Project Overview

Tailings Storage Facilities (TSFs) rank among the largest and most critical engineered structures in mining. These embankments impound fine-grained, saturated tailings and must maintain integrity over decades, including under extreme seismic loading. In high-seismicity regions, the risks of earthquake-induced deformation, liquefaction, or progressive failure are primary concerns.

This TSF was undergoing a capacity lift, increasing both stored volume and failure consequences. Public roads and downstream communities lay directly in the potential inundation zone, placing the facility in the highest dam-safety criticality category. Continuous, reliable deformation monitoring capable of detecting millimetre-scale movements was therefore essential for regulatory compliance, operational risk management, and social licence to operate.

Key Requirement

A thorough technology review evaluated options against project needs: full-crest coverage, high temporal frequency, sub-millimetre precision, low latency, environmental resilience, and acceptable total cost of ownership.

No single legacy system fully met all criteria. Ground-based radar provided excellent spatial coverage but at prohibitive cost for the embankment length. InSAR (already in use for regional context) lacked the temporal resolution needed for rapid post-event assessment. Prism monitoring offered targeted high accuracy but suffered from line-of-sight and environmental intermittency. Conventional high-end GNSS delivered the required precision but was economically unviable at the sensor density needed. Low-cost GNSS alternatives introduced unacceptable detection latency due to sparse sampling and aggressive averaging.

The project required a solution that combined the economic scalability and high point density of modern GNSS with true sub-millimetre precision and minimal latency, without the power consumption or cost penalties of traditional high-precision systems.

Solution: RTK Flex GNSS

RTK Flex is a purpose-engineered GNSS monitoring solution from Pangea Technology, developed specifically for demanding mining and civil infrastructure applications. It integrates high-channel-count, multi-constellation GNSS hardware with proprietary AMASIA™ processing software to achieve exceptional accuracy and robustness in harsh environments.

A network of RTK Flex rover units was installed at representative locations along the TSF embankment crest. A single RTK base station was established on stable ground well clear of the deforming structure, delivering high-quality differential corrections. This classic RTK architecture (stable base plus rovers on monitored points) eliminates common-mode errors and produces true 3D displacement vectors (ΔE, ΔN, ΔZ) in a consistent local coordinate system.

Installation and commissioning were completed entirely by the mine's existing slope-stability contractor team, no specialist survey or GNSS expertise required. Units operated continuously 24/7 with redundant power and communications.

Image 1 – RTK Flex Installation

Core Technical Innovation

The receivers run at high epoch rates, generating a rich observation stream that supports multiple, complementary data products from the same sensors without compromise. On this occasion an independent 3-hour average and rolling 24-hour average were configured.

The independent 3-hour averages use non-overlapping blocks processed independently. This provides a maximum latency of approximately three hours with repeatability of ~0.5 mm from the long-term mean, making it ideal for rapid-alert Trigger Action Response Plans (TARPs). The rolling 24-hour averages use a continuously updated overlapping window. The heavier temporal integration yields ultra-low noise (better than 0.1 mm from mean), perfect for precise quantification and long-term trend analysis.

This dual-output capability, powered by AMASIA™ software, elegantly resolves the classic precision-versus-latency trade-off that constrains lower-density or lower-power GNSS systems.

Results

Baseline monitoring quickly established the system's noise floor. The 3-hour independent averages remained within ~0.5 mm of the long-term mean, already sub-millimetric and suitable for reliable change detection. The 24-hour rolling averages were stable to better than 0.1 mm, confirming exceptional precision for quantification.
Several weeks after commissioning, a M6.4 earthquake struck with its epicentre only ~1 km from the TSF. The event caused significant damage over 100 km away. Post-event RTK Flex data delivered clear, consistent results.

The 3-hour averages showed three consecutive periods immediately after the event plotting above the pre-event mean. The series then stabilised at a new mean ~1.25 mm different from baseline. This enabled an initial integrity assessment and confirmation of no progressive movement within three hours.

The 24-hour rolling averages provided initial smoothing due to the longer window, then transitioned cleanly ~24 hours post-event to a new stable mean ~1.5 mm different from pre-event values, delivering high-confidence quantification of total co-seismic displacement.

The close agreement between the two independent streams (1.25 mm vs 1.5 mm) in both direction and magnitude validated the result. The small difference aligns with the differing integration windows and any very short-term transients averaged out in the 24-hour product. Full 3D vectors allowed the geotechnical team to assess whether movement was primarily vertical, lateral, or combined, which proved critical for back-analysis and stability modelling.

Discussion

This deployment highlighted several fundamental advantages of the RTK Flex approach. It achieved cost-effective spatial density because the lower per-point cost compared with traditional high-end GNSS or radar arrays enabled representative coverage across the entire crest. It eliminated the precision–latency trade-off through dense, continuous high-rate sampling plus AMASIA™ processing, allowing simultaneous fast-alert (3 h) and ultra-precise (24 h) products from the same hardware.

The system demonstrated proven seismic resilience and sensitivity. It survived a nearby M6.4 event and resolved ~1.3–1.5 mm of permanent displacement at 1 km distance, confirming its suitability for early-warning and post-event assessment on high-consequence structures. Finally, it integrated seamlessly with existing tools, complementing InSAR for broad context and prisms for targeted verification while filling the gap for high-frequency, high-precision, 3D-point monitoring at scale.

Conclusion

Deployment of RTK Flex GNSS proved to be the right engineering decision, powerfully validated by a real-world M6.4 seismic event shortly after commissioning. The system met or exceeded every requirement: sub-millimetre precision, high temporal density, scalable coverage, 24/7 reliability in a mining environment, and most importantly, tiered, actionable information within hours rather than days.

Response times for post-seismic assessment dropped from multiple days to a few hours. Geotechnical teams gained high-confidence 3D displacement data with known uncertainty bounds, enabling timely, defensible decisions. The dense dataset and AMASIA™ software maximised value from every sensor by generating multiple complementary products.

For operators of high-risk TSFs, especially in seismically active regions with downstream populations, RTK Flex offers a mature, field-proven solution that closes the gap between monitoring aspirations and practical, cost-effective implementation. When integrated with InSAR, prisms, and other instruments, it strengthens dam safety management and regulatory compliance while materially improving both safety and operational efficiency.

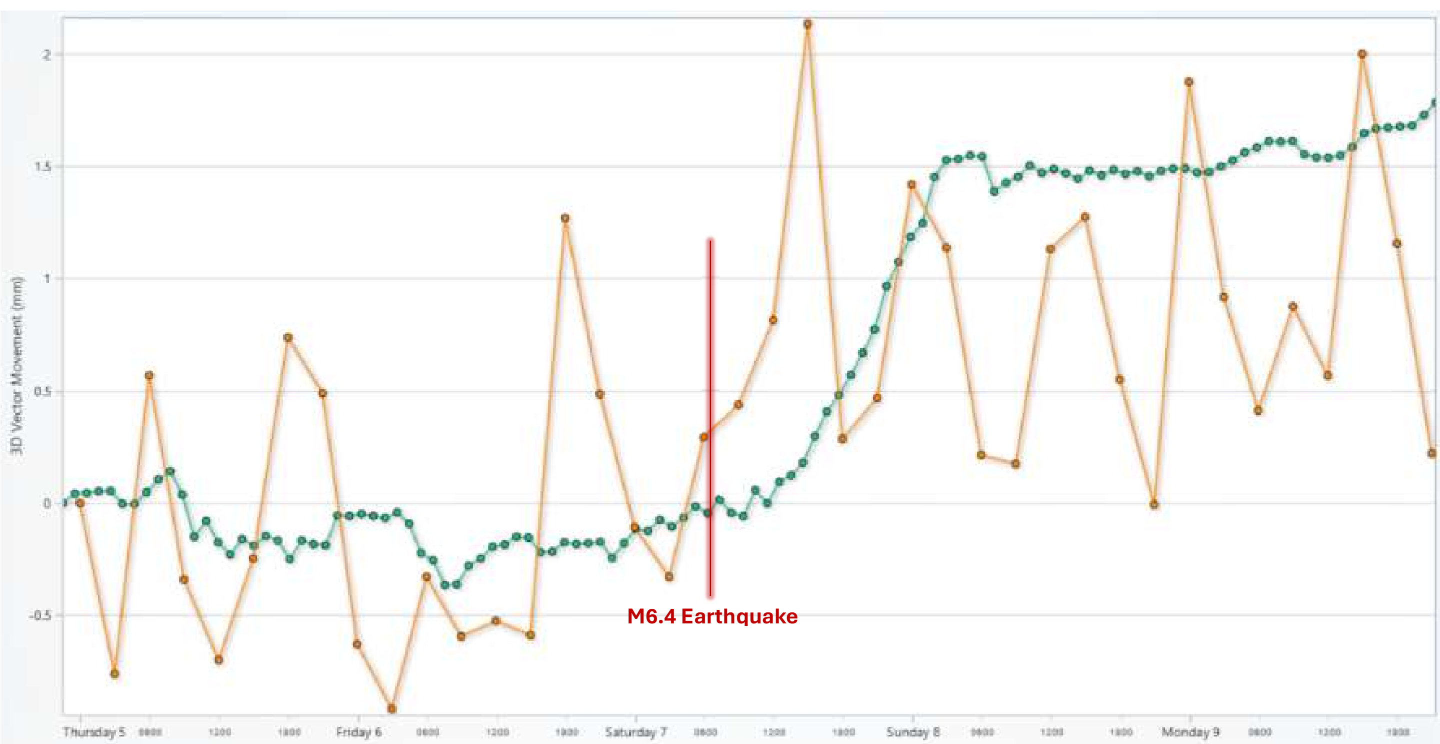

Image 2 – Real World Data - 24h Rolling Average (Green), 3h Independent Position (Orange)