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UNDERSTANDING CRITICAL STABILITY FACTORS: INTEGRATING OLD AND NEW DATA TO IMPROVE FOUNDATION STABILITY ASSESSMENTS

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EXTENDED ABSTRACT

1 INTRODUCTION

1.1 USING TELEVIEWERS AND 3D MODELLING FOR FOUNDATION ASSESSMENTS

Televiewer and 3D geospatial modelling tools bring significant benefits to large-scale engineering and geological projects, particularly during the safety review and maintenance phases of complex infrastructure like dams and water-retaining structures. These tools augment traditional surface mapping and limited borehole data, delivering a clearer, more complete picture of the foundation rock mass. The result is more reliable design, safety, and risk management decisions.

1.2 FILLING GAPS IN BOREHOLE DATA

For historic boreholes where core samples might be missing or data is sparse, televiewers can help provide new, detailed insights. Acoustic and optical televiewers allow us to capture the orientation, size, and behaviour of foundation defects, turning what would be costly, invasive investigations into more efficient, low-risk processes. This is especially useful in well-maintained boreholes, like those used for dam drains, where televiewer data lets us understand the continuity, shape, and orientation of faults and smaller defects.

1.3 UNDERSTANDING FOUNDATION DEFECTS AND STABILITY

Understanding these factors is critical for assessing foundation behaviour, spotting potential failure modes, and evaluating foundation strength and stability. This data-driven approach not only improves structural assessments but also guides risk management and economic decisions for infrastructure upgrades. Reliable investigations using these tools can help ensure that safety and upgrade assessments are based on thorough and realistic analysis.

2 USING TELEVIEWERS IN A DAM SAFETY REVIEW

2.1 REGIONAL FAULTING

A routine safety review of a large concrete dam provided an opportunity to use televiewer surveys to improve understanding of foundation conditions.

The investigation focused on the Jurassic dolerite foundation, where faulting and discontinuities play a key role in dam stability. Three regional neotectonic features are significant to the area's broader structural setting and existing seismic risk. The closest of these is located more than 50 km from the dam, and appears to show repeated movement since at least the Cambrian, with three surface-rupturing events recorded in the late Quaternary, each displacing the ground by 2.4 to 3.1 m. No regional faults have been identified nearby aside from these neotectonic features, in part because the extensional fault system related to the Derwent Graben is not readily investigated or understood.

At the site scale, faulting trends northwest with variable orthogonal relationships, though no detailed local studies of these faults have been completed. This faulting is part of a broader regional structural trough forming the River Derwent – the Upper Derwent Graben – possibly related to the Lake Echo Scarp fault system. Studies of the Derwent Valley suggest that extensional faulting has influenced the geomorphology of the area since the Jurassic into the Cenozoic. While these regional features provide important geological context, the focus of this investigation was on the foundation faults and discontinuities most relevant to dam stability.

2.2 FOUNDATION DEFECTS FOUND DURING CONSTRUCTION

During construction, foundation defects were a major focus, with detailed surface mapping providing high-quality records of the exposed rock mass. The mapping suggests that some defects persist through the foundation at excavation scale. The most significant geological fault features identified during excavation and mapping include a metre-scale sheared zone with crushed seams, along with two smaller but similar features to the north. These faults, located beneath the left side of the dam, share moderate dips to the north. These features were extensively excavated and concrete-backfilled prior to construction of the dam. Construction borehole logs offer some additional data, but they were not detailed enough to assess how foundation faults could influence dam stability.

2.3 USING FOUNDATION DRAINS FOR TELEVIEWER SURVEYS

The foundation drains within the dam gallery provided an opportunity to address these gaps using televiewer surveys. These drains offered a low-cost, non-destructive way to expand the dataset and improve understanding of fault continuity and persistence. To build on existing data and address uncertainties in the dolerite foundation, we conducted televiewer surveys on foundation drainage holes. These surveys covered 347 metres of foundation drains and mapped out the position and orientation of key discontinuities, like crushed seams and sheared zones. In total, we identified 868 individual discontinuities, with 121 standing out as significant, including crushed seams and sheared zones as well as weakened areas with measurable widths. We then analysed this data in stages, using orientation comparisons and detailed spatial analysis and interpretation.

3 DATA ANALYSIS AND MODEL BUILDING

3.1 COMPARING TELEVIEWER DATA WITH FOUNDATION MAPPING

To validate the televiewer data, we compared the orientations of key defects with those from prior detailed foundation mapping. This helped us identify any systematic differences between the two methods. The most detailed geological dataset for the dam site comes from foundation mapping, which provided extensive records of rock discontinuities. These features were a major focus during past investigations, with mapping, documentation, and lab testing carried out to understand their role in the stability of the concrete dam. The primary types of discontinuities at the site include joints, altered and weathered seams, sheared zones, and crushed seams. Less common or absent features include partings, sheared surfaces, and infilled seams, likely due to the nature of the dolerite and the concentrated data collection efforts around the dam footprint and nearby areas.

The dataset shows a strong prevalence of defects striking northwest, with dips ranging from 45° towards the northeast through vertical to 45° towards the southwest. Some of these defects contain decomposed zones, which required additional excavation and foundation treatment. While many defects were mapped during construction, most persist at excavation scale, are non-planar, and include joints as well as altered and moderately to highly weathered seams. This understanding comes from lab testing, site inspections, and classification systems used during design and construction. The mapping classification system assigned measured feature widths to each defect segment and categorized them as weathered, carbonate-zeolite, soft-rock defect filling, or chlorite.

Both the existing mapping datasets and the new televiewer dataset showed two main groups of non-vertical defects, with some small differences in one of the sets. We noted two other differences: high-dip angle defects appeared less often in the televiewer data and were harder to constrain, while some low-dip angle defects, visible in the televiewer surveys, were missing from the foundation mapping. These findings show why it is important to map both horizontal and inclined surfaces to accurately capture high-dip angle features, and vertical boring and mapping vertical surfaces being essential for identifying low-dip angle features.

3.2 USING 3D TOOLS FOR BETTER FOUNDATION ASSESSMENT

To go beyond basic comparisons and historic datasets, we used 3D geospatial modelling to better analyse and interpret defects (Figure 1). This allowed us to look at the continuity and persistence of these features through the foundation and to group and model related features. Using data from foundation mapping, borehole logs, and televiewer imaging, we examined details such as infills, thickness, defects around crushed seams, and the intensity of sheared zones. We also considered positions, associations, orientations, and potential shifts in defect direction. By identifying patterns across these elements, we could determine if defects extended between boreholes, which is important for understanding foundation behaviour and stability risks.

4 FINDINGS

4.1 PATTERNS IN FAULTS AND DEFECTS

Discontinuities and faults showed up throughout the foundation in clear orientation patterns, with only about 1% of these features reliably matching across borehole surveys, core logs, and surface mapping. This is likely due to the limits of the sample data and the complexity of the foundation itself. Despite the small percentage, the analysis helped us understand the persistence and larger-scale shape of many surveyed defects. The most consistent features were the thickest defects, which, after comparing various datasets, seemed likely to extend from the surface through to the foundation drains. The largest fault was linked to three persistent features showing an intermediate dip toward the northeast. Only small numbers of other faults could be confidently connected across the datasets, and in most cases, their characteristics changed between data points. This suggests that shear strength varies depending on scale, making it difficult to estimate strength in a way that is both realistic and relevant to the load scenario.

4.2 ASSESSING FOUNDATION STRENGTH AND STABILITY

The fault models and visualisations of discontinuities we have developed are critical to understanding foundation behaviour, potential failure modes, and stability. The quantity of data reveals the real complexity of discontinuities within the rock mass, which is now better understood. This detailed picture of how these features persist, change shape, and vary over distance means we can now discount simple failure mechanisms that were once considered possible.

While the foundation mapping showed some changes in how these features appear, our findings that significant defects don’t continue between boreholes give us more confidence in the foundation’s high strength. Foundation mapping alone leaves unanswered questions, but these insights show a clearer picture and build confidence in the foundation.

5 IMPLICATIONS

5.1 USING DEFECT INTERPRETATIONS FOR SAFETY AND RISK DECISIONS

Getting a clear picture of the continuity, shape, and orientation of faults and smaller discontinuities is essential for understanding how the foundation will behave. This information helps us identify potential failure modes and assess the overall strength and stability of the foundation. Beyond structural assessment, this knowledge can also guide risk management and economic decisions for infrastructure upgrades. Reliable investigations that measure and interpret these factors accurately are a must. A data-driven approach ensures risk assessments are thorough with safety and upgrade decisions backed by solid analysis.

5.2 TELEVIEWER SURVEYS AS PRACTICAL AND COST-EFFECTIVE INVESTIGATION TOOLS

This case study highlights the value of televiewer surveys on existing drain holes as a low-cost, effective, and non-destructive method for subsurface data collection. The rock defect data obtained was particularly valuable for identifying flat-lying defects and improving understanding of fault continuity and potential failure modes within the foundation. Combined with other geological datasets, including surface mapping and borehole logs, this information provided a more complete basis for analysis. Developing a 3D geospatial model was key to integrating these datasets, allowing for a detailed exploration of their relationships and the identification of critical stability features.

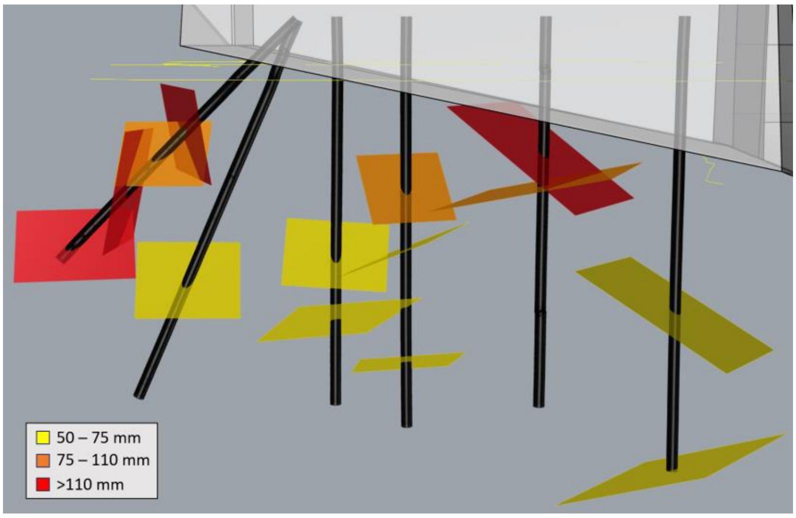

Figure 1: Extract from 3D geospatial model showing high confidence fault extents, and the lack of continuity between adjacent sample locations.

This paper is written to be accessible to a diverse audience.