbituminous seams (without any substantial test data), assumed coal extraction, and the assumed overburden depth are not known. Also, there is no discussion in the mine application of the effect of multiple seam mining (including overlying or subjacent old works presence) [NISOH ARMPS-HWM]. Moreover, the proposed utilization by Ramaco of the coal tensile strength to assess pillar strength is not standardly done in the industry [D5-10].

There is no governing roof and floor design criteria on what will dictate the barrier and web pillar width and spacing, and panel width to avoid complete overburden instability, based on the variable ground/mining conditions which may be encountered (see Figure 5.1). This is especially problematic given the reported very poor roof and floor consisting mostly of claystone although resistance augmented siltstone and sandstone zones exist there locally (see Figure 4.13 to 4.24).

With the poor identification of the following conditions, it is impossible to obtain a reasonable understanding of the short and long term stability of the proposed mining (or even the slope/highwall). This includes:

- More definitive room-and-pillar layout.

- Sufficient understanding of the engineering properties of the roof, pillar, and floor materials.

- Sufficient understanding of the geologic structure including the nature and orientation (strike and drip) of all faults and shears; and fissure/slickenside concentrations.

An idea of the mine stability conditions can be obtained, however, from the available information. From Table 4.1, mine depths of over 400 ft. are planned with extraction heights reaching 18+ ft. Given the mine depths and planned panel extraction ratios, tributary pillar pressures up to close to 1,300 psi will exist. Even assuming a higher bituminous coal strength at pillar width to heights of one (as proposed), the stability factor calculates to an unacceptable value of less than one at this pillar pressure where the panels are sufficiently wide.[1] This was calculated using the Mark-Bieniawski pillar strength equation, which is the same one used by Ramaco and cited by MSHA. Also, this pillar bearing load will be well in excess of the reported claystone roof and floor (Marino and Bauer, 1989).

Other concerns which have not been addressed but can play a role in the stability of the proposed mine workings include:

- The effect of flooding or pooling of groundwater. Saturation or repeated cycles of wet and dry of the clay roof, pillar (partings) and floor can dramatically effect it's inplace strength, and subsequently causing failure. Inflows of groundwater are

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[1] Note the MSHA criteria for pillar strength were based on pillar heights of 7 ft. or less whereas 18 ft. heights are proposed.

noted by Ramaco from drainage and where aquifers are saturated [MP-45]. Although a 500 ft. coal barrier is planned between the old works and the Brook Mine [MP67-8], there is also the potential that the proposed mining can be inundated from the presence of adjacent old Carney workings that may contain water. This risk is attributed to unmapped workings and unknown geologic structures. Note on Figure MP-6.1-1, the old works are not shown buffered with barrier pillars 500 ft. in width. Moreover, the drainage of pool or flooded old workings can reactivate or cause additional land subsidence in those areas.

- Effect of stacking of pillars on stability with change in interburden thickness; and the accumulated void height and the effect on chimney subsidence.

- As noted in the permit application, a clay parting cuts the Carney seam into upper and lower benches. There is not discussion or analysis of when the parting becomes sufficiently thick to cause pillar instability and consequently resort to mining the upper or lower bench. How the remote continuous miner "blindly" cuts just coal is not discussed.

Although not a mine subsidence concern, there can be serious slope/highwall instability given the extent of claystone throughout the reserve in addition to the evidence of faulting. The proposed benches for support of mining equipment and personnel are also similarly subjected to instability, especially since these claystone areas will tend to collect slope runoff and minewater.

SUBSIDENCE POTENTIAL

The subsidence of the proposed Brook Mine is discussed in the Subsidence Control Plan of the mine application. Subsidence can basically come in the form of pits (sinkholes) and sags. Pits form on the ground surface from the complete collapse of the overburden into a mine entry. Sags are mine subsidence events which are bowl-shaped depressions. They are caused by overburden collapse in the mine entry, a pillar failure, and a bearing failure in the roof or floor. Entry-induced sag events tend to be significantly smaller than those from a pillar or bearing failure. (See MEA Engineering UPDATE Issue 14).

The pit subsidence over the old workings in the mine application area can be seen in the aerial photographs as shown in Figure 7.1 to 7.5. These photographs show areas of more isolated to intense patterns of pit subsidence indicating poor overburden roof conditions. This is consistent with the vast majority of the rock overburden described as claystone without resistant durable interbeds. There also appears to be some subsidence-induced slop instability (i.e. slump features in Area 2, Figure 7.2). The mine depth is estimated to reach up to 160 ft. in visible subsidence areas. Broader subsidence events (i.e. sags) from pillar or pillar bearing failure or mine fire are not noticeable on aerials photographs examined but also are reported in the region.

Ramaco's subsidence analysis treats entry-induced subsidence (i.e. chimney subsidence) by analyzing pit subsidence over the historic Mine No. 44 by utilizing a roof stoping equation by Dyne, 1998 for a four-way equal width room intersection which is provided below.

$$z = 12/ (\pi (k-1) (d_{base}^2 + d_{surf}^2 + d_{base}d_{surf})) (\pi/12t (d_{base}^2 + D^2 + Dd_{base}) - ((D-w) /6 \tan \theta) (D^2 \arccos (w/D) = D^2/2 \sin (2\arccos (w/D)) - \pi D^2/4 + w^2))$$

The equation is based on the following variables:

- w = width of mine rooms (ft.)
- t = height of seam (ft.)
- k = bulking factor = V_B/V where V is the initial volume and V_B is the volume of rubble
- θ = angle of repose of caved rock within mine room
- d_{base} = diameter of collapse-chimney at base (ft.)
- d_{surf} = diameter of collapse-chimney at surface (ft.)
- D = diameter of caved rock foot print on mine room floor (ft.)

Ramaco “confirms” that with use of the above relationship that this relationship is representative of the observations of pit subsidence to a depth of 150 ft.[2] by assuming certain parameter values. Ramaco does not, however, use this same stoping relationship which was ‘confirmed’ based on historic pit subsidence to actually assess

[2] Using assumed parameter values by Ramaco, z calculates to 124 ft. and 145 ft. for chimney diameters/roof spans of 25 ft. and 20 ft., respectively.

the stoping potential of the proposed mining. It is only stated that the "proposed highwall mining opening widths of 11 to 11.5 ft. are significantly less than" the historic Mine No. 44 [MP-6-7]. When assuming the above chimney subsidence relationship, with intersecting entries were assumed at 11-11.5 ft., as proposed, and considering the same Ramaco assumed parameter values, z (or the stoping depth) becomes 219-227 ft. However, assuming a four-way equal room width intersection, as in the above stoping equation, does not represent any of the actual pit locations as indicated by the mine map.

Considering pit subsidence along entries without intersections, which is more representative of the underlying historic subsidence conditions, and assuming a repose angle of slaked claystone cavein of 20° and the other Ramaco assumptions, a bulk factor of 1.33 is calculated. Under the proposed mining conditions and considering this back-calculated bulking factor, the potential stoping height (or mine depth) becomes about 225 ft. Clearly, with the claystone overburden of limited reported resistant, durable beds, reported Carney thickness of 15-20 ft. (in lieu of the assumed thickness of 14 ft.), and greater mine depths experiencing pit subsidence reaching up to about 160 ft. (see Figures 7.1 to 7.5), there is a serious risk of surface subsidence from roof collapse in the proposed mining. Also, Ramaco does not address the proposed stacking of mine entries (i.e. pillar stacking) effect on the upward chimney propagation. Clearly the accumulated void height could produce greater exposure to land surface subsidence.

Although there is no substantial geotechnical exploration or testing or analyses that were, or could be performed - from our experience with the claystone roof and floor, the proposed mining can result in sag subsidence. Pillar failure can also result in sag subsidence. Calculations and assumptions made by Ramaco to demonstrate that short and long term failure from pillar crushing are not provided. Ramaco asserts that pillars with width to height ratios in excess of one are adequate without any substantial coal strength or clay parting data and further states that an approved MSHA-approved ground control will be obtained. This statement is "putting the cart before the horse" when this is a requirement of the subsidence control plan. Moreover, the ground control that is required by MSHA will likely not include mine stability analysis as highwall mining does not require miner ingress.

SUMMARY AND CONCLUSIONS

As requested by the Powder River Basin Resource Council, MEA has performed a subsidence engineering review of the proposed Brook Mine application submitted by Ramaco, LLC. This investigation primarily consisted of examination and evaluation of pertinent sections of the application to assess the subsidence potential of the proposed plan. The findings from this investigation are provided immediately below, however this report should be read in its entirety to obtain a complete understanding of its contents.

1. The proposed Brook Mine is located about 8.5 miles north of Sheridan, WY. The mine plans to mine primarily two sub-bituminous coal seams. These seams are the Carney and the underlying Masters. The Carney Seam is reported to split in

the western half of the application area into upper and lower beds. The clay parting between the upper and lower beds is said to reach more than 30 ft.

2. The coal will be extracted primarily by highwall mining methods. The highwalls will be created by strip mining slots or areas.

3. Based on the reported data, for the Carney, Masters, and other overlying seams, the mining depth is expected to range from near the surface to about 420 ft. with extraction heights that can range as low as 2.5 ft. and exceed 18 ft.

4. The vast majority of the associated coal measures are described as claystone with isolated interbeds of sandstone/siltstone. These coarser grained interbeds are laterally discontinuous but where present exist up to a thickness of 36 ft.

5. The proposed highwall mining is expected to result in 11-11.5 ft. wide parallel entries up to 2,000 ft. into the highwall face with panel extraction ratios of 60 to 70%. Given this range of extraction and mine depth, tributary pillar pressures up to close to 1,300 psi can be expected.

6. A detailed and advanced subsidence engineering analysis is required given the reported geologic and mining conditions. However, the mine subsidence potential investigation provided in the mine application is wholly inadequate and thus renders it impossible to perform an adequate peer review. Of most particular

concern is: 1. the lack of codified rock mass classifications, geologic structure, and geotechnical properties of the relevant coal measures; 2. essentially no short and long term mine stability analyses of all potential failure modes that can lead to surface subsidence; and 3. no appropriate examination of risk, severity, and types of potential subsidence.

7. Given the pervasive extent of claystone reported above, throughout, and below the proposed mining interval, there is serious concern for short and long term mine instability. There are a number of problematic conditions which are discussed above.

8. There is a massive amount of surface subsidence in the area at mine depths similar to that proposed. Based on the reported data, chimney subsidence analyses, and examination of historic air photos in the area, both sag and pit subsidence would be expected at the Brook Mine.

If you have any questions, please don't hesitate to contact me.

Sincerely,

Professional Engineer (Civil)
GENNARO G. MARINO
PE 12993
Date 11/23/17
WYOMING

Gennaro G. Marino, Ph.D., P.E., D.GE
President

Enclosures:

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