Ground Support Audit at Brunswick Mine – Data Collection and Results Management

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ABSTRACT: Ground support audits are sometimes necessary in ageing underground mines. Usually, the purpose of such audits is to assess the state of the ground support in various parts of the mine, identify areas that require attention and establish rehabilitation requirements. In 2005, Brunswick Mine, located in Bathurst, New Brunswick, Canada, completed a comprehensive mine-wide ground support audit. The areas examined included excavations in several mining blocks, as well as ramps, shaft stations, garages, shops, etc., throughout the mine. A vast amount of data was collected over a period of two weeks by multiple auditing teams. The audit was followed by a data digitisation exercise, and the creation of a data management system to store audit results and keep track of subsequent rehabilitation activities as they occur. One aspect of the data management system was the incorporation of a function for reporting on ground rehabilitation progress, along with the capability of updating mine level plans for easy visual presentation of this progress. This article describes the approach implemented at the mine to carry-out the audit, as well as the database constructed to manage the results.

1 INTRODUCTION

In the life of any ageing underground mine comes a moment when the quality of previously-installed ground support needs to be evaluated. This can be driven by a number of reasons:

- Old mine workings need to be used again. Existing ground support must be evaluated and likely brought to the current standards.
- Critical infrastructure must remain problem-free during the entire life of the operation. Any potential instabilities have to be identified early and addressed.
- Management wants to ensure that the underground infrastructure is in good condition and continuously maintained.

At such times, a mine-wide ground support audit may be commissioned. Usually, its purpose is to identify areas where ground support rehabilitation work is required and to what extent, and to categorise these areas based on urgency. Unfortunately, after enormous efforts were spent on data collection there is often no efficient mechanism that allows the mine's ground control personnel to organise and quantify the gathered information, track rehabilitation work, and report on progress with respect to the initial state.

In the Fall of 2005, Itasca Consulting Canada, Inc. (Itasca Canada) was asked by the Xstrata Zinc Brunswick Mine to assist the operation's Ground Control Department with a mine-wide ground support audit. This paper presents some aspects of this project, particularly how the information was collected and organised.

2 PROJECT BACKGROUND

The Xstrata Zinc Brunswick Mine is an underground zinc-lead operation situated near Bathurst, New Brunswick, in Atlantic Canada. The ore body was discovered in 1953, and the mine began production in 1964. It currently produces over 9,000 tonnes of ore per day.

In the Fall of 2005, Itasca Canada helped the mine's Ground Control Department to carry out the inspections of various underground infrastructures. The areas examined included excavations in several mining blocks, as well as ramps, shaft stations, garages, shops, etc., throughout the mine.

These inspections had two principal objectives. Firstly, they were meant to obtain a snap shot of the ground support conditions in the underground workings. Secondly, they were to provide mine management with the means of assessing the resources necessary to rehabilitate the underground workings that required, or would require in the medium term, reconditioning.

The inspections themselves were carried out over a two-week period, and were followed by digitisation of the collected data and the development of a custom data management system.

3 INSPECTIONS

Prior to the commencement of the audit, the Ground Control Department had a clear idea on how the audit was going to be carried out and had established ground support classification guidelines to be followed by all people involved. The results of the audit were to be in the form of colour codes implemented directly on paper level plans, with concise accompanying notes. The inspection teams were to assign colour categories to the back and both walls everywhere the audit took place. The following criteria were followed and applied to the back and walls:

- *Green Category*. The ground support in the area is either as per, or above, mine standards. Importantly, assessing whether or not the support in place will remain adequate in the future (if, for example, seismic activity is triggered in the area, or relaxing conditions conducive to structurally-controlled gravity-driven failures are created) was not undertaken. This would have required a detailed knowledge of the upcoming mining plan, and would have taken much more time than was allocated for this work.

- *Blue Category*. The ground support system is below standards, but the ground conditions in the area are good, and, hence, shortcomings in the support system do not pose an immediate fall of ground hazard; or, the ground support in the area is still as per standards, but is deteriorating to the point of requiring rehabilitation work within the foreseeable future.

- *Yellow Category*. The ground support system is below standards and the ground conditions in the area are poor. Although there is no immediate risk, the area will require rehabilitation in the short term.

- *Red Category*. The ground support system is largely ineffective and the ground conditions in the area are poor (unstable ground, loose material). There is an immediate risk of ground fall, and the area is to remain closed until rehabilitated.

The inspections were carried out by teams of two people, one from the mine and one from Itasca Canada. This was done to minimise the risk of potential problematic areas being missed by a single inspector. All the inspections were done on foot, also to minimise the risk of missing potentially problematic areas. Although a certain level of inconsistency between teams is unavoidable in this type of work, an effort was made to minimise bias by continually rotating members in the teams. At the start of the project, all members of the project spent half a day carrying out inspections as a group. This helped to bring everyone to the same level of understanding in terms of ground support performance assessment, classification categories, and mechanism for data recording.

Three two-member teams carried-out the inspections. The audit covered mine workings on 49 levels and sublevels, with a total linear extent of nearly 60 km.

At the end, the work represented a snap shot of the state of the ground support in the mine at the time of the inspections. Importantly, it was not a direct assessment of the risk of ground falls. A green rating, for example, did not guarantee that no ground instability would ever occur in the area, but, rather, that the ground support installed in it was at the time of the inspection as per mine standards.

Also, it is understood that ground conditions evolve and ground support elements deteriorate over time. What was rated "Green" in September 2005 can conceivably become "Blue", "Yellow", or even "Red" after a while. As a result, the ratings produced during the audit cannot be directly used in the future by planning personnel for the purpose of assessing ground rehabilitation needs prior to bringing a given area into production (by then, the rating may well have changed, or a rehabilitated area may have deteriorated again).

4 DATA MANAGEMENT

Once the audit was completed, its main product was a stack of mine level plans full of coloured lines and written comments. Leaving collected information in such form significantly limits its future usefulness. First, information stored on paper tends to be under-used as it is awkward to search and is time consuming to process. Second, such information is likely to remain static as updates to it, again, take time to implement. This was well-understood at Brunswick Mine, where the results of the audit were converted into a digital form.

Having coloured lines on a paper mine level plan, however, has one significant advantage: it is a very visual and efficient mechanism for data presentation. By looking at such plan one can immediately see where trouble areas are located and the level of attention required to address them. This was something that had to be preserved when converting the collected data from "analogue" form into a "digital" form. In addition, the presentation of the data had to be dynamic, i.e., able to show conditions at present day, not only conditions at the time of the audit.

The solution was to develop a two-component system for the audit data storage. The first component was a database containing the collected information and tracking changes as rehabilitation work took place. The second component consisted of a series of CAD drawings that showed audited areas using the same system as when the information was collected, i.e., coloured lines on excavations' backs and walls. The system had to have the ability to convey any changes made in the database into the drawings.

4.1 *Database Engine*

The *Microsoft Access* database software package was chosen to facilitate data storage. The reasons for such choice were as follows:

- Powerful. *MS Access* is a powerful full-featured Relational Database Management System (RDBMS).
- Simple. Many people are already familiar with the software. If not, learning the package is fairly easy.
- Rapid development. Custom database applications can be developed rapidly and efficiently using *MS Access*.
- Ease of deployment. An application resides entirely in a single file, and minimum time is required on site for its setup and configuration.

- Availability. Brunswick Mine already had *MS Access* on site; no additional software needed to be obtained.

The database for the management of the audit data was designed with two functions in mind. The first one was to be a repository for the collected data, i.e., a snapshot of the ground conditions observed at the time of the audit. Any reconditioning work carried out at the mine was to be based on this information. The second purpose of the database was to track progress with respect to rehabilitation work. Updates made to ground support conditions as reconditioning is carried out should be recorded, allowing for updates to the CAD system.

4.2 *General Data Organisation*

In relation to data organisation, the two main challenges faced prior to the development of the system were 1) how to organise the collected data such that they conform to a relational database record structure and 2) how to reference the database records to physical locations underground and to CAD drawings. Coming up with a concept of *Area* helped solve both issues.

In order to organise the collected data and facilitate their storage in the RDBMS, every piece of information entered into the database was related to a particular *Area*. In a physical sense, an *Area* is a section of mine workings where classification category for the ground support conditions, as determined by the audit, remains unchanged. To constitute an *Area*, categories for each of the walls and the back do not have to be the same but only remain constant in a section of an excavation. Figure 1 illustrates the idea.

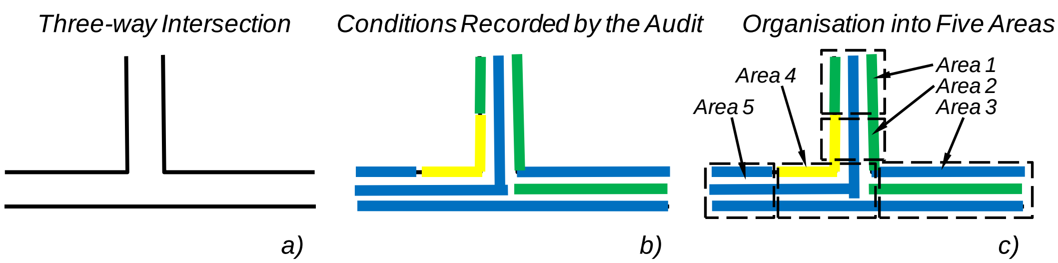

Figure 1. The concept of *Area* is illustrated using an example in a three-way intersection (a). The audit established ground support condition categories in accordance with the guidelines (b). The audited section is subdivided into *Areas* (c). In each *Area*, the audited condition in either wall or back remains constant.

The subdivision of the inspected underground workings into *Areas* was straightforward. Some time was spent by a ground control technician at the mine inspecting the information collected on paper, and identifying and marking *Areas* according to the definition.

The next required step was to digitise the collected information, producing an electronic record of the audit's results. Brunswick Mine uses *AutoCAD* (a product of Autodesk, Inc.) and *AMINE* (a product of Flairbase, Inc.) to create and manage CAD data and mine layouts. The digitisation of the audit results was carried out similarly to how the information was collected in the first place: a technician drew coloured polylines over existing level plans. The difference was that the digitisation was performed such that the polylines were drawn by *Area*, i.e., they were not allowed to cross *Area* boundaries. The end product was a set of CAD files with audit data, which could be superimposed on level plans similarly to any other mine-related information. This ensured that the advantage of presenting results visually was preserved.

Once the initial digitisation was completed, the post-processing and data entry phase began. Post-processing was required for tying the audit information in the database, which was organised by *Area*, to *Area* entities in the CAD files. In order to accomplish this, each individual *Area* was assigned a unique identification (ID) number. Once the ID for a particular *Area* was established, the data relevant to that *Area* were entered into the database.

4.3 *Area ID Tagging in CAD*

In order to make each polyline belong to a specific *Area* in the CAD files, a method was developed for tagging polylines with *Area* ID numbers. This was essential for making the entire system dynamic, and capable of updating the colour status of the various *Areas* as rehabilitation work took place.

The CAD entity tagging was developed using the *extended entity data* (*XData*) functionality of *AutoCAD*. The use of *XData* allows one to attach auxiliary non-graphical information to graphical objects in *AutoCAD* drawings. The *XData* functionality is not normally accessible through the standard *AutoCAD* interface and some custom programming was required for its implementation. To carry out the task, custom routines were developed to facilitate entity tagging with *Area* IDs. In the end, it was a point-and-click operation, making it very easy for an operator to carry out the tagging efficiently.

4.4 *Database Organisation*

The design of the database developed for the management of the audit data is relatively simple. Figure 2 shows a diagram depicting the various tables used for data storage. The database contained only ten tables, the functions of which being separated into three categories: storage of collected data, tracking of data related to reconditioning underground, and storage of application's metadata or data about data.

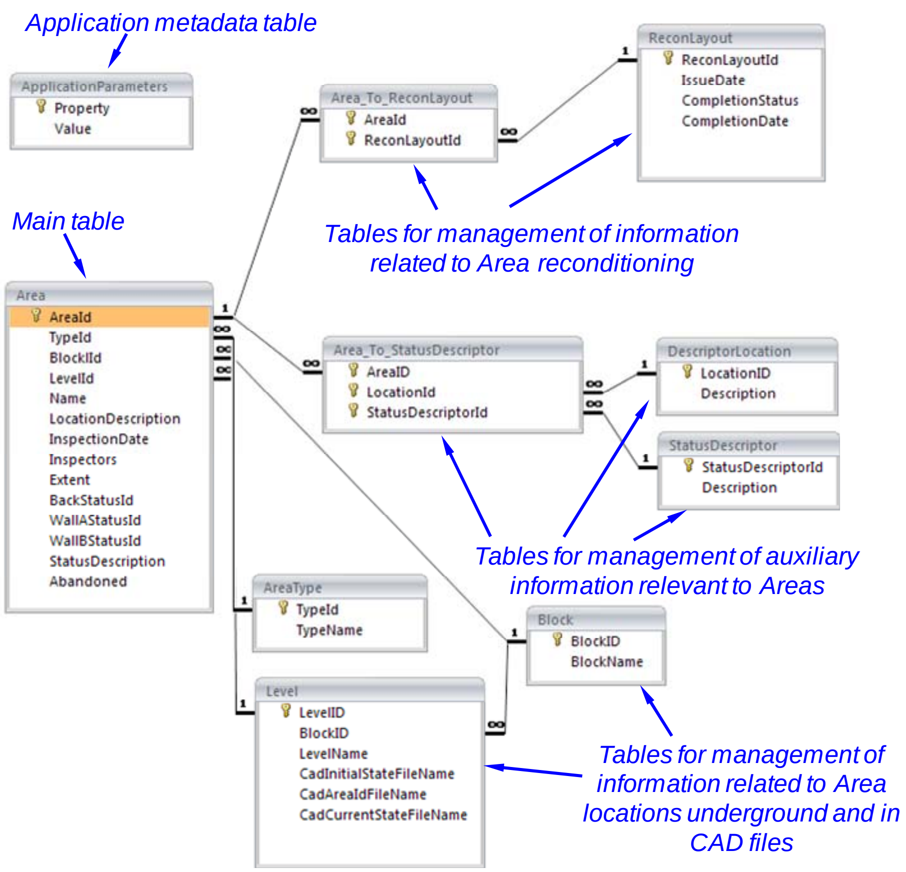

Figure 2. Diagram showing the *MS Access* database tables and the general structure used to manage the audit data.

One can see from the diagram in Figure 2 that the *Area*, which is uniquely defined by its ID number, is the governing entity of the database. The existing audit data and the data related to reconditioning work are based on it.

The purpose of the metadata table is to store data relevant to the functionality of the application and has nothing to do with the audit. The reason for having these data in the database was to facilitate application configuration during its development, as well as testing and deployment at Brunswick Mine. Alternatively, all of these data could have been hard-coded into the application, but such an approach would have prevented easy modifications of the application's operational parameters and its easy maintenance by mine personnel, requiring unnecessary Itasca involvement in the future.

4.5 *Reconditioning Layout Tracking*

The dynamism of the audit data was accommodated by including functionalities geared towards tracking the reconditioning work issued for inspected underground workings.

In terms of attaining the level of information related to the reconditioning work, the functionality itself was rather rudimentary. Reconditioning layout ID, date of issue, completion status, and date of completion were the only parameters the database was designed to track.

At Brunswick Mine, the standard practice is to issue a reconditioning layout per area. Once these areas are rehabilitated, the reconditioning layout is considered complete. Naturally, the database application was designed to conform to the way the process is organised at the mine. The system was thus setup such that a single reconditioning layout was able to address multiple areas, and multiple layouts could be issued for a single area.

In the end, the main purpose of having the application being capable of tracking reconditioning work was to provide the Ground Control Department with the information on how the results of the 2005 audit were being addressed. Based on the data, the application was designed to provide its users and mine management with up-to-date quantitative information on reconditioning and update information in the CAD system for visual presentation of the progress.

4.6 *Reporting*

Basic reporting functionality was implemented as part of the system's development. Its main purpose was to provide a general overview (summary) of existing ground support conditions at specific timeframes with respect to the original results generated by the audit.

Normally, reports in *MS Access* are generated dynamically based on a predefined query. The data extracted by the query are dynamic; as data in the database are changed, the query will reflect these changes in the data it is designed to track. The query itself, however, remains static; in other words, parameters for data addressing or data extraction do not change.

The design of the standard report generation tool for the ground support audit data management database followed a completely opposite approach. The data addressing was based on dynamic database querying, and the reports generated by the reporting tool were static rather than dynamic.

Dynamic querying means that queries are not predefined and invariable but, rather, are constructed actively based on the user's input every time a new report is created. This approach allows for flexible data querying without the knowledge of the underlying database table structure. With an appropriate user interface, dynamic queries can be made very transparent and user-friendly.

The standard report generation tool was designed to produce static reports. This means that once a report is created, the data shown in the report will not change even if the source information in the database is modified. The main purpose of a standard report was to show information related to rehabilitation progress with respect to the audited conditions. Though possible to implement, the reporting mechanism for showing rehabilitation progress over time was not put together. Static reports compensate for this lack of functionality as time-varying information can be extracted using multiple reports, each created using dynamic querying with the time-period parameter varying for each report.

The information gathered, analysed and presented as part of a standard report included summaries of linear metres inspected and rehabilitated, with the inspected information being separated into walls and back categories, and both the inspection and rehabilitation information being broken down by the areas original status classification (green, blue, yellow or red).

4.7 *Updates to CAD System*

The purpose of updating the CAD system was to have mine plans show updated information related to reconditioning work carried out since the ground support audit. By looking at updated mine plans one could immediately see which areas of the mine had been reconditioned.

Updates to the CAD system were initiated directly from inside the database application. Updating changed the colour of reconditioned areas from their original to grey, in order to indicate that the area had been reconditioned. At the same time, the system also retained the original information for comparison purposes. This was done by keeping two copies of digitised audit data in the CAD system. One copy was never changed, and a spare copy was modified to show the current state.

5 DISCUSSION

As developed, the data management system had a number of advantages and disadvantages related to its use. These are discussed below.

5.1 *Advantages of the Data Management System*

Without question, the main advantage of the data management system was its dynamic nature, as well as its ability to track and display the progress of the rehabilitation work carried out. The means by which the information was conveyed back to the system's user were both visual, in the form of level plan updates, and quantitative, in the form of generic reports.

Other advantages of the system included its portability and ease of use. The *Microsoft Access* database management system does not require extensive deployment nor on-site configuration; the database is contained in a single file and can be accessed from any computer with *Microsoft Access* software installed on it. Many people are familiar with *MS Access*, so the learning curve is often minimal.

5.2 *Limitations of the Data Management System*

The main limitation of the management system lied in the basic implementation of the rehabilitation progress tracking. Once rehabilitation information was entered into the database, the system has no mechanism for tracking rehabilitation progress until the reconditioning work is complete. Therefore, if substantial reconditioning work is to be carried out under a single or multiple reconditioning layouts and is scheduled to be completed over an extended time period, reports generated during this time frame will not reflect any progress, even if substantial work has been completed in some of the targeted areas.

5.3 *Opportunities for Improvement*

Improvements to the data management system can be made in a number of areas. Enhancements in the area of rehabilitation work tracking is the most obvious. To make the application more functional, it would be advantageous to implement a mechanism for rehabilitation progress tracking over time.

The reporting functionality built into the system could also be expanded. The report generation tool could be modified such that it becomes fully dynamic. This is somewhat tied to the enhancements to the reconditioning work tracking functionality mentioned above. With the application being able to properly track changes in rehabilitation work with time, the generation of static reports would not have been necessary. A time-based report could instead be created once, each subsequent execution returning up-to-date data.

As designed, the system relied heavily on the mechanism developed for the ground support audit at Brunswick Mine and, therefore, lacked flexibility with respect to what kind of, and how, information was collected. For example, the system is tied to the four categories initially defined for the project. Reducing or increasing the number of categories would require significant modifications to the system. The system can be significantly improved by allowing its users to decide what assessment categories should be used, their gradations and what additional information needs to be collected.

6 CONCLUSIONS

Ground support audits are fairly common in ageing underground mines. The one carried out at Brunswick Mine in 2005 was standard, focusing on identifying areas requiring ground support rehabilitation. The unique part about it, however, was the approach adopted for the audit data storage and management. Following an audit, the collected information quite often remains in its original form, as comments scribbled on paper plans, i.e., in the “analogue” so to speak form. In the case of Brunswick Mine, the collected information was digitised, catalogued in a database and linked to the mine’s CAD system. It this form, it became available electronically and, hence, easy to query. Having an ability to relate collected information to ongoing rehabilitation work made the database application more versatile, providing its users with means of assessing how the information collected by the audit was addressed.