Report of Investigation of an Underground Mine Blowout near Delbarton, West Virginia and Possible More Widespread Ramifications

Photograph courtesy of the WVDEP

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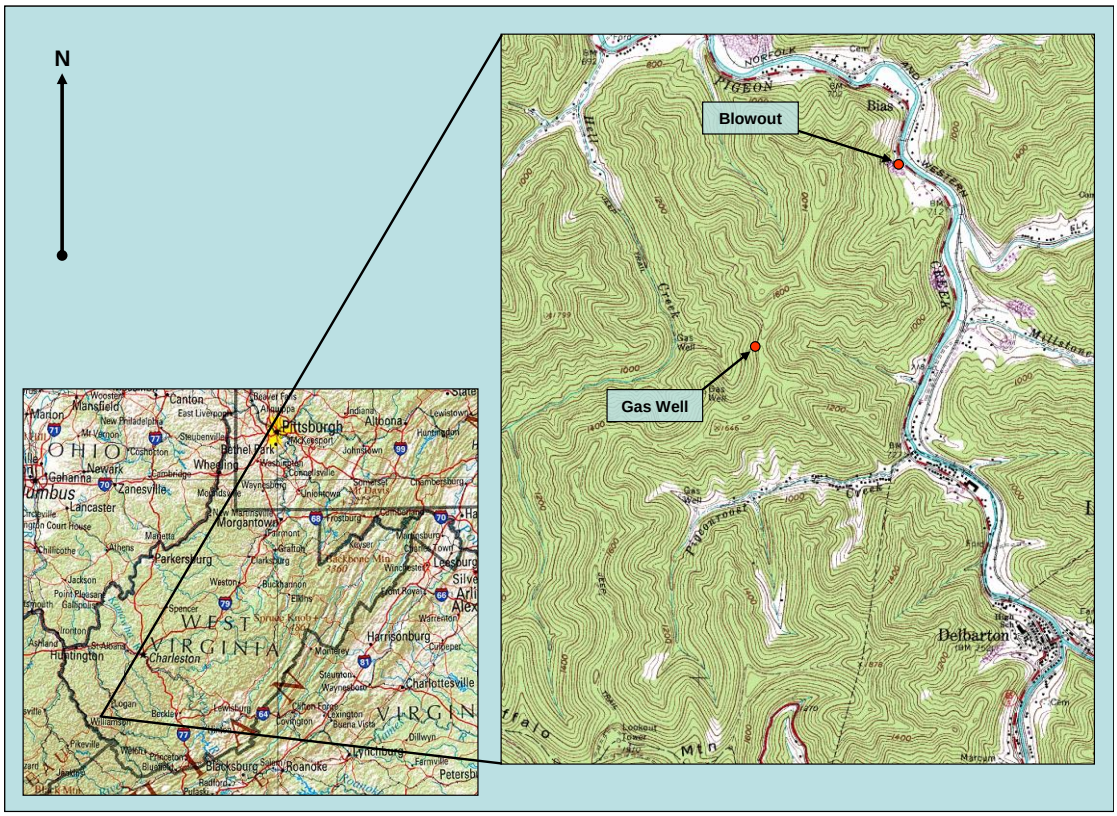
Introduction:
In the very early hours of February 12, 2008, there was a blowout from reclaimed mine portals behind the home of Geraldine Mahone, near the town of Delbarton, West Virginia (Map 1). The rapid-flowing, high-volume discharging water woke Mahone about 7:00 a.m. The mine water flowed chiefly from the northern-most portal directly behind the home with a lesser quantity emanating from the adjacent portal to the south (Photograph 1). The water ran down gradient beneath and around the Mahone dwelling and continued down slope to the highway below (Route 65). The high volume of water overwhelmed the drainage culverts along Route 65 and the subsequent flooding caused the road to be closed for a period of time (Photograph 2).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Photograph 1. The blowout behind the Mahone residence on February 12, 2008.

The WVDEP personnel, present during this period, related that they noticed that the mine water flow at the portal would cease when the circulation air flow at the drill rig was stopped and that a short time after the air was turned back on the mine would begin to overflow at a very high discharge rate. This relationship was observed several times. Since gas well was cased and grouted through the mine section with the void, no further large-scale mine water outflows have been reported.

On February 20, 2008, I was requested to provide technical assistance to the Office of Surface Mining (OSM) Charleston Field Office in terms of investigating this incident. A cooperative agreement was made between Roger Calhoun, Charleston Field Office Director, and Randy Huffman, WVDEP Cabinet Secretary, for a dual purpose investigation into the cause of this blowout specifically (Task 1), and in the larger picture, can these types of incidents be predicted and/or prevented (Task 2). The latter task is a charge that will look at the situation on both an interagency and interstate levels.

The Delbarton Blowout (Task 1)

Brief Hydrogeologic Background and Mining History:

The underground mining in the Upper Cedar Grove coal seam was conducted by Flex Enterprises Inc. The coal averages 34 inches in thickness and is underlain by a hard shale unit that was designated as “slate” in the permit application. The immediate roof rock is a “weak shale” stratum that is up to 8 inches thick. Above the immediate shale roof rock is

a more competent “blue shale” unit 12 feet thick with an overlying sandstone unit of undetermined thickness.

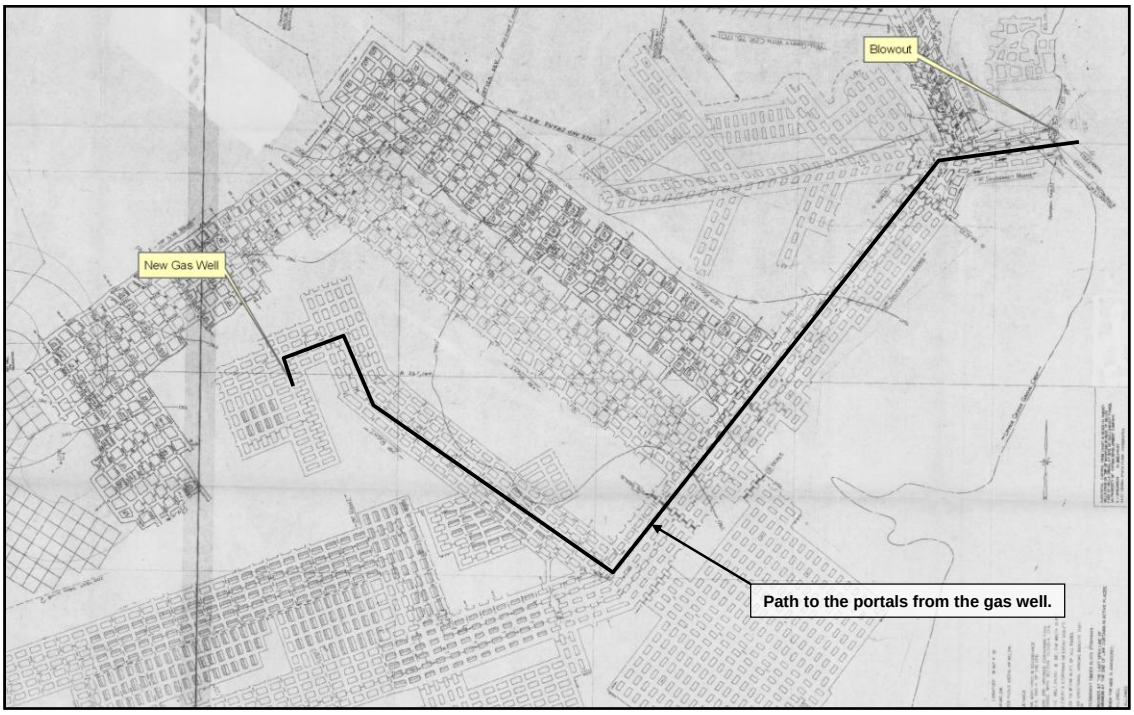
The dip of the strata across the site is relatively low (<1°). The slight dip is overall to the west-southwest from the portals. The low dip angle accentuates the many rolls and swales within the pit floor (see Figure 1, structure contour map). Based on the structure contours created from in-mine data, there appears to be a small localized fault that parallels the northeastern edge of the “4th Right” section. The abrupt change could also be caused by a sharp roll in the pit floor elevation but a fault with minor displacement appears likely. In addition to the possible fault, the strata in this area have considerable the stress-relief fracturing that is ubiquitous throughout much of the Appalachian Plateau.

Photograph 2. Flooding along Route 65 caused by the blowout.

Throughout much of this region, most ground-water movement through undisturbed strata is via the secondary permeability and porosity facilitated by fractures in the rock. Found mainly at shallow depths (generally less than 150 to 200 feet), these fractures were created in large part by stress-relief forces. Stress-relief forces are generated by rock mass removal from natural erosion processes. Stress-relief fractures tend to be vertical or near vertical along the hill sides paralleling the main valleys and horizontal bedding plane separations become common approaching the valley bottoms (Wyrick and Borchers, 1981). The frequency and aperture size of these fractures tend to decrease with increasing depth (Hawkins and others, 1996). The sedimentary rocks in this region are generally well cemented; thus, intergranular (primary) porosity and permeability of these well-

indurated rocks is for all intents and purposes nonexistent. The only prominent intergranular ground-water flow in the Appalachian Plateau occurs in unconsolidated alluvium and glacial deposits in the northern areas.

Tectonic activity has also created fractures and prominent fracture zones that greatly influence ground water movement. These fractures tend to be more oblique (subvertical) than stress-relief factures and generally extend to much greater depths. Photo lineaments, noted primarily through remote sensing means, often indicate the existence of long relatively-narrow, heavily-fractured zones which substantially facilitate ground-water movement. The fracture zones indicated by the lineaments are frequently expressed in the subsurface at mine level and associated with in-mine roof control problems and ground water inflow zones (Phillipson and Tyrna, 2002). The potential fault previously mentioned was created by these tectonic forces.



Map 2. Mine map

Brief Mining History

The underground mine in question was initially permitted by Adanac Coal Company, Inc. The permit to begin "surface mining" activities to prepare the portal area was issued on March 6, 1985. By January 1987, the permit to conduct underground mining had been transferred to Flex Enterprises Inc. Subsequent to the permit transfer, C.J. Mining, Inc. was brought in to conduct the actual mining on a contract basis.

Mining was completed no later than August, 16 1991. The sealing of the portals was completed by September 18, 1991. A letter of that date indicated that the "dirt seals" for the portals were completed to or exceeded regulatory requirements. This letter was accompanied by an engineering certification as to the portal seal construction. The post-

mining land use was listed as residential and by September 23, 1997, the date of the Phase III bond release, there were two residences on the site.

The total underground mine works encompasses 305 acres. Approximately 150 acres of the total acreage are voids created by coal extraction. If completely flooded to the portals, the mine has the potential to store 18.5 billion gallons. However, it is likely post-mining subsidence has greatly reduced the storage capacity of the mine. The second-mined areas shown on the final mine map indicate that some subsidence has likely occurred.

Analysis and Discussion

Discussions with personnel from New River Development Corporation (New River), the operator conducting the gas well drilling, on April 17, 2008, yielded some additional information about this incident. The New River people related that the driller noted that air circulation was lost between 4:00 and 4:30 a.m. on Tuesday February 12, 2008. The rig operator pulled back one or two steels and circulation returned. He then proceeded to start drilling again and the air circulation was nearly completely lost a second time. At that point, a tri-cone bit was installed and drilling commenced again.

New River personnel stated that at the time, based on their original map, they believed that they were not over top the mine. They stated that they subsequently found a revised map that did show that they had intersected the mine. They further contended that: 1) the portals are lower in elevation than the point that they drilled into the mine; thus, the mine could not be filled with water and 2) the 350 pounds per square inch (p.s.i.) pressure exerted by the rig was not strong enough to push the water out of the mine.

The morning of February 12th, personnel from the WVDEP arrived at the drilling site. As related above, the WVDEP personnel noted that whenever the circulation air was turned on the mine would flow, and once the air was shut off the outflow would stop. This cause-and-effect relationship was noted several times in the course of the day. John Flesher of the WVDEP noted that the "tool pusher" on the rig at the time of the incident observed that the mine water was approximately 4 feet above the mine roof (void space). Flesher also noted that the map he observed at the drill rig on the day of the blowout did show the mine workings in question.

A final mine map dated July 31, 1991, was obtained from the West Virginia, Office of Miners' Health & Safety Training. This map was subsequently georeferenced with respect to the 7.5 minute topographic quadrangle map. The location of the gas well was plotted on the georeferenced map based on the coordinates given in the permit for the gas well. The exact well location was confirmed by taking an on-site measurement with a handheld GPS unit. The mapping shows that the gas well intersected the mine workings of the "2nd Right" section farthest inby the portal of the 2nd Southwest Mains.

The exact pit floor elevation at the point the gas well intersected the mine is not noted on the mine maps. However, extrapolation from structure contours created from elevations given for other parts of the mine, indicate the pit floor elevation at the gas well is between 735' and 740' above mean sea level (a.m.s.l.) (Figure 1). The elevation of the pit floor at

the portal area is between 770’ and 774’ a.m.s.l. These data indicate that the maximum head pressure in the mine created by the mine water at the gas well location is about 39’ or 16.7 p.s.i. If, as the tool pusher stated, the water was 4 feet above the mine roof at the gas well, then the water pressure there would have been about 3.0 p.s.i. (4 feet above the coal plus the coal thickness of 34 inches).

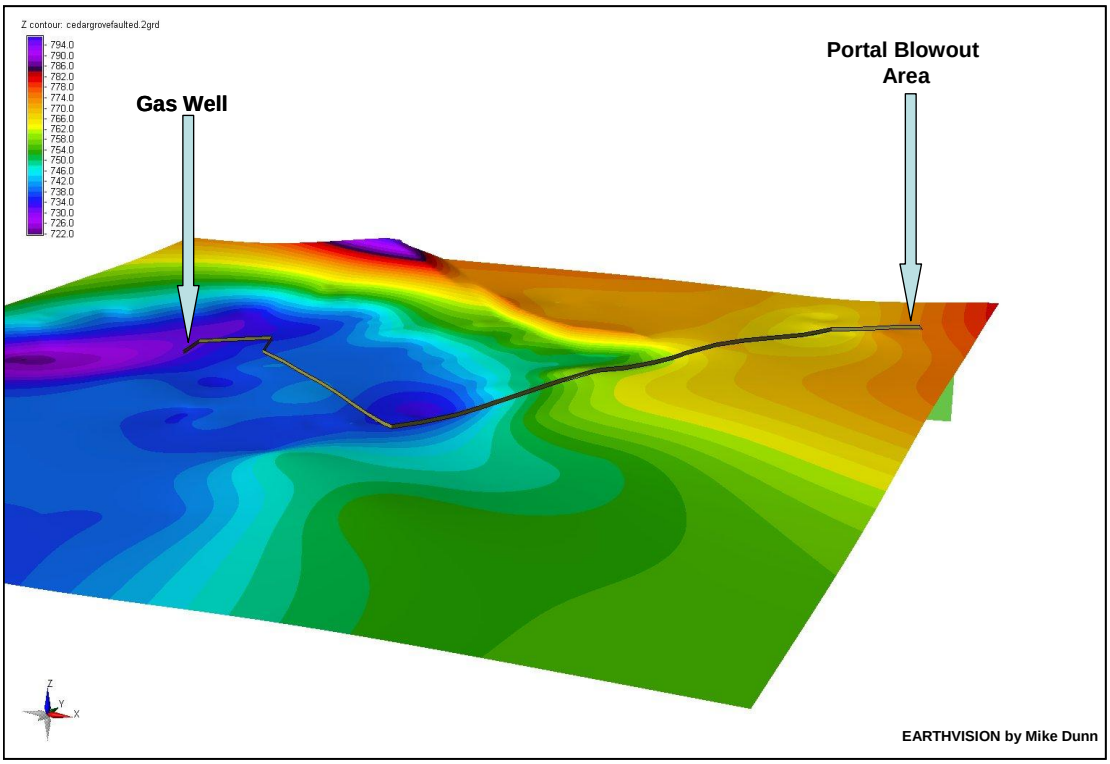


Figure 1. Structure contour map of the bottom of the coal and in-mine pathway from the gas well to the portal.

At the time the drilling intersected the mine, New River was using a 12 3/8^{ths} inch air hammer bit attached to a 4-inch drill stem. They were using an air pressure of 350 p.s.i. at a flow rate of 1,170 cubic feet per minute (cfm). Given a potential maximum head pressure of 16.7 p.s.i., even if a substantial portion of the air pressure was relieved by flowing back up the drill hole, the mine could be, and was, sufficiently pressurized to force the water from the flooded mine to the portals. As stated previously, New River rig personnel indicated that the circulation air was totally lost at first and then on the second try they had just a small amount of return air. This indicates that most of the air pressure was entering the mine workings, pressurizing them and forcing the water out via the path of least resistance. In this instance, the path of least resistance is the portal area. The flow path and elevation differences are shown on Figure 1. Map 2 illustrates the flow path with respect to the mine workings.

The mine permit file included schematic drawings of the plans to seal the portals after mining was completed. Figures 2 and 3 are redrawn facsimiles of the cross sectional, front and plan views of the internal seal and closure configuration as submitted for the

permit application. The surficial area around the portals was to be graded to closely resemble the pre-mining slope configuration.

Inside the mine workings, a 16-inch thick "solid cinderblock" wall seal was to be installed. The block wall seal was to be keyed into the roof, floor and ribs to create a permanent seal. The blocks were to be solid with a coating of an acid and waterproof material. The portal closure plans also called for a pipe with an air trap be installed along the pit floor to allow for drainage from the mine. The pipe would pass through the block

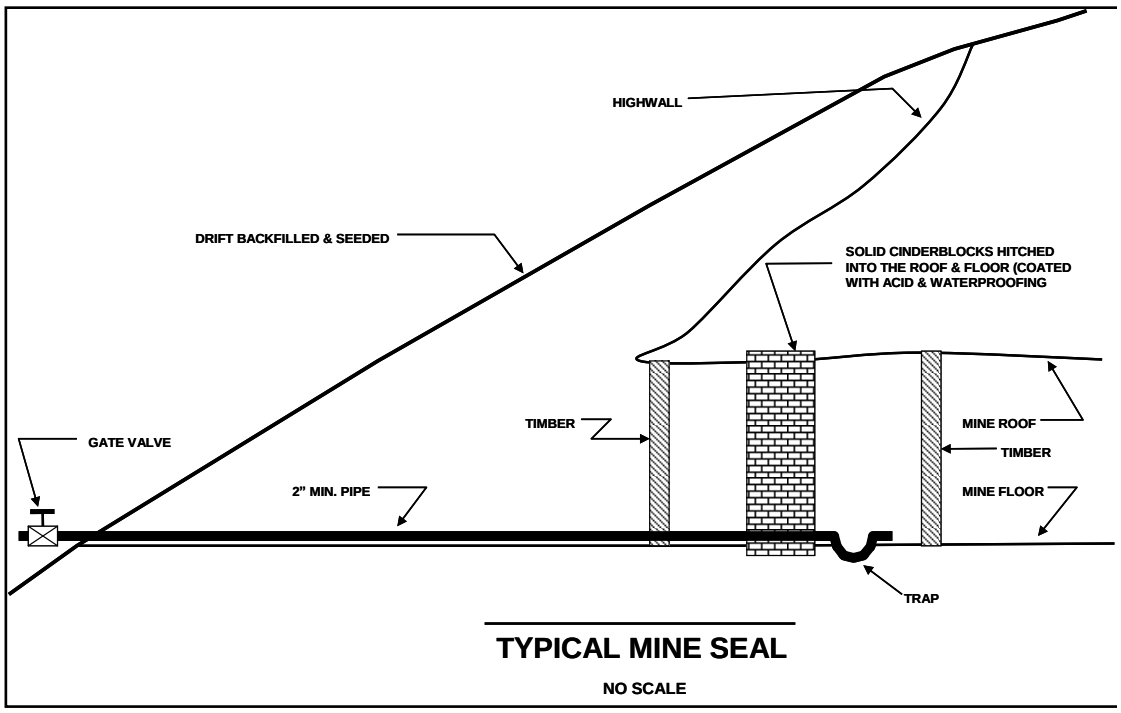


Figure 2. Facsimile of the proposed mine sealing plans (cross section view).

seal exiting the mine. The cross section schematic indicated that the pipe was to be no less than 2 inches in diameter. On the other hand, the "Front View" shows a 6-inch pipe was to be installed.

Additional internal seals were planned to be constructed in at least two of the three main sections. Seals were supposed to be installed in 2nd Southwest Mains about 700' inby the portals (Map 3). A second set of seals were to be constructed in the 1st Southwest Mains roughly 750' inby the portals. The 1st Northwest Mains show "proposed emergency" seals no more than 240' inby the portals. There was also a final set of seals "proposed" to be installed at the portals (1st Southwest Mains) approximately 20' inby the face.

Based on visual inspection of the portals and the high-volume discharge that occurred on February 12, 2008, it appears that the final configuration of the portal area and seals differs substantially from the schematic drawings and final map. The following observations and information are strongly indicative of the changes from the "as proposed" originally to the "as built."

1. Period photographs during the final mine sealing and the present surface configuration indicate that soil and rock were pushed up against the portals to a lesser degree than originally planned (Photographs 3 and 4). This may be due the surface owner's plan to place dwellings on the site. Therefore, a bench area was left in place, thus less material was available to reclaim the portals closer to pre-mining conditions.

2. It appears that a black plastic pipe (2.75" internal diameter) was installed into the northern most portal. However, there is also a galvanized corrugated 9-inch pipe that appears to be connected to the mine works at the north portal. This corrugated pipe was flowing less than 1 gpm on April 17, 2008. The photographs and short videos of the site taken on the day of the blowout showed this pipe flowing at a much higher level. It is alleged that one of the dwellings septic systems is also plumbed into this pipe. The remaining two portals do not appear to have had pipes installed. The resident stated that she had not seen any other pipes below the portals. No visual evidence of other pipes was observed during the field examination April 17, 2008.

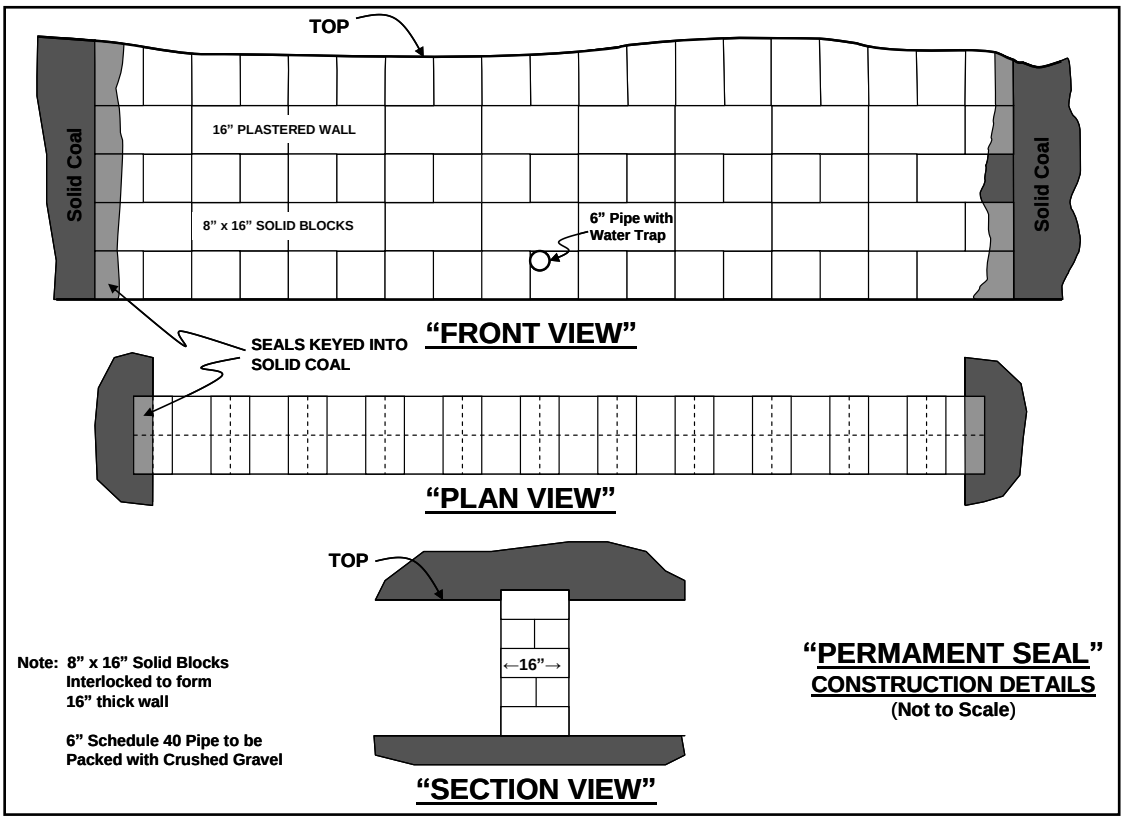
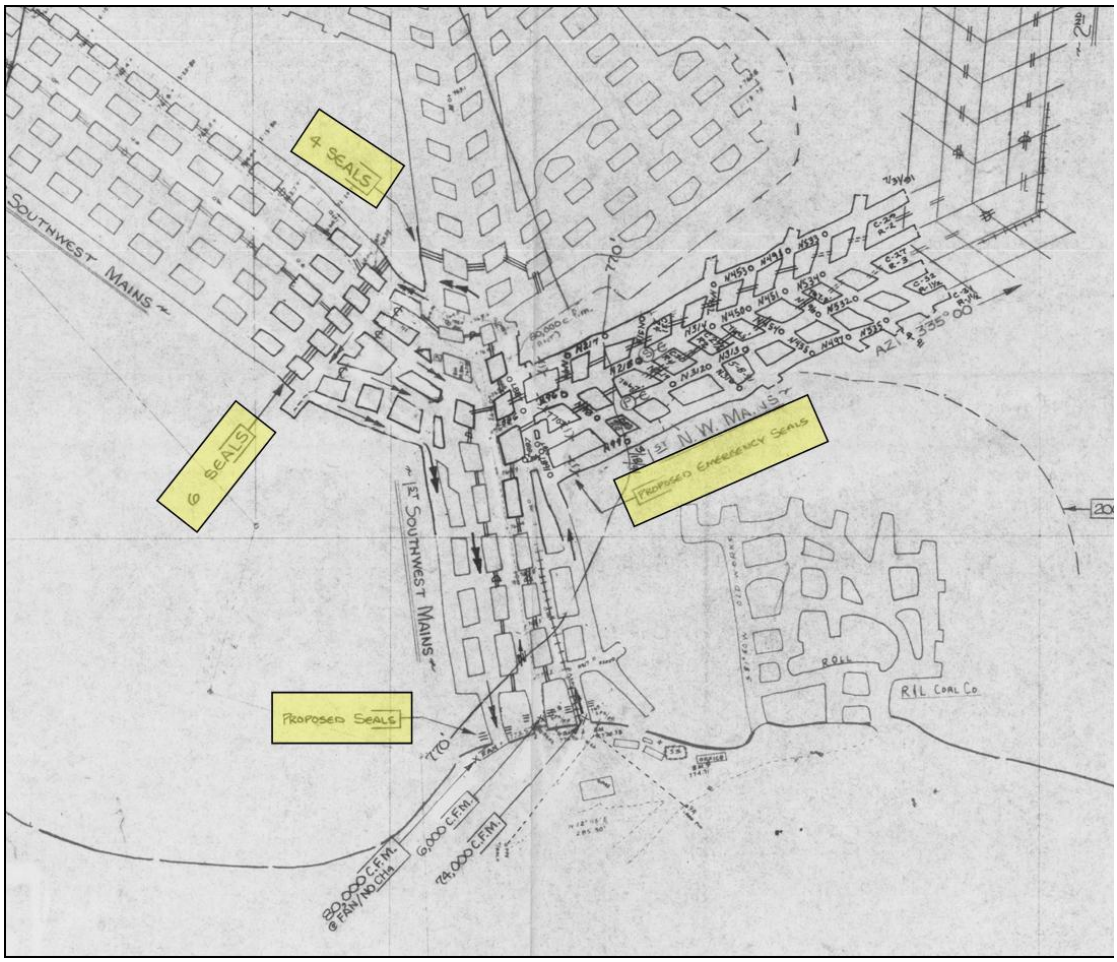


Figure 3. Facsimile of the proposed mine sealing plans (multiple views).

3. The high volume of water that emanated from the northern two mine portals during the blowout incident are strong evidence that at the present time there are no intact mine seals between the point at which the drill rig intersected the mine and the portals. These seals were either not built as originally proposed, the closure plans changed substantially subsequent to the permit issuance or they failed to be installed at all. It is possible that the seals were built and installed as designed but have been

breached due to crushing brought on by post-mining subsidence or the aforementioned hydraulic pressures created by the gas well drilling.

In discussions with Mrs. Geraldine Mahone, she indicated that a minor blowout had occurred from the “east side” in September 2004, as best as she could remember. This time period roughly coincides with the drilling of two other gas wells (API # 5901663 and 5901664). Based on the mine map, it appears that these two wells did not directly intersect the mine but were relatively close. It is possible that one of these two gas wells was hydrologically and/or, in this case, pneumatically connected to the mine via transmissive fractures which are common in this area. Additional, information and analysis are needed to show this connection.



Map 3. Map of seal locations near portals.

A previous investigation of water emanating from the mine portals and causing flooding around Geraldine Mahone’s home and in her yard was conducted by Jason Swann of the WVDEP. On December 28, 2005, Mahone complained of the some flooding from the portals overflowing. At that time, she indicated to Swann that there had been previous incidents of unchecked water discharging from the portals. Mahone further noted that the flow rate from a “12 inch” metal discharge pipe, which was damaged when the driveway

was installed and later by the electric utility company, increases in response to precipitation.

This earlier investigation by WVDEP personnel illustrates that the February 12, 2008 incident was not isolated. It appears that the mine has overflowed to a lesser degree in the past, and the some of the previous incidents may have been related to antecedent precipitation. In the four days prior to the December 28, 2005 complaint, there was between 0.8 and 0.9 inches of precipitation. This much precipitation by itself is not a large amount but given the time of the year, when evapotranspiration is near its lowest point during the year, the volume may have been enough to trigger a minor overflow event. Additionally, the damage to the portal discharge pipe, thus constricting its ability to keep the mine sufficiently drained, has further exacerbated the problem. This pipe was

Photograph 3. Present condition of the northern-most portal.

discharging about 1 gpm the day of my site visit but was partially filled with 2-B gravel. The gravel greatly reduces the drainpipe's efficacy.

The blowout of February 12, 2008 was clearly not related to the preceding precipitation, nor would it have been prevented if the discharge pipe was functioning properly. The extremely high flow rates observed and the clear relationship to the drilling activities illustrate the true cause of this latest flooding.

In the course of this investigation, other potential causes of the February 12, 2008 blowout incident were explored. Other possible causes include, abnormally high

precipitation preceding the blowout or a catastrophic subsidence event that captured an overlying stream. The latter possibility was dispelled by the WVDEP in their field examination of the streams and the fact that the flow ceased once the gas well section through the coal was cased and grouted.

Higher than normal precipitation could cause a mine blowout by increasing the mine recharge rate above the capacity of the drainage system. The precipitation data for nearby Williamson, WV prior to the February 12, 2008 blowout indicate that the area was under relatively normal conditions. January had a total of 3.51 inches of precipitation while the average is approximately 3.57 inches. The total precipitation for February was 3.27 inches, which is well within the normal range about the mean of 3.22 inches. The preceding four days prior to the event there was no precipitation except for a trace of precipitation on the fourth day. Five days prior to the blowout, on February 7th, there was 0.51 inches of rain. In short, there is no indication that abnormally high antecedent precipitation caused the blowout. However, the Palmer Drought Severity Index indicated that in the long term, precipitation for the area was slightly above normal during this

Photograph 4. Present condition of the first portal south of the northern-most portal.

period (Palmer, 1965; Heddinghaus and Sabol, 1991).

Conclusions for the Delbarton Blowout Investigation

The information and data gathered to date, indicate that during the drilling of the gas well (API Well # 47-5901826) mine workings of the abandoned underground mine, formerly

permitted to Flex Enterprises, Inc. (State Id. #U-16-85), were intersected in Section 2nd Right off of the 2nd Southwest Mains.

Underground mines, at depth, commonly behave hydrologically as a confined aquifer systems (Hawkins and Dunn, 2007). These confined aquifer systems are created by extremely high transmissive open mine voids that are overlain and underlain by much less transmissive or confining units. Once the drilling entered the mine void, the bulk of the circulation air pressurized the mine. This pressure built up within the mine to a point that the water was forced toward the surface. With an air flow of 1170 cfm at a pressure of 350 p.s.i., it would not take long for the hydrostatic pressure at the point the mine was intersected (maximum ~16.7 p.s.i.) to be exceeded and the mine water to be pushed out. The portals, without intact seals and only loose soil and rock pushed against them, provided the egress path of least resistance. Therefore, given the aforementioned circumstances, it would be expected for the blowout to occur and specifically to be expressed at the portals.

The information and data collected in the course of this investigation have eliminated abnormally high precipitation or stream capture as possible causes for the blowout on February 12, 2008.

Photograph 5. Photos facing the portal area with the black plastic pipe and corrugated metal pipe in the foreground, respectively.

Even if the in-mine and portal area seals were installed as originally proposed, it is doubtful that they would have held up to the pressures exerted by the gas well drilling. If all 350 p.s.i. was pushing against a seal that was 34” high and 16’ wide (estimate), the total pressure would exceed 1100 tons. Additionally, the entry adjacent to the northern-

most portal that was mined close to the coal outcrop (Map 3) would have likely failed under the pressure as well. The coal and rock close to the outcrop tend to be highly fractured and weathered, thus quite weak.

Overall Assessment of the Interaction of Oil and Gas Well Drilling with Active and Abandoned Underground Mines (Task 2)

The permitting process for oil and gas wells (well work permit) requires that the applicant check the immediate area for active underground mines in coal seams that will be intersected during drilling. If an active mine exists, the "coal operator, owner, or lessee" must be notified of the proposed well, and are given the opportunity to object. A map of the active mines is not required for the permit application. The application must note the presence or absence of active mining on form WW-2B. Once a permit is issued, there appears, at present, to be no programmatic mechanism by which information concerning the site location and depth of the permitted drill hole, such as a map showing the drilling location or coordinates for the drill hole, is forwarded from the Office of Oil and Gas to the Division of Mining and Reclamation.

Programmatically, the well work permit need not reflect the existence of the abandoned mines. Based on discussions with WVDEP Office of Oil and Gas personnel, many gas drilling operators attempt to determine if there are abandoned underground mines that may be intersected. It is in their best interest to do so from, at the very least, the sake of safety and to preclude complications during well installation. Information and maps of the presence, location and configuration of abandoned underground mines with respect to the proposed well will dictate well completion procedures. The specifics of casing off and grouting the mined sections should be known ahead of time to minimize drilling and completion costs.

The Office of Miners' Health, Safety & Training (Miners' Health & Safety) maintains copies of maps for active and completed underground mines. Individuals and entities, such as oil and gas drillers, contact Miners' Health & Safety to determine if active mining is occurring on the seams to be drilled through. When needed, copies of mine maps can be obtained from Miners' Health & Safety.

The fact that oil and gas drilling operators are not statutorily or programmatically required to determine the proximity of abandoned underground mines is potentially problematic. The Delbarton blowout illustrates the reality of well drilling intersecting and pressurizing an abandoned mine full of water; thus potentially causing a catastrophic event. Only vigilance, based mainly on internal company concerns, can incidents like the Delbarton blowout be averted.

Not all underground mines are inundated. Abandoned mines with no standing water or partially flooded could contain buildups of methane (CH_4) and other hazardous gases. The same pressurization mechanism that pushed the mine water out of the Flex Enterprises, Inc. mine near Delbarton, could force fugitive methane to the surface at or above explosive levels. Methane (density of 8, unitless), being lighter than air (density of 14.48), would be pushed toward the surface first. A substantial amount of methane

entering an occupied dwelling or other structure is a recipe for disaster. If the fugitive methane level is within the explosive limits (5 and 15%), only an ignition source is needed for an explosion. A methane concentration above 15% is easily diluted down to explosive levels.

Other potentially noxious gases common to mines, such as carbon monoxide (CO), carbon dioxide (CO_2) and hydrogen sulfide (SO_4) can build up to dangerous levels in unflooded portions of underground mines. The injection of high volumes of air under pressure can cause these gases to also be problematic. Carbon monoxide and carbon dioxide are not explosive but they can displace oxygen. Low oxygen levels are life threatening. At 16% oxygen, a person's breathing and pulse rate increase. Fatigue and impaired judgment occur as oxygen levels drop to 14%. Nausea, vomiting and permanent heart damage are associated with oxygen levels of 12.5%. Death occurs when the oxygen concentration drops to 10%. Hydrogen sulfide is toxic, corrosive and explosive. A concentration of 0.015% can cause loss of smell in humans due to an overwhelming of the olfactory nerve. Exposures of 0.05 to 0.08% normally cause death. At 0.1% hydrogen sulfide, a single breath can cause a person to lapse into an immediate comma. Hydrogen sulfide is explosive at levels between 4.3 and 46%.

Conclusions

Based on discussions with personnel from the Office of Oil and Gas, Division of Mining and Reclamation and the Office of Miners' Heath Safety and Training, it is clear that there has been little official communication in the past between these agencies related to the potential intersection of underground mines by drilling operations. This lack of communication is not unique to these agencies or to West Virginia. In fact, it has been my experience that this situation is common and nearly ubiquitous in other States, and is especially common within the Federal Government.

It is recommended that a systematic way of cross communication between agencies involved with mining and oil and gas drilling be initiated. Continued lapses in communication and crosschecking of well drilling with respect to abandoned underground mines leave the potential for catastrophic events like the Delbarton blowout and perhaps fatalities in the future.

An interagency meeting with OSM, the Office of Oil and Gas and Division of Mining and Reclamation was held on this subject on July 16, 2008 in Kanawha City. During this meeting, it was made clear that both Office of Oil and Gas and the Division of Mining have already begun to take steps to remedy this lack of communication. The problems created by the Delbarton blowout are a driving force for these changes. Effective use of geographic information systems (GIS) and other computer-aided means to disseminate information are being discussed and developed.

Recommendations

1. When a new application for an oil or gas well is submitted to the Office of Oil and Gas, a copy of the topographic map showing the well location or, perhaps better, the coordinates (e.g., latitude and longitude) should be forwarded to both the Office of

Miners' Health Safety and Training and the Division of Mining and Reclamation. One of these latter two agencies should take up the task of determining if the drilling will have an impact on an abandoned underground mine. This hazard potential determination and assessment with regard to abandoned mines is in addition to the drilling company's responsibility concerning active mines. Additionally, either the Office of Miners' Health Safety and Training or the Division of Mining and Reclamation should verify drilling company's information as to the location of a well with respect to active mining on intersected seams.

2. If the proposed well will intersect or is in close enough proximity to potentially impact an abandoned underground mine, a set standard of drilling procedures need to be established that should forestall any problems experienced at the surface. A scientifically-based definition of "close proximity" will need to be defined. Perhaps a starting point for close proximity could be 200 feet. At a minimum, the effect of pressurizing the mine from the drilling needs to be evaluated in terms ramifications of forcing water to the surface as a blowout and/or forcing methane or other gases out where they could possibly migrate into domestic water wells, homes and other structures.
3. It is recommended that the Office of Oil and Gas clarify their set of standard procedures for drillers that will encounter underground mine works. Drillers should be systematically trained on these standard procedures and institute them immediately once mine workings are intersected.
4. There also should be a standard set of procedures established for drillers to be instituted immediately after they lose their air circulation and/or encounter mine voids in areas where minable coal seams exist but there is no known mining. Drill rig operators should be trained on recognizing when old mine works are drilled into and what procedures to follow when this happens. Suggested standard procedures might include: shutting down the rig until it is determined that no harm will be caused by pressurizing the mine, the mine works are cased and grouted off within a predetermined depth below the mine works to preclude pressurization and notification of Office of Miners' Health Safety and Training and the Division of Mining and Reclamation as they presently notify the Office of Oil and Gas.
5. In addition to West Virginia, interagency notification of a potential oil or gas well, where oil and gas wells are located near State boundaries, the appropriate agencies in the adjacent State should likewise be sent the pertinent information. Underground mines are not necessarily constrained to political boundaries. A mine permitted in one State may cross into another without the second State having all the essential information. This interstate notification should be triggered automatically if a well falls within a set distance from the State line. Perhaps any wells within 1 mile of the State boundary would elicit interstate notification.

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