REPORT
OF
POTENTIAL EFFECTS OF SURFACE MINE BLASTS UPON BAT HIBERNACULUM

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ABSTRACT

Issues arising in 2006, with respect to effects of surface mine blasting on the underground habitat for the endangered Indiana (Myotis sodalis) and Virginia big-eared (Corynorhinus townsendii virginianus) bats sparked debate between federal and state regulatory authorities and the private industry. Because of the concerns of the National Park Service (NPS) and the Fish and Wildlife Service (FWS), seismographs were installed at two abandoned mine portals in the New River Gorge National River Park where the bats have been observed and to ensure that agreed blasting vibrations were not exceeded.

Seismographs were also placed on the mine-site to record blasting impulses that would be analyzed for ground vibration decay rates over horizontal distances. The roofs in the abandoned mines were not monitored for blasting vibrations due to the portals being gated by the NPS for safety. At an active underground mine in southern West Virginia additional research was conducted. Seismograph geophones were bolted to the mine roof of this active underground mine with surface geophones places directly overhead.

Blast and seismic data as related to bat survey data is very limited. There is little data available to compare the relationship of blasting vibration levels and the impact on bat populations. This study is being conducted to provide data and findings that can be used to predict the effects of blasting on any existing endangered bat populations.

INTRODUCTION

Comments were made on a surface mine permit application by the NPS and FWS, both federal agencies, to the coal mine permittee in mid-2005, concerning proposed surface mining near old underground mine workings that potentially harbored endangered Indiana and Virginia big-eared bats. This proposed mining would be conducted on property adjacent to the New River Gorge National River Park, where the abandoned mine portals are located.

The four main concerns of the NPS and FWS with regards to the proposed surface mine blasting are as follows;

1) Potential damage to the mine portal used by Indiana bats (November 15 to March 31) and Virginia big-eared bats (year round).
2) Potential for substantial collapses within the abandoned Fire Creek coal mine workings from surface blasting that potentially could destroy roosting habitat for the endangered bat species.
3) Concerns of partial collapses of the mine workings that could make the mines unsuitable for bat habitat due to changes in airflow patterns and/or internal temperatures.
4) Concerns that hibernating bats would be disturbed by blasting vibrations, that could result in loss of energy stores and starvation.

In response to these concerns, West Virginia Department of Environmental Protection (WVDEP), Office of Explosives and Blasting (OEB) agreed to monitor blasting compliance at the nearest gated portals.

NPS and FWS comments brought to attention the following issues that needed to be investigated:

1) Determine the maximum blasting vibration levels to be allowed at the Fire Creek coal mine portals;
2) Establish those levels within the mine necessary to maintain roof integrity;
3) Determine the distance the bats travel underground to hibernate or roost;
4) Quantify the maximum blasting vibration levels that would not disturb hibernating bats in the winter months; and
5) Quantify the relationship between surface and underground seismic responses from surface blasting.

Consultations between the NPS, FWS, the coal mine permitee, and Office of Surface Mining (OSM) resulted in an agreed vibration limit of 0.30 inches per second (ips) that should not be exceeded at the abandoned mine portals. Given that the underground Fire Creek seam was not accessible, the permitee's blast design was based upon the use of the scaled distance formula. Scaled distance is defined as $D / W^{0.50}$ where D equals the distance from the blast to a protected structure and W equals the maximum pounds per delay initiated on the blast. In this case, the protected structure was considered the abandoned coal mine roof located approximately 455 feet below active mining.

Regulatory scaled distance factors and maximum peak particle velocities allowed at a structure for protection and prevention of plaster cracking in houses from blasting are defined below:

DISTANCE FROM BLAST TO PROTECTED STRUCTURE	MINIMUM SCALED DISTANCE REQUIRED	MAXIMUM PEAK PARTICLE VELOCITY (PPV)
0' – 300'	50	1.25 ips
301' – 5,000'	**55**	**1.00 ips**
5,001'+	65	0.75 ips

For example, a particular blast that is 550 feet above the abandoned coal mine roof could not exceed a maximum of 100 pounds per delay ($W = (550 / 55)^2$). Since existing data on blasting vibration levels indicate 1.00 ips will more than adequately maintain roof integrity, this very conservative approach was agreed to by OEB, NPS, FWS, and OSM to implement the scaled distance formula to minimize vibration effects on the abandoned underground mine works.

A 2005 report titled, "Bat – Swarming Inventory at Abandoned Mine Portals at New River Gorge National River, West Virginia", states,

> "Neither spring emergence, nor fall swarm surveys, will absolutely confirm presence of hibernating bats in NERI [New River Gorge Area] mines. Conducting internal surveys is the only method that can reliably assess hibernating bat communities. However, that is very dangerous and should only be attempted by qualified personnel aware of the risks to life and limb."[1]

This same study includes bat survey data stating that 2,346 bats were captured from 19 mine portal entries including the Virginia big-eared and Indiana bats. It is assumed, for the sake of this report, bats do use the abandoned mines in the New River Gorge National River Park as hibernacula.

Using hibernating information obtained from published and unpublished research, the New River Gorge Park study conducted by OEB focuses on the predicted blasting vibrations on potential underground bat hibernacula. Previous studies measured vibrations of approaching blasting at other cave openings where bats were found. OEB research compared blasting impacts to the roof of the abandoned underground coal mine, and vibration levels that would not cause adverse effects on endangered bats during their hibernation periods.

FIELD DATA COLLECTION SITES

Abandoned coalmine portals 2D and 2A are located in Fayette County, West Virginia, where the Fire Creek seam was mined in the 1940's. These portal sites were used as data collection points for vibration and temperature monitoring. The Fire Creek seam lies approximately 455 feet below the Sewell coal seam that is currently being mined. Figure 1 shows the plan view of the permitted area with respect to the portal openings.

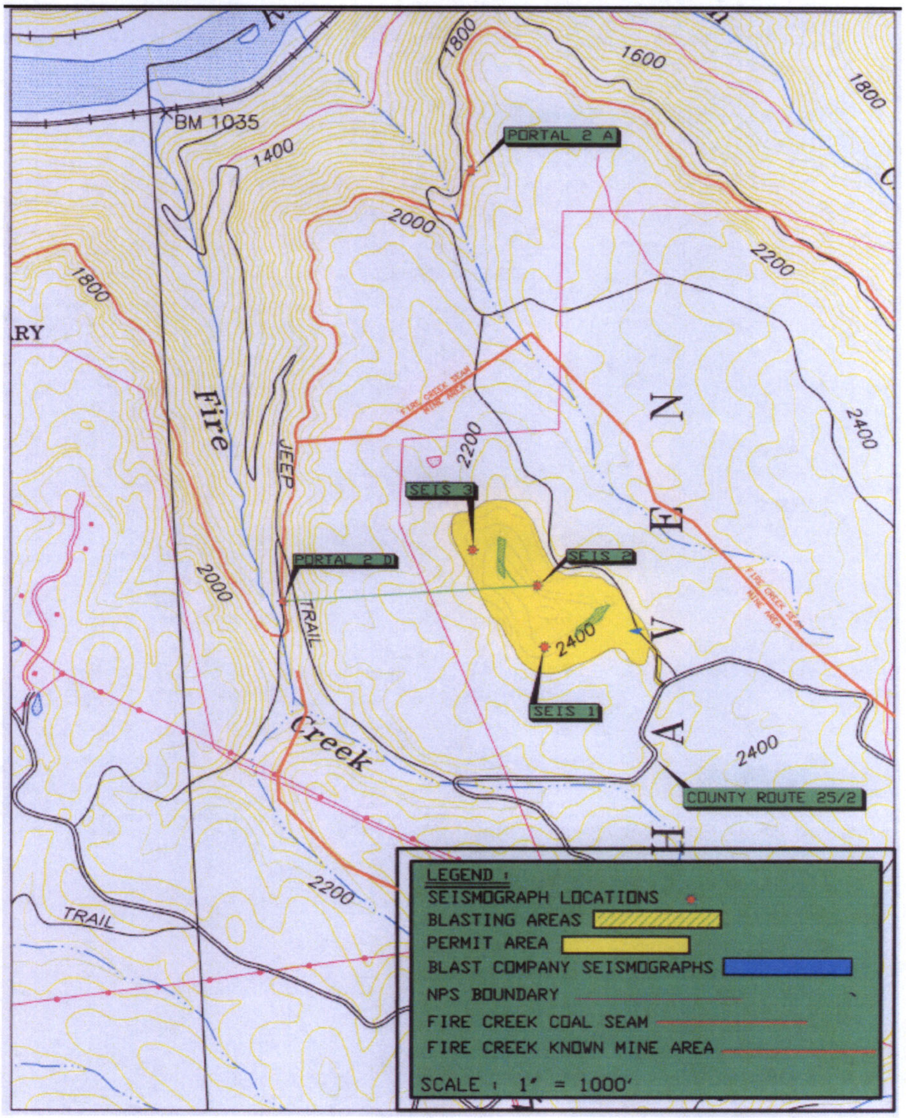
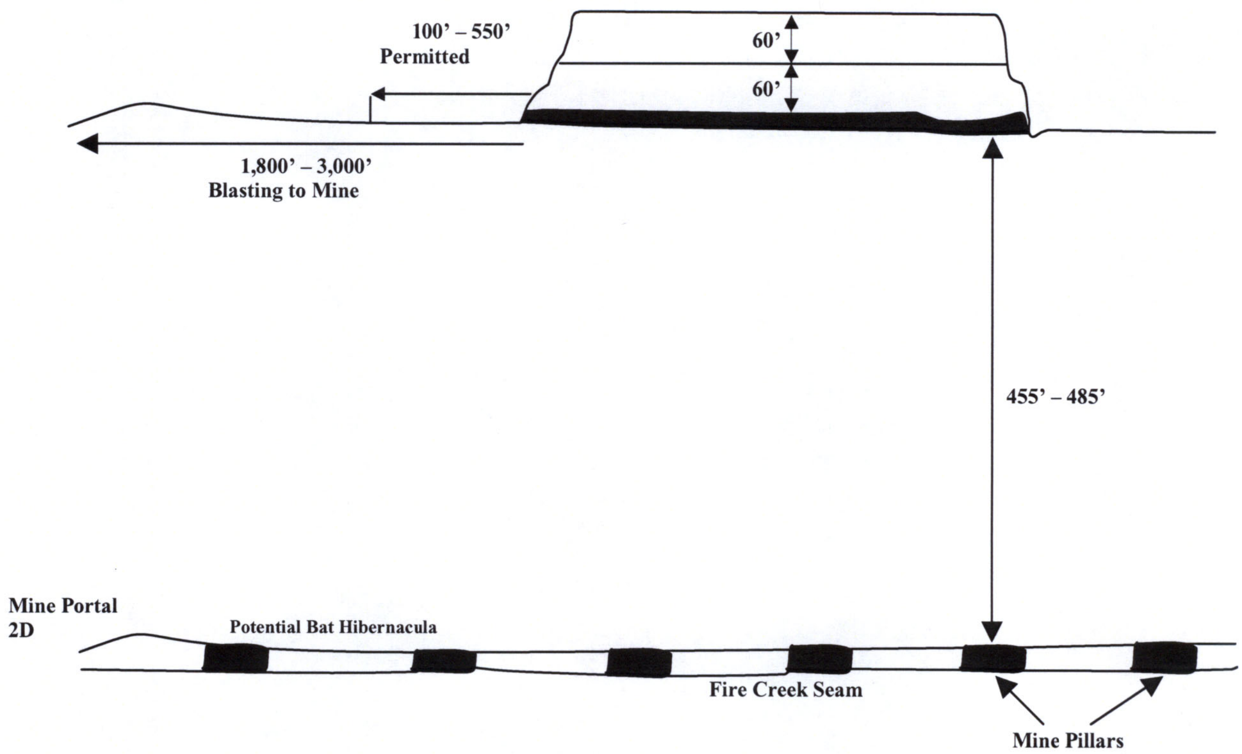


Figure 1

Figure 2 represents the vertical relationship between the permitted area and the abandoned mine works in the Fire Creek seam.



Not To Scale

Figure 2

Geologic strata between the Sewell "B" seam (proposed to be surface mined) and the bat hibernacula (Fire Creek seam) as described by the West Virginia Geological Survey[2] are as follows:

MATERIAL	THICKNESS (FEET)	TOTAL FEET
Coal, Sewell "B"	0 - 5	2,540
Shale	10 - 24	2,564
Coal, Sewell "A"	0 - 1	2,565
Sandstone, Lower Guyandot	0 - 50	2,615
Shale, Hartridge	0 - 5	2,620
Coal, Sewell	0 - 10	2,630
Shale	0 - 5	2,635
Sandstone, Welch	0 - 50	2,685
Shale	0 - 5	2,690
Coal, Welch	0 - 5	2,695
Shale	0 - 5	2,700
Sandstone, Upper Raleigh	50 - 75	2,775
Coal, Little Raleigh "A"	0 - 3	2,778
Shale	0 - 25	2,803

MATERIAL	THICKNESS (FEET)	TOTAL FEET
Coal, Little Raleigh	4 - 2	2,805
Shale	15 - 5	2,810
Sandstone, Lower Raleigh	100 - 50	2,860
Coal, Beckley "Rider"	0 - 2	2,862
Shale	0 - 17	2,879
Coal, Beckley	0 - 10	2,889
Sandstone, Quinnimont	0 - 66	2,955
Shale, Quinnimont	0 - 35	2,990
Coal, Fire Creek, "Quinnimont"	0 - 5	2,995

This table indicates 22 various stratigraphic layers between the Sewell "B" coal seam and the bat hibernacula in the abandoned Fire Creek seam. It includes nine layers of shale (126 feet thick), five layers of sandstone (291 feet thick), and eight layers of coal (33 feet thick).

Figure 3 depicts the bat gates installed to protect bat roosting and hibernacula in portal 2D.

Figure 3

Due to the inability to gain access to the abandoned mine roof of the bat hibernacula, seismograph geophones were bolted to the mine portal roof, or rib, outside the bat gates of portal 2D and 2A to monitor for compliance.

Figure 4 – Geophone Bolted to Roof of Portal 2A

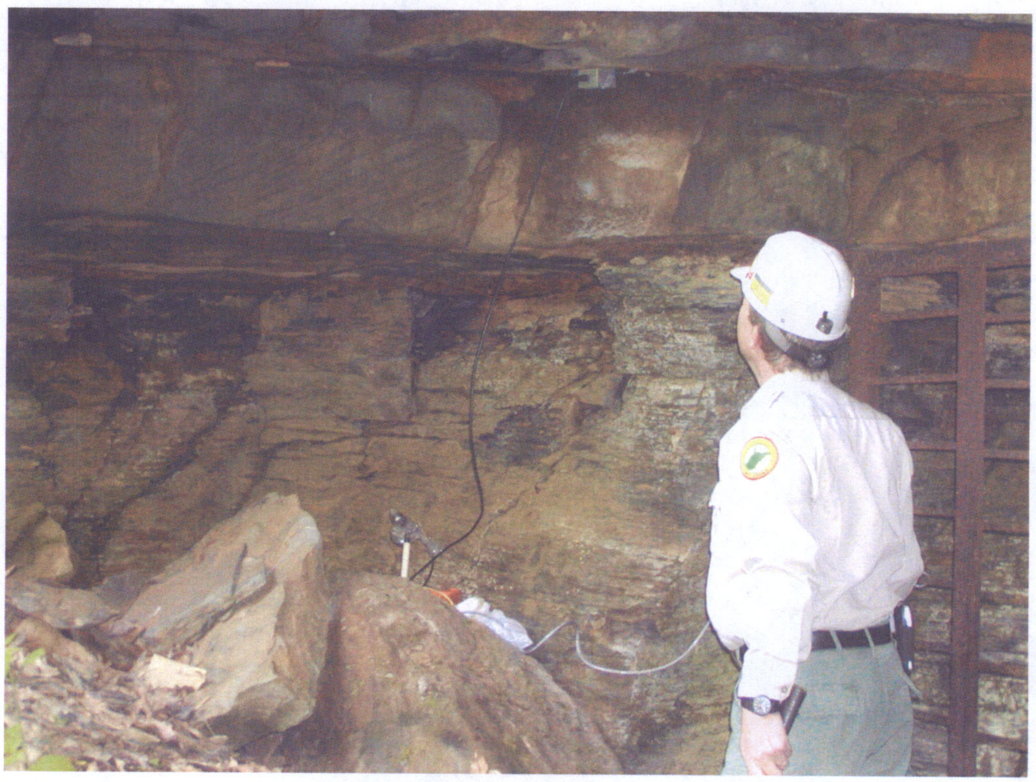


Figure 5 – Geophone Bolted to Roof of Portal 2D

Seismographs were put into place on May 24, 2006, although blasting did not begin until June 19, 2006. This was to record baseline data and possibly measure any natural movement of the roof before blasting began. The seismographs were manufactured by White

Seismology and were able to detect ground vibration levels as low as 0.002 ips. Seismic results prior to blasting at portal 2D are as follows:

DATE	TIME	PPV (IPS)	AIRBLAST (dB)
5/30/2006	12:05 AM	.005	<100
5/30/2006	12:07 AM	.0075	<100
5/30/2006	12:12 AM	.0113	<100
5/30/2006	12:58 AM	**.0288**	<100
5/30/2006	1:00 AM	.0188	<100
5/30/2006	1:09 AM	.0025	<100
6/2/2006	7:28 PM	.0025	**134**
6/14/2006	8:11 AM	.0075	<100

Seismic results prior to blasting at portal 2A are as follows:

DATE	TIME	PPV (IPS)	AIRBLAST (dB)
5/24/2006	11:10 PM	.0125	<100
5/28/2006	11:00 PM	.0025	<100
6/9/2006	5:29 AM	.005	<100
6/11/2006	4:32 AM	.0025	<100
6/13/2006	10:20 PM	**.0300**	<100
6/15/2006	1:00 PM	.0175	**106**

A maximum vibration of 0.03 ips was recorded at Portal 2A on June 13, 2006 (Figure 6). This can be attributed to any number of non-blast occurrences, such as wind moving the geophone cable, animal disturbances, thunder storms, etc. Figure 6 shows 134 decibels (dB) recorded on June 2, 2006. Normally this measurement would be considered non-compliant in regards to blasting outside a permitted area. Although the unit of airblast measurement is denoted as decibels, it is actually recorded in pounds per square inch (psi). The 134 dB equates to 0.0145 psi, which is equivalent to a wind gust of 20 – 28 miles per hour. It is not known what caused this air overpressure pulse.

Once blasting began on June 19, 2006, bi-weekly hikes were made into the park to retrieve seismographs for data download and to install fresh machines.

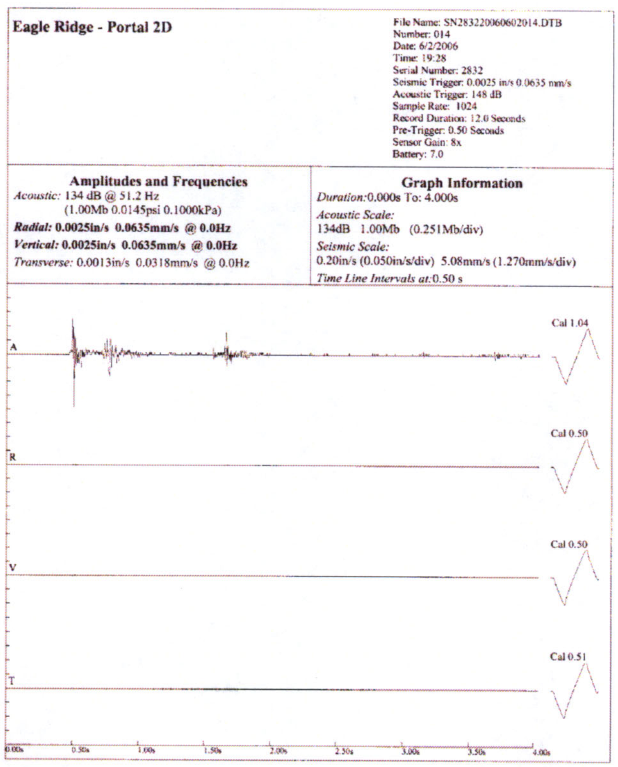


Figure 6

Blast distances varied from 1,887 to 2,828 feet at portal 2D. Seismic data obtained from June 19 to November 21, 2006, is as follows:

SHOT #	DATE	TIME	PPV (IPS)	AIRBLAST (dB)
1	6/19/2006	1:01 PM	0.0100	106
2	6/22/2006	12:48 PM	0.0150	106
3	7/10/2006	1:36 PM	**0.0225**	**120**
4	7/11/2006	2:45 PM	No Trigger	No Trigger
5	7/13/2006	3:35 PM	0.0075	106
6	7/18/2006	3:50 PM	No Trigger	No Trigger
7	7/27/2006	5:28 PM	0.0125	<100
8	8/2/2006	2:51 PM	0.0075	106
9	8/10/2006	2:43 PM	No Trigger	No Trigger
10	8/21/2006	2:58 PM	No Trigger	No Trigger
11	9/7/2006	2:39 PM	0.0100	<100
12	9/13/2006	2:47 PM	0.0075	<100
13	9/18/2006	11:21 AM	0.0075	<100
14	9/20/2006	11:25 AM	0.0100	<100
15	9/22/2006	1:05 PM	No Trigger	No Trigger
16	9/27/2006	1:34 PM	0.0100	<100
17	10/9/2006	5:06 PM	0.0100	<100
18	10/11/2006	3:14 PM	0.0075	<100
19	10/16/2006	5:03 PM	0.0200	<100
20	11/3/2006	3:02 PM	No Trigger	No Trigger
21	11/8/2006	1:38 PM	No Trigger	No Trigger
22	11/13/2006	3:57 PM	0.0100	<100
23	11/21/2006	5:03 PM	0.0100	<100

Blast distances varied from 3,514 to 4,514 feet at portal 2A. Seismic data from June 19 to November 21, 2006:

SHOT #	DATE	TIME	PPV (IPS)	AIRBLAST (dB)
1	6/19/2006	1:01 PM	0.0050	106
2	6/22/2006	12:48 PM	0.0050	**106**
3	7/10/2006	1:36 PM	**0.0075**	<100
4	7/11/2006	2:45 PM	No Trigger	No Trigger
5	7/13/2006	3:35 PM	No Trigger	No Trigger
6	7/18/2006	3:50 PM	No Trigger	No Trigger
7	7/27/2006	5:28 PM	No Trigger	No Trigger
8	8/2/2006	2:51 PM	No Trigger	No Trigger
9	8/10/2006	2:43 PM	No Trigger	No Trigger
10	8/21/2006	2:58 PM	No Trigger	No Trigger
11	9/7/2006	2:39 PM	No Trigger	No Trigger
12	9/13/2006	2:47 PM	No Trigger	No Trigger
13	9/18/2006	11:21 AM	No Trigger	No Trigger
14	9/20/2006	11:25 AM	No Trigger	No Trigger
15	9/22/2006	1:05 PM	No Trigger	No Trigger

SHOT #	DATE	TIME	PPV (IPS)	AIRBLAST (dB)
16	9/27/2006	1:34 PM	No Trigger	No Trigger
17	10/9/2006	5:06 PM	No Trigger	No Trigger
18	10/11/2006	3:14 PM	No Trigger	No Trigger
19	10/16/2006	5:03 PM	0.0063	106
20	11/3/2006	3:02 PM	No Trigger	No Trigger
21	11/8/2006	1:38 PM	No Trigger	No Trigger
22	11/13/2006	3:57 PM	No Trigger	No Trigger
23	11/21/2006	5:03 PM	No Trigger	No Trigger

These recordings show that the maximum ground vibration as of November 21, 2006, at either mine portal is 0.0225 ips. Since a maximum blast vibration level of 0.30 ips is allowed at the portal for compliance, the scaled distance formula is a very conservative blast design criteria to protect the portal openings.

EXISTING BAT RESEARCH

Review of existing research revealed the following relevant information:

1) Maximum blasting vibrations that would maintain roof integrity.

David Siskind's book titled "Vibrations From Blasting" had very encompassing information on maximum blasting vibrations and underground mine roof failures. Dr. Siskind evaluated nine separate studies from the United States, India, and South Africa. These studies included coal and hard rock. He declares:

> "There is much variation between the structure and geologic conditions represented by the nine studies (and 12 sites) detailed above. A general observation is that major failure such as roof collapse and pillar failure would require vibrations greater than about 12 in/s. In some cases, loose pieces were dislodged at lower vibration levels of about 1.2 to 5 in/s. Low-level vibrations, certainly below 1.0 in/s, have been found to be totally harmless to underground workings, even active ones where rockfalls are a personal hazard." [3]

2) Distances that bats migrate underground for hibernation.

Temperature, humidity, and airflow levels generally determine how far bats migrate underground for hibernation. Temperatures need to range from 37° to 43° F and have an average relative humidity of 87%. Only two references could be found that documented distances that hibernating bats were found underground. The first was a report written by Dr. Richard F. Myers, in 1975 titled "Effect of Seismic Blasting on Hibernating *Myotis Sodalis* and Other Bats".[4] Dr. Myers' winter study in east-central Missouri determined that several bat clusters were found anywhere from the cave entrance to 500 feet inside the limestone cave. The other reference was from a 2005 winter bat survey performed at Greer Lime's Hellhole Cave in Pendleton County, West Virginia. This survey revealed that bats had migrated up to 614 linear feet from the limestone cave opening, see figure 7. Discussions with Alan Hicks, biologist with the New York State Department of Environmental Conservation, revealed that endangered bats migrated up to 2,300 feet in abandoned iron ore mines in New York.

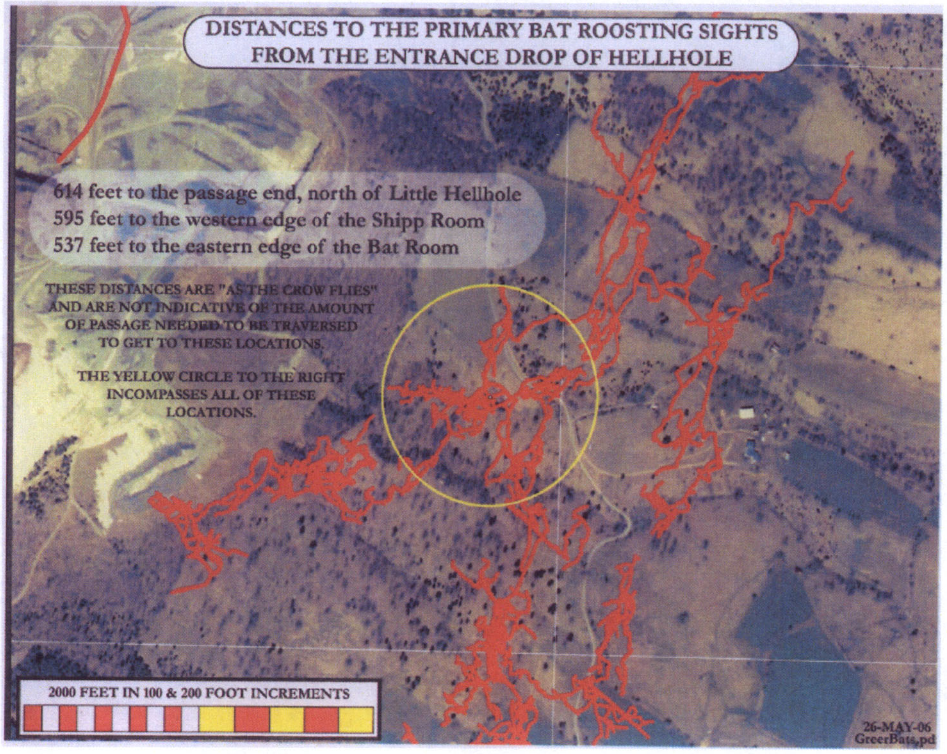


Figure 7

3) Maximum blasting vibrations that would not disturb hibernating bats.

Little has been published on vibration levels that might awaken bats during their hibernation period. Dr. Myers report concluded,

> "There is no evidence from this study that blasting of the type and magnitude used here, as close as 120 m (394') to M. *sodalis* and 30 m (98') to P. *subflavus*, is disturbing to these species during hibernation. Nor is there reason to think other types of blasting in which PPV reaches 0.02 ips will affect them. The presence of humans was the most disruptive force acting upon the bats during the study." [4]

This study was disputed by Alan Foster, of Vibra-Tech Engineers, Inc., after his study at Germany Valley Limestone (Greer Lime Hellhole Cave) in 1985. Mr. Foster states,

> " … there is very little source data available to enable us to determine what vibration levels can be expected to disturb the hibernating bats. The one published paper; 'Effect of Seismic Blasting on Hibernating *Myotis Sodalis* and other Bats' 1975 by Richard F. Myers, simply states that the bats were not disturbed at 0.02 inches per second. This is an unrealistic criteria since no disturbance was noted and in the same report it states that four people walking within 6' of the geophone produced levels of 0.055 inches per second."[5]

Mr. Foster also references the "Glen Park Hydroelectric Project", a study conducted in Watertown, New York, by James A. Besha P.E., by saying, "Another unpublished study, carried out by Glen Park Associates, on a hydroelectric project in Watertown, NY, involved the video taping of bats using infra-red lights during a period from January to May, 1985. All blasts were monitored at the cave entrance and peak levels of up to 0.20 inches per second were recorded. … This more relevant data tends to indicate that 0.20 inches per second as recorded at the cave entrance, is a more practical lower limit since it has been shown to cause no disturbance to the Watertown bats."[5]

The "Glen Park Hydroelectric Project" study states,

"As reported in the Conservationist (Nye), a habitat of *Myotis* is located in the Jamesville are near Syracuse in a limestone formation that has been under continuous quarrying activity by the Allied Chemical Corp. since 1920. This quarrying activity involves blasting of all types. Loading limits of 200 pounds of explosive per delay as close as 1,000 feet from the caves during the winter are common. Observers have recorded PPV of 0.05 ips 1,400 feet from the blast site. The habitat is located 1,000 feet from the quarrying operation, thus seismic velocities are certainly higher at the caves. It is extrapolated that the PPV at the caves is no less than 0.25 ips. … There has been no decrease in the population at Jamesville since observations began in 1969 (Hicks) recent observations since 1977 have found increasing number of bats."[6]

This same bat study concludes in the Blast Plan,

"Based upon the experience of [Richard] Myers, the observations at the Jamesville site, and the Off Site test blast program, a limitation of 0.10 inches per second of peak particle velocity is planned." [6]

Another method to determine vibration levels that disturb hibernating bats is an attempt to correlate blast log and seismic recordings with bat survey data. Information from Vibra-Tech Engineers report in 1985; blast log and seismic records from 2004 through 2005; and data from a winter bat study at Greer Lime Hellhole Cave in Pendleton County, West Virginia, were analyzed. Although many blasts were conducted, there were numerous no triggers recorded at the Hellhole site.

VIBRA TECH SEISMIC DATA – HELLHOLE CAVE			
DATE	**SCALED DISTANCE**	**SURFACE PPV (IPS)**	**SUB-SURFACE PPV**
8/13/1985	129	0.05	0.03
8/14/1985	100	0.10	0.05
8/15/1985	98	0.10	No Recording
8/16/1985	102	0.05	0.0375
8/21/1985	99	0.12	0.0435
8/28/1985	133	0.12	No Recording
9/5/1985	94	0.07	No Recording
9/10/1985	101	0.07	No Recording
9/26/1985	162	0.02	No Recording

2004-2005 GREER LIME SEISMIC DATA – HELLHOLE CAVE		
DATE	SCALED DISTANCE	SURFACE PPV (IPS)
1/8/2004	106	0.10
1/12/2004	327	0.01
1/23/2004	323	0.01
1/29/2004	107	0.10
2/19/2004	175	0.06
2/27/2004	173	0.06
3/26/2004	176	0.06
4/5/2004	98	0.16
5/11/2004	80	0.16
4/13/2005	212	0.04

Regression analysis of the data determined its validity as a predictive model for various scaled distances. This is important for predicting surface blast vibrations in areas directly over bat nesting areas of the cave system.

As can be seen in Figure 8, a minimum of 0.70 has been obtained as a correlation coefficient (R^2). Although only 19 surface data sets were obtained, it is felt that the calculated regression surface equation has some validity as a predictive model.

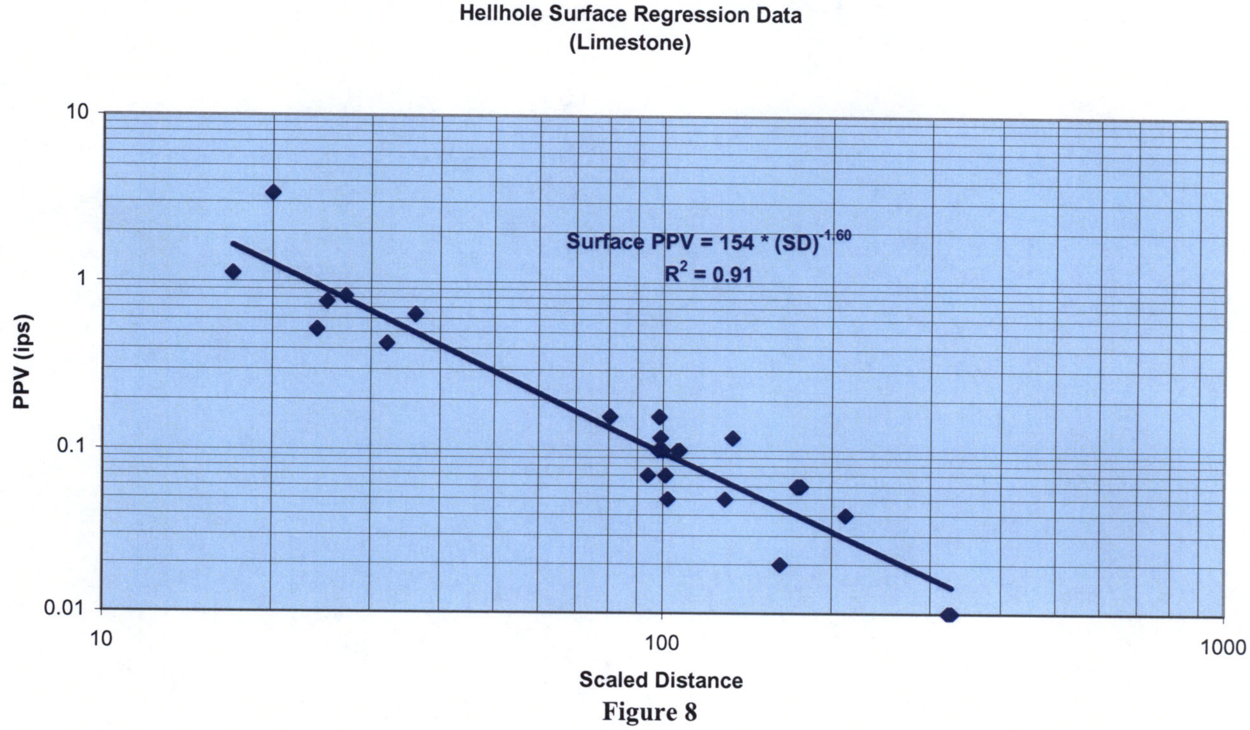


Figure 8

Figure 7 on page 11, labeled as "Distances to the Primary Bat Roosting Sights From the Entrance Drop of Hellhole", shows that the endangered bats are roosting approximately 537 to 614 feet farther than the seismograph locations.
Using the predictive equation of $154 * (D / W^{.5})^{-1.6}$ where:

D = Seismograph distance from the blast

W = Maximum pounds per delay detonated within an 8-millisecond delay period

Calculations can now be made to predict the surface ground vibrations at a point 614 feet from than the cave openings. For the blast of May 11, 2004,with a scaled distance of 80 and a recording of 0.16 ips at the cave opening, 614 feet away would equate to a surface vibration of 0.081 ips.

Another potential set of valuable data is subsurface ground vibration measurements and corresponding surface vibrations. The table "Vibra Tech Seismic Data – Hellhole Cave" on page 12, reveals that underground measurements are 1.33 to 2.76 times less than surface measurements. The predicted 0.081 ips surface vibration would now indicate a subsurface vibration level of 0.03 to 0.06 ips.

In 2005, federal and state regulatory authorities and private industry conducted a winter bat survey at a West Virginia surface limestone operation. Blast and seismic data and bat survey data were used to compare the relationship of blasting vibration levels and the bat population at this location. These findings could be indicative of the effects of blasting on any existing endangered bat populations.

During the winter of 2005, a bat survey was conducted at Hellhole Cave by the West Virginia Division of Natural Resources (WVDNR) and included participants such as FWS, and consultants with bat expertise. This report concluded that between 2001 and 2005, the Indiana bat population increased from 8,566 to 11,890 bats. The Virginia big-eared bat increased from 5,286 to 5,359 bats over the same time period. It is surmised from the analyzed data and research that endangered bat populations can prosper even when exposed to blasting vibration levels of 0.06 to 0.20 ips. According to FWS, hibernating bats awaken every 8 to 10 days to join small bat clusters or fly about elsewhere in the cave. Vibration level intensities necessary to waken a bat during this sleep cycle would vary.

UNDERGROUND / SURFACE GEOPHONE DATA

To establish the relationship between surface and subsurface ground vibration differences, research was conducted at both an active underground and surface mine. Initial discussions with mine managers conducted in May, 2006, established a monitoring location for research. Coordinates were obtained for an existing underground geophone being used as a compliance point for the active underground mine. A surface seismograph geophone was placed directly above the underground geophone using these same coordinates. Fortunately, the surface location was not in the path of surface production blasting or excavation operations. The surface geophone was kept at this location from May 3, 2006 until June 13, 2006. Three events were recorded on the surface and underground geophones during this period. The seismic trigger information is as follows:

DATE	SURFACE EVENT (PPV)	UNDERGROUND EVENT (PPV)	SURFACE/UNDERGROUND RATIO
5/16/2006	0.220	0.060	3.7x
5/18/2006	0.230	0.060	3.8x
5/22/2006	0.110	0.040	2.8x
		Average	**3.4x**

Because mining was progressing away from the seismographs, it was decided to establish a new OEB surface and underground geophone location for research purposes. On July 13, 2006, geophones were placed vertically in-line with each other (Figure 9 and 10).

Figure 9

Figure 10

Underground seismic trigger levels were reduced to 0.005 ips to ensure as many blasts as possible were recorded. From July 13, 2006 to November 13, 2006, a total of 40 surface and underground blast events were recorded. They are as follows:

DATE	SURFACE EVENT (PPV)	UNDERGROUND EVENT (PPV)	SURFACE/UNDERGROUND RATIO
7/13/2006	0.095	0.020	4.8x
7/17/2006	0.235	0.030	7.8x
7/20/2006	0.110	0.028	5.5x
7/25/2006	0.155	0.033	4.7x
8/2/2006	0.140	0.030	4.7x
8/4/2006	0.120	0.020	6.0x
8/8/2006	0.145	0.038	3.8x
8/9/2006	0.025	0.005	5.0x
8/10/2006	0.025	0.010	2.5x
8/16/2006	0.080	0.025	3.2x
8/18/2006	0.020	0.005	4.0x
8/21/2006	0.065	0.018	3.6x
8/24/2006	0.020	0.005	4.0x
8/25/2006	0.055	0.015	3.7x
8/28/2006	0.120	0.048	2.5x
8/29/2006	0.075	0.020	3.8x
8/31/2006	0.235	0.058	4.0x
9/5/2006	0.020	0.008	2.5x
9/6/2006	0.210	0.033	6.4x
9/7/2006	0.020	0.010	2.0x
9/11/2006	0.025	0.008	3.1x
9/12/2006	0.400	0.085	4.7x
9/15/2006	0.300	0.058	5.2x
9/18/2006	0.115	0.023	5.0x
9/19/2006	0.165	0.028	5.9x
9/21/2006	0.088	0.028	3.1x
10/17/2006	0.050	0.010	5.0x
10/18/2006	0.090	0.018	5.0x
10/19/2006	0.030	0.013	2.3x
10/20/2006(1)	0.500	0.095	5.3x
10/20/2006(2)	0.020	0.008	2.5x
11/9/2006	0.030	0.010	3.0x
11/13/2006	0.030	0.010	3.0x
11/14/2006(1)	0.035	0.013	2.8
11/14/2006(2)	0.100	0.020	5.0
11/15/2006	0.020	0.008	2.7
11/20/2006	0.120	0.023	5.3
11/21/2006	0.085	0.020	4.3
11/27/2006	0.170	0.025	6.8
11/28/2006	0.105	0.013	8.4
		Average	**4.3x**

Figure 11 depicts the surface blast locations in the above table from August 25 to October 20,2006, in relation to the underground seismograph geophone locations and coal pillars.

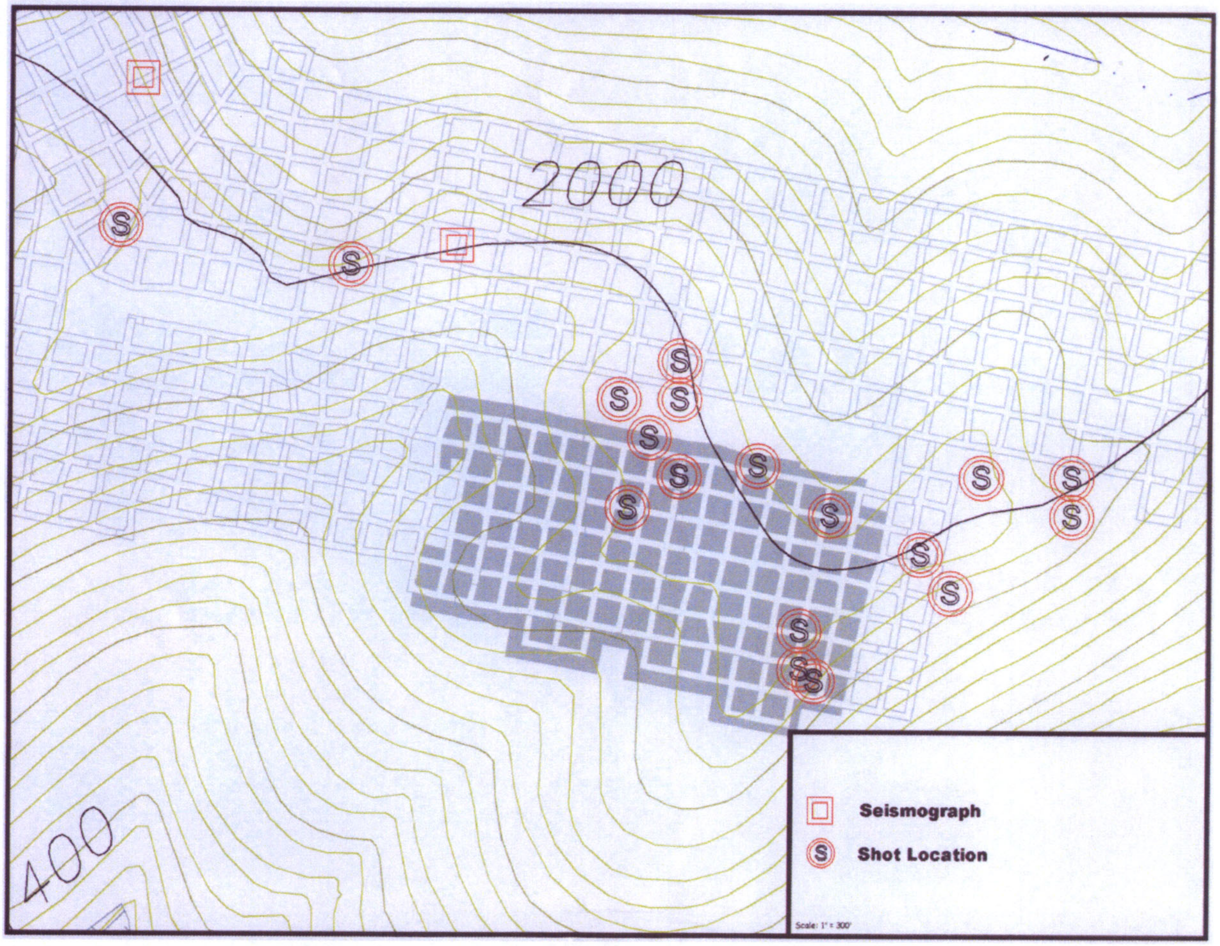


Figure 11

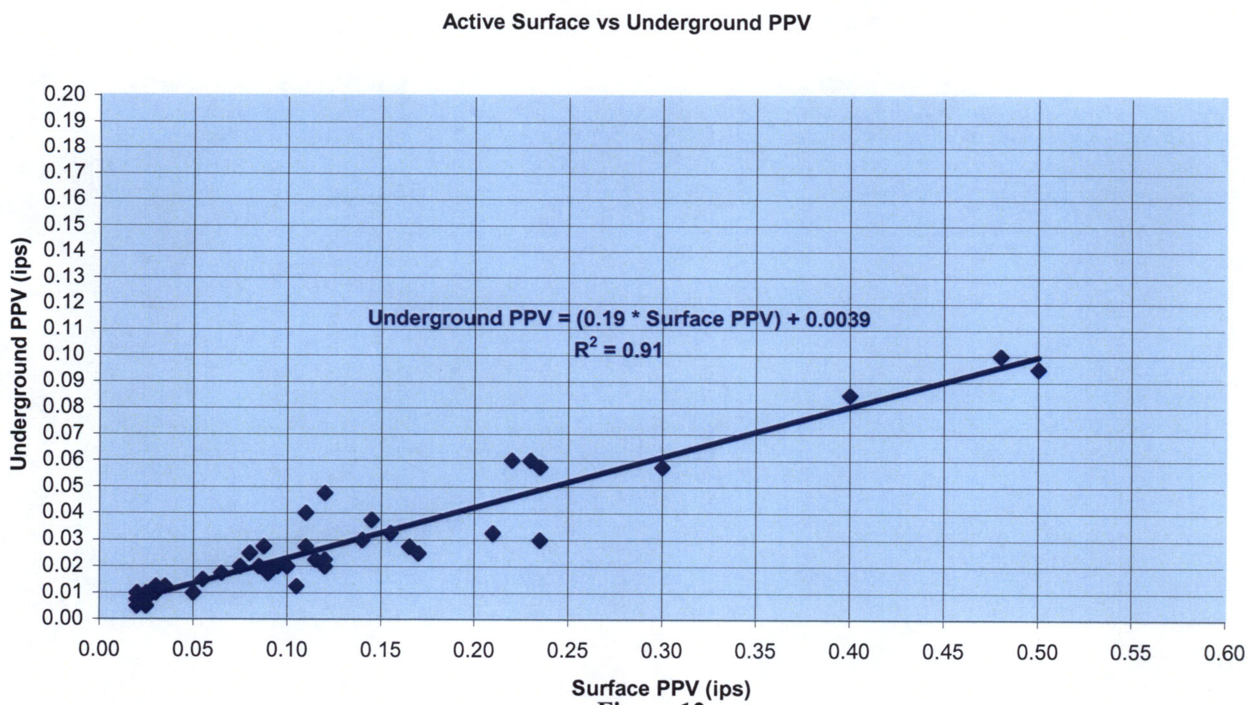


Figure 12

By plotting the surface PPV recordings versus the corresponding underground PPV measurements, a linear trend line can be created (Figure 12). This trend line allows the prediction of underground roof vibrations based on surface vibration levels of 0.50 ips or less.

Reasons for the difference between Hellhole cave and coal mine ratio levels are thought to be from:

- Larger vibration data sets for the active surface and underground mine;

- Differences in geophone placement - Hellhole Cave had the subsurface geophone coupled to the cave entrance floor, while the active mine geophone was bolted directly to the mine roof. A 1980 report from Hayatdavoudi and Brown states

> "During the course of investigation, seismic monitoring had to be standardized. In essence, several places in the underground mine were investigated for instrumentation. Later on, it was found that monitoring of pillars and mine floor vibration should be avoided and the best place that gave the highest response was found to be the center of crosscuts."[7]; and

- Strata type and thickness were varied. Hellhole Cave seismic responses were measured in limestone to an approximate vertical difference of 190 feet. The active coal mine seismic events were measured through sandstone, shale, and coal layers to a depth of 376 feet. This is shown in the table below.

- Differences between quarrying and surface mine blasting techniques.

MATERIAL	THICKNESS (FT.)	TOTAL FT.
Sandstone	30	30
Sandy Shale	4	34
Sandstone	4	38
Coal, Upper Kittaning	2	40
Sandstone	5	45
Coal, Middle Kittaning	2	47
Sandstone	20	67
Coal, Middle Kittaning Rider	5	72
Shale	3	75
Sandy Shale	27	102
Sandstone	16	118
Coal, Lower Kittaning Rider	2	120
Sandy Shale	10	130
Shale	22	152
Coal, Lower Kittaning	4	156
Sandstone	80	236
Shale	6	242

MATERIAL	THICKNESS (FT.)	TOTAL FT.
Sandy Shale	6	248
Sandstone	16	264
Coal, Stockton	10	274
Sandstone	46	320
Sandy Shale	11	331
Sandstone	45	376

Other research on surface to underground vibration ratios reflected in the table below, are varied because of many blasting, seismic, and geologic variables. This type of research could be enhanced by studies conducted at other surface and underground operations with different rock strata and thicknesses.

OTHER SURFACE / UNDERGROUND PPV RATIO RESEARCH			
MINE TYPE	GEOPHONE LOCATION	VERTICAL DISTANCE	SURFACE / UNDERGROUND RATIO
Coal[8]	Mine roof and rib	160'	Avg. 2.4
Limestone[9]	Inside Borehole	50'	Avg. 2.0
Coal[10]	Mine rib	100'-187'	1.26 – 2.99

RESEARCH FINDINGS

OEB research revealed that surface seismographs would record ground vibrations at a level of 2.0 to 7.8 times higher than underground vibrations. To calculate theoretical vibrations on the Fire Creek mine roof, surface seismograph units were placed at various distances from the blasts to generate data used for regression analysis. Data from the mine portals were also used in the analysis. A regression analysis on 44 seismic data points can be used to predict surface vibrations at various distances from the blast site. The regression curve is shown in Figure 13.

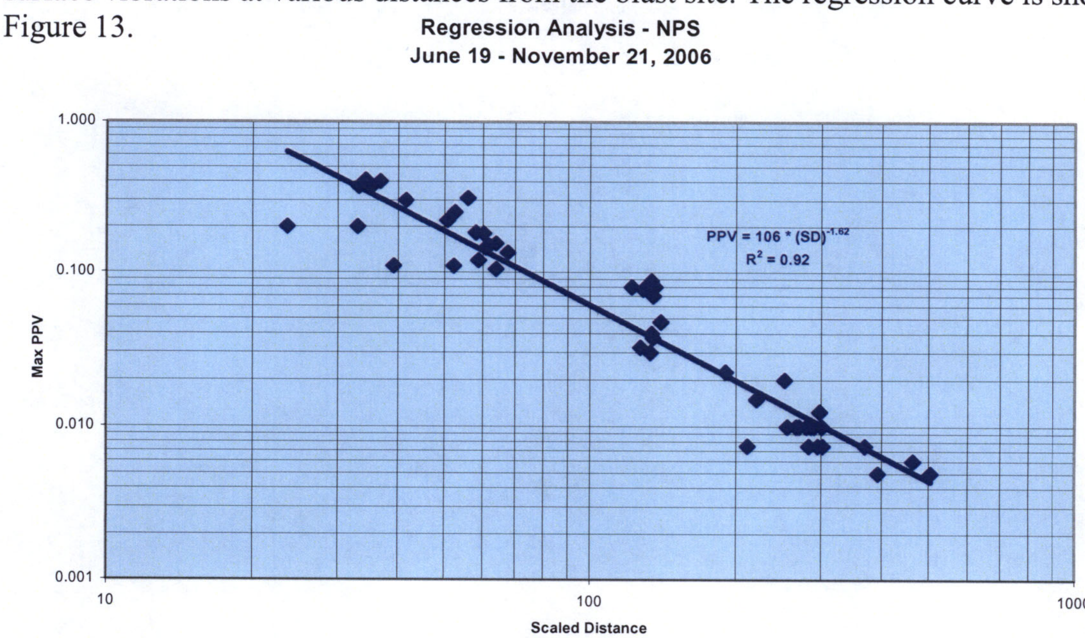


Figure 13

The Figure 13 graph indicates several important parameters. Mainly, with an R^2 of 0.92, the data is of sufficient quality and quantity to use as a predictor of blast vibrations at this site.

Using the predictive equation ($PPV = 106*(SD)^{-1.62}$), current surface blasting near the NPS using a maximum of 100 pounds per delay, would calculate a surface vibration of 0.065 ips at 959 feet from the permitted area (approximate extent of the bat hibernacula). Using the underground predictive equation 0.19 * surface vibration + .0039, a value of 0.016 ips is calculated for a roof vibration.

A maximum of 0.41 ips was recorded on during a blast on July 13, 2006. Seismograph location was 306 feet from the blast and 1,887 feet from portal 2D. Based on calculations using this data, should the bats hibernate more than 1,887 feet from the portal opening, a roof vibration of 0.082 ips is predicted.

In reference to data indicating that hibernating bats can withstand vibration levels of up to 0.20 ips, this current research implies not only is the scaled distance formula adequate to protect the immediate Fire Creek roof, but that current blasting would not affect hibernating bats. Based on available data the bat hibernacula would still be protected at higher vibration levels. This scenario is depicted in Figure 14.

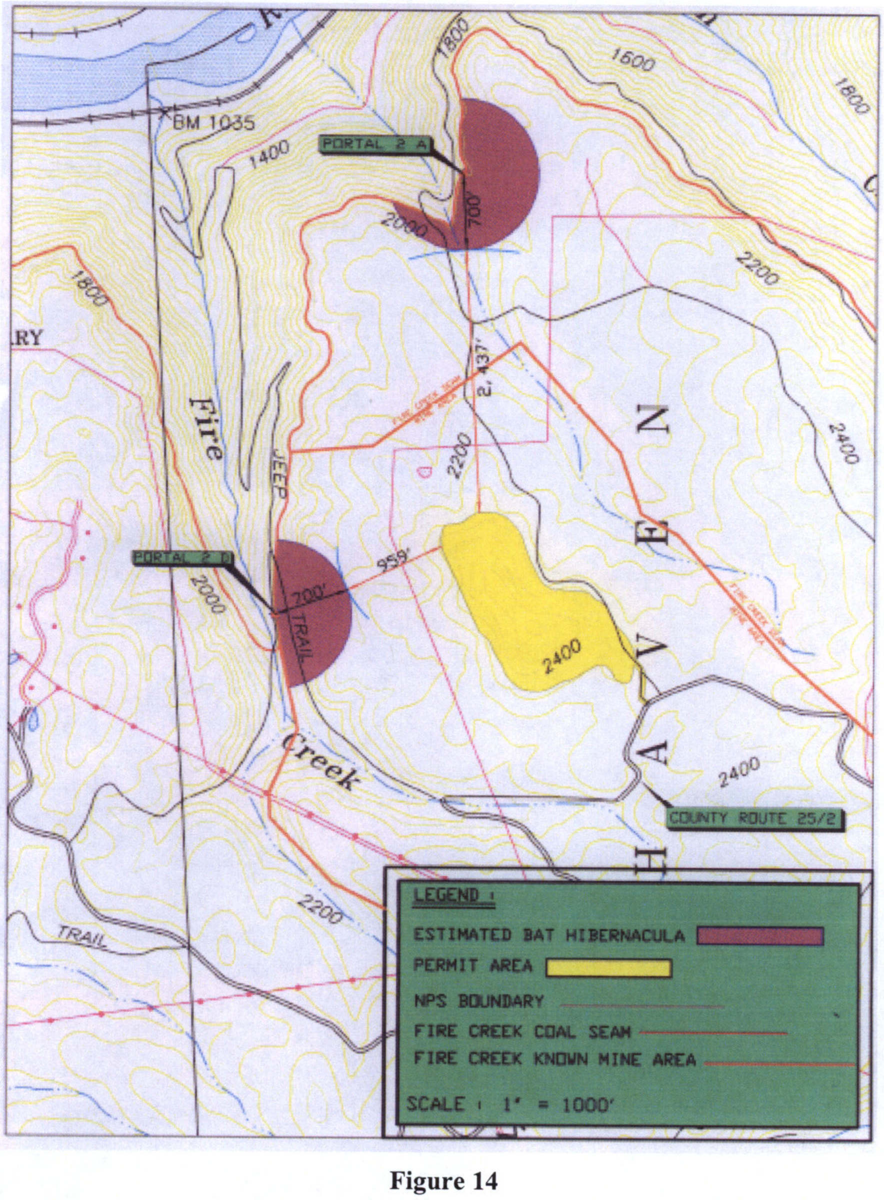


Figure 14

CONCLUSIONS

Information concerning blasting vibrations and bat hibernacula is very scarce. OEB research indicates:

- As proposed by the permittee in the Blast Plan, scaled distance is more than adequate for compliance at New River Gorge National River Park portals and will protect the integrity of the abandoned underground coal mine roofs (bat hibernacula). The scale distance formula is also sufficient for protecting hibernating bats that may migrate up to 1,877 feet into the Fire Creek seam.

- The immediate Fire Creek roof should not be jeopardized by vibration levels of 1.00 ips;

- Per OEB data, underground vibration levels are 2.0 to 7.8 times less than surface vibration levels. A predicted linear equation for underground PPVs [0.19 * (surface vibration) + 0.0039] was generated for surface vibrations of less than 0.50 ips;

- Hibernating bats can withstand vibration levels of 0.06 to 0.20 ips (Hellhole and Watertown conclusions) without adverse effects; and

- Bats have migrated up to 2,400 feet in abandoned iron ore mines. In West Virginia limestone caves, bats have migrated up to 614 linear feet into their hibernacula.

Research collected for this project will also have great benefit for site-specific blast plans submitted to OEB by surface coal operators. These site-specific blast plans are required when blasting within 500 feet of active underground operations.

Currently, the coal mine permittee mentioned in this report has submitted a Surface Mining Application for mining near other bat hibernacula near the New River Gorge National River Park. A worthwhile endeavor might be a collaborative effort between OEB, the permittee, NPS, FWS, and OSM on effects of surface blasting on endangered bat populations. It is assumed this project would be one to two years in length.

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