Geotechnical data management and visualization systems: Meeting the data challenge of the 21st century and maximizing value for open pit mines

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ABSTRACT: Since the turn of the century, advances in the computing, information technology and telecommunication sectors have empowered geotechnical engineers to collate vast and large amounts of data on a daily basis. More recently, with instability in commodity prices, most mining companies have been reluctant to proportionally increase staffing levels. Effectively and logically storing this wide array of data, and moreover, enabling the validation, analysis and subsequent presentation of the data are paramount in an ever faster paced mining environment where we aim to proactively manage emerging risks and uncertainty.

Geotechnical databases for open pit and underground mining operations have been created on a combination of the acQuire Geoscientific Information Management System and Navstar Geoexplorer. The purpose of these systems is to establish and maintain a central source of data that is easily collected, entered, analyzed, visualized or exported by relevant stakeholders. This paper presents an overview of the system capability and flexibility to meet geotechnical engineers 'requirements at unique and complex mining operations. Through system upgrades and the training of personnel, the output from geotechnical sections has markedly increased while staffing levels have remained relatively constant over last three years.

1 INTRODUCTION

The modern mining industry needs to provide stakeholders with guarantees that the promised return on investment will be realized. It also needs to ensure that personnel and equipment are kept safe during the mining process. This means that the company identifies hazards that can impact on production, assesses the associated risks and provides controls to manage the risks (Hamman et al. 2017). Geotechnical engineers are tasked to manage one of the biggest risks in a mine – unpredicted and uncontrolled ground movement. In order to optimize a geotechnical design and mine plan that incorporates a certain level of risk, the geotechnical engineer should follow a systematic, traceable design process and an implementation plan and risk mitigation strategy. Both of these require a robust structure or system such that the foundation is always reliable data. This data can be collected, stored in, and analyzed with geotechnical databases.

Geotechnical databases have developed from spreadsheets to Microsoft Access and now SQL-based systems with improved reliability for data integrity and data security over the last 20 years. The integration and transformation of different databases to common systems has also become ever more possible.

Technology for data collection is constantly improving and datasets are getting larger and acquired more quickly and more frequently. For example, in the 1990s deformation monitoring was practicable with the manual surveying of a few survey prisms on a weekly or monthly basis. Today, automated robotic total stations can survey 200 prisms every 90 minutes or so without the need for a surveyor. Similarly, mapping of geological structures on slopes or in underground excavations with a geological compass in the 1990s was the only option and it took several hours if not days to obtain a statistically valid dataset for analysis. Today, with laser scanning and digital photogrammetry, digitally mapping structure orientations can be undertaken for very large areas, very quickly. Of course, mapping is still required for understanding the geomechanical properties of the geological structures and validation of the digital data.

A major challenge faced by many geotechnical engineers in the 21st century is collecting, storing and analyzing large volumes of data. Another challenge is being able to readily and easily access, interrogate and visualize these large volumes of data.

Figure 1 illustrates the (simplified) role of data management within the geotechnical engineering discipline and the mining environment. Data collection aspects vary in complexity depending on the specific task or monitoring instrument. Similarly, both data analysis and the feedback of processed information to the geotechnical engineer as well as the hazard management process with mine operations and management varies in complexity depending on the specific data and situation. However, in both instances, several manual tasks from data collection to data processing can be avoided, reducing time, cost and potential for human error.

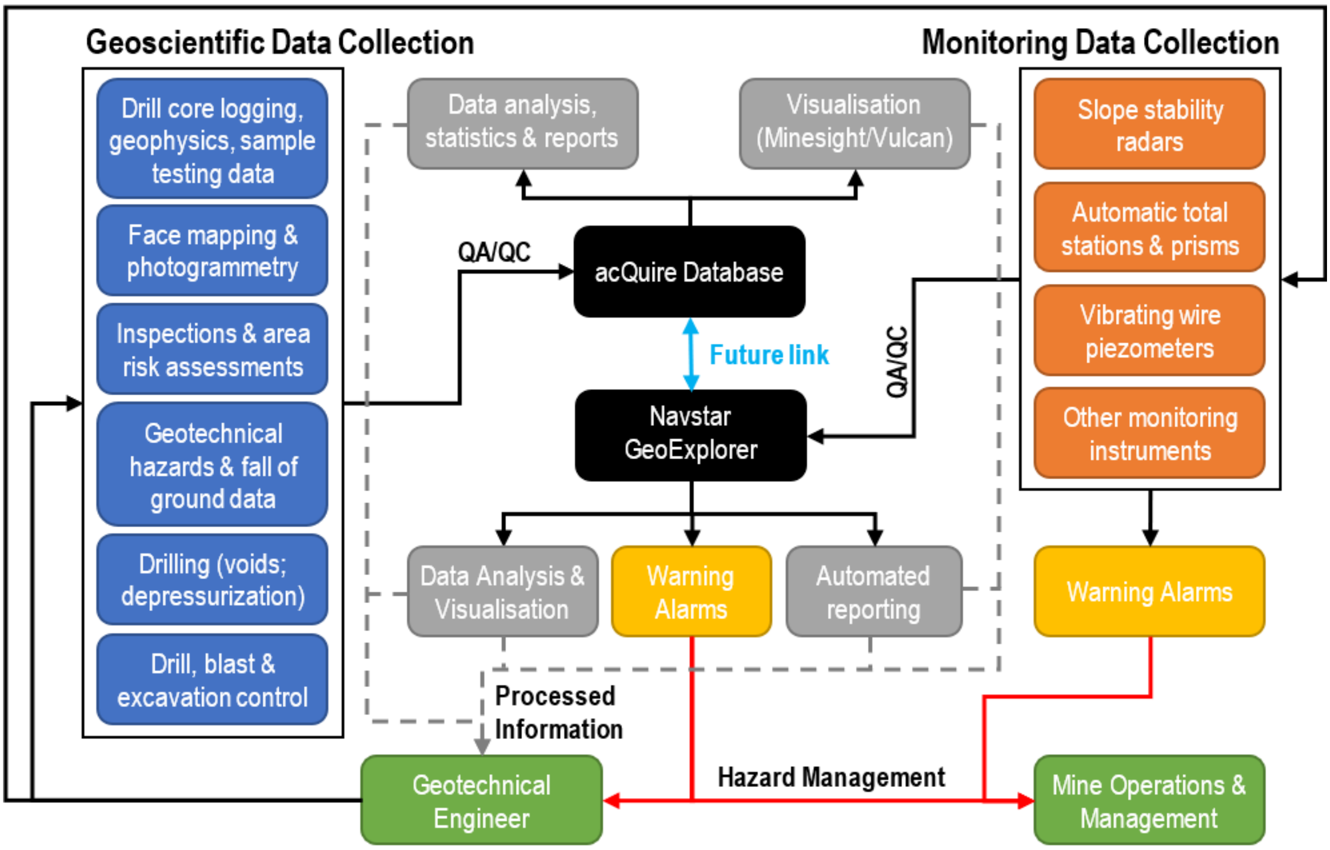

Figure 1. Database Process or Workflows

2 GEOSCIENTIFIC DATA MANAGEMENT AND VISUALIZATION

The acQuire Geoscientific Information Management System is commonly used by geology teams in the mining industry and has been proven to be a suitable platform for geotechnical data management. Pere et al. (2011) utilized it for logging of drill core and borehole televiewer geophysical surveys. Several similar, and equally sophisticated geoscientific data management software are available including Centric or Maxwell Datashed. In this instance, acQuire was selected as the most cost-effective options since the mining company already used the system in their geology teams. The geoscientific databases can integrate well with mine modelling software such as Vulcan and Minesight as shown in Figure 2.

The acQuire geoscientific database was set up to capture geologic, geotechnical, geothermal and hydrogeological data directly or 'live' in the field using laptop or tablet computers through either a wireless network in the pit or offline and synchronizing when returning to the office. The use of a handheld GPS and live data capture enabled geotechnical engineers to carry out inspections of pit slopes, waste dumps and provide up-to-date information to coworkers and the management team in the office.

The system was set up with data collection and report generation functionality with inbuilt QA/QC features to ensure reliable data capture and presentation. The data is viewable in the database itself or in 3D-space through connected mine modelling software. The following components have been successfully implemented at multiple operations:

- Engineering geological data from drill core logging for rock and soils, face mapping and photogrammetry on slopes or in underground excavations. Report generation included statistics of collected and calculated parameters including RMR and Q.
- Geomechanical laboratory and field test work data for rock and soils.
- Routine inspection and risk assessments of pit slopes, underground excavations, waste dumps, stockpiles, tailings and water storage dams. Example of data entry from a tablet PC in the field or in the office and report generation shown in Figure 4.
- Geotechnical hazard management and fall of ground reporting (identifying new and updating the status or changes in existing geotechnical hazards such as rock fall risk zones, potential landslides or fall of ground areas).
- Trigger-action-response-plan (TARP) management.
- Slope depressurization drilling management.
- Probe drilling and hole temperature logging for geothermal outburst and geyser risk areas or for potential subsidence or void zones where historic underground workings are present below.
- Drill, blast and final wall excavation performance management (blast design verification for desired fragmentation and wall control).

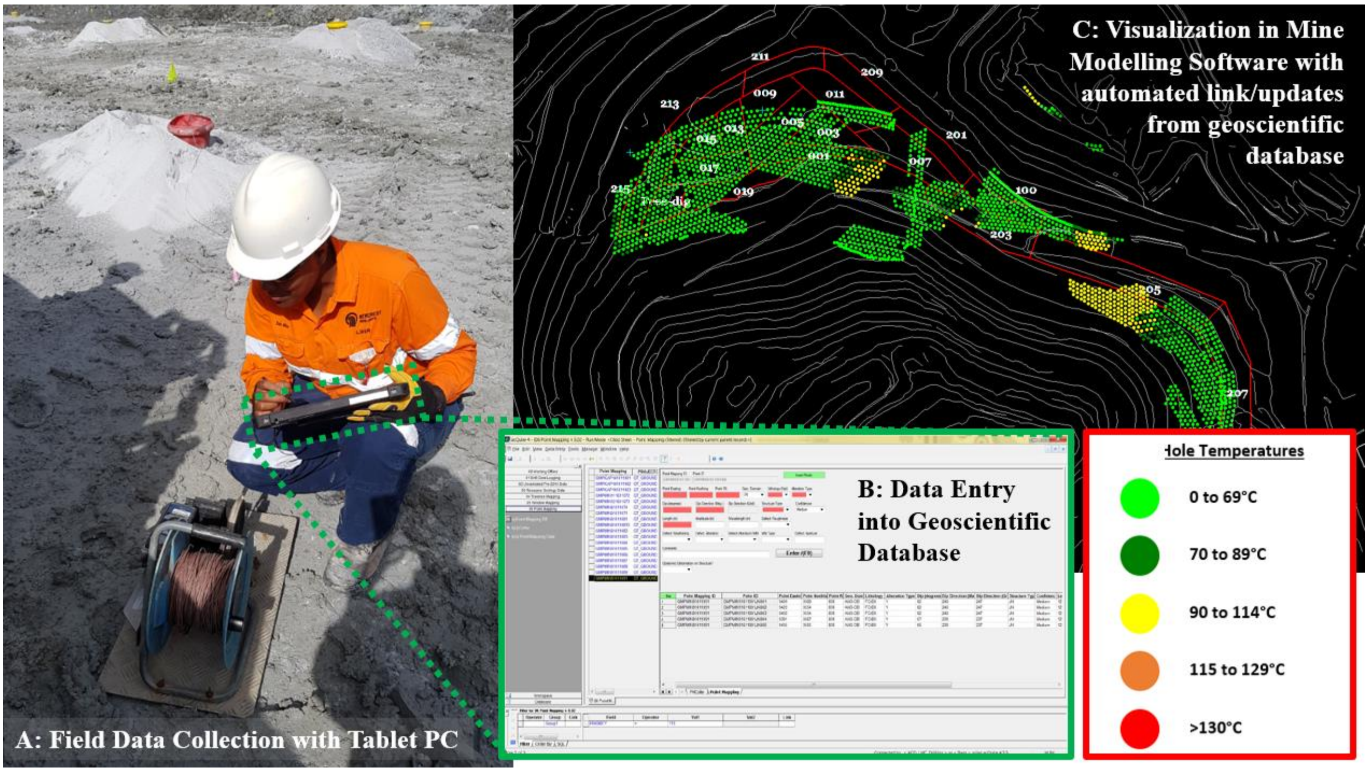

Figure 2. Example of part of the streamlined geothermal outburst and geyser risk management process from field data collection using a tablet PC (A) directly into the geoscientific database (B) and automated visualization capability in mine modelling software (C).

The process of updating geological and structural models can be facilitated by field data collection in the form of pit wall mapping (and drill core logging) directly to the geoscientific database on a tablet computer and visualizing the data in a mine modelling software (e.g. BasRock GEM4D as illustrated in Figure 3). The automation of the data management process enables engineers and geologists to view and even make adjustments to geological and structural models in the field and, of course, in the office.

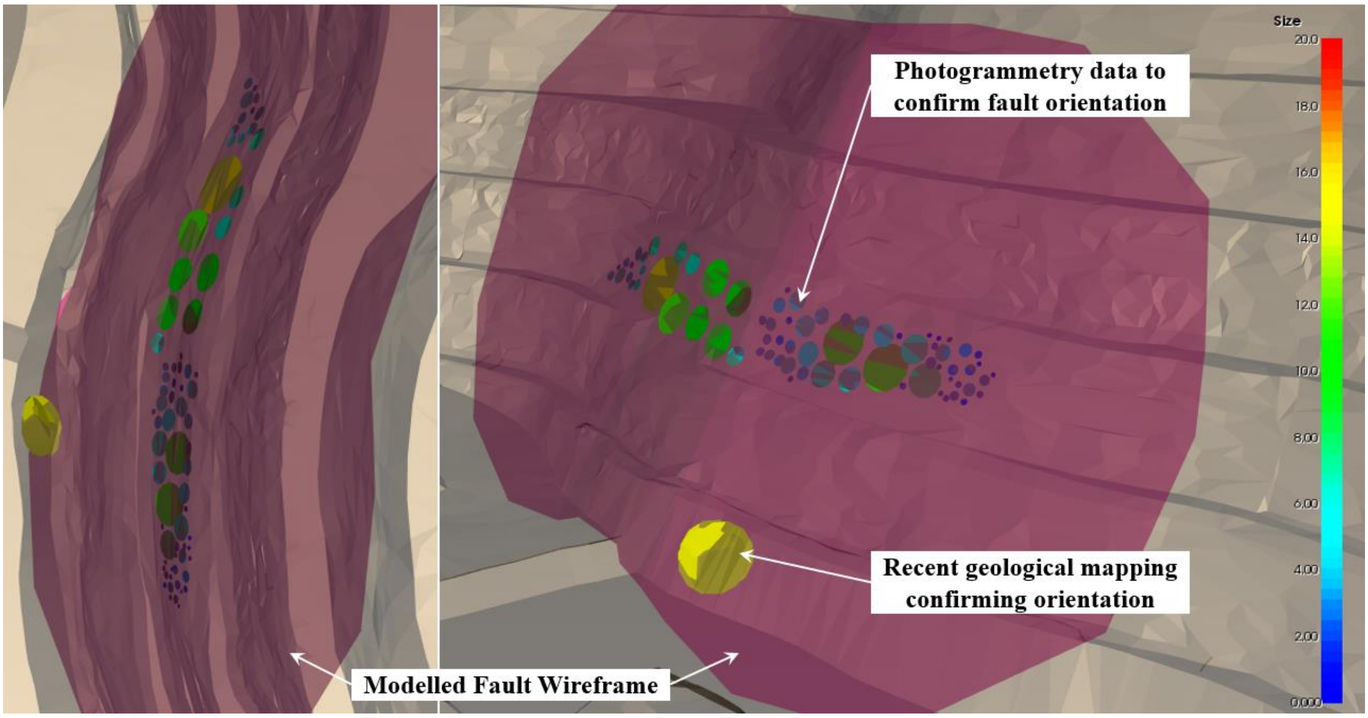

Figure 3. Example of a geological fault model (purple wireframe) being validated with geological mapping and photogrammetry data (represented as scaled, oriented circular disks). Each disk represents an individually recorded orientation of a structure.

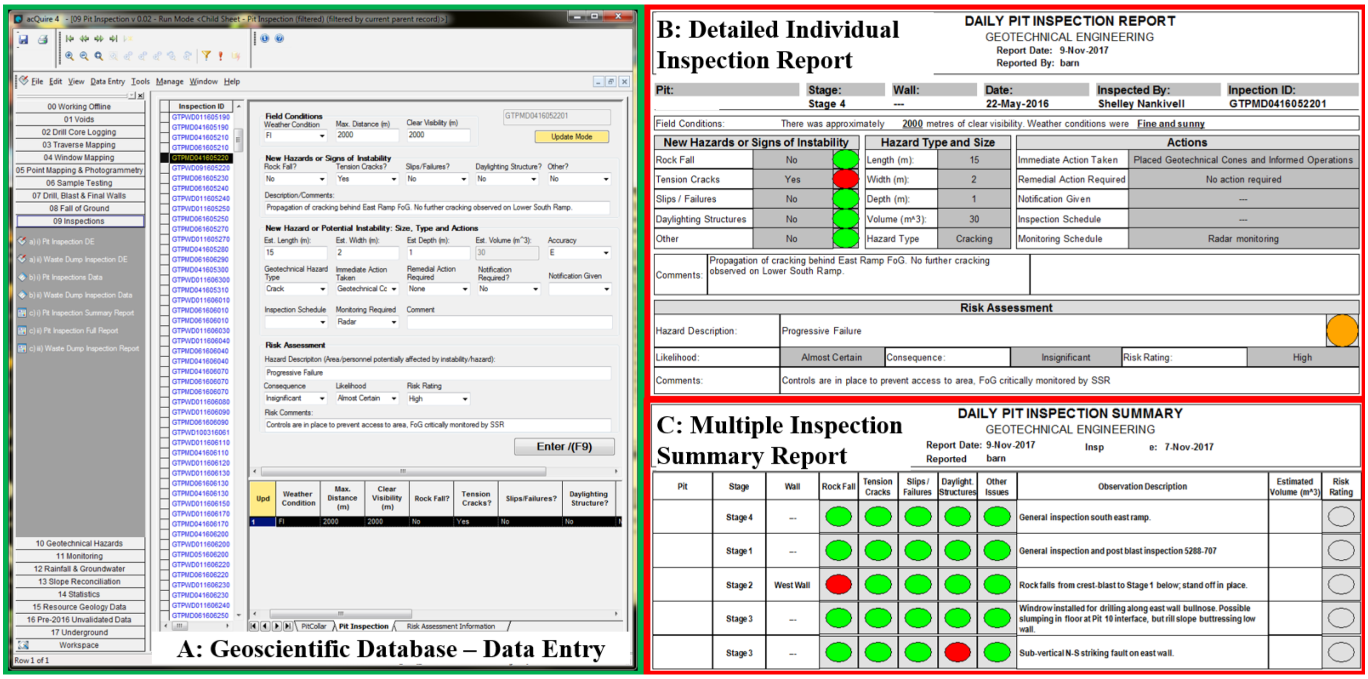

Figure 4. Example of data entry into geoscientific database for pit inspections (A) and automatically generated individual (B) and multiple (C) reports

3 MONITORING DATA MANAGEMENT AND VISUALIZATION

The Navstar Geoexplorer database and visualization package was utilized to capture deformation and groundwater data in real-time, at set-intervals or manually from an array of field instruments.

Alarms can be created for each instrument for system downtime, deformation or groundwater pressure and levels to generate emails, SMS or visual warnings to relevant stakeholders. It facilitates warnings from all available monitoring instrumentation through a single system that can provide warning to geotechnical engineers, mine supervisors and managers of impending risks when mining geotechnically hazardous areas.

It allows the integration of all data sources and the simple and easy generation of reports. For example, a group of survey prisms, vibrating wire piezometers and rainfall gauges can be selected and simply 'dragged' into a report that remains 'live' while open and continues to update as new data can become available. The following instruments have been successfully integrated at a large open pit mine in Papua New Guinea:

- 6 automatic, robotic total stations surveying over 1,700 individual survey prisms on pit slopes, waste dumps and stockpiles, cofferdam and culturally sensitive heritage areas.
- 3 slope stability radars for high risk areas (1x IDS IBIS-FM and 2x Groundprobe SSR-XT).
- >330 vibrating wire piezometers and pumping well head pressure gauges with a combination of manually entered or uploaded data and connection to loggers with telemetry.
- 5 tip-bucket rainfall intensity gauges.
- Pit water levels (linked to acQuire where manual survey data is routinely entered).
- Routine inspections of pit slopes, underground excavations, waste dumps and stockpiles.
- Inspection photographs (camera and aerial unmanned vehicle – UAV) with annotations, and even reports can be stored at specific geographic locations related to their content.

Figure 5 presents a sample of Navstar Geoexplorer data collection, analysis and visualization for the two types of slope stability radar and survey prisms (ATS).

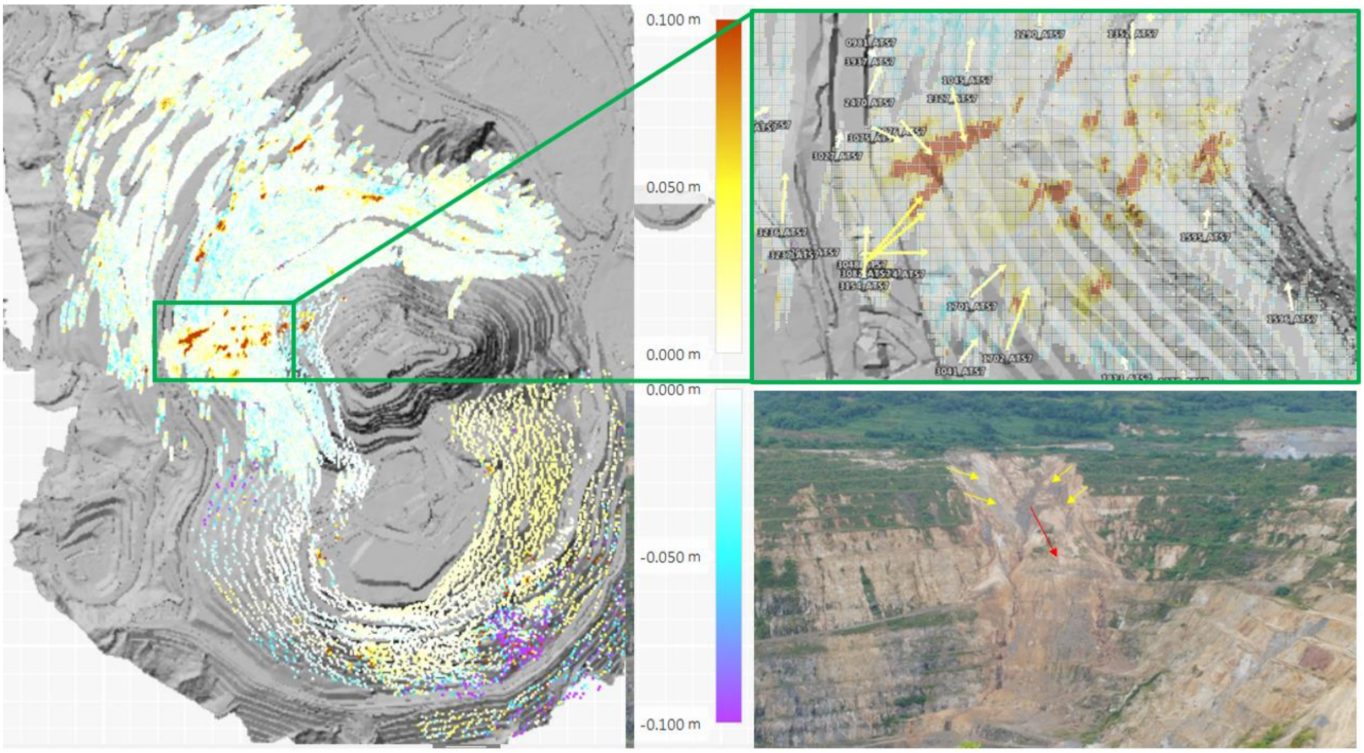

Figure 5. Navstar Geoexplorer: Pit terrain model overlain with deformation data from three slope stability radars (left); inset: IBIS-FM radar data combined with scaled vectors for individual survey prisms showing direction and magnitude of deformation around a historic landslide back scarp; photograph: historic landslide back scarp and failure debris continuing to deform.

4 DISCUSSION

The data management challenge in the 21st century is expected to get bigger and more difficult to deal with as technology continues to rapidly advance. It is now possible to integrate several data capture systems and manage data more effectively and efficiently in various SQL-based databases. There are many such systems currently available in industry, and it is not the intention of this paper to promote one system over another. Prospective users are encouraged to investigate various options, particularly since the technology continues to rapidly improve.

Geotechnical engineers are at the forefront of technological improvements in the mining industry since unwanted or unforeseen geotechnical events have the potential to significantly impact upon safety and the economic value of a mine.

Benefits of implementing the geoscientific and monitoring data management systems have so far included:

- Elimination of hundreds of complex spreadsheets and dozens of stand-alone access databases.
- A centralized location for viewing and comparing data from different data sources and provision for flexible visualization.
- Elimination of human error (e.g. Navstar Geoexplorer automatically reports via email, SMS and visual alerts when any of the connected monitoring systems are down; geotechnical data collection is automatically validated upon entry into acQuire).
- Reduced reliance on human resources and repetitive manual labor (e.g. transferring data from paper to computer systems and then into modelling packages is removed; logger units and telemetry systems remove the need for repetitive field work collecting monitoring data).
- Improvements in safety and awareness.
- Reduction in rework by site teams and consultants – cost reduction.
- Allows for work to be done at the right level (i.e. data collection, analysis and interpretation can be done by site teams).
- Systems have the capacity to grow with increasing mine complexity and size.
- Less engineers are required to manage and analyze more data from more systems.

The data management systems presented in this paper meet the needs of complex, modern mining operations. However, it is very difficult to predict or foresee how data management requirements will evolve over the next 20 years with further technological advancements.

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