Caving 2026 – A van As, D Cumming-Potvin & J Wesseloo (eds)
© 2026 Australian Centre for Geomechanics, Perth, ISBN 978-1-7636842-3-2
doi:10.36487/ACG_repo/2645_11

Enhancing data integration and visualisation for block cave operations

Robyn Teet [a,*], Jack Mowen [a]

[a] *Resolve Mining Solutions, Australia*

Abstract

Modern block cave operations have seen a substantial increase in monitoring points over the past decade, driven by the adoption of automated and manual technologies. While this expansion improves visibility across multiple disciplines, it also introduces challenges associated with data overload, where large volumes of information cannot be effectively leveraged for timely decision-making.

To address this, a well-established caving operation has implemented significant modifications to the mXrap (Harris & Wesseloo 2015) Caving Sandbox over the past 18 months, creating a unified platform that integrates data from multiple sources for their operations. This approach reduces reliance on multiple applications and enhances accessibility for technical teams. Key integrations included grade and lithology data, drawpoint status, classification of fines and water status at each drawpoint, and rill event visualisation to improve risk communication. Additionally, functionality was introduced to compare predicted lithology, grade, and fragmentation against actual recorded values, providing deeper insights into cave performance and behaviour. This latter feature was also designed to support reconciliation of forecast models, further aiding in the cave management and performance processes.

This paper outlines the development process, integration methodology, and benefits achieved through improved data visualisation and interpretation, demonstrating how customised platforms can unlock the full value of complex datasets in modern caving operations.

Keywords: *data visualisation, block cave, interpretation, risk management*

1 Introduction

The challenge of managing growing geotechnical datasets in the mining industry has been emerging over the last 10 years as a direct result of the advances in technology and the transition towards big data. Advancements in real-time or near-real-time data collection on many geotechnical monitoring systems and production management systems rapidly results in large datasets which require analysis and interpretation to inform many aspects of risk management at a mining operation. This often results in multiple data sources which can be in various formats including conventional Excel workbooks, SQL databases or original equipment manufacturer (OEM) specific software. As an operational geotechnical engineer, being able to efficiently access, analyse and interpret this data is essential, and this is often accompanied by a time pressure which further adds to the challenge. This is especially prevalent in a caving operation prior to cave breakthrough when the management of production, airblast risk and transition from ramp-up to production requires regular and routine feedback mechanisms from the geotechnical team.

In some instances, the visualisation of the individual datasets also is processed through a black box type solution and the ability of the user to understand the data processing method and associated impacts on the data output is limited. Ultimately, this results in limited data ownership with the personnel onsite utilising the data to make data-driven risk-management decisions. This combined with the numerous data sources

* Corresponding author. Email address: robyn@resolvemining.com.au

typically available can lead to inefficient data processing, limited confidence in data outputs and increased frustration of those needing the data to support their core work functions onsite and management relying on feedback and input from operational personnel.

The inefficiencies in handling multiple large datasets also results in increased time taken to provide decision inputs and, where multiple teams are involved, has the potential to introduce errors in data interpretation, data version control issues and ultimately, in the worst-case scenario, result in improper guidance being provided that threatens the safety of personnel.

2 Drivers for project initiation

When reviewing published work from industry over the last 15 years of how geotechnical risk management is approached in a block cave environment, there are numerous examples from caves around the world including Northparkes (Teet et al. 2024; Snyman & Webster 2022), Cadia East (Lett & Cuello 2024; Lett et al. 2022), PT Freeport Indonesia (Vanegas-Palacio et al. 2024; Lolon et al. 2024; Fonataba et al. 2024; Nguz Tshisens et al. 2022; Llewelyn et al. 2022; Edgar et al. 2020; Pierce et al. 2020), El Teniente Andes Norte (Landeros Córdova 2022), Oyu Tolgoi (Moorcroft et al. 2022) and more broadly at the strategic and corporate level (van As & Noppe 2024; Butcher & Fallon 2011; Atkins & Webster-Smith 2011; Dunn et al. 2011).

Whilst this list is not considered exhaustive by any stretch, these papers all have one key thing in common; data-driven risk-focused management is utilised to mitigate the risk of various caving and geomechanical hazards that are present in any given operation. Collecting and using data for decision-making is by far the most appropriate method to adopt in these situations and is aligned with the scientific method that technical specialists strive for. This approach does however present a challenge in terms of data management and storage. With so many data inputs relating to so many different aspects of caving operations, what is the best practice for not only ensuring the data is captured and is accessible, but also that it is validated/QAQC checked and in a format that is not just accessible, but is quickly and easily integrated into the platform(s) of choice for data interpretation?

Typically, sites end up with a combination of spreadsheets, SQL databases or similar, OEM specific portals and platforms, and depending on the scale and stage of the project and workforce development level, paper-based data which is subsequently scanned and potentially digitised into a relevant dataset (but often remaining in scanned format only). Whilst the latter is becoming less of an issue as technology adoption increases, the combination of multiple other data sources still poses a threat to efficient data analysis and interpretation. As new systems are added into the cave monitoring toolkit, often this adds another spreadsheet, database or dashboard, and in many cases, no consideration for consolidation of data visualisation and analysis tools is made. What is commonly encountered is the instruction to use the tools that already are available under the assumption that there are plenty available and therefore the solution must be there. Essentially, make what you have work for you for no additional cost.

This difficulty of integration, consolidation and analysis is compounded by the scale and complexity of an operation. At block cave operations, these challenges can often be subdivided into 3 main categories:

- seismicity
- cave propagation and its impact on mining operations
- water.

These categories also applied at Mine A who engaged Resolve Mining to support their site in addressing visualisation of precursor data supporting the management of cave propagation, inrush and production forecasting. Due to the operational complexities encountered at the underground block cave operations at Mine A, an extensive risk-management approach has been implemented to assist in the management of hazards at the underground operations. To manage the complexities, data-driven risk management is required to support safety management systems.

The collaboration between Resolve and Mine A began with a discussion that fundamentally was underpinned by the above. Mine A was aware that Resolve had been working on developing an Inrush app within the mXrap (Harris & Wesseloo 2015) platform to assist users in visualising various data sources with the goal of graphically displaying inrush risk at any given drawpoint on an extraction level. The ability to modify existing mXrap features and introduce new ones was not something that Mine A had previously considered, and early in the discussion, they identified several data sources that would be advantageous to display and interact with in mXrap instead of additional software programs. From this initial conversation, the mXrap implementation project emerged and the development process began.

Whilst the primary focus of the use of mXrap for data visualisation was to streamline and improve efficiency of data visualisation and interpretation, integration of the philosophies outlined in this review proved fundamental in ensuring successful project execution.

3 Development process

Like many caving operations, Mine A utilises mXrap for seismic risk management and cave management using the existing features within the Caving Sandbox. Several existing features in the Caving Sandbox had not fully been implemented and were flagged for inclusion in the project, as well as adopting existing features and modifying them to suit the additional data Mine A wanted to visualise. The functionality and features of the mXrap suite is well-established across the mining industry and recent publications specific to the Caving Sandbox suite have been included in both MassMin, Deep Mining and Caving conferences in recent years (Reid & Cumming-Potvin 2024; Banjwa et al. 2024; Poulter et al. 2022; Morkel et al. 2022; Woods et al. 2018). There are, however, alternative platforms that other operations could consider in attempting to solve the challenges outlined in this paper and they should be pursued if appropriate.

With the mXrap platform in mind, a workflow was developed which considered the typical software development life cycle (Figure 1). The adoption of this approach provides a roadmap that was able to be clearly communicated and integrated into the project approach for Mine A whilst maintaining flexibility to align with the needs of the mining operation in place of the software company.

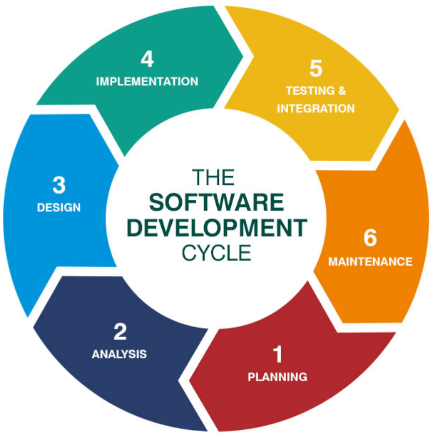

Figure 1 The software development cycle (Saigon Technology 2025)

The resulting workflow applied to the Mine A project can be seen in Figure 2, and a number of interaction points between key stakeholders and Resolve were added to ensure that as the project advanced, opportunities for scope modification were built in. Whilst scope creep was not intended to occur, it was acknowledged at the start of the project that though there was a high-level understanding of what was wanted, as the key stakeholders became more familiar with the software's capabilities, the planned ideas and requirements were likely to change. This was ultimately reflected in the final project output with additional features added and several scope items dropped following a reassessment of their business value against operational life expectancy.

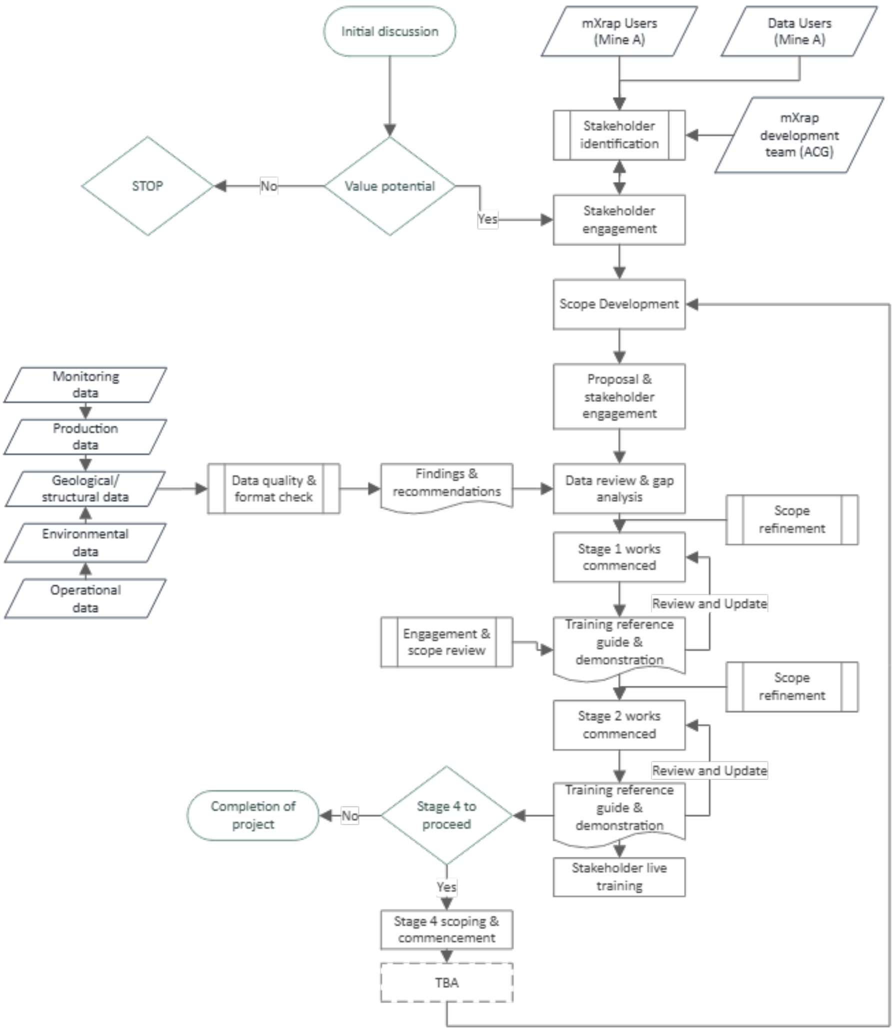

Figure 2 Implemented project workflow for Mine A mXrap customisation

For a few features to be included in mXrap, Mine A had existing examples of required outputs and/or marker styles to adopt. This made alignment of the new features to those onsite much more streamlined and supported the goal of avoiding conflicts with existing systems and processes.

4 Integration methodology

A key focus area for this project was ensuring that the new features developed for Mine A in mXrap were integrated as seamlessly as possible. Several key concerns were outlined by the stakeholder group:

- avoid generating conflicts with existing systems and processes
- avoid interruption to existing use of the mXrap platform by engineers onsite
- avoid generating conflicts in the baseline mXrap deployment to limit rework and implementation timelines for other footprints onsite.

To ensure these concerns were avoided, a number of contingencies and controls were defined early in the project method discussions and implemented from the project commencement:

- develop a staged integration approach
- develop and deliver problem-based training for Mine A personnel

- develop technical reference guides that highlight the key requirements including data formats and sources to support ongoing use of the introduced features
- ensure repeated engagement with stakeholders throughout the project
- review scope of work at the end of each phase of work to ensure alignment against the project goals and objectives

The definition of the project stages (Figure 3) were intentionally left somewhat ambiguous to maintain flexibility in the deliverables and enable detailed scope definition to be achieved at each project stage.

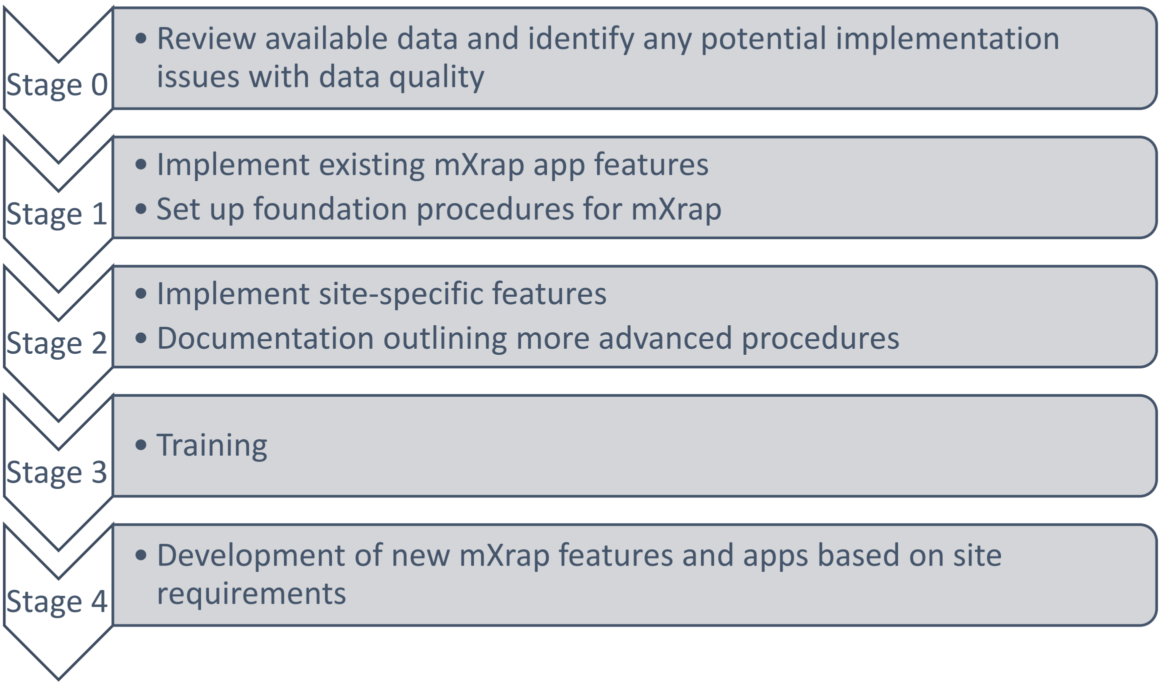

Figure 3 Staged approach developed to support the development and integration of new features in mXrap for Mine A

The first key step involved reviewing data against initial ideas and thought processes from Mine A stakeholders, and assessing what was needed to consider implementing the initial ideas. By undertaking this initial gap analysis, concerns and any points requiring clarification in the input datasets could be identified and addressed prior to the main changes being made. This not only streamlined the main stage implementation but also enabled discussions with data owners and alignment of strategies, maintaining the required output whilst minimising the impact and changes required on existing systems and data sources. The key datasets reviewed are highlighted in Table 1.

Table 1 Key datasets reviewed in the gap analysis

Data component	Sub-component
Production data	Firing data, tonnes mined and draw order
Environmental data	Rainfall tracking data
Geotechnical monitoring data	Elexon system, open holes, convergence and extensometers
Geological data	Wireframes, expected and actual grade and lithology at each drawpoint
Drawpoint data	Fragmentation and water status, rill event tracking and fragmentation

Following this initial gap analysis, features already available within mXrap that required no customisation were implemented. This formed stage 1 works and included:

- firing data
- production data
- fragmentation data
- monitoring data (Elexon data, extensometers and convergence data)

After subsequent discussions with Mine A, it was recommended that monitoring data was linked to the existing site databases to avoid rehandling data and the potential introduction of errors in data import. This was handled by the mXrap team at the Australian Centre for Geomechanics to ensure database connections were set up with appropriate permissions. Firing data and production data was imported by the Mine A team following the gap analysis and data review and implementation of recommendations to ensure inter-app functionality.

Stage 2 was much more involved because it required developing custom features for Mine A. The approach taken is outlined in Figure 4. It involved greater stakeholder engagement to ensure the deliverables met Mine A's requirements. Because there are multiple mXrap baseline projects for different footprints, changes in the primary root folder would be implemented in the secondary root folder only after all key stakeholders approved the changes. This minimised rework and avoided complicating the update process with multiple versions of the solutions for the same data source.

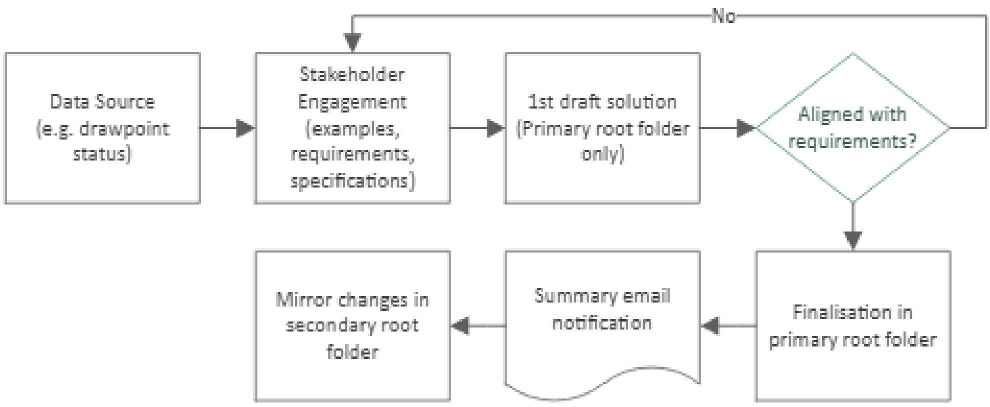

Figure 4 Stage 2 implementation approach

With the implementation of the requested changes, Stage 3 of the project commenced and consisted of providing training for Mine A on the new features implemented in the mXrap Caving Sandbox. The intent of the training was to provide problem-based learning, giving participants the opportunity to use the features and update relevant data themselves. This training was completed over 2 sessions. The initial session provided the overview of the changes (as not all personnel in training were key stakeholders in the development process), an overview of the features in mXrap and a step-through of the updating process. At the end of the first session, participants were provided with a series of tasks to consolidate their understanding of the new features, and the second session served as a question and answer session for any challenges they had encountered. In addition, a training team chat was established to allow participants to ask questions outside training sessions. This training was provided in addition to the development of training reference guides, which were developed as the implementation phase of the project advanced and outlined key data sources, formats and requirements to use the new features.

This training stage was crucial for gaining broader buy-in for the system and for adopting features that many personnel had not been directly exposed to previously. It is an often-overlooked component of software deployments and is critical to ensuring that deployments such as these are not orphaned due to a lack of technical and operational understanding.

5 Project outcomes

All projects inherently involve both benefits and challenges, and the implementation of customised features for Mine A was no exception. A summary of the key learnings can be found in Table 2, and it is important to acknowledge that several of the challenges resulted from the protracted implementation timeline that this project experienced. Several delays occurred through no fault of the key stakeholders and ultimately led to personnel turnover on the project, which impacted the timeline for deliverables. This turnover also meant that foundational skills in mXrap had also been lost from some of the intended site team, which introduced challenges to the training stage. None of these challenges are insurmountable; however, they were not foreseen at the commencement of the project.

Table 2 Summary of benefits and challenges of the mXrap implementation project

Benefits	Challenges
Requested features implemented	Skill set required to implement further changes is currently limited onsite
Aligned features to existing colours and layouts	Personnel turnover within the stakeholder team
Training documents	Root folder conflicts
Ongoing discussions and capability awareness	Implementation of grade data and subsequent commercial sensitivity challenges
Ongoing opportunity to edit/update	Time for implementation

However, even considering the challenges the project experienced, the aim of introducing additional data to mXrap to assist in the visualisation of data and, ultimately, to support risk management at Mine A was achieved. Datasets to support active risk management (including water status and closure status of drawpoints) were successfully integrated (Figure 5). Other datasets that support an understanding of cave behaviour, including comparisons between predicted and actual gold and copper grades and dominant lithologies, were implemented. The inclusion of drawpoint rill events tracking and visualisation was also implemented (Figure 6). In all, every element of Table 1 was successfully implemented on the one mXrap platform upon completion of the works, enabling the Mine A team to have a single visualisation and data analysis platform to work from.

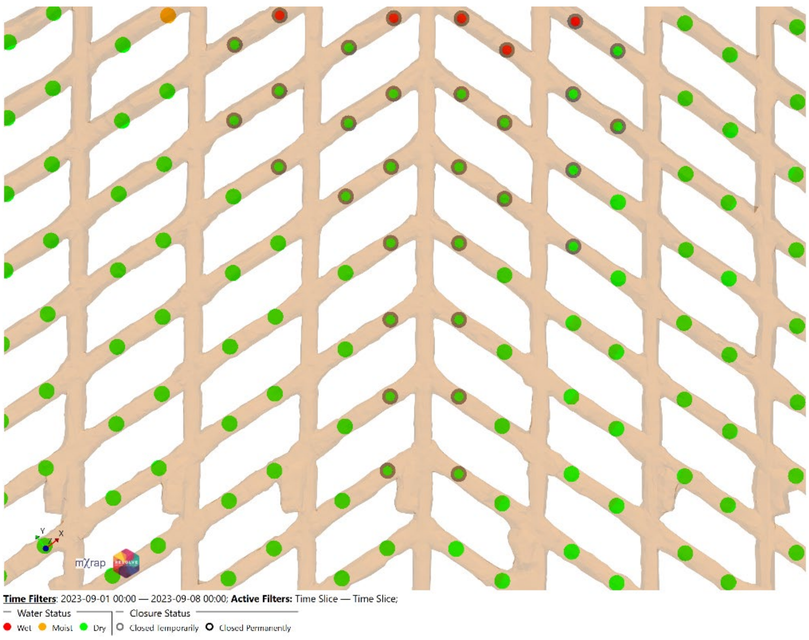

Figure 5 Example of water and closure status for Mine A. One-month time window shown

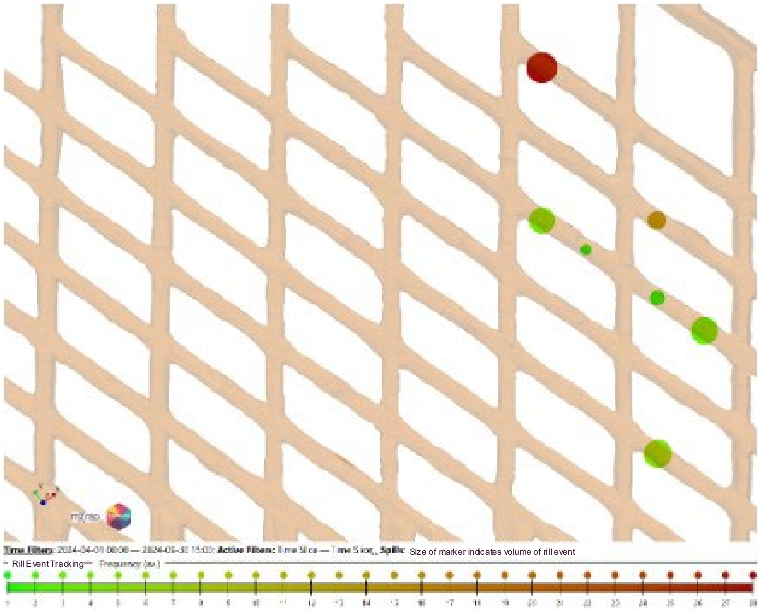

Figure 6 Drawpoint rill events for 6 months at Mine A. Colour represents frequency within the time window, and size is the average volume of material in the event

The adopted approach also enabled participants to develop a deeper understanding of how data classifications and ratings are defined and applied. Working through the process of visualising data in specific ways created an opportunity to review existing categories, assess their relevance and applicability, and update them where necessary. Additionally, documenting the calculation steps allowed all participants to understand how the results were derived. This level of transparency is often not achievable with off-the-shelf solutions, where calculations are typically opaque and cannot be modified to suit site-specific requirements.

6 Industry implications

Following completion of the project, there were several learnings taken from the project that the authors believe can be applied to the caving industry and beyond:

- Check your capabilities onsite and within teams
- Keep an open mind when developing training programs and professional development
- Don't 'just make do'
- Communicate and consider other teams and end users
- Prioritise developments based on value added
- Roadmap your proposed solution.

As technology continues to reshape mining operations, organisations should look beyond traditional role definitions and recognise the secondary skill sets that exist within their current workforce. Skills such as basic programming, data analysis, and system understanding can often be developed alongside core technical competencies and applied effectively without formal qualifications. The project described in this paper demonstrates how individual interest and aptitude, when supported appropriately, can be leveraged to deliver meaningful outcomes. Actively identifying and developing these secondary skills within existing teams not only improves organisational capability and adaptability but also reduces reliance on specialist recruitment and accelerates the adoption of value-adding technologies.

In addition, a key industry lesson from this project, and others undertaken by the authors, is the need to move away from a 'just make do' mindset. Small issues that are not addressed, such as suboptimal tools, processes, or software, may have limited impact in isolation but can collectively result in meaningful productivity gains if optimised. This includes ensuring that technical services teams have access to appropriate software, with the cost of licensing weighed against productivity losses from workarounds.

A broader recommendation arising from this work is the importance of deliberately road-mapping solutions-focused projects and engaging a wider group of stakeholders beyond the immediate project team. Early and ongoing engagement with team members who may not be directly involved in delivery but who will benefit from or be affected by the outcomes helps ensure solutions are aligned with operational needs, improves adoption, and identifies opportunities for additional value. This approach supports more robust decision-making, reduces rework, and increases the likelihood that project outcomes are effectively embedded into day-to-day operations. In the example highlighted within this paper, numerous teams within Mine A were involved, some within the direct stakeholder team but many outside of it, extending beyond the geotechnical discipline.

This project has demonstrated the relative ease of producing a series of visualisation tools for various datasets within an existing software platform. The importance of this cannot be overstated for all the reasons outlined in this paper. With no formal training but with inquisitive minds, lateral thinking, and an understanding of the challenges that not having a single platform poses for technical services personnel, the project successfully delivered its intended outcome.

7 Conclusion

In conclusion, the project undertaken by Mine A and Resolve succeeded in delivering an interface where multiple data sources could be visualised and interpreted through a single software package rather than multiple. Works are ongoing at the time of writing to ensure that skills are transferred to the existing Mine A team and new members in future. Several challenges were encountered during the project, largely due to its extended delivery timeframe; however, despite these challenges, many industry learnings and applications were developed. The intent of these learnings and applications is to challenge the industry to reconsider the conventional approach to professional development and the ethos of making do. It has been demonstrated that thinking outside of the box can, and did in this case, negate the need for a large expenditure on a custom software solution, whilst simultaneously supporting the technical team onsite to effectively visualise and interpret data used in risk management.

More broadly, during the project development and execution phase, this project demonstrated the importance of allowing sufficient time for discussions and questions about how the project is progressing and how it aligns with the aims and objectives. Whilst no project is intentionally set up not to deliver its outcome, resource shortages and people being time-poor can often result in a set-and-forget mentality with project scopes. In this instance, as technical understanding of the possible solutions increased among all key stakeholders, allowing 30–60 minutes for everyone to openly challenge, question, and suggest ideas at key stages of the project resulted in a dynamic scope. The project's built-in flexibility was key to its ultimate success and to the delivery of the final features developed in mXrap.

References

Atkins, A & Webster-Smith, T 2011, 'OHS management systems for geotechnical risk', in Y Potvin (ed.), *Strategic versus Tactical 2011: Proceedings of the Fourth International Seminar on Strategic versus Tactical Approaches in Mining*, Australian Centre for Geomechanics, Perth, pp. 367–375, https://doi.org/10.36487/ACG_rep/1108_30_Atkins

Banjwa, P, Andrews, PG & Morkel, IG 2024, 'The effectiveness of preconditioning: utilising mXrap for analysing data and transforming raw scans into a functional database', in P Andrieux & D Cumming-Potvin (eds), *Deep Mining 2024: Proceedings of the 10th International Conference on Deep and High Stress Mining*, Australian Centre for Geomechanics, Perth, pp. 1253–264, https://doi.org/10.36487/ACG_repo/2465_82

Butcher, RJ & Fallon, M 2011, 'Block caving strategic risks', in Y Potvin (ed.), *Strategic versus Tactical 2011: Proceedings of the Fourth International Seminar on Strategic versus Tactical Approaches in Mining*, Australian Centre for Geomechanics, Perth, pp. 359–366, https://doi.org/10.36487/ACG_rep/1108_29_Butcher

Dunn, MJ, Basson, FR & Parrott, TT 2011, 'Geotechnical data – a strategic or tactical issue?', in Y Potvin (ed.), *Strategic versus Tactical 2011: Proceedings of the Fourth International Seminar on Strategic versus Tactical Approaches in Mining*, Australian Centre for Geomechanics, Perth, pp. 21–30, https://doi.org/10.36487/ACG_rep/1108_03_Dunn

Edgar, I, Prasetyo, R & Wilkinson, M 2020, 'Deep Ore Zone mine wet ore mining empirical learnings, mining process evolution and development pathway', in R Castro, F Báez & K Suzuki (eds), *MassMin 2020: Proceedings of the Eighth International Conference & Exhibition on Mass Mining*, University of Chile, Santiago, pp. 385–393, https://doi.org/10.36487/ACG_repo/2063_24

Fonataba, O, Beaulavon, A, Singgir, Y & Nugraha, S 2024, 'Hydrological risks and water management in the transition of underground block cave mining: a case study of Deep Ore Zone–Deep Mill Level Zone transition', in P Andrieux & D Cumming-Potvin (eds), *Deep Mining 2024: Proceedings of the 10th International Conference on Deep and High Stress Mining, Australian Centre for Geomechanics*, Perth, pp. 1453–1466, https://doi.org/10.36487/ACG_repo/2465_95

Harris, PC & Wesseloo, J 2015, *mXrap*, computer software, Australian Centre for Geomechanics, The University of Western Australia, Perth, https://mxrap.com

Landeros Córdova, P 2022, 'Geomechanical risk management and control at Andes Norte project: El Teniente mine', in Y Potvin (ed.), *Caving 2022: Proceedings of the Fifth International Conference on Block and Sublevel Caving*, Australian Centre for Geomechanics, Perth, pp. 31–48, https://doi.org/10.36487/ACG_repo/2205_0.003

Lett, J & Cuello, D 2024, 'Rill swell risk management in block caving', in Daniel Johansson & Håkan Schunnesson (eds), *MassMin 2024: Proceedings of the International Conference & Exhibition on Mass Mining*, Luleå University of Technology, Luleå, pp. 501–520, https://doi.org/10.36487/ACG_repo/2435_D-03

Lett, J, Castro, R, Pereira, M, Osorio, A & Alvarez, P 2022, 'BCRisk applications for rill swell hazard analysis in PC1: case study at Cadia East Operations', in Y Potvin (ed.), *Caving 2022: Proceedings of the Fifth International Conference on Block and Sublevel Caving*, Australian Centre for Geomechanics, Perth, pp. 561–572, https://doi.org/10.36487/ACG_repo/2205_38

Llewelyn, K, Campbell, R, Yuniar, A, Sullivan, M & Di Ciolli, M 2022, 'A risk-based approach to practical scope definition and management at PT Freeport Indonesia', in Y Potvin (ed.), *Caving 2022: Proceedings of the Fifth International Conference on Block and Sublevel Caving*, Australian Centre for Geomechanics, Perth, pp. 67–78, https://doi.org/10.36487/ACG_repo/2205_02

Lolon, S, Campbell, R, Edgar, I, Priatna, A & Haque, I 2024, 'Implementation of major mining strategy changes at the Deep Mill Level Zone (DMLZ) mine, PT Freeport Indonesia ', in Daniel Johansson & Håkan Schunnesson (eds), MassMin 2024: Proceedings of the International Conference & Exhibition on Mass Mining, Luleå University of Technology, Luleå, pp. 73-85, https://doi.org/10.36487/ACG_repo/2435_A-07

Moorcroft, TH, Simanjuntak, K, Dorjsuren, O, Sanaakhorol, M, Enkhtaivan, E, Watt, G, Eickhoff, V, Cerny, L, Deasy, C & Zimmermann, T 2022, 'Oyu Tolgoi and Rio Tinto partnership with Palantir Technologies to provide effective geotechnical risk management', in Y Potvin (ed.), *Caving 2022: Proceedings of the Fifth International Conference on Block and Sublevel Caving*, Australian Centre for Geomechanics, Perth, pp. 877–890, https://doi.org/10.36487/ACG_repo/2205_60

Morkel, IG, Wesseloo, J & Potvin, Y 2022, 'Seismic event location uncertainty in mining with reference to caving', in Y Potvin (ed.), *Caving 2022: Proceedings of the Fifth International Conference on Block and Sublevel Caving*, Australian Centre for Geomechanics, Perth, pp. 445–460, https://doi.org/10.36487/ACG_repo/2205_30

Nguz Tshisens, J, Moss, A, Sullivan, M, Yuniar, A, Casten, T & Zimmer, C 2022, 'Organising for the successful management of complex underground caving mines', in Y Potvin (ed.), *Caving 2022: Proceedings of the Fifth International Conference on Block and Sublevel Caving, Australian Centre for Geomechanics*, Perth, pp. 81–94, https://doi.org/10.36487/ACG_repo/2205_03

Pierce, ME, Campbell, R, Llewelyn, K, Fuenzalida, M, Simanjuntak, K, Kurniawan, A, Haflil, D, Meiriyanto, F & Rogers, S 2020, 'Cave propagation factor for caving rate and drawpoint productivity forecasting at PTFI', in R Castro, F Báez & K Suzuki (eds), *MassMin 2020: Proceedings of the Eighth International Conference & Exhibition on Mass Mining*, University of Chile, Santiago, pp. 519–534, https://doi.org/10.36487/ACG_repo/2063_35

Poulter, M, Ormerod, T, Balog, G & Cox, D 2022, 'Geotechnical monitoring of the Carrapateena cave', in Y Potvin (ed.), *Caving 2022: Proceedings of the Fifth International Conference on Block and Sublevel Caving*, Australian Centre for Geomechanics, Perth, pp. 487–500, https://doi.org/10.36487/ACG_repo/2205_33

Reid, J & Cumming-Potvin, D 2024, 'Cave back propagation estimation using monitoring data analysis in mXrap', in D Johansson & H Schunnesson (eds), *MassMin 2024: Proceedings of the International Conference & Exhibition on Mass Mining*, Luleå University of Technology, Luleå, pp. 406–419, https://doi.org/10.36487/ACG_repo/2435_C-09

Saigon Technology 2025, *6 Stages for Software Development Procedure You Need to Know*, viewed 1 March 2026, https://saigontechnology.com/blog/6-stages-for-software-development-procedure-you-need-to-know/

Snyman, L & Webster, S 2022, 'Northparkes E48 block cave: the mining history of a successful block cave', in Y Potvin (ed.), *Caving 2022: Proceedings of the Fifth International Conference on Block and Sublevel Caving*, Australian Centre for Geomechanics, Perth, pp. 95–108, https://doi.org/10.36487/ACG_repo/2205_04

Teet, R, Snyman, L & Jalink, B 2024, 'The evolution of caveback monitoring at Northparkes L1N block cave', in D Johansson & H Schunnesson (eds), *MassMin 2024: Proceedings of the International Conference & Exhibition on Mass Mining*, Luleå University of Technology, Luleå, pp. 426–439, https://doi.org/10.36487/ACG_repo/2435_C-11

van As, A & Noppe, M 2024, 'Sufficient geotechnical data for reliable mine design during mining studies', in D Johansson & H Schunnesson (eds), *MassMin 2024: Proceedings of the International Conference & Exhibition on Mass Mining*, Luleå University of Technology, Luleå, pp. 194–207, https://doi.org/10.36487/ACG_repo/2435_B-01

Vanegas-Palacio, C, Otto, S, Ginting, R, Kothari, U, Campbell, R & Tshisens, JN 2024, 'Managing excavation closure risk in caving operations', in D Johansson & H Schunnesson (eds), *MassMin 2024: Proceedings of the International Conference & Exhibition on Mass Mining*, Luleå University of Technology, Luleå, pp. 963–974, https://doi.org/10.36487/ACG_repo/2435_G-08

Woods, MJ, Poulter, ME & King, RG 2018, 'Progression and management of seismic hazard through the life of Telfer sublevel cave', in Y Potvin & J Jakubec (eds), *Caving 2018: Proceedings of the Fourth International Symposium on Block and Sublevel Caving*, Australian Centre for Geomechanics, Perth, pp. 623–636, https://doi.org/10.36487/ACG_rep/1815_48_King