OSM's Underground Mine Mapping Initiative[1]

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Abstract. Mine maps have been created for centuries by miners, mine engineers and surveyors for use in mine planning and management decisions. Today, mine maps provide vital information for engineers, scientists, community planners, developers and regulators for making decisions on land use, development, property purchase, and environmental protection. Accurate and readily available underground mine maps are essential resources for efforts to prevent future events such as the Quecreek Mine incident in Pennsylvania and the Martin County Coal Company impoundment failure in Kentucky. The Office of Surface Mining (OSM) has proposed a new initiative that provides enhanced technology to the States and OSM; allowing preservation of underground mine maps and ensuring electronic accessibility to stakeholders. This initiative includes improved service to OSM customers, partners and stakeholders, through technical assistance, technology transfer, and providing a sound technical foundation for informed decision-making.

OSM is continuing to work with the States and others on development of plans for this initiative as a follow up to a benchmarking forum held in 2003. OSM and the States are working to identify best practices for preserving, archiving, and distributing mine maps. A part of this effort is the identification of practices for georeferencing and manipulation of electronic maps using standard geospatial tools. These best practices will allow OSM and the States to identify resource needs and develop a set of voluntary standards for addressing the need for underground mine maps in a cost efficient manner.

Additional Key Words: standards, best practices, electronic accessibility, geo-referencing

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Introduction

Mine maps have been created by miners, mine engineers, and surveyors for use in mine planning and management decisions for centuries. Maps can provide information today for use by mine engineers, community planners, developers and regulators when making decisions on land use, development, property purchase, and environmental protection. Mine maps normally contain information regarding the depth of a mining operation, location of mine shafts and entries, geologic faults, aerial extent of mine tunnels and workings, water levels and other valuable information that may effect contemporary mining operations or surface improvements. The most frequent users of this information are state and federal agencies, mining companies, consultants, and engineering firms. Other users include research and planning organizations, real estate developers, highway engineers, pollution control boards, city and industrial planners, oil and gas companies, public organizations, special interest groups, universities, architectural firms, transit authorities, attorneys, private citizens and even law enforcement agencies.

Use of mine maps for planning and public/environmental protection efforts presents many challenges. The first challenge is one of acquiring a rapidly disappearing resource. Historic mine maps are quickly disappearing as older mining companies go out of business, sell their properties or are acquired and merged into a larger company. Many old maps are hidden away in the attics of retired mine engineers, basements of county historical societies, or archives of land holding companies. In addition, time has not been kind to maps and records that may now be well over one hundred years old. Without a concerted effort to find and preserve these maps, within a few years these valuable resources will be lost to society forever. This effort is needed to develop and implement an outreach program to assure that other sources of maps, particularly older maps, are identified, collected, copied (or scanned) and properly stored. Once these maps are destroyed or damaged beyond use the information is lost forever.

Another challenge is that mine maps are not readily available in easily understandable form. Many old maps are not directly referenced to the features on the modern land surface. Most historic mine maps were made on paper or linen. In order to be usable in modern public planning departments, mine company offices or by the public, they must be transferred to electronic media. This requires a process of map preparation, scanning and digitization to strict quality control standards. Once in electronic form, old maps must be correlated to modern

landmarks such as roads, railroads or other common map features in a process called geo-referencing. The process of geo-referencing must be done for each mine and is labor intensive, but essential for effective use of the maps.

Once mine maps are scanned, digitized and geo-referenced, they must be made available so that all interested parties, including mining industry managers, real estate developers, environmental protection personnel and individual citizens, may make informed decisions regarding lands overlying underground mines. The most efficient method for distribution of this data is by way of the internet. A few states, most notably Indiana, have made effective use of this technology to help all citizens and businesses to become more aware of the risks and opportunities associated with lands overlying underground mines. However, most states have not yet scanned the maps they have and few have moved the data to a readily available electronic format.

Finally, there appear to be some questions as to the liabilities that may arise as a result of making mine map information available to the public. Policy makers need to send a clear message that the collection and distribution of abandoned mine location data is in the public interest and should be promoted. Federal and state agency officials who manage the maps will need to work with mining industry officials to establish policies that dictate how confidential information contained on those maps will be protected to protect legitimate industry financial interests.

Background

Why the Lack of Maps Is a Problem

On October 11, 2000, the Big Branch Slurry Impoundment in Martin County, Kentucky broke through to an underground mine. Over 300 million gallons of coal-waste slurry flowed through the mine and contaminated miles of creeks and rivers. Investigation of the incident revealed that one factor that may have contributed was the lack of accurate maps of the underground mines (Thompson et al., 2001). This was the most notable of several accidents in recent years where slurry from coal-waste impoundments has broken into underground mine workings. These accidents have caused environmental damage, and have the potential to endanger persons working in the underground mines or living in the affected areas.

The Quecreek Mining Company Inc., Quecreek No. 1 Mine in Pennsylvania was flooded when miners cut into an adjacent flooded mine. Maps collected by the company during the mine planning process apparently showed the active workings to be more than 300 feet away from any other underground mine works. However, on the evening of July 24, 2002 miners breached the barrier pillar separating the active mine from the abandoned Saxman Coal and Coke Co., Harrison #2 Mine. Water from the abandoned and flooded old mine works rapidly poured into the active mine. While nine workers were able to escape the rising water, nine additional workers were trapped by the waters and backed into an air pocket about 600 feet underground and 8,000 feet from the mine entrance. In a rescue that many consider a miracle, the nine trapped miners were hoisted alive from a large diameter hole drilled by emergency crews. They returned to the surface 78 hours after the accident (Wu, 2003). During the response to the accident, more accurate maps of the abandoned mine were discovered which showed that the works were in much closer proximity (Brady et al., 2003). Mine Safety and Health Administration (MSHA) personnel estimate that inundation events occur on average every two to three weeks (Wu, 2003). While most are not so dramatic, each event has the potential to affect public safety, property and may result in unnecessary deaths.

These are just some of the incidents of this type that have occurred in the past 10 years which have threatened the safety of the public and the environment which could have possibly been avoided if accurate underground mine maps were readily available. The Commonwealth of Virginia estimates that its underground mine mapping efforts have prevented 4 incidents of this nature per year and have saved the state over $100,000 in costs annually and have avoided costs to industry in excess of $10 million (Collins, 2004).

The availability of accurate underground mine maps also protects public investment in public infrastructure. In Pennsylvania, millions of dollars have been spent to repair sections of Interstate 70 and other roads that have been damaged when underlying underground mines have subsided (Pieper, 2004). The same types of repairs have been necessary for portions of Interstate 70 in Ohio and Interstate 40 in Oklahoma and Kansas, among other roads throughout the country. With three interstate highways and numerous other public road projects being planned for the coalfields of West Virginia, billions of dollars of additional public investment may be at risk of damage from subsidence. If accurate underground mine maps are available, the roads can be routed or designed to minimize the damage or underground mines can be backfilled in order

to protect this public investment. The same is true of public investment in schools, hospitals and other infrastructure throughout the coalfields. The State of Maryland estimates that it has spent over $7 million in recent years to address impacts of subsidence and underground coal mining to roads, buildings and stream channels. Nearly $1 million was spent at Frostburg State University to stabilize land for new construction, some of which could have been minimized or the costs reduced if accurate maps were available (Garner, 2004).

In addition, thousands of homes and businesses lie over abandoned underground coal mines. These homes and businesses represent private investments of billions of dollars. In some cases, the homeowners and business owners have no way to find out where the mines are and what should be done to protect their investments and to minimize the threat to their safety posed by these mines. Readily available maps allow for planning and for actions to protect the public, such as reclamation of these abandoned underground mines.

The Citizen's Coal Co. abandoned its underground "B" coal mine in 1925 after 27 years of coal mining. In the years since, many of the features indicating the presence of the mine faded away and disappeared. The mine was largely forgotten and the extent of mining, although considerable, is unknown because no final map survived to this time. In the 1990's several residential subdivisions were created and approximately 280 new homes were built creating an affluent area in the north-west side of Springfield, Illinois. Recently, the forgotten Citizen Coal Co. 'B' Mine has made itself known to residents and city leaders. Twenty-five subsidence events have occurred in the new subdivisions causing significant damage to 140 homes. Damage exceeding half the home value was common and several homes were total economic losses. Roads and infrastructure were also damaged by these subsidence events and will require repeated repairs--a continuing economic burden to the city. The economic impact of building in this area, where no mine map was available, is enormous. So far, the total cost of damage to homes exceeds $17.5 million and it is expected that the city will lose about $5.6 million in tax revenue because of these 25 subsidence events. Long term additional costs of infrastructure maintenance are incalculable. Because subsidence events in the Springfield area typically take 10 years to reach stability, the rebuilding of these affected areas will present significant long-term challenges (Meier, 2003).

According to information provided by the State of Pennsylvania, the costs for repairs at two developments in Pennsylvania, where homeowners were unaware of the mining and had no

subsidence insurance, were nearly $2 million. In addition, Pennsylvania indicates that in areas where underground mine maps are limited or unavailable, the state and OSM spend significant resources conducting exploratory drilling programs to make proper judgments related to the protection of residences (Pieper, 2004).

Finally, many of these abandoned underground mines are flooded, and in some areas of the country many of these mines in the same area are hydrologically connected to one another, creating massive underground mine pools. These pools of water may contain contamination, such as alkaline or acid mine water and metals. In some cases, the volume of water is increasing to the point where the pools will soon begin discharging to the surface. These discharges could threaten the quality of surface water, disrupt public drinking water supplies, or directly threaten the lives of downstream residents if they occur in an uncontrolled manner. The availability of accurate maps of the abandoned mine workings will allow for more accurate calculations of the volume of water contained in these mine pools and for planning to deal with the discharges. In some cases, the water contained in these pools can be used for industrial or other purposes. Knowing the volume of the water would allow for investment based on the availability of the water supply and for potential economic redevelopment in the coal fields.

Historical Efforts

In fiscal year 1970, the U.S. Bureau of Mines (BOM) initially funded four regional mine map repositories located in Denver, Colorado, Spokane, Washington, and Pittsburgh and Wilkes-Barre, Pennsylvania. This repository system was set up to obtain and microfilm maps of past mining operations in the United States. High priority was assigned to mine maps of areas where the adverse impact to the environment or public safety was most severe.

OSM was established by Congress with passage of the Surface Mining Control and Reclamation Act (SMCRA) in 1977. In that law, Congress sought to establish a nationwide program to protect society and the environment from the adverse effects of surface and underground coal mining operations, and assure that the coal supply essential to the Nation's energy requirements and to its economic and social well-being is provided for. In late 1984, responsibility for the Pittsburgh and Wilkes-Barre Repositories was transferred to the OSM, with the Denver and Spokane Repositories remaining with the BOM. During fiscal year 1996, the BOM closed their Denver and Spokane Repositories and all maps and related information were

transferred to the Pittsburgh Repository. With the acquisition of these western mine maps, the Pittsburgh Repository expanded its mission nationally.

The Pittsburgh Repository, which became the National Mine Map Repository (NMMR), serves as a reference facility for information on abandoned surface and underground mines throughout the United States. The repository is able to satisfy the Title II requirements of SMCRA and support the abandoned mine land and regulatory activities of SMCRA. The NMMR provides all customers seeking mine information (public, business, State, Federal, etc.) with an expert service ranging from evaluating related data for economic analysis to assessing the potential risk associated with underground mining at specific locations. Through analysis of mine maps and related information, assistance has been given to both the private and public sectors in industrial and commercial development, highway construction and the preservation of public health, safety and welfare.

The NMMR collection currently contains approximately 250,000 mine maps from states throughout the country. Of those, about 82,000 maps have been scanned and stored electronically. The NMMR implemented its scanning program in 1998 and currently scans about 5,000 maps a year. At this rate, it will take over 30 years to put all of the Pittsburgh collection into digital form for use in computer applications. In addition, there is still a large inventory of data and other mine maps archived in Denver (from the former BOM repositories) that needs to be scanned. The NMMR does not currently have the data in an internet format where the public could perform inquiries using the internet from their office or home computer.

MSHA provides the NMMR with closure maps of abandoned coal mines that are received from operators when mining is completed. These closure maps include the notes recorded concerning geologic conditions, water inflows, roof falls, etc. The mine maps are forwarded to OSM for cataloging and microfilming, scanning and returned to the respective District office in MSHA. Returned maps bear the microfilm catalog numbers assigned by the NMMR. The NMMR has also developed arrangements with some states to scan their map collections. The state of West Virginia has had the largest collection of maps scanned to date. Others states working with the NMMR include Ohio and Illinois.

Part of the NMMR mission includes an assertive outreach program for the acquisition of abandoned mine maps. However, due to inadequate resources the NMMR has not been able to

collect and process all maps that have been made available by state agencies, mining companies, private individuals, universities, etc.

In order to address the lack of resources and meet the renewed need for the collection of mine maps, the NMMR has developed a five-year plan. This plan addresses funding requirements and refines the need for the NMMR to provide a more customer friendly product to its customers. The objectives of the plan coincide with several recommendations of the National Research Council's (NRC) report – "Coal Waste Impoundments" – and actions that MSHA and OSM have taken in response to the NRC report. The objectives include developing a plan to improve outreach to map owners, improved technical capability for the electronic copying and storage of mine maps, and the development of a web based retrieval system for mine maps to improve information access to the public and other government agencies.

A national geological mapping program has given some guidance and encouragement to the formation of mapping programs. The National Geologic Mapping Act of 1992 established the National Cooperative Geologic Mapping Program to implement and coordinate an expanded geologic mapping effort by the United States Geological Survey (USGS), the State geological surveys, and universities. The primary goal of the program is to collect, process, analyze, translate, and disseminate earth-science information through geologic maps. The geological information (mostly topographical) is being made available on GIS Clearinghouse internet sites. The availability of mining information so far is in-house or limited.

State agencies have established their own standards for collecting and cataloging maps, and the NMMR has developed a liaison with the States for the purpose of exchanging information on scanning technologies. In October 2003, in response to the NRC report, OSM, MSHA and the Interstate Mining Compact Commission (IMCC) co-sponsored a benchmarking workshop to allow the States to discuss their standards and their ongoing efforts to address the need for accurate underground mine maps. The workshop provided detailed discussions of practices being used in acquisition of maps, map preservation, scanning and geo-referencing, data storage, public access to maps, and other related topics. While the workshop provided a successful information exchange, no standards were adopted nor were best practices identified. At the workshop, MSHA announced some funding for States to use to enhance their underground mine mapping efforts aimed at protecting mine workers. This funding was distributed early in 2004.

The Initiative

Goals

The goals of the initiative focus on achieving improved reclamation of AML through increased knowledge of existing underground coal mines and the ability to better plan for reclamation and to prevent emergency events. In addition, the initiative will result in reduced offsite impacts from active mining by allowing for better planning of operations near existing underground coal mines to prevent breakthroughs and other similar events. The initiative will also allow for a reduction in safety risks and in the potential for fatalities and serious injuries posed by abandoned underground coal mines by providing for better information on the location of these mines through readily available mine maps. These efforts will help protect investments in public infrastructure, as well as private investment in homes and businesses. Finally, the initiative will provide stakeholders with access to needed scientific information.

Details of the Initiative

OSM proposes to enhance the capabilities of OSM and the States to make underground coal mine maps available to stakeholders in a digital format by developing standard practices and, where necessary, acquiring hardware, software and personnel resources. This initiative is composed of four significant parts: identification of best practices and adoption of voluntary standards; establishment of underground mine map centers of expertise in several States and the enhancement of the capabilities of the NMMR; acquisition of underground mine maps to ensure the best possible coverage; and, development of a distributed structure of managing underground mine maps which makes them available in a secure electronic format over the internet.

To this end, OSM will work with the States to identify ongoing efforts and best practices related to issues such as:

- Preservation and storage of deteriorating hard copy maps.
- Availability and accuracy of mine data and information.
- Gaps in information and how these will be addressed.
- Computer system requirements.
- Digitizing standards.
- Special requirements for geo-referencing.

- Preservation of engineering notations and other information from original maps.
- Portals and other linkages of state and federal databases and map collections.
- Internet accessibility for federal, state and private needs.

As the initiative progresses, there will be a continuing need to address emerging technologies and other geospatial data standards and approaches that are being developed, such as those underway at the USGS.

The second part of the initiative involves enhancement of the NMMR's capabilities and the establishment of underground mine mapping centers of expertise in several States. This would involve upgrading the ability of the NMMP to process maps, complete scanning functions and create an internet access portal to the repositories databases and scanned maps. The repository would function as a national data archive and a backup to the state repositories containing the original paper and linen maps, copies and scanned image databases. It would serve to link State and other agency electronic archives.

The second part of the initiative also involves providing adequate resources to several States for equipment and in-house personnel to carry out proper scanning, geo-referencing and placing maps in an acceptable format and storing in databases. The size of the programs in the States would be determined by their inventory of underground coal mines, their capabilities to manage a program, and their desire to house a center of expertise. There may be several other States interested in developing programs but smaller than the full centers of expertise. These states may not have enough underground mining activity to justify a full time program, but nevertheless may have unique characteristics in their mine map program to justify an "in house" mapping program. For States that would not have these centers, the major responsibilities mentioned above will be carried out by the NMMR in Pittsburgh. It is anticipated the backlog of known underground mine maps could be collected and processed within a five-year period.

For the third part of the initiative, OSM, working with the States, will conduct an outreach campaign working with industry, landowners, the public and other State and Federal agencies to acquire underground coal mine maps, particularly for known mines where no map is currently available.

The fourth aspect of the initiative involves making maps available to the various customers electronically using the internet. One efficient method for distribution of this data is by way of

internet map server technology. A few states, most notably Indiana, are making effective use of this technology to help all citizens and businesses to become more aware of the risks and opportunities associated with lands overlying underground mines. However, most states have not yet moved their existing data to the internet. To ensure long-term viability there is a need to continually enhance the program by identifying means for improvement of the availability and quality of underground coal mine maps.

Some funding would be necessary under this initiative to manage the program and evaluate mapping center of excellence proposals. This would involve evaluating the needs for hardware, software and personnel, administering the selection of States receiving funding, the amount of funding, and providing the necessary oversight and accountability of the funding and results. The funding would also provide for preparation of reports based on the mapping initiative. Finally, some funding would be used for technology transfer and technical assistance activities to ensure that the results are made available to interested parties and utilized by Federal and State agencies, AML programs, the coal industry, and the multitude of other potential customers for underground mine maps.

The proposed funding would provide for the States and OSM to preserve underground mine maps and to provide them to stakeholders in an electronic format. This initiative will also fund additional tasks essential to develop a comprehensive underground coal mine map resource. In addition, NMMR will be continuing to implement its five-year plan, which includes improving the coordination with the States on the development of a national electronic database of mine maps. While this funding would not complete the required work, it would allow the States and OSM to take meaningful steps to protect the public and the environment.

Current Status

Since the 2003 benchmarking workshop, OSM and the States have been in ongoing discussions aimed at identifying the next steps necessary to protect the public, infrastructure and the environment by enhancing the availability of underground mine maps. These discussions have centered primarily on a second workshop for the purpose of developing a compendium of best practices in several areas related to underground mine mapping, including scanning, data

formatting, geo-referencing and data management. It is anticipated this meeting will occur during 2005.

OSM's Technical Innovation and Professional Services (TIPS) program has begun development of a class focused on using the standard geospatial tools that are a part of the TIPS software suite (ESRI GIS tools and AutoCAD-based tools) for georeferencing and utilizing underground mine maps which have been scanned. Additional work has been going on to identify what map quality and metadata are necessary in order to accurately complete the work. This effort has been in conjunction with the ongoing efforts to establish best practices and standards.

Additionally, OSM has been working to develop a budget initiative to provide the necessary resources to achieve the goals of the initiative. These efforts have been directed to the internal Federal budget process and have also included working with other agencies, such as the USGS, the Department of Homeland Security, and MSHA to identify other compatible programs within the Federal government. Some initial funding may be included in the FY 2006 budget. However, to complete this work, it will be necessary to secure a stream of funding for the long term. To achieve all the goals, this initiative could cost millions of dollars and take over 10 years to complete.

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