SIMPLE ENGINEERING DATABASES:
CRITICAL ABANDONED MINES DECISION-MAKING TOOLS

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ABSTRACT

Abandoned mines represent major hazards for infrastructure as well as the population, but remain relatively unknown with little information surviving their closure. Databases containing basic site information are important to supply information for more advanced databases and infrastructure engineering and emergency response to mine failures. An example of such a database is presented, highlighted by a 3D mine reconstruction visualization technique which can incorporate a wide range of geology, geomechanics, infrastructure and other information. Application case studies are presented as are options for information handling and downloading from databases.

1. Introduction

Like any growing industry with a rich history, mining left its mark on the United States and Canada. Prior to the enactment of stringent local, state/provincial and federal environmental laws and regulations, operational convenience rather than environmental and stability concerns guided mining. With economic mining terminated, operators commonly abandoned sites with little, if any, thought to public and infrastructure protection, and reuse of the land.

Until recently, few mine plans and basic site information have survived mine closures. Yet, there are increasing requirements for such information with regards to avoiding impacts to active mine operations as witnessed by the 2002 Quecreek Mine accident and to the ongoing impacts to the population, roads and other infrastructure.

Collating and storing abandoned minesite information is the first step in maintaining and providing accurate records for a large cross-section of mining and abandoned mine stakeholders. Databases may contain a variety of information pertinent to basic storage needs and transmission. To date, such databases have consisted mainly of primary information such as coal seam/ore deposit location, location of surface features such as mine shafts and adits and occasionally more extensive information assembled and made available by government authorities, such as claims and prior mine titles, electronically-stored mine maps, reference location of mines, basic mining extraction information, surface geotechnical and road specifications, and linking of abandoned mine location to city streets [1][2][3][4].

Such information is essential to all users of abandoned mines data. It also forms the foundation source for other electronic abandoned mine database application, such as engineering projects. In the case of locating abandoned mines in situ, evaluating stability or planning remediation or new roads, such basic data has to be translated to engineering information and the database structured in consequence of providing the information within an engineering useable format.
2. Database Treatment

Registering and collating abandoned minesite information is best performed using modern computing and database management technology.

A database must function under an efficient structure to meet the requirements of and remain flexible for users, and be capable of evolving with advancing computer technology. It will feature:
- An adaptable database structure
- Easy, selective data retrieval
- Interface capabilities between the data and analytical/expert systems that import data directly (e.g. numerical modeling, GIS)
- Existing, relevant data
- Data that is current

Table 1 displays the range of information such a database should contain, for understanding site issues, locating problems and previous site work, and perform in-depth site stability analysis, risk analysis, and remediation design.

For regulatory agencies and impact-driven organizations such as the Federal Highway Administration (FHWA) and the Mine Safety and Health Administration (MSHA), a logical extension of the use of an abandoned mines database resides in using the information to obtain a view of:
- Types of hazards that exist
- Trends in decommissioning strategies
- Quality, extent of remediation measures applied
- Effective decommissioning strategies for rock mass types and mining regimes
- Extent of the risk associated with mines which will become inactive
- Ability to monitor and manage risk over the long term
- Site ranking in a given risk prioritization system

A good example of such a database was established by the CANMET Mining and Mineral Sciences Laboratories as part of major abandoned metal mining projects (in Ontario) and coal mining projects (in Nova Scotia). Specialized computer techniques and software were established to create and manage a comprehensive database interactive with external users (Figure 1), containing attribute data (single minesite characteristics and details which combine to describe common themes) and documents data (literary and graphical representations of information converted to digital format) [5].

Through specially developed CANMET-MMSL software, users accessed the database and performed complex queries of attribute data to create selection sets consisting of only the data and documents they wished to view (including 3D reconstructions and spatial GIS relationships), searches from various criteria, manual browsing and selection, and actual document display for viewing (Figure 2).
Table 1. Decommissioning shallow stope database information content.

**Literal Description** (word processed)

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Site</strong></td>
<td>Name of mine&lt;br&gt;Mine location (province, township, UTM coordinates, NTS location, site grid)&lt;br&gt;Property boundaries, shaft coordinates</td>
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<tr>
<td><strong>Tenure</strong></td>
<td>Mining/surface rights owner&lt;br&gt;Caretaker contacts</td>
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<tr>
<td><strong>Mining history</strong></td>
<td>Production date&lt;br&gt;Closure date&lt;br&gt;Operation shut-downs</td>
</tr>
<tr>
<td><strong>General minesite</strong></td>
<td>Production statistics (yearly, total)&lt;br&gt;Reserves left&lt;br&gt;Commodities mined&lt;br&gt;Mining methods and the application to shallow stopes&lt;br&gt;Mine extraction progression&lt;br&gt;Conditions or events occurring under a previous owner before their shut-down</td>
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<td><strong>Geology</strong></td>
<td>Class (igneous, metamorphic, sedimentary)&lt;br&gt;Rock type, formation history&lt;br&gt;Shape, attitude of orebody&lt;br&gt;Interrelationship, contact, conditions (country rock, ore zone, hangingwall/footwall, intrusive)&lt;br&gt;Relation to mine workings&lt;br&gt;Structural geology, main features; folding and faulting trends</td>
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<tr>
<td><strong>Openings to surface</strong></td>
<td>Type (mine access, ventilation, failure)&lt;br&gt;Dimensions&lt;br&gt;Geographical, mine grid coordinates&lt;br&gt;Nomenclature</td>
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<tr>
<td><strong>Underground failures</strong></td>
<td>Type (self stopping, to surface)&lt;br&gt;Dimensions&lt;br&gt;Start and end location&lt;br&gt;Geomechanical descriptive and timeline&lt;br&gt;Monitoring information</td>
</tr>
<tr>
<td><strong>Underground failures</strong></td>
<td>Type (self-stopping, to surface)&lt;br&gt;Dimensions&lt;br&gt;Start and end location&lt;br&gt;Geomechanical descriptive and timeline&lt;br&gt;Monitoring information</td>
</tr>
<tr>
<td><strong>Subsurface inventory</strong></td>
<td>Nomenclature and date of stope excavation (location above 200 m)&lt;br&gt;Depth from surface&lt;br&gt;Dimensions&lt;br&gt;Rock mass quality 30 m around stope and above to surface&lt;br&gt;Ground control issues&lt;br&gt;Ground support and pattern rational&lt;br&gt;Type, design, location of mine fill, bulkheads; % stope filled&lt;br&gt;Date of surface crown pillar recovery</td>
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<tr>
<td><strong>Surface infrastructure</strong></td>
<td>Type (waste piles, tailings, buildings, accessways, utilities, etc.)&lt;br&gt;Date of construction&lt;br&gt;Location, coordinates&lt;br&gt;Status, integrity</td>
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Table 1. Decommissioning shallow stope database information content (continued).

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<th>Table 1. Decommissioning shallow stope database information content (continued).</th>
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<td><strong>Future land use</strong></td>
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<td><strong>Remediation inventory</strong></td>
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(Geotechnical parameters have a wide variation of values which must be available to grasp the nature of the material when performing stability analyses. It is therefore equally important to provide information on the range of the parametric value, the tests performed and the confidence the mine operators attach to the data that is quantified: is there sufficient information, is it complete?)

**Spatial information of mine features**
(in the form of mine plans, sections, maps, and reconstructed 2D and 3D features, digitized)
(based on information from geophysical means if original information is unavailable)

Nomenclature of underground openings
General geology
Structural geology aspects, main features
Orebody
Shaft collar and site survey benchmark
Underground openings
Location of mine fill, % filled, bulkheads
Site remediation location, type

As well as 3D graphical format of:

Underground openings combined with overburden, surface infrastructures, bodies of water, tailings areas; where possible combined with GIS maps, borehole information, monitoring and rock mass displacement aspects, site remediation measures (concrete caps, fencing, removed pillars, etc.), rock mass ratings, characterization aspects, bedrock weathering/rock mass variability, etc.

Designation of underground aspects: location and details of filled stopes, extent of underground failure, zones of different types of ground support, rock mass quality, location of bulkheads, main geological structures, etc.

**Important written, graphic and photo records and references (scanned)**

Photographs (annotated)
Graphical representations
Mining extraction progression
Site engineering reports
Articles, company reports, etc.
Authors of mine decommissioning plan
Design of remediation measures
Design, location of concrete caps
Site remediation, chronological, location
Correspondence with province, municipality on site issues, decommissioning

**Results of physical stability analyses (word processed, scanned)**

Monitoring instrumentation type, location, data (word processed, scanned, digitized); program and procedures

Risk analyses (word processed, scanned)
Figure 1. The CANMET-MMSL inactive mines integrated database information system. The attributes database portion relates to single mine site characteristics and details which combine to describe common themes. The documents database portion contains literary and graphical representations of information which have been converted to digital format.
Figure 2. Detail of a selection of attribute information from the CANMET-MMSL database.
The database has been used by the Governments of Ontario and Nova Scotia to collect information on each province’s 100 most hazardous abandoned sites and linked it to their exploration databases. Furthermore, they have allowed it to be used by mining operators within their mine decommissioning plans.

The database is an important complement to planning site rehabilitation or new roads and identification of existing hazardous situations. Information on underground features and site reconstruction (Figure 3) provides knowledge of spatial relationships. The location and nature of surface features such as mine and civil infrastructure can be related in such reconstructions.

Such 3D spatial reconstructions will provide a better perspective tool than 2D mine plans and sections and offer an ideal opportunity to combine several types of information on one master document. Placed in perspective, and available on close-ups, sections, etc, can be drill core data, distinct rock mass quality zones, predicted numerical modeling rock mass movements, instrumentation rock mass displacement information, expected failure path, remediation measure, surface and buried infrastructure. Furthermore, rotational and fly-in/fly-out capability can be used. This combination of information alone represents a most powerful decision making-tool.
CANMET-MMSL has developed interfaces to import 3D database mine drawings developed in AutoCAD®, to a format which can be processed directly by numerical modeling software. This simplifies the application of numerical modeling to delineate failure mechanisms and provide factors of safety when possible from the type of modeling code.

In emergency situations such as collapse of a minesite which affects infrastructure, the database can be available full time to provide graphical images of the site and vital location and geomechanical information in support of remediation.

3. Application Examples

A major site investigation project was undertaken by CANMET-MMSL and Procter Redfern Consultants for the Ontario Ministry of Northern Development and Mines to evaluate an abandoned minesite beneath an important and unique access road beyond the mine. CANMET-MMSL carried out an extensive review of the site applying a number of site characterization and stability analysis techniques in order to provide information for various remediation or road relocating options.

Comprehensive information about the minesite was stored in CANMET’s inactive mines database. This included the complete range of site, extraction, stability and remediation information that could be used to provide valuable information at any point for minesite evaluation and to visualize the impact of new information on site physical features, monitoring displacements and numerical modelling results.

The consideration of the stored information, started with confirmation of underground workings location, from a longitudinal section which when evaluated with the existing written information on the extraction history led to the development of underground and surface site reconstruction using 3D techniques (Figure 3). In this manner, spatial relationships of underground openings, surface crown pillars and the highway were established. The depth to the old mine workings under the highway was estimated to be less than 10 meters.

A two-phase drilling program was undertaken at the site to more precisely identify the relationships between surface and the underground openings. The drilling confirmed that the 3D reconstruction of the depth of workings below surface was accurate (correct to within 0.3 m). Drilling information was incorporated in the 3D reconstruction. Drilling showed the overburden to be a thick layer of unconsolidated, incompetent coarse sand. The rock crown above the stope was relatively thin: drilling also identified a zone of failed ground, characterized by voids up to 0.3 m wide above the back of the original stope. Under the western edge of the road, only 1 m of weak rock remained between the yielded ground and the unconsolidated overburden material.

Two different failure mechanisms were identified and also incorporated into the 3D reconstruction, as were possible surface remediation measures such as a concrete slab. Eventually, an option was chosen to bridge the unsafe zone.
The database was successfully employed at another Ontario abandoned mine area where several public buildings and roads are located in close proximity to shallow stopes (Figure 4). The 3D model helped to understand the spatial relationships between the buildings and the road with the underlying stopes, allowing for strategic siting of drill holes to delineate areas of concern and apply long-term rock mass displacement instrumentation.

Figure 4. Reconstructed Howey Mine, Ontario.
4. Practical Issues

To meet the requirements of a fully useable database (outlined in section 2), the database must be designed as a flexible system capable of evolution as the understanding of the impact of inactive mine sites on the environment evolves and as a computer technology and its application to the treatment of this understanding progresses.

For example, graphical user interface to handle information from the database will have to improve with respect to file size handling in real time in order to successfully use large 3D files with various incorporated information (modeling results, etc.).

A wide range of options for obtaining information contained in a database is required to provide support to the wide range of electronic capabilities of users and in emergency situations. Electronic link-up through modems with voice grade communications, while not expedient, may still be in use by certain organizations. The use of the internet has become the standard for information transfer. Yet some of the most significant situations in which the data may be of importance could be under conditions which preclude direct electronic access. Some information can be quickly sent by facsimile to a cellular phone, or website access with this portable technology, or sent to a location which does not have the requisite computer capabilities for direct access.

5. Summary

An abandoned mine database can provide basic site information related to mining history and geological, geomechanical and other engineering information that will provide critical support to failure avoidance, understanding, and remediation, and new infrastructure construction.

Advanced visualization using 3D spatial reconstructions will provide a better perspective tool than 2D mine plans and sections and will provide an opportunity to combine any or all site, rock mass, remediation and other site evolution information.

All database information can now be downloaded or effectively queried from its original site using current electronic communication strategies, which is a significant advantage during emergency or remote location situations.

6. References


