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# Void model construction for enhanced mine planning and geomechanical stability at Fazenda Brasileiro mine

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## Abstract

*This paper presents a comprehensive methodology for developing void models in open cut mining operations, with application to sites transitioning from underground to surface extraction. The approach combines historical mine data, geotechnical investigations, and advanced scanning technology to accurately map subsurface voids. Key aspects include processing historical stope records, implementing targeted drilling programs, and evaluating backfill characteristics through reverse circulation drilling. The methodology emphasises continuous model refinement to address geomechanical changes and ensure operational safety during concurrent open cut and underground mining activities. Implementation resulted in 25% decrease in unplanned ore loss through proactive risk management and optimised resource allocation. Examples of geotechnical incidents include crown pillar collapses, uncontrolled subsidence, and rib pillar failures. Geostatistical void density models were used to prioritise drilling locations, eliminating redundant investigation in low-risk areas.*

**Keywords:** *void modelling, open cut, underground mining, void scanning, geotechnical engineering*

## 1 Introduction

The Brazilian mining sector has undergone significant transformation in recent decades, with technological innovation driving improvements in safety, efficiency and environmental performance. At Fazenda Brasileiro mine, this evolution is particularly evident in its 40-year operational history that has progressed through multiple mining methods. Originally developed as an open cut operation in the early 1980s, the mine transitioned to underground extraction using sublevel stoping methods after just 4 years of surface mining. The underground operation has expanded to depths exceeding 1,000 m below surface, establishing extensive networks of open stopes stabilised by engineered rib and sill pillars.

Recent economic conditions and technological advancements have prompted a strategic shift back towards open cut mining, particularly in the high-grade crown pillar zones between historical underground workings and the surface. This operational transition presents unique geotechnical challenges, as approximately 82% of planned production will originate from open cut areas that directly intersect or closely approach historical underground voids. The complex interaction between current surface mining activities and underground excavations requires robust void modelling methodologies that can accurately represent both documented and undocumented subsurface voids. Such methodologies align with best practices for geotechnical data management and empirical design frameworks (AMIRA International 2018; Pakalnis 2016).

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# 2 Mining context

## 2.1 Operational history

The Fazenda Brasileiro mine represents a classic example of mining method evolution in response to changing economic and technical conditions. Initial operations (1980–1984) employed conventional open pit mining techniques to exploit near-surface oxide gold mineralisation. As mining progressed to deeper sulphide ores, the operation transitioned to underground methods, primarily using sublevel stoping with top down sequencing. This underground mining approach maintained open stopes stabilised by 5 m rib pillars and 3 m sill pillars, contrasting with bottom up methods that require backfill placement to permit mining of upper levels.

Over its 36-year underground phase, the mine developed more than 40 production levels between 100 and 1,050 m below surface, extracting approximately 21 million tonnes of ore at an average grade of 5.1 g/t of gold. This extensive underground operation created significant void spaces, many of which were not completely documented in mine surveys due to the technological limitations of early mining periods. The transition back to open cut mining in these areas requires careful reconciliation of historical production data with modern geotechnical investigations.

## 2.2 Current operations

The current mine plan represents an integrated approach combining residual underground production with new open cut developments in crown pillar zones. Figure 1 illustrates this interaction, showing historical underground workings in red and planned open cut boundaries in blue. The strategic plan anticipates that 82% of future production will come from open cut operations, many of which directly overlie or intersect previous underground excavations. This operational configuration demands precise void mapping to ensure both safety and economic optimisation, as undocumented voids can lead to unexpected ground collapses or ore loss.

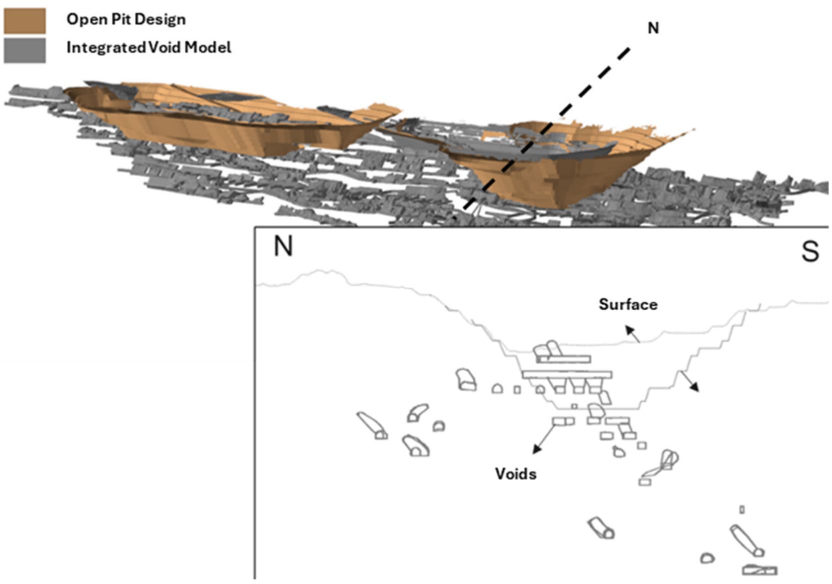


**Figure 1 Integrated mine–void interaction model**

Focus areas included the open pits of CLX (West, Central, East), where 82% of planned production intersects historical voids. Investigations prioritised CLX West, using void density models to guide drilling from existing ramps (e.g. East orebody).

# 3 Methodology

The void modelling framework developed for Fazenda Brasileiro mine comprises 4 interconnected components designed to address the specific challenges of the site: historical data compilation and validation, targeted investigation programs, advanced void characterisation, and continuous model updating. This systematic approach ensures all available data sources are utilised while maintaining flexibility for incorporating new information as mining progresses.

## 3.1 Historical solids processing

Initial void models were developed through a comprehensive review and digitisation of historical mine records, including more than 1,200 individual stope designs and production reports. Particular attention was paid to areas intersecting planned open cut operations, where accurate void representation is most critical for safety and planning. Older mining levels typically exhibit more complete records of development and stope geometries, as these areas benefited from more rigorous survey protocols implemented during later phases of underground operation.

The confidence rating system applied to historical data categorises voids into 3 classes based on data quality and corroboration (Table 1):

**Table 1 Void data confidence classification system based on source verification**

| Rating | Criteria | Typical sources | Percentage of voids |
|---|---|---|---|
| A | Laser-scanned + corroborated | Modern surveys | 15% |
| B | Surveyed + geological mapping | Production maps | 35% |
| C | Estimated from records | Historical logs | 50% |

## 3.2 Investigation program design

Areas without existing void documentation or identified as high-risk zones undergo targeted investigation programs combining several complementary techniques. Drill spacing is determined through geostatistical analysis of known void distributions, typically ranging from 6 m spacing in high-risk areas to 12 m spacing in zones with lower expected void density. All investigation holes are oriented to maximise intersection probability with potential voids based on the dominant structural orientation of the orebody.

## 3.3 Void characterisation techniques

### *3.3.1 Attribute classification*

Each void solid receives standardised attributes. Key attributes include:

- Geometric: volume, centroid coordinates, estimated or scanned.
- Geotechnical: rock mass rating classification, lithology.
- Operational: type of excavation, backfill percentage.

The geotechnical classification for rock masses is based on the Geotechnical Model, using the RMR classification system proposed by Bieniawski (1989), widely applied in rock mechanics and stability assessments (Brady & Brown 2006). The RMR classification considers five parameters to classify the rock mass: uniaxial compressive strength, RQD, spacing between discontinuities, characteristics of discontinuities, and the presence of water.

### *3.3.2 Void scanning*

The GSM-19 (GEM Systems 2023) laser scanner was deployed for void characterisation, generating high-resolution 3D point clouds with ±2 cm positional accuracy. Key specifications and setup are as follows:

- Functionality: performs 360° scanning at 10,000 points/second up to 150 m range.

- Limitations: accuracy reduced in water-filled voids (>30% turbidity) and unstable boreholes.
- Gyroscopic orientation module (±1° azimuthal accuracy).

Borehole casing (polyvinyl chloride or metallic) to ensure stability and alignment, as per Figure 2. The scanner assembly is deployed within either a polyvinyl chloride or metallic casing installed in the investigation borehole. This casing provides a stable, cylindrical pathway, centralises the scanner string, and protects the equipment during deployment, particularly in potentially unstable ground conditions.


**Figure 2 Borehole scanning initiation workflow. Step-by-step preparation for void scanning. Step 1: drilling and casing installation. Step 2: scanner calibration. Step 3: deployment into borehole. Step 4: real-time monitoring interface**

Complementing borehole scanning, autonomous drones equipped with LiDAR (Grenon & Hadjigeorgiou 2012; Hadjigeorgiou et al. 2015) were deployed to map accessible voids from surface or underground openings (Figure 3). This technique scanned 154,398 m³ of voids across 10 campaigns, identifying unmined areas and adding remnant ounces to reserve estimates. Data from drones and borehole scanners were consolidated into computer-aided design models, updating historical excavation geometries and prioritising critical zones (e.g. CLX pits).

**Figure 3 Drone-based void scanning in accessible stopes. Autonomous drone with LiDAR mapping unmined areas (154,398 m³ scanned across 10 campaigns)**

#### *3.3.2.1 Point cloud processing*

Void volume estimation applies Monte Carlo simulation (Rubinstein & Kroese 2008) to account for uncertainty:

- Confidence ratings define uncertainty buffers (±0.5 m for rating 5, ±5 m for rating 1).
- 1,000 iterations generate probabilistic volume distributions.
- Final volumes reported as P90 values (90% confidence level).

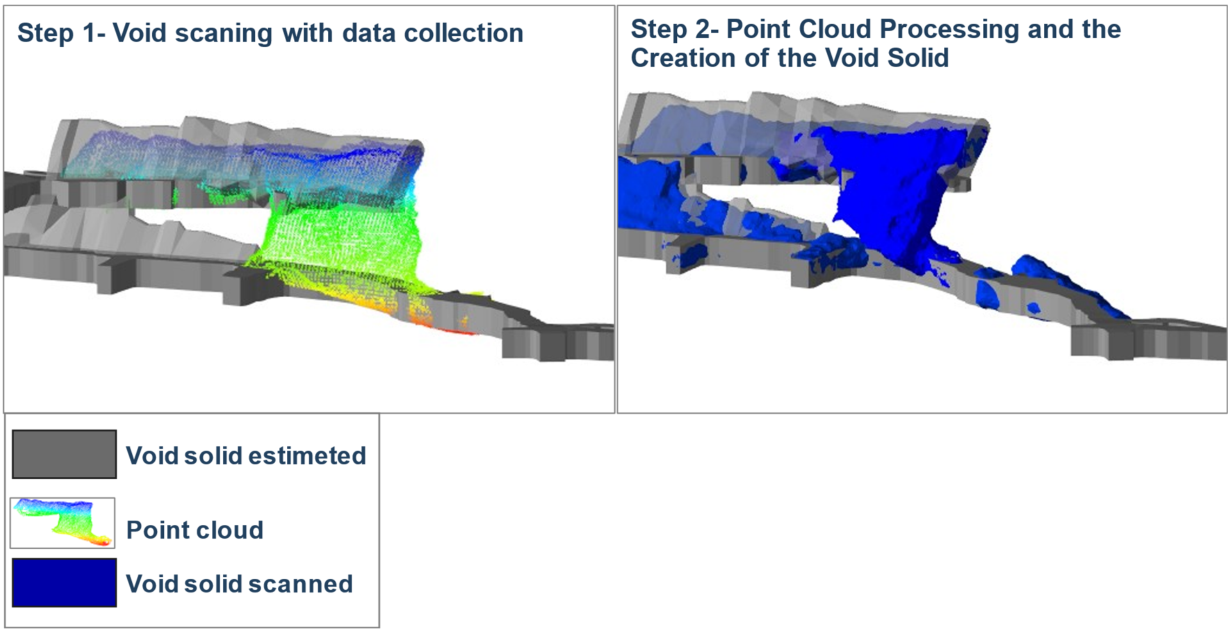


**Figure 4 Point cloud processing after void investigation. Collecting the point cloud and creating the void solid**

# 4 Results and discussion

Implementation of the integrated void model in 2025, as shown in Figure 5, has achieved:

- 100% coverage of planned production voids by Q2, investigating 149 voids via reverse circulation drilling (7,629 m), borehole scanning, and drones.
- The 41% reduction in planned drilling metres resulted directly from void density models identifying low-risk zones (void density < 0.5 voids/100 $m^3$) where investigation was eliminated, evidenced by kriging variance reductions from 0.8 to 0.2 in CLX Central.
- Proactive risk mitigation in CLX pits, where 19 voids (161,324 $m^3$) were reassigned to drone campaigns, avoiding costly reverse circulation drilling.

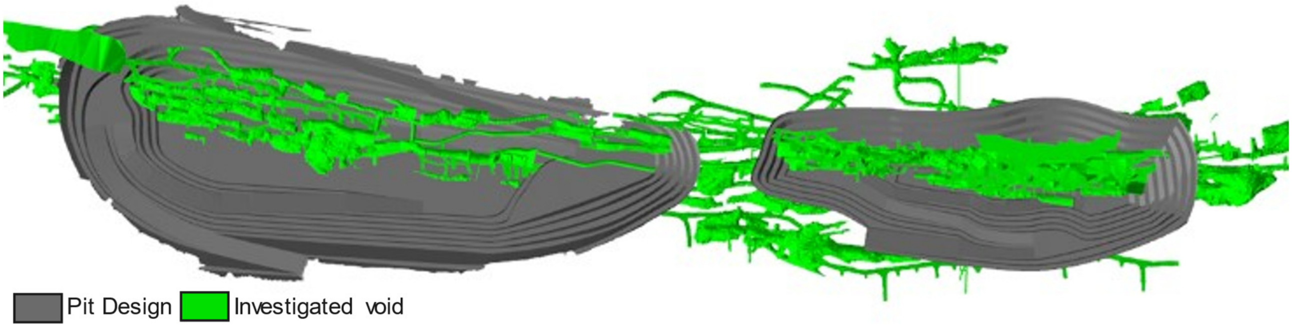


**Figure 5 Void model integration in mine design. Green surfaces represent validated voids within the CLX West pit design**

The implementation of void model, derived from the compiled void data, was used to prioritise drilling locations. The model identified areas of high uncertainty and high predicted void density, focusing investigation efforts there. Conversely, the model provided sufficient confidence to eliminate or significantly reduce redundant investigation drilling in low-risk, low-void-density areas identified by the model. This targeted approach, driven by the model's predictive capability, optimised the drilling program.

The continuous model refinement process proved particularly valuable as mining advanced into complex ground conditions, this iterative approach supports stability analysis principles described by Brady & Brown (2006). Weekly model updates incorporating new scan data and geotechnical observations reduced planning errors by 32% in transitional zones where underground and surface operations interact, directly enhancing safety and efficiency in these critical areas.

The investigation of 100% of planned voids by Q2 2025 – a milestone for FBDM – enhanced planning reliability and reduced incidents in high-risk zones like crown pillars and CLX pits. The integration of drone data further demonstrated the model's adaptability to evolving technologies.

# 5 Conclusion

The developed methodology provides a robust framework for void modelling in complex mining environments where modern surface operations interact with historical underground workings. Key success factors include the systematic integration of multiple data sources, standardised quality control measures, and operational flexibility to adapt to changing ground conditions. The Fazenda Brasileiro case study demonstrates that comprehensive void modelling can significantly enhance both safety and economic outcomes in transitional mining operations through proactive risk management and optimised resource extraction. The direct links between the model's outputs (confidence ratings, risk maps, accurate void geometries) and the realised improvements (reduced incidents, less ore loss, efficient drilling) underscore the value of this approach.

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