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# Utilising database algorithms and three-dimensional visualisation software to optimise ground-control management

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## Abstract

*Records of manual scaling, ground-support checks and ground-support installations are commonly kept in handwritten daily logbooks, as required by mining regulations in Canadian jurisdictions and elsewhere. This process can be fraught with challenges in a large mature underground mine that has been subjected to changing ground-control approaches over its history. Accurate records of ground-support as-builts and of completed maintenance and rehabilitation are needed to show compliance with ground-control management-plan requirements.*

*By combining the power of a database, three-dimensional (3D) visualisation software and simple scripting language driven by ground-support design criteria, the daily logbook can be uploaded to a system that helps the mine confirm ground-support compliance with its ground-control plans and provides a basis upon which to estimate material requirements and ground-support installation duration.*

*The individual mine's ground-support standards can be entered into the database, along with the mine geometry information and local geology, and when compared with records of installed ground support and maintenance records, can be used to digitally check on compliance in a spatial manner. When combined with modern mine design software, all data can then be viewed in 3D or on two-dimensional plan maps to assess where ground-support maintenance, rehabilitation or upgrades are required as well as where periodic check scaling is required.*

*As ground support is installed and the ground-support system maintained, the database can be updated, and a workflow can be followed to visualise where work is required. Maintaining a record of ground-support information with such a tool can be simple and cost-effective and an efficient way to show compliance with a ground-control management system.*

*This paper describes a case study of the application of such a system to a large mature future underground hard-rock gold mine that is to be rehabilitated to allow gradual closure of the property.*

**Keywords:** *underground ground support, mining ground support, ground-control management, quality control, check scaling, information management, Ground Control Management Plan (GCMP), ground support, ground control*

## 1 Introduction

Records of manual scaling, ground-support checks and ground-support installations for underground mines are commonly kept in handwritten daily logbooks. In northern Canada, a ground-control logbook must be maintained. The *Mine Health and Safety Act 2014* states that:

> *"A ground control logbook … be maintained for surface and underground mines showing:*

- *The time, date and location of all tests relating to the requirements of the quality control program for ground-support systems …;*
- *If there is any ground movement in the mine, details of the records of ground monitoring devices in the area affected before the ground movement;*
- *Details of uncontrolled falls of ground;*
- *Details of working ground, tension cracks, or other signs of instability;*
- *Details of rockbursts and seismic events;*
- *Damaged supports; and*
- *Measurements taken from monitoring devices …"* (Northwest Territories 2014).

The ground-control logbook is to be read and signed each day by the shift boss and by the mine engineer. An example of a page from a ground-control logbook is shown in Figure 1.

All other mining jurisdictions in Canada have similar provisions in their respective acts (e.g. British Columbia Ministry of Energy and Mines 2017; Government of Ontario 1990). This requirement provides for written proof of inspection, installation and testing, which is important from a regulatory standpoint. From an operations point-of-view, however, the shortcomings of handwritten records become apparent. Without a way to organise and categorise entries according to location, the data contained in the ground-control logbook cannot easily be utilised for ground-support maintenance or planning. Location-of-work records are typically anecdotal and are not readily auditable with regard to what work was done and where it was done. Additionally, keeping only handwritten records presents a risk in data retention and security and may pose risks when ownership and contracts change hands. Creating digital copies of ground-control logbooks will ensure that the data is stored in multiple locations and will not be lost due to accident, such as fire, flood or misplacement.

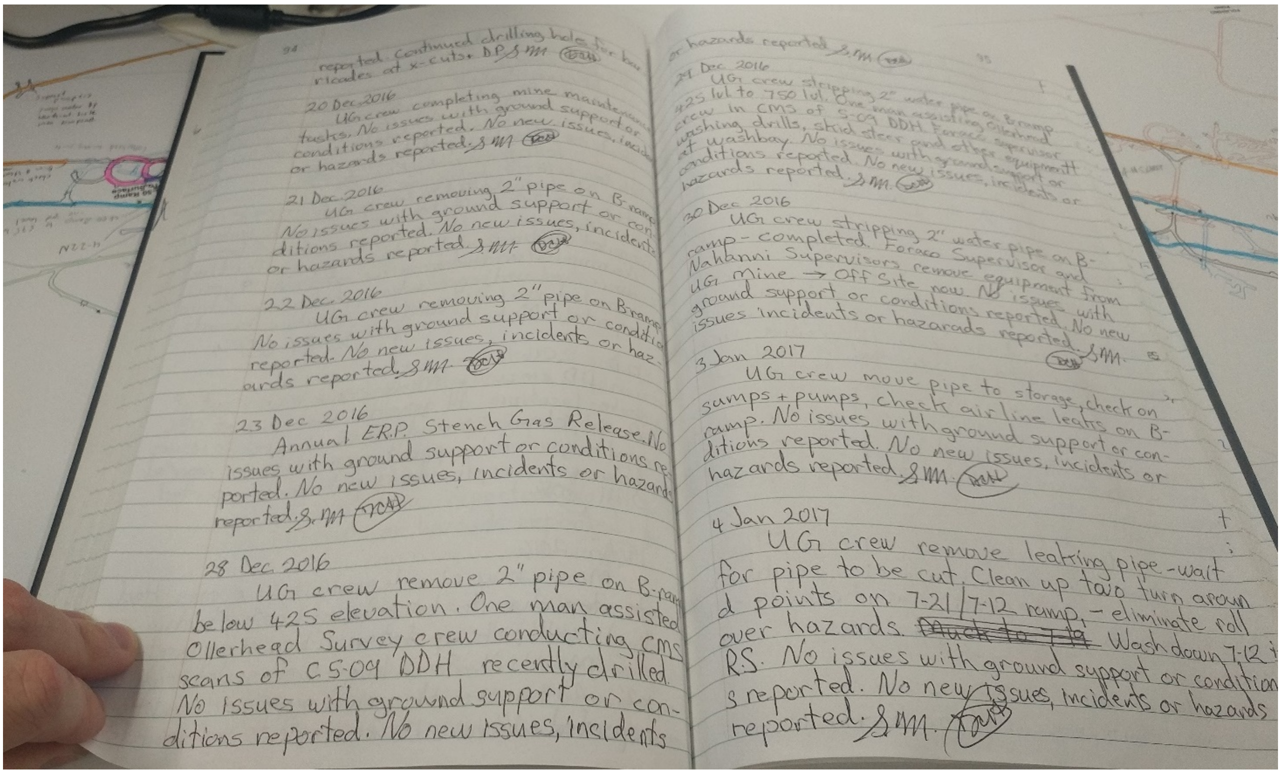


**Figure 1 Example of a handwritten ground-control logbook (Giant Mine Remediation Project)**

With modern database technology, the ground-control logbook can become a valuable tool to evaluate the needs of an underground mine. The entries can be categorised by location, either by simply naming the travel-ways that were inspected or by specifying distances along each travel-way from a known surveyed point (i.e. chainage). When these data are saved into the database, a simple script can be run to pull the most up-to-date information about each of the travel-ways in the mine and use that information for planning or review purposes.

Now that the location of travel-ways is known, the database can be taken a step further. Using a standardised chainage, the data can be displayed in two dimensions (maps) or in three dimensions (models). These visualisations can be used to create maps of ground-support conformation, quality-control requirements, scaling requirements and many other useful tools.

This method was implemented in northern Canada at the Giant Mine Remediation Project (GMRP), which is currently under care and maintenance, but future remediation work to close the mine will be undertaken. During the life of the mine, ground-support standards and requirements in Canada have changed significantly, leaving some areas of the mine under-supported by today's common standards while other areas meet current standards of practice. Furthermore, the mine has been run by multiple owners, each with a different ground-support practice and different naming conventions for travel-ways, making it difficult to correlate the ground-control logbook to specific areas of the mine. The database approach was therefore requested by the current underground care and maintenance contractor to help maintain a record of underground scaling and to determine the conformance of the underground routes of travel to the current Ground Control Management Plan (GCMP) at the mine. The GCMP provides a guideline for supporting underground travel-ways based on the geology and the span of the excavation. Broadly speaking, the mine consists of three main rock types: mafic volcanics, sericite altered shear zones, and chlorite altered shear zones. The volcanics and the sericite altered shear zones display similar rock-mass characteristics and discontinuity patterns throughout the mine. The chlorite altered shear zones are generally weaker but remain consistent in rock-mass quality throughout the mine. Therefore, although the ground support is largely determined by excavation size, it is also specific for two groups of geology: (i) the volcanics and sericite zones combined and (ii) the chlorite zones. Ground-support design upgrades focused on kinematic limiting equilibrium and empirical approaches.

# 2 Methodology

To compile the ground-control logbook into a comprehensive database, the following steps were taken:

- The key underground routes of travel were located, and their use identified.
- Existing ground-support information, information on excavation dimensions, and rock-quality information was collected in underground mapping campaigns.
- A database was established, including entry forms to enable easy input of ground-control entries and queries in order to update tables automatically with the most current information.
- Travel-ways were inputted into the database as a series of named coordinates.
- The handwritten ground-control logbook was digitised using the new database tools.
- Using underground level plans cross-referenced with measurements of span in the field, the span of the travel-ways was calculated at 1-m intervals.
- Based on the span and lithology, the ground-support requirements were determined by chainage.
- These support requirements were cross-referenced with the existing support to determine conformance. If nonconformance existed, the amount of support required was computed based on existing ground-control requirements and guidelines for the mine.
- Maps and three-dimensional (3D) representations were created to display the conformance and ground-support requirements.

# 3 Giant Mine Remediation Project pilot test

## 3.1 Project area definition

The former Giant Mine has hundreds of kilometres of underground development drifts that were excavated over the mine life from 1949 to 2004, when operations ceased. The current model of the mine is shown in Figure 2. The current extent of the mine workings, which are regularly traversed to maintain the underground mine (e.g. to service mine water pumps), was not well known at the beginning of the project. Therefore, the main routes of travel in the mine were comprehensively reviewed to determine which areas were being travelled and which areas could conceivably be travelled for future planned work. Currently travelled routes must conform to the GCMP. Through meetings with the underground supervisor, the routes, frequency and purpose of travel were determined and inputted into the database. Using computer-aided design (CAD) software, a series of connected line segments (polylines) were digitised in the 3D model for the main travel-ways and then included in the database as a list of named coordinates. Each travel route was given a chainage based on standard underground surveyed reference points. These chainages could be marked on the walls of the underground to allow accuracy in recording inspections and installation.

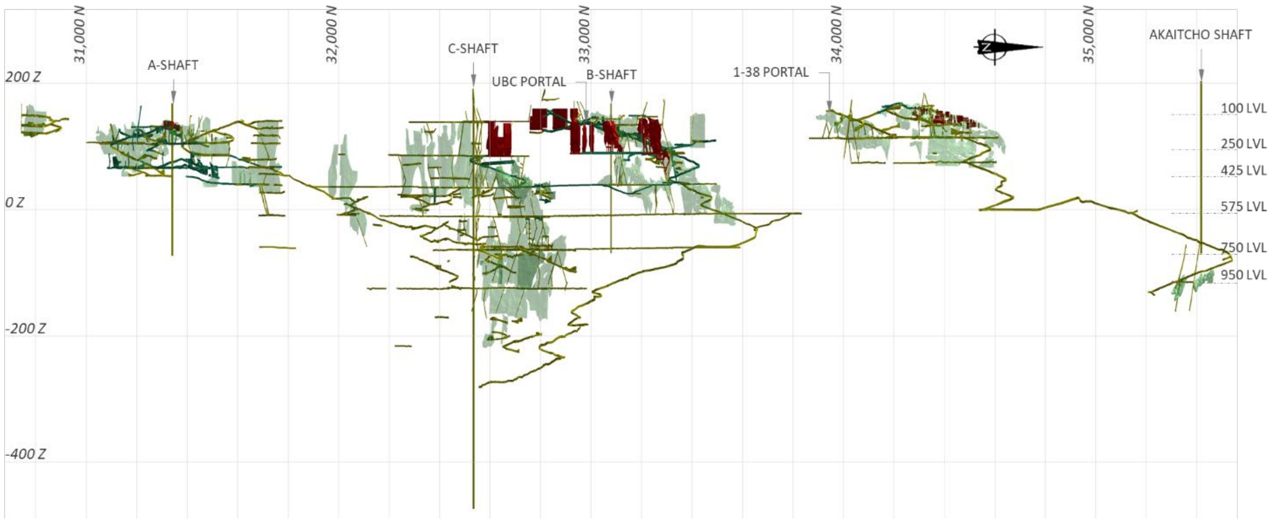


**Figure 2 Cross-section view of the Giant Mine three-dimensional model (looking west, 2.5× vertical exaggeration). The section is approximately 5 km north to south and 700 m vertical (Surpac™)**

The handwritten ground-control logbook for the mine was interpreted, and relevant check-scaling data were inputted into the database for the previous year. Given that scaling and ground-support inspections must be completed at least yearly at the mine according to the current GCMP, entries entered earlier than a year before the inputting date were considered out of date and no longer relevant.

## 3.2 Data collection for pilot test

Numerous underground mapping campaigns had been conducted at the mine previously, and those data were compiled and included in the database. In order to fill the remaining gaps in the data, a field visit was organised, the intention being to record current installed ground support, map general geology and confirm that the drift span measurements aligned with the geometry of digitised level plans.

Digital level plans and 3D mine models of the mine had been developed previously during the project using historical mine maps and cross sections. The level plans were used to determine maximum span measurements every metre along each route of travel. The level plans were first compared with the field measurements of span to confirm that the level plans were accurate enough for analysis.

## 3.3 Comparison of field data with mine plan data

The database was edited to include forms that would permit easy input of ground-control logbook entries. The fields included in these forms identify the name of the travel-way, chainages, observations and records of completed scaling, ground-support quality-control testing and types of ground-support installations.

When an entry is inserted, tables of check-scaling records, ground-support testing records and existing ground support are updated with the current data. This information can then be easily queried using a report—developed by the database—that provides the user with a summary of the areas that conform to the ground-support requirements and those that do not, based on the user input data.

In general, the field measurements of span aligned reasonably well with span measured from the digitised level plans, and it was therefore determined that the latter could be used to reliably assess opening span. An AutoCAD (AutoDesk 2016) script was used to draw the largest possible circle (or span of the drift) within the level plan line work at 1-m intervals along the centre-line of the tunnel (Figure 3). Note that the script was designed to slightly adjust the location of the circle in order to maximise the span within intersections and areas of slightly wider spans (e.g. at a safety bay).

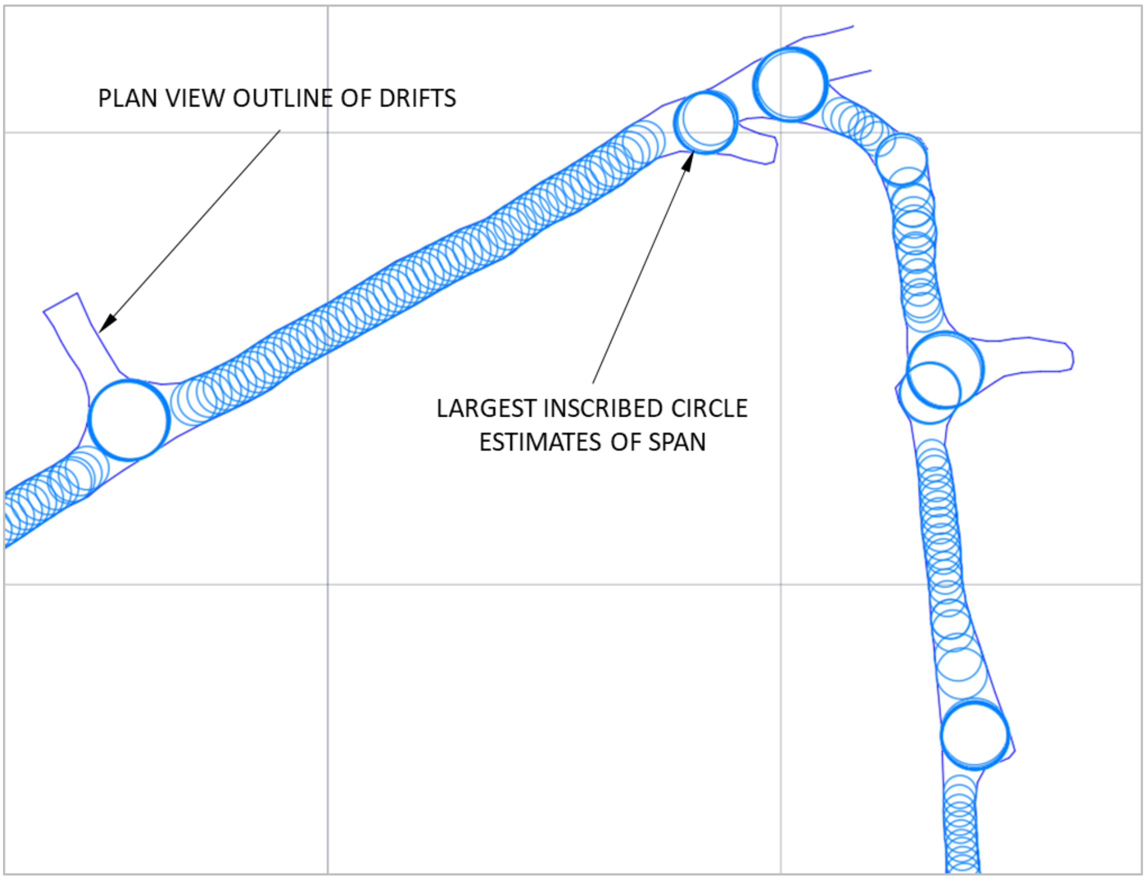


**Figure 3 Span determination from level plans**

The GCMP at the GMRP generally calls for three main support types or categories based on the general geology and span of the underground drifts. These categories are:

- Spot bolting.
- Systematic bolting with welded wire mesh.
- Systematic bolting with welded wire mesh and long bolts for intersection support.

The general geology of the site is the main factor for determining ground-support requirements (Figure 4).

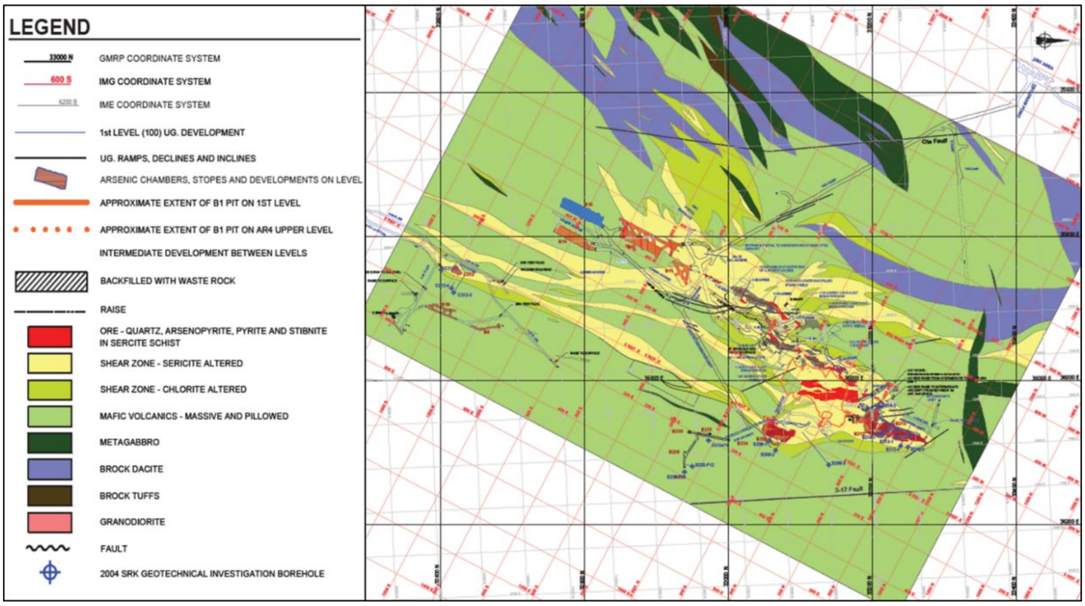


**Figure 4 Geology map of Giant Mine—100 level (Golder Associates Ltd 2018)**

The types of ground support used at Giant Mine are shown in Figure 5. Recently supported areas use suitable lengths of full-column resin-grouted threaded rebar for tendon support, but most historical areas use end-anchored (mechanical) rockbolts.

(a)

(b)

(c)

**Figure 5 (a) Spot bolting ground support; (b) Systematic bolting and welded wire mesh ground support; (c) Systematic bolting and welded wire with longer bolts for intersection support**

# 4 Results of pilot test

Using the start and end coordinates for each individual unique section of the development, the database was queried, and the calculated conformance and ground-support requirements were determined. The state of conformance, ground-support requirements and existing ground support were then tagged as a description for each end coordinate for the section of a drift. By including this information as a description, the data could then be plotted in 3D programs. Once plotted in the 3D program, an export to CAD-based software could then be completed and the data shown in two-dimensional CAD drawings for specific reporting requirements.

The project output consisted of a series of maps containing visual representations of the following elements:

- Locations of existing ground support.
- The conformance of ground support to the GCMP.
- Recommendations for additional ground support.

The span data exported from the AutoCAD script were cross-referenced with the data collected during mapping campaigns. The general geology was combined with the span measurements in a spreadsheet to determine which category of ground support was intended for each metre of the travel-way (Figure 6). The categories were based on the GCMP implemented at the mine and, specific to this pilot test, were generally governed by the geology at the location and the span measurements.

The category of ground support required per metre along the travel-way was compared with the existing ground support. Where the existing ground support did not meet the required ground support, a nonconformance for that section was determined (Figure 6c). Wherever nonconformance was determined, the database script provided an output of the amount of support required for the travel-way to bring the support up to conformance (Figure 6d).

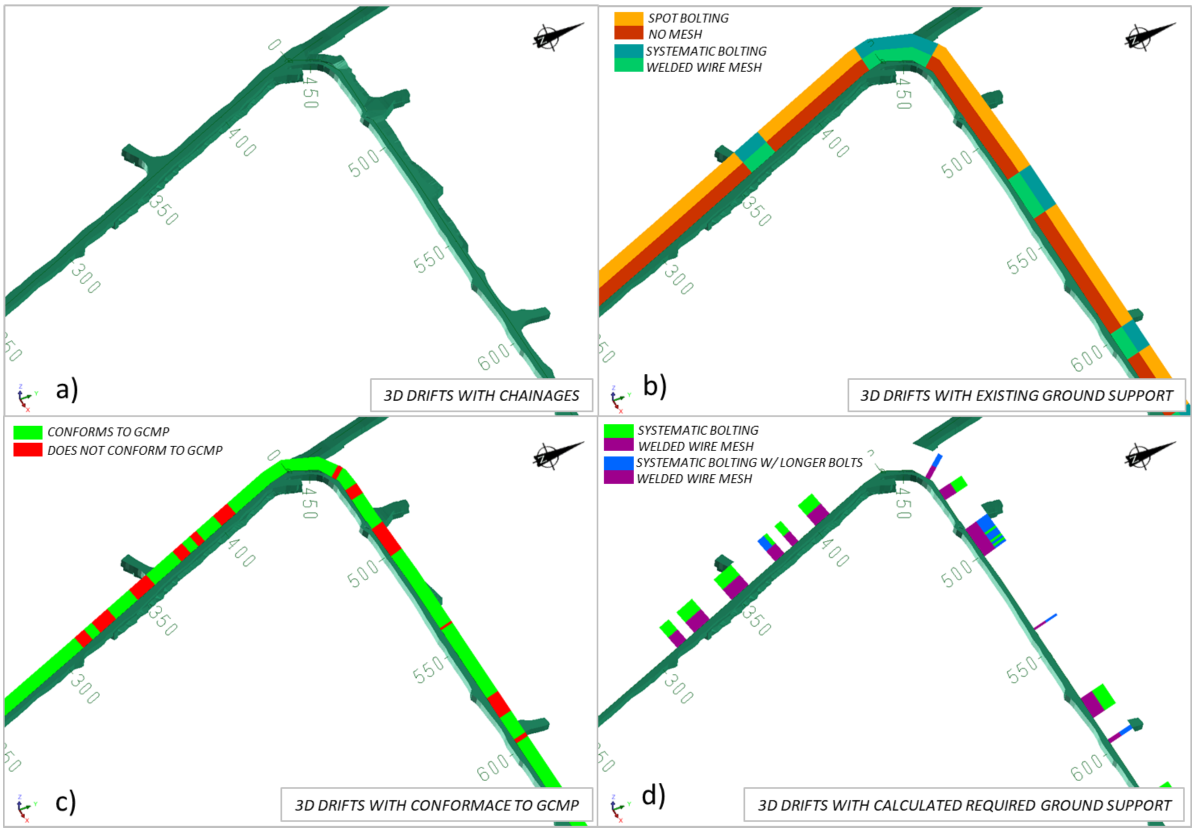


**Figure 6 Three-dimensional model with ground-support overlays**

These maps are currently being used by the underground contractor for planning the ground-support upgrade at the GMRP to ensure that the main routes of travel as well as areas that will be required for future work conform to the GCMP.

As ground support is installed and inspected, the database can be updated, and new maps of conformance can be generated. Once ground-support record details are available, the database will be updated with this information.

# 5 Planned improvements

The database is a work in progress, and many additions and improvements are planned. These include the following:

- The ability to export visual representations of scaling records and rockbolt pull-testing data.
- An overall streamlining of the process—currently, several programs are used to analyse the data, contain it, compare it and present it visually. Using Python or a similar coding language would allow for all the processing to be completed in a series of simple commands.

# 6 Conclusion

The use of handwritten records on issues related to ground-control management makes both auditing and providing proof of compliance to plans problematic. A comprehensive digital database of this information is a logical solution. Most mining regulations will continue to require hardcopy logbooks that can be hand signed and stored. Moving towards also maintaining digital records of installed ground support will allow mining operations to quickly and accurately plan ground-support upgrades and confirm where their installed ground support conforms or does not conform to their GCMP.

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