MSHA Mine Void Detection Demonstration Project Update

Interstate Technical Group on Abandoned Underground Mines (ITGAUM) Sixth Biennial Workshop, Rochester, NY

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Pittsburgh Technical Support Center
Diagrammatic cross section of typical subsidence resulting from mine-roof collapse. No scale implied.
Subsidence pit, about 6 feet in diameter and 8 to 10 feet deep, on I-70 resulting from roof collapse of a mine in March 1995. Photo courtesy of Gannett Fleming Inc.
Subsidence pit behind a residence in North Canton, Stark County. This pit was 35 feet in diameter and 25 feet deep. Photo courtesy of Ohio Division of Mines and Reclamation.
Recent High-Profile Incidents Related to Underground Mines

- **Impoundment Breakthrough Incidents**
  - Miller’s Cove, Lee Co. VA, August, 1996
  - Miller’s Cove, Lee Co. VA, October, 1996
  - Buchanan, Buchanan Co. VA, November, 1996
  - Big Branch, Martin Co., KY, October, 2000

- **Mine Inundation**
  - Quecreek No. 1 Mine Inundation and Rescue, July 2002
Example of potential for breakthrough created by mine workings located near an impoundment.
Martin County Coal Company
Big Branch Refuse Impoundment
October 2000
Approx 300 Million Gallons Released
Breakthrough Location

Discharge Exited Mine at No. 2 North Portals

Approx. limit of inundation in North Mains

Discharge Exited Mine at South Mains Portal
South Mains Portal

Eroded by slurry discharge
Coldwater Creek
Reuter - Oct. 18th - “A massive spill of slowly spreading coal slurry triggered water shortages and school closings across eastern KY...prompting the governor to declare a state of emergency.”

“Communities throughout the affected 10 county area were forced to close off water intake pipes.

“Some public schools were forced to close indefinitely pending restoration of safe water supplies...
Abandoned Coal Mines

<table>
<thead>
<tr>
<th>State</th>
<th>No. of Abandoned Mines</th>
</tr>
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<tbody>
<tr>
<td>Kentucky</td>
<td>150,000</td>
</tr>
<tr>
<td>West Virginia</td>
<td>100,000</td>
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<tr>
<td>Pennsylvania</td>
<td>40,000</td>
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<tr>
<td>Virginia</td>
<td>6,000</td>
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</table>
Impoundments and Mining

- 220 Impoundments in Appalachia built over or adjacent to mine workings
- MSHA rated and prioritized impoundments in terms of potential and consequences of failure
- 54 Sites had a high potential for breakthrough
- Mine Operators were required to evaluate potential for breakthroughs and design against them
Congressional Study

- National Research Council, Committee on Coal Waste Impoundments
- $2,000,000
- Developed report, “Coal Waste Impoundments: Risks, Responses, Alternatives, 2002"
NRC Recommendation

• The council recommends that demonstration projects using modern geophysical techniques be funded, and that results be widely conveyed to the mining industry and to government regulatory personnel through workshops and continuing education.
Quecreek No. 1 Mine Inundation and Rescue, July 24-28, 2002
1 Left Section
By 4:07 PM on Thursday, Water Stabilized in Pit at about 1852’, 3 Diesel Pumps operating (~15,000 GPM)
No. 1 Borehole Drilling
Started at 8:00 PM, Breaks into Mine at 10:16 PM

No. 2 Borehole Drilling
Stopped 204 Feet

204 Feet  240 Feet
Active Mines: Inundation Accidents
Magnitude of the Problem

• From 1995 through June 2002, mine operators reported 181 mine inundations.

• Of these, at least 107 were unplanned cut-throughs that resulted in water inundations.
House/Senate Conference Agreement

• "$10,000,000 for digitizing mine maps and developing technologies to detect mine voids, through contracts, grants, or other arrangements, to remain available until expended."

– MSHA Allocation:

• $3.9M to Mine Mapping – Disbursements to States
• $6.1M to Void Detection – Funded Projects to Demonstrate available technologies for void detection.
Request for Proposals (RFP)

• Purpose: “The U.S. Department of Labor, Mine Safety and Health Administration is seeking sources to conduct demonstration projects for advancing the current state of technology in detecting underground mine voids.”
Progress of Demonstration Projects

- Pre-solicitation Notice
- Request For Proposals
- Objective Scoring System Developed
- MSHA Contracted with outside technical reviewers
- Review Teams Formed
  - MSHA Representative
  - Other Government (generally USACE) Representative
  - University Professor of Geophysics
  - 11 Respondents to receive further consideration
- Negotiations 8/2004 - Present
Response to RFP

- 58 Proposals
- 23 Sources
- Methods Covered
  - Surface Seismic Reflection
  - Inseam Seismic Reflection
  - DC Resistivity
  - Seismic Land Streamer
  - Synthetic Aperture Radar
  - Underground Electromagnetics
  - Microgravity
  - SASW
  - Ground-penetrating Radar
  - Look-Ahead Radar
  - Forward-Looking Seismic
  - Mobile Field Robotics (dry voids)
  - Mine Fish (wet voids)
  - Gravity Gradiometer
  - Time Domain Electromagnetics
  - Airborne Electromagnetic Conductivity
  - Drillstring Radar
  - MASW
  - 3-D Sonar
  - Cross-hole Seismic Tomography
  - Radio Imaging
  - 3-D Downhole Laser
  - Residual Potential Mapping
14 Selected Projects Now Underway

- Surface Seismic Reflection (2)
- Borehole Seismic Tomography (2)
- Vertical Seismic Profiling (1)
- In-seam Seismic (ISS) (various sources) (4)
- Electrical Resistivity (1)
- Time Domain Electromagnetics (1)
- Look Ahead Radar (1)
- Borehole Radar Tomography (1)
- Delta EM Gradiometry (1)
Surface Seismic Reflection Projects

• Blackhawk Division of Zapata Engineering
  – Black Beauty Coal Co., Riola Mine Complex

• LM Gochioco Associates
  – Sterling Coal Corp., Carroll Hollow Mine
Surface Seismic Reflection

Diagram showing the reflection of seismic waves from different layers, illustrating the concepts of shortest and longest paths, and path difference.
• MicroVibrator source units set up along designated source location capable of generating shear (S) waves or primary (P) waves independent of one another.
• Two source units were required to provide a stronger signal during shear (S) wave data acquisition.
Close-up view of the 3 component system. Notice the orientation of the orange spring housings. (Nov 23, 2004)
Oyo Geospace DAS-1 recording equipment
Borehole Seismic Tomography Projects

• Blackhawk Division of Zapata Engineering
  – Black Beauty Coal Co., Riola Mine Complex

• Colorado School of Mines
  – Edgar Experimental Mine, Army Tunnel
Borehole Seismic Tomography
Downhole source is a DHSS-5500 air gun, 2000 psi
• Full-waveform Sonic probe – measures velocity within rock strata
Vertical Seismic Profiling (VSP) Project

• L.M. Gochioco & Associates Inc.
  – Sterling Coal Corp., Carroll Hollow Mine

• Blackhawk Division of Zapata Engineering (RVSP)
  – Black Beauty Coal Co., Riola Mine Complex
Vertical Seismic Profiling (VSP)
Inseam Seismic (ISS) Reflection Projects

• Pennsylvania State University
  – Anthracite Coal Mine
  – Bituminous Coal Mine
  – Trona (Soda Ash) Mine

• L.M. Gochioco & Associates Inc.
  – Sterling Coal Corp., Carroll Hollow Mine
  – Paramount Coal Corp., Mine No. 4

• Marshall Miller Associates, Inc.
  – Sources and Receiver at Outcrop

• Wright State University
  – Continuous Miner vibration source, receivers on Surface
Inseam Seismic (ISS)

In-Seam Seismic Probing Using Reflected Waves

Active Mine

Inaccessible Mine Workings
(Location/extent is uncertain)

Seismic Source

Geophones

Projected Rooms

Ray Reflections

Safe Distance
In-seam Seismic Reflected Wave Principles

Coal Outcrop
Seismic Energy

Triggering Device
Multi-Channel Seismograph

Geophone (string)
Transmitted Ray
Reflected Ray

Coal Barrier
Inaccessible Mine Void
Installed Sensors in a Barrier
Dr. Hauser during data acquisition. (Nov 23, 2004)
Electrical Resistivity Project

• D’Appolonia Engineering Division of Ground Technology Incorporated
  – Pine Ridge Coal Company, Lot’s Branch Impoundment
Electrical Resistivity
Lots Branch Aerial Photo

Location of Electrical Resistivity Survey

Upstream Toe of the Main Embankment

Pool Area
Electromagnetic and Radar Projects

• D’Appolonia Engineering Division of Ground Technology Incorporated
  – Pine Ridge Coal Company, Lot’s Branch Impoundment

• Stolar Research Corporation – EM Gradiometer
  – Consolidation Coal Company, Emery Mine

• Colorado School of Mines – Borehole Radar Tomography
  – Edgar Experimental Mine
Electromagnetic and Radar Methods

Figure 6-3. Traveling electric field components illustrate the tilt in the vertical electric field component when the downward-traveling wave interacts with the Earth's surface.
Gradiometer receiver at first survey area. Depth of cover over the entries is approximately 80 to 100 Feet.
Look-Ahead Radar
Anticipated Final Project Completion Dates

- Blackhawk Division of Zapata (6/9/06)
- Colorado School of Mines (8/31/06)
- D’appolonia (7/15/06)
- L.M. Gochioco Associates (6/30/06)
- Marshall Miller Associates (6/30/06)
- Pennsylvania State University (6/30/06)
- Stolar Research Corporation (9/29/06)
- Wright State University (6/30/06)