2015

Development and Implementation of a Geotechnical Database Management System

Sean Keen
University of Queensland

Alex Hossack
Rio Tinto Coal Australia

Mehmet S. Kizil
University of Queensland

Publication Details

Sean Keen, Alex Hossack and Mehmet S Kizil, Development and Implementation of a Geotechnical Database Management System, 15th Coal Operators' Conference, University of Wollongong, The Australasian Institute of Mining and Metallurgy and Mine Managers Association of Australia, 2015, 347-357.

DEVELOPMENT AND IMPLEMENTATION OF A GEOTECHNICAL DATABASE MANAGEMENT SYSTEM

Sean Keen[1], Alex Hossack[2] and Mehmet S Kizil[1]

ABSTRACT: Geotechnical Engineering is classified by many mining companies as the highest corporate, investor and operational risk associated with the development and successful exploitation of a mineral resource. Given the shift in culture towards geotechnical engineering and the influx of new exploration projects, the quantity and complexity of geotechnical data is increasing at exponential rates. Unfortunately, in some cases, data management techniques have lagged behind data capture processes, resulting in relatively primitive technologies to store highly sensitive and costly data. Under these primitive systems, there is no quantifiable handling on the quantity or quality of geotechnical data. The rollover effects of poor data management standards are significant and in severe cases, areas require redrilling or revaluation to capture lost data. The aim of this project was to capture, extract and upload geotechnical data into an easily accessible, single source geotechnical database. Using Rio Tinto Coal Australia (RTCA) as a case study, the project formed a framework for future database implementations by outlining the systematic project progression from data extraction to population and application of the database. By providing a single source database, frequent engineering tasks at RTCA were automated which significantly increased engineering efficiency and accuracy. Additionally, comprehensive Quality Assurance and Quality Control (QAQC) checks improved overall data integrity, resulting in enhanced data confidence.

INTRODUCTION

Geotechnical engineering is a relatively young field of expertise in the resource industry (Harrison and Hudson, 2007). In its most simplistic form, geotechnical engineering involves the acquisition of geological, structural, hydrogeological and geomechanical data to feed a geotechnical model (Hanson, Thomas and Gallagher, 2005). This geotechnical model forms the basis of decisions surrounding pit geometry, slope and batter angles, mining method and equipment selection and plays a factor in virtually all other strategic planning decisions (MOSHAB, 1997). Due to the inherently anisotropic and inhomogeneous geological makeup of resource deposits, huge data sets are required to accurately depict geotechnical behaviour over a single mine site. These data sets require extensive exploration drilling programs and subsequent laboratory and geophysical analysis of the samples (Hanson, Thomas and Gallagher, 2005). The extensive coring and drilling involved to obtain geotechnical data incurs enormous capital and operational costs to companies, rendering any subsequent datasets extremely valuable.

Rio Tinto Coal Australia (RTCA)'s Orebody Knowledge (OBK) team is responsible for the collection and management of geotechnical data for Rio Tinto's five coal mines and nine exploration projects in New South Wales and Queensland. Presently, the data captured from field and laboratory investigations are kept in servers, archives and libraries. Under the current system, there is no quantifiable handling on the quantity or quality of geotechnical data, resulting in significant and costly rollover effects. The Geotechnical Database Management System (GDMS) is designed to capture and update the existing geotechnical database with relevant information from RTCA archives, servers and libraries. Relevant information will be extracted from digitised and electronic documents and uploaded into the database system. At a minimal cost to RTCA, the new database will aim to collate all existing data into a single database and provide secure storage of highly valued information. The database will undergo a strict validation process prior to and following the population of the database to ensure the entries fall within acceptable limits, do not contain errors and allow for effective modelling.

Implementing a geotechnical database, at a minimal cost, has huge cost benefits for Rio Tinto. By securing the geotechnical data into a readily available database management system the risk of losing and/or corrupting data is almost negligible. By removing this risk, the need to redrill or revaluate areas would be extremely rare. Furthermore, by creating a single source database, engineering efficiency will increase significantly and allow for superior geological and geotechnical models. By reporting the pitfalls

[1] *School of Mechanical and Mining Engineering, The University of Queensland, Queensland, Australia, E-mail: m.kizil@uq.edu.au*
[2] *Rio Tinto Coal Australia, 123 Albert Street, Brisbane QLD 4000; Tel (H) +61 07 38787612 +M: 0450 906 307*

and inefficiencies of the project and outlining recommendations, the process can be streamlined and a framework for future projects can be drafted. Figure 1 shows the slope failure occurred at Bingham Canyon mine in 2013. Such events may be detected earlier and be avoided with the availability of better geological and geotechnical models.

Figure 1: Slope instability causing landslide, Bingham Canyon (Pankow *et al.,* 2013)

Following the implementation of the database, the system will be used to source a drill and blast fragmentation model with geotechnical data for RTCA's open cut mines. The model will output fragmentation distributions based on the information provided by a live link to the database. The model will serve as a useful tool for site drill and blast engineers and demonstrate the benefits of the database to disciplines outside the realms of geotechnical engineering.

GEOTECHNICAL DATA IN MINING

Before a geotechnical database can be scoped and implemented, the geotechnical data required for the database must be identified. For population and implementation purposes, simply identifying the parameters is not enough. For a database to undergo a population and implementation stage with rigorous validation, the data and the format of the data needs to be understood. Additionally, crucial metadata – data relationships must be recognised to ensure data within the database retains fundamental explanatory information.

Geomechanical Data

Geomechanical data aims to quantify the intrinsic strength of rock specimens gathered through field sampling. The data gathered from geomechanical testing forms the essential inputs for numerical and empirical design tools (Hadjigeorgiou, 2012). These design tools identify areas within a mine that are susceptible to instability or require increased support and reinforcement infrastructure. Hoek (1994) cautioned that inadequate emphasis placed on the collection of geomechanical data can result in data limited models and designs. With limited data, highly advanced and technical models cannot operate at desired accuracy levels. Hence, any design modelling requires significant quantities of geomechanical data to accurately gauge the strength of the geological formation. Unfortunately the process to acquire and test specimens for geomechanical data is costly though any subsequent data is highly valuable.

Field Test Data

Field data refers to the information captured on site through manual and automated logging as well as *in-situ* tests not specifically related to hydrogeological data. The majority of field data is captured during exploration drilling where geologists and geotechnical engineers log information regarding the extracted core (Harrison and Hudson, 2007). The highly manual task produces detailed logs of grain size, lithology, defects, strength and overall appearance of rock mass down-hole. These logs form the basis of geological models and rock domain classifications. The labour intensive process has a high risk of human error and the logs depend heavily on the skill of the geologist or geotechnical engineer. When establishing a database, terminology standardisation is paramount to ensure consistency across logs and to support electronic data validation processes.

Hydrogeology Data

Hydrogeology is a broad term used to describe issues related to ground and surface water. Atkinson, Dow and Brom (1984) postulated that ground water issues in mining operations take two general forms:

1. Engineering associated challenges relating to seepage forces, water inflow, piping and slaking; and
2. Environmental controls identifying the effect of mining on the water table, water quality and nearby water resources.

The data formats vary greatly for different hydrogeological tests, however the testing can usually be classified as either monitoring or discrete in-situ testing. Water levels, quality readings, seepage rates and hydraulic forces can all be measured continuously under monitoring type scenarios or as a discrete measurement.

Geotechnical Monitoring Data

Monitoring data is associated with the surveillance of engineering structures, either visually or through instrumentation. Brady and Brown (2004) proposed monitoring data, in a geotechnical context, is carried out for one of four main reasons:

1. To record the variation in geotechnical parameters such as water table level and seismic activity;
2. To ensure safety during development and operations by alerting management to excessive ground deformations, groundwater pressures and loads;
3. To control and ensure the stability of ground reinforcements and remedial works; and
4. To check the validity of assumptions, conceptual models and rock mass properties.

Although monitoring data is cheap to acquire, the time dependent and non-repeatable nature of the data renders the information extremely valuable. Additionally, the continuous data capture associated with monitoring means the subsequent data is significant in quantity.

Legacy Data

Legacy data is defined as information that is 'inactive' – stored in physical or electronic format and is not currently understood, used or managed (Perez *et al.,* 2002). Companies dealing with existing geotechnical information in a legacy format are required to undergo a process of inventory, extraction and migration of the data. This process fosters successful population of the geotechnical database utilising structured QAQC processes.

GEOTECHNICAL DATA MANAGEMENT

Companies and contractors that deal with large sets of geological and geotechnical data often struggle with storing, recalling and manipulating data in an accurate and efficient manner. Data management tools are available, however the quality of these tools vary, as does the quality of the data stored within them. Many systems lack the proper validation, interrogation and querying capabilities required to maintain an effective and accurate database. Bad experiences and rudimentary thinking has resulted in companies storing data in excel spreadsheets or in poorly organised servers and archives (Caronna, 2010). In some veteran departments, the use of paper-based reports is common practice which is becoming increasingly impractical as projects become larger and more advanced (Caronna, 2010).

An advantage of a GDMS is the ease in which data can be viewed, filtered and manipulated. Furthermore, through business rules, data validation and thorough QAQC processes the risk of inaccurate information is greatly reduced. A properly designed database will only require data to be entered once, eliminating the need for re-entry and reformatting. A study performed by Goldin *et al.,* (2008) showed on average 1.24% of data entries in excel are entered incorrectly; the error then compounds every time the data is re-entered. The 'single entry multi-use' set up of a well-designed database reduces human transcription errors which is a major source of inaccuracy for companies dealing with large quantities of geotechnical data (Antoljak and Caronna, 2012).

Reportbase vs Database

Understanding the importance of a GDMS is an important first step to successful data management, however, the development of a database system is not as intuitive as it may seem. Caronna (2006) discussed a common pitfall that geotechnical engineering firms encountered during the implementation of a GDMS. Caronna used the term 'reportbase' to describe databases designed for the sole purpose of generating specific reports. Companies that followed this line of thinking created a disparity between the raw data and the formatted information within the database. This was a result of the extensive use of computer aided design (CAD) software, excel and word programs to enter data into the database, creating formatted information for specific reporting needs. This approach to database implementation limited the usability and functionality of the data.

The defining characteristic of a reportbase, as outlined by Caronna (2006), is the structure of the database mimicking a one-to-one image of the desired report. The advantage of this layout revolves around the simplicity of setup, the ease of use and the uncomplicated table arrangement. Despite the simplicity, data in this form had limited to no reusability, no electronic validation and limited automation.

Caronna (2006) described that a database, in its truest form, contains data free from the constraints of formatting, where each individual parameter is captured in its own field. The unformatted, but controlled layout allows data to be easily queried and manipulated into reports, graphs and tables for a broad range of functionalities. The configuration of the database tables does require a reporting engine and increased querying capabilities to manipulate the data into the desired format. The higher database complexity requires increased design work and generally an increased implementation cost (Caronna, 2006). The increased complexity and cost of the database is more than offset by the advantages of this configuration, most notably:

- Database contains data, not formatted information;
- Data reusability;
- Improved querying functionality;
- Electronic validation;
- Enforced standardisation of data descriptions; and
- Electronic data capture.

Quality Assurance and Quality Control

QAQC of data is an essential process to ensure the integrity and accuracy of any database. An effective QAQC system identifies the key errors associated with the data and employs controls and risk management techniques to mitigate or fully eliminate the issue, with the ultimate goal to perform modelling or design work without unacceptable influence of inaccurate entries. The key errors associated with geotechnical data are not attributable to one source and an effective system takes into account a broad range of possible errors, most notably (Baecher, 1987):

- Human incompetency/error;
- Sample degradation;
- Data tampering;
- Laboratory errors;
- Mislabelled information;
- Unrepresentative values; and
- Data entry errors.

Extensive literature regarding QAQC processes is widely published in both print and electronic formats. A brief summary of important QAQC practices for geotechnical data management are outlined in Figure 2.

CASE STUDY

A database management system was created using data collected from all existing RTCA mines and development projects. The sites are located in the Bowen Basin in Queensland and the Hunter Valley in New South Wales. The geographic spread of sites and complexity of the legacy data provided a good basis for determining a robust system for the development of a database management system. The creation of the database was conducted in successive stages, which allowed the process to be broken down and successfully managed throughout the entirety of the project. The eight stages were:

- Data collation;
- Business rules
- Data inventory;
- Data extraction;
- Database scoping study;
- Database implementation;
- User acceptance testing; and
- Data migration.

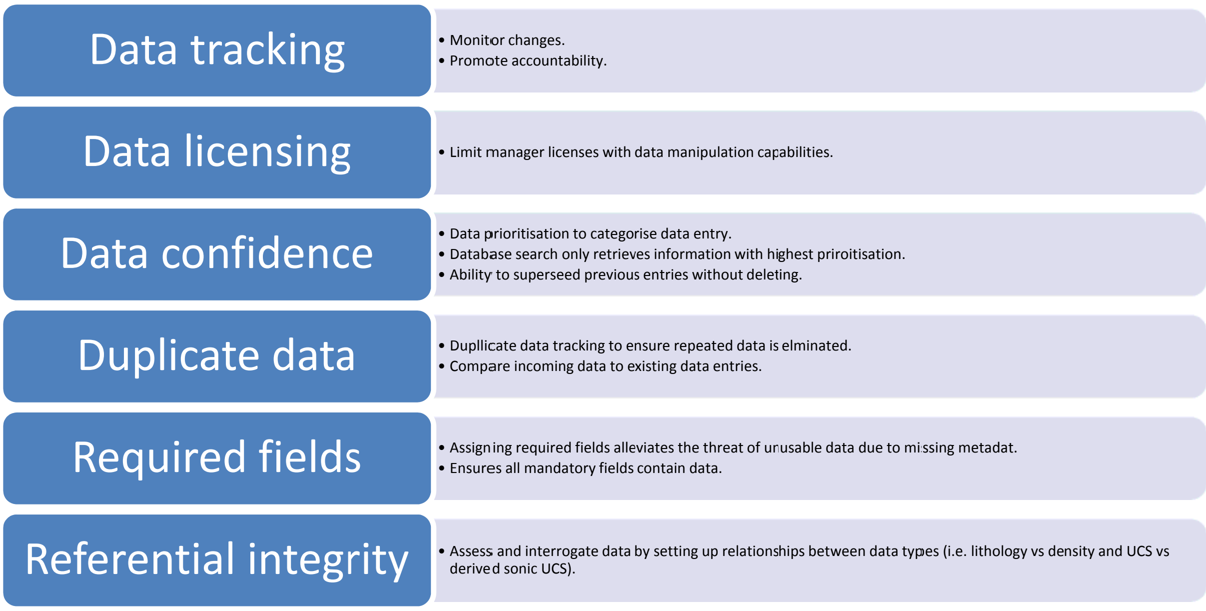


Figure 2: Important QAQC processes for a GDMS

Data Collation

Data collation was performed progressively through March to May 2014, where all pertinent geotechnical information was compiled onto a single server. The majority of the geotechnical data existed on site specific servers and within existing repositories on the RTCA Brisbane corporate server. A total of 64,334 electronic geotechnical data files were collated and sorted into corresponding project codes over a period of ten weeks. The Rio Tinto archives were also searched to retrieve any applicable information utilising key search words i.e. geotechnical, groundwater and geomechanical. In total, 947 files in hardcopy format were scanned and the subsequent electronic files collated and sorted according to site.

Business Rules

Individual business rules were created for all possible geotechnical parameters and their related units to ensure inventoried and extracted datum was entered under the correct heading and followed accepted data values. Additionally, dictionary codes and reference tables were created for some fields to ensure standardisation of terms throughout the database. By reducing the spread of possible entries and enforcing consistency, the database had dramatically improved querying and reporting capabilities.

Data Inventory

The physical data inventory process was outsourced. The data inventory process began on the 15th of April and concluded on the 11th of July. During the process 11,004 files were inventoried, with weekly deliveries of ~2000 reports over the three month period. The data inventory process created a detailed list of files and the information contained within each data file. Data types were prioritised based on necessity and strategic impact to the business. Interoperability of data types was also a significant driver in the selection of inventoried files. The process was controlled using inventory headings and a thorough QAQC process.

Data inventory headings were created to act as a template for the inventory process. Geotechnical data types were classified into 44 umbrella headings which represented the column headers for the inventory sheet. When a data file contained relevant geotechnical information, a Y was scribed underneath the corresponding column header, to signify this type of data existed within the file. Each new data file was captured on a new row in the data inventory sheet. In the case where multiple boreholes exist within the one data file, each new borehole was captured on a new row under the same file name. All inventoried files were subject to stringent QAQC checks by the inventory team and once the delivery had been made to RTCA.

Data Extraction

The data extraction phase aimed to extract all relevant geotechnical information from selected files under data extraction headings. Similarly to data inventory, the extraction process was outsourced, however, duplicate files were identified during the inventory stage, and as such not all inventoried files required extraction. The data extraction process began on the 2nd of July and is expected to conclude on the 16th of January. During the process 6,401 files are scheduled for extraction, with fortnightly deliveries of ~500 reports over the seven month period. Like the inventory process, data extraction was controlled using extraction headings and a comprehensive QAQC process.

A total of 541 headings were created, each tasked with capturing a particular piece of data. The extraction headings acted as column headers and the relevant data was entered into the corresponding column. Each new data file was entered on a new sheet and files with more than one borehole or files containing numerous datasets were entered on separate rows. Additionally, the extraction heading sheets were used as a template for the legacy importer objects, successfully eliminating the need for further data manipulation.

The manual nature of data extraction can lead to extensive human transcription errors within the geotechnical data. Three QAQC stages were implemented during data extraction to ensure data integrity was maintained, the full QAQC flowchart is summarised in Figure 3. Maskell (2014) outlined the first stage of quality control used for the extraction of RTCA's legacy data, identifying five QAQC checks throughout the extraction phase, these are:

1. Manual check for completeness and correctness of data;
2. Quality control check of 100% of the extracted data (quality must exceed 92%);
3. Electronic validation of data (0% defect tolerance);
4. Quality assurance check of 20% data sample (quality must exceed 95%); and
5. Electronic validation against business rules (0% defect tolerance).

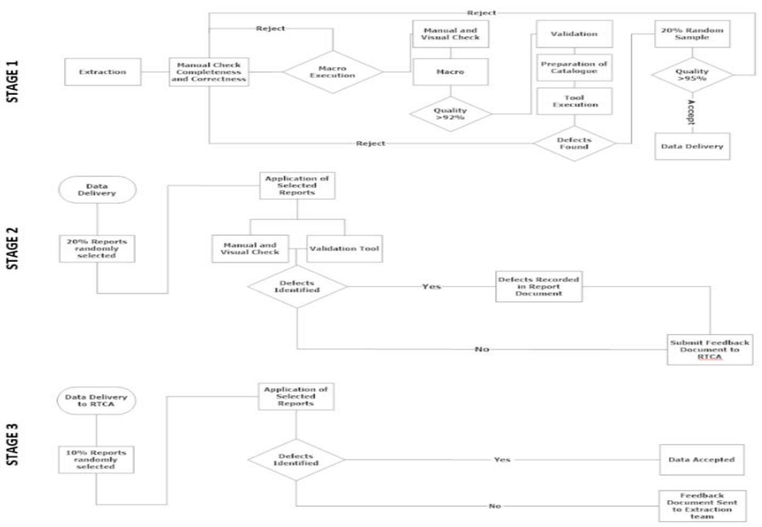


Figure 3: Data extraction QAQC flowchart

Should any of the data checks fail, the data flows back through the process to fix inaccurate data and remove defects. The process ensures not only data accuracy, it fosters data totality by certifying all relevant data is captured. During the extraction of RTCA legacy data, 20% of the personnel allocated to data extraction were exclusively assigned to QAQC to ensure the process was thorough.
When data passed the QAQC checks, the files progressed to a separate team of analysts to perform quality assurance on an additional 20% of randomly selected files forming stage 2 of the QAQC pocess. The extracted data was cross referenced against the business rules and specification documents to ensure accuracy. If defects were present, a feedback document was constructed and sent to RTCA with the extracted files. If the defects proved to be a systemic issue, the data was typically recirculated through the entire extraction process.

The data packages sent to RTCA were subject to a final QAQC process undertaken by the OBK team. Of the extracted files, 10% were randomly selected and checked to ensure all data was captured and accurate. Files containing errors were corrected and feedback was provided to ensure accuracy was maintained. If errors were unacceptably high, the batch would require re-extraction.

Database Scoping Study

Prior to implementation of the database, a scoping study was conducted to personalise the database to RTCA's specific customary requirements. The scoping study outlined the most effective workflow for the database implementation to satisfy the habitual necessities of the RTCA legacy data and the required outputs. The solution of the scoping study addressed three fundamental aspects of the technical deployment:

1. People – the roles required to run the system;
2. Process – workflow and practices to optimise data management; and
3. Technology – technological components that the implementation will be based upon.

Database Implementation

The implementation process was undertaken after the completion of the scoping study, ensuring the key attributes outlined within the scope were included to produce the proposed workflow. A relational database structure was chosen for the GDMS using a process known as data normalising. Under a relational database system, data is identified and placed in relevant tables with strict rules governing duplication of data through identification of uniqueness. Data uniqueness was controlled by primary keys which consist of one or more fields in a table. A primary key is completely unique to a data entry and cannot be repeated in any other data set. For example, when describing collar data, the hole ID and project code fields were used as the primary keys, as no two boreholes have the same entries for these two fields. Any primary key consisting of two or more fields are referred to as composite keys.
Given that relational databases place data in separate tables, it is also important that correlated data in separate tables be linked together using a derived relationship. A derived relationship links data to metadata or dependant data, forming a parent – child table relationship. This relationship is defined using a foreign key which enforces referential constraint by referencing a key field in the child table which relates it to the parent table. By normalising data into parent – child relationships, data integrity is enforced and the possibility of redundant data is eliminated.

User Acceptance Testing

Database acceptance testing was carried out during the implementation of the database, to ensure objects within the database were up to standard. During testing the functionality, layout and aesthetics were evaluated, and were only accepted into the database once approval was granted. User acceptance testing was also carried out after the completion of the database implementation phase and during data migration to ensure objects were fit for purpose and to minimise or altogether mitigate start up issues.

Data Migration

The migration of the RTCA legacy data was the first step involved in populating the database. Using the extraction sheets completed by Cyient, the data was transferred into the database using the legacy template importers. Given the age and complexity of the data, a number of issues were encountered during the migration phase of the project which are summarised in Figure 4.

The legacy template importers were created to support the populated extraction sheets. Creating importers that could populate the database without further data manipulation offered significant costs benefits and reduced the likelihood of human transcription errors. An importer was created for every extraction sheet, which was capable of reading multiple rows of data from the CSV file.

Additionally, fourteen import objects were built for the project, tasked with identifying and performing a defined expression on the data, and subsequently writing it into the database. Import objects differed to the legacy template importers, in this case, the data being loaded does not follow the extraction sheet template.

Inconsistent datum's	• Different coordinate systems used for data given the age and geographical spread of information.
Missing collar data	• Lare amounts of data exisiting without relevant collar or coordinate information. • Coordinate information was recovered from previous systems.
Continuation in lithology files	• Lithology files used continuation, where the same interval was split over multiple rows. • Required altercation to existing importer.
Data truncation	• In some cases data was too long and required truncation to fit within specified character limits.
Undefined lithology codes	• Lithology codes that were not defined in the dictionary codes.
Discrepancies between data	• Drilling times (start times later than end times). • Different logged depths for geophysics, geotechnical logs and lithology logs for same hole.

Figure 4: Legacy data issues discovered during data migration

Generally, data entered through an import object is computer generated with numerous entries in a set form i.e. geophysical LAS files. Extracting and manually writing this information into the legacy template would be time consuming and inefficient. Therefore, import objects were created to read the data from the original file type, as such the data must follow a predetermined template which can be viewed in the individual importer objects.

Finally, data entry tools were used for data types that could not be entered via importers, or for entries where importers were inefficient. Each data entry tool was strategically designed to incorporate validation rules to ensure data integrity was maintained.

Database Outputs

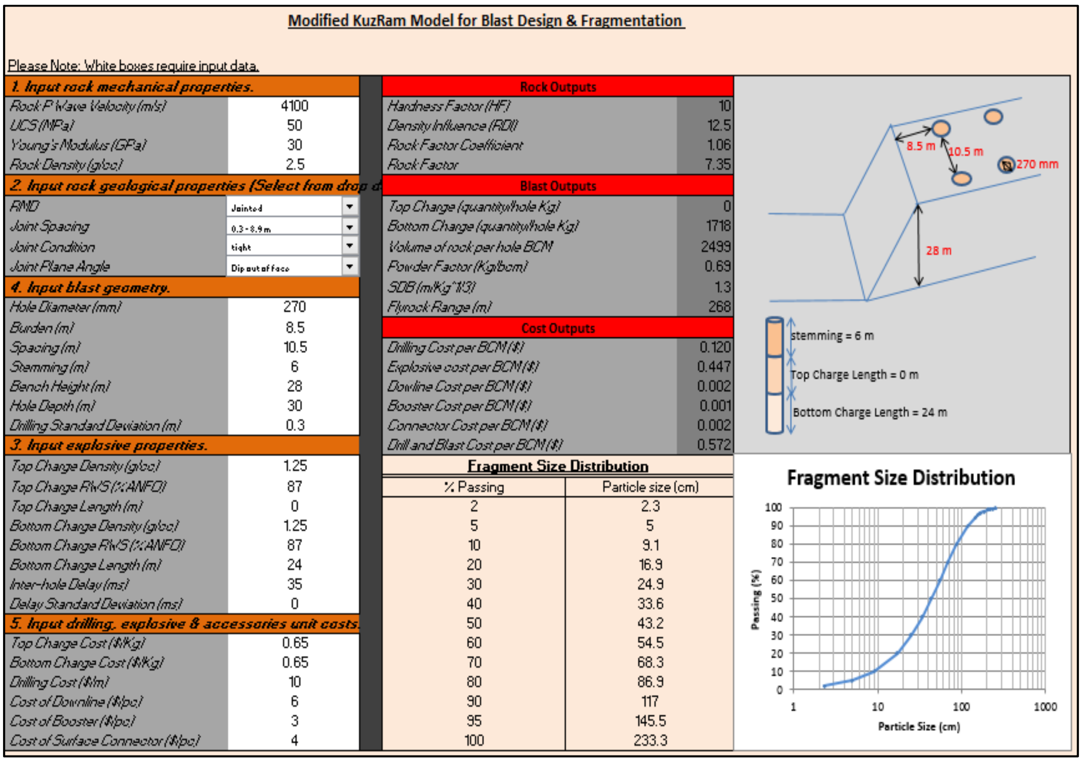
With the database successfully populated, the functionality of a relational database now becomes an issue for querying and viewing data. Whilst code and relational tables provide an efficient mechanism for storing site specific attributes, information presented in this format is not intuitive or easy to comprehend. To aid viewing, the database is 'flattened' so that field names appear as column headers and their values appear in the associated column. The GDMS database provides the means to flatten using a feature known as compound definitions. Compound definitions create a view accessible through user specified filters. Data accessible through compound definitions are not stored in the database as a distinct object, rather a 'SELECT' statement which is triggered by the user forming the view.

In the GDMS Project, views were created through a separate program to the core database. The program incorporates an intuitive 'drag-and-drop' functionality with inbuilt filters to mould a table to specific requirements and purposes. For specific data outputs that are frequently required, a form object within the database workspace can be created.

DATABASE APPLICATION – FRAGMENTATION MODEL

Fragmentation models are an important feature of drill and blast designs. The model acts as a cheap tool for engineers to evaluate and compare outputs from different blast designs. All models require input relating to bench parameters (spacing, burden and hole diameter) and explosive properties, the somewhat uncontrollable error in models originates from the input of geotechnical and geological data. Rock mass by its very nature is inhomogeneous and anisotropic, hence assigning a global value for faults, joint spacing, UCS and other properties is a necessary, and all be it, inaccurate assumption (Kanchibolta, Morrell and Valery, 1999).

Fragmentation models can be generalised into two main categories; empirical models and numerical models. Numerical models follow a mechanistic approach, tracking the physics of detonation in well-defined rock mass for specific blast geometries. This type of model requires very specific and detailed data regarding detonation, the rock mass and the end result. Empirical methods offer a more generalised model which is more suitable for daily blast design. The Kuz-Ram empirical model is one of the most established simulation, used for its simplicity for garnering data, simple calculations and clear outputs (Cunningham, 2005). The Kuz-Ram algorithms are easily incorporated into spreadsheets for ease of modelling, Figure 5 is an Excel fragmentation model created for RTCA.



Modified KuzRam Model for Blast Design & Fragmentation

Please Note: White boxes require input data.

1. Input rock mechanical properties.	
Rock P Wave Velocity (m/s)	4100
UCS (MPa)	50
Young's Modulus (GPa)	30
Rock Density (g/cc)	2.5
2. Input rock geological properties (Select from drop d	
RMD	Jointed
Joint Spacing	0.3 - 0.9 m
Joint Condition	tight
Joint Plane Angle	Dip out of face
4. Input blast geometry.	
Hole Diameter (mm)	270
Burden (m)	8.5
Spacing (m)	10.5
Stemming (m)	6
Bench Height (m)	28
Hole Depth (m)	30
Drilling Standard Deviation (m)	0.3
3. Input explosive properties.	
Top Charge Density (g/cc)	1.25
Top Charge RWS (%ANFO)	87
Top Charge Length (m)	0
Bottom Charge Density (g/cc)	1.25
Bottom Charge RWS (%ANFO)	87
Bottom Charge Length (m)	24
Inter-hole Delay (ms)	35
Delay Standard Deviation (ms)	0
5. Input drilling, explosive & accessories unit costs.	
Top Charge Cost ($/Kg)	0.65
Bottom Charge Cost ($/Kg)	0.65
Drilling Cost ($/m)	10
Cost of Downline ($/pc)	6
Cost of Booster ($/pc)	3
Cost of Surface Connector ($/pc)	4

Rock Outputs	
Hardness Factor (HF)	10
Density Influence (RDI)	12.5
Rock Factor Coefficient	1.06
Rock Factor	7.35
Blast Outputs	
Top Charge (quantity/hole Kg)	0
Bottom Charge (quantity/hole Kg)	1718
Volume of rock per hole BCM	2499
Powder Factor (Kg/bcm)	0.69
SDB (m/Kg^1/3)	1.3
Flyrock Range (m)	268
Cost Outputs	
Drilling Cost per BCM ($)	0.120
Explosive cost per BCM ($)	0.447
Downline Cost per BCM ($)	0.002
Booster Cost per BCM ($)	0.001
Connector Cost per BCM ($)	0.002
Drill and Blast Cost per BCM ($)	0.572

Fragment Size Distribution

% Passing	Particle size (cm)
2	2.3
5	5
10	9.1
20	16.9
30	24.9
40	33.6
50	43.2
60	54.5
70	68.3
80	86.9
90	117
95	145.5
100	233.3

Figure 5: RTCA Kuz-Ram fragmentation Model

Advantages of a Fragmentation Model

Drilling and blasting of a rock mass is used to condition rock and ore for extraction and is the first phase of the comminution process. The Run Of Mine (ROM) fragmentation is considered ideal, from an operations stand point, if the dig rates and haul requirements are satisfied. For this reason drill and blast engineers design blasts to meet the minimum fragmentation requirements of the operation. Although this approach maximises mining productivity relative to operational expenditure, it ignores the potential impact of downstream processing and the productivity of production equipment (Kanchibolta, Morrell and Valery, 1999).

A study conducted by Doktan (2001) reviewed the effects of blast fragmentation on truck and shovel fleet performance. The study showed better fragmentation resulted in the following operational improvements:

- Increased digability (up to 35%);

- Higher bucket payload (reduced void ratio and increased fill factor);
- Higher truck payload; and
- Reduced maintenance requirements on truck and shovel fleet.

Given the importance of proper fragmentation, the use of a fragmentation model can represent significant production and fiscal advantages to a business.

Creating a Live Link between the GDMS and the Fragmentation model

Even with inherent errors, the advantages of fragmentation models are considerable, however these models are often put in the too hard basket and dismissed. The ability of drill and blast engineers to acquire the correct geotechnical information to accurately model a blast design is the most time consuming component of the process. Finding the information for a blast at a specific location can be a struggle and the data is often incomplete and inaccurate. When mines have multiple blasts a day, it is understandable that many sites do not utilise fragmentation models.

A Kuz-Ram script was created during the database implementation to query relevant geotechnical information for the fragmentation simulation. The algorithm queried two key types of geotechnical information to fulfil the requirements of the model, that is, geomechanical data and structural properties. Given the significant quantity of relevant information in the database, filtering the results for the blast zone was crucial. By outlining the coordinates of the blast through Easting, Northing and RL ranges the data was restricted to the blast horizon, limiting the geotechnical data to the most pertinent entries.

The RTCA geotechnical database system was linked to the Excel fragmentation model through an SQL database connection. The generated data could be dumped into the fragmentation model from any computer with access to the RTCA server and a current installation of SQL. Assuming the blast geometry and explosive data had previously been entered into the model, by refreshing the excel sheet a fragmentation distribution, drill and blast cost per BCM, peak particle velocity at nearest structure, and flyrock range was immediately generated using the updated geotechnical data.

CONCLUSIONS

The aim of this project was to capture, extract and upload RTCA's geotechnical data into an easily accessible, single source geotechnical database. At a minimal cost to RTCA, the database system aimed to increase data security and accuracy; allowing for more efficient engineering processes.

The GDMS at RTCA was used as a case study to document a systematic database implementation process from start to finish. The inventory and extraction processes were analysed, with significant emphasis placed on the development of specific business rules to ensure data integrity and totality was maintained. Furthermore, the manual nature of the data extraction process demanded intense QAQC procedures to limit human transcription errors. Three separate QAQC workflows were implemented to ensure the data was extracted correctly, involving re-extraction of random data samples to ensure quality and running data through macros against business rules to limit defects.

The database scope and implementation process was discussed, identifying a relational database as the most suitable structure given the variety and complexity of the RTCA legacy data. Primary keys and foreign keys were established throughout each table to remove redundant and duplicate data and ensure correlated data could be linked by forming derived relationships. Importer objects were developed and analysed to outline the data migration process and the strict validation procedures associated with these objects.

Finally, the advantages of creating a live link between the geotechnical database and a blast fragmentation model were discussed. By querying the database for geomechanical and structural information within the blast coordinates; accurate and up-to-date geotechnical data can be fed into the model. The model was developed to create a cost effective comparative tool to compare blast outputs for varying blast geometries and explosives.

ACKNOWLEDGMENTS

The authors would like to thank the Rio Tinto Orebody Knowledge team who were instrumental throughout the project. The authors would especially like to acknowledge the contributions of Mark

Sjoberg and Sabine Stam for their constant guidance, geotechnical expertise and willingness to assist in the project.

REFERENCES

Antoljak, S and Caronna, S. 2012, Subsurface databases in geoenvironmental engineering, *Chemical Engineering Transaction*, 28:97-102.

Atkinson, T, Dow, R and Brom, R. 1984, A review of hydrological investigation for deep coal mines, with special reference to petrophysical methods, *International Journal of Mine Water*, 3(3):19-34.

Baecher, G. 1987, Error analysis for geotechnical engineering [online], Nexus Associates. Available from: <http://pm.umd.edu/files/public/water_library/1987/Report_Error%20Analysis%20ffo%20Geotechnical%20Engineering_Sep%201987_Baecher.pdf> [Accessed 4th May 2014].

Brady, B and Brown, E. 2004, Rock Mechanics for Underground Mining, pp 85-120 (*Springer: Delhi*).

Caronna, S. 2006, The comparative value of geotechnical databases vs. reportbases, *in Proceedings Geotechnical Engineering in the Information Technology Age*, pp 145-149 (GINT Software: Atlanta).

Caronna, S. 2010, Fundamentals of geotechnical database management, *Geotechnical News*, 28(2):37-40.

Cunningham, C. 2005, The Kuz-Ram fragmentation model 20 years on, *in Proceedings European Federation of Explosives Engineers*, pp 201-210 (ISBN: Brighton).

Doktan, M. 2001, Impact of blast fragmentation on truck shovel fleet performance, *in Proceedings 17th International Mining Congress and Exhibition of Turkey*, pp 375-380 (IMCET: Turkey).

Goldin, S, Parks, D, Skeate, R and Wahi, M. 2008, Reducing errors from electronic transcription of data collected on paper forms: a research data case study, *Journal of the American Medical Informatics Association*, 15(3):386-389.

Hadjigeorgiou, J. 2012, Where does the data come from [online], Lassonde Institute of Mining. Available from: <http://www.acg.uwa.edu.au/__data/page/2139/DHS12_Hadjigeorgiou_keynote.pdp> [Accessed: 8th May 2014].

Hanson, C, Thomas, D and Gallagher, B. 2005, The value of early geotechnical assessment in mine planning [online], University of Wollongong. Available from: <http://ro.uow.edu.au/cgi/viewcontent.cgi?article=1064&context=coal> [Accessed: 10th March 2014].

Harrison, J and Hudson, J. 2007, Engineering Rock Mechanics, pp 1-9 (Pergamon: Oxford)

Hoek, E, 1994, *The challenge of input data for rock engineering, ISRM News Journal*, 2(2):23-24

Kanchibolta, S, Morrell, S and Valery, W, 1999. Modelling fines in blast fragmentation and its impact on crushing and grinding, *in Proceedings a Conference on Rock breaking*, pp 137-144 (AusIMM: Kalgoorlie).

Maskell, J. 2014, Personal communication, 16 May.

MOSHAB. 1997, Geotechnical considerations in underground mines [online]. Available from: <http://www.dmp.wa.gov.au/documents/Factsheets/MSH_G_GeotechnicalConsiderationsUGGeote.pdf> [Accessed: 11 March 2014}.

Pankow, K, Moore, J, Hale, M, Koper, K, Kubacki, T, Whidden, K and McCarter, M. 2013, Massive landslide at Utah copper mine generates wealth of geophysical data, *GSA Today*, 24(1):4-9.

Perez, J, Ramos, I, Anaya, V, Cubel, J, Dominguez, F, Boronat, A and Carsi, J. 2002, Data reverse engineering of legacy databases to object orientated conceptual schemas [online], *Theoretical Computer Science*, Available from: <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.99.6293&rep=rep1&tyty=pdf> [Accessed: 8th May 2004].