Use of the variable energy DCP Panda for landslide risk assessment and slope analysis

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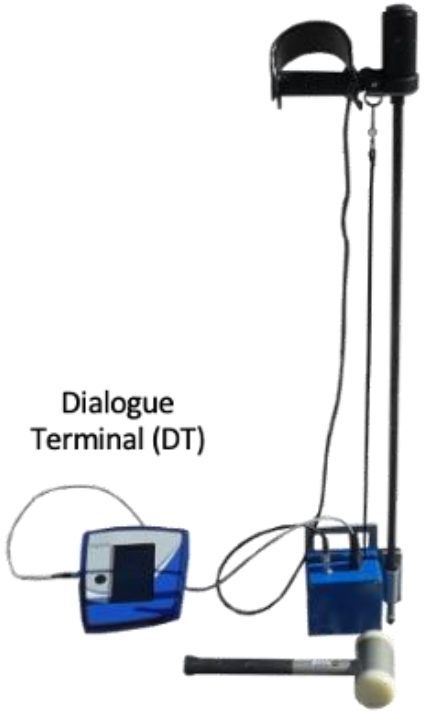
- Landslides triggered by:
  - Heavy rainfall
  - Earthquakes
  - Weak or saturated soils
- High risk to: Roads, railways, pipelines, utilities & property
- Key need: Rapid understanding of near-surface ground conditions

LIMITATIONS OF CONVENTIONAL METHODS

- Boreholes, SPT, laboratory testing:
  - Some insight but slow
  - High mobilisation time
  - Not suitable for immediate post-failure conditions
- Difficult to get access in unstable terrain
- Provide discrete (not continuous) data

- Lightweight portable dynamic cone penetrometer (~20 kg)
- Measures continuous penetration resistance (qd)
- Variable hammer energy system:
  - Soft soils → low energy
  - Dense soils → higher energy
- Can test:
  - Vertical or at right angles to the slope
- Real-time digital data acquisition + GPS logging



Cone resistance Qd is calculated using the Dutch Formula as follows:

$$q_d = \frac{1}{A} \times \frac{E}{e} \times \frac{1}{1 + \frac{P}{M}}$$

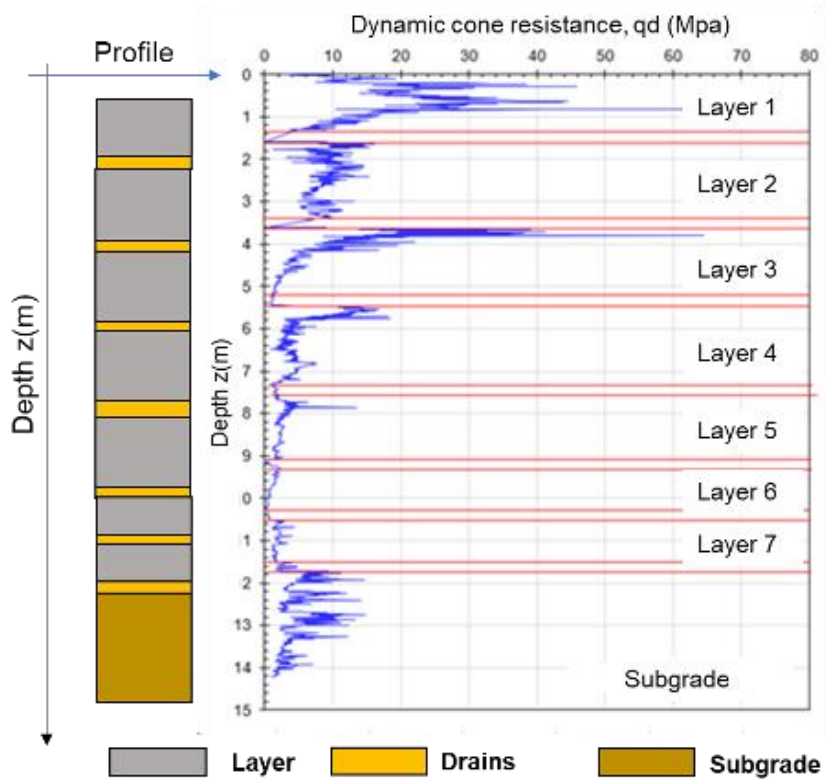
A = the cone area (2, 4 or 10cm²)

E = the variable energy given to the system each blow

e = the depth measured each blow

P = the weight of the driven system into the soil (anvil + rods + cone)

M = the weight of the hammer (manual, automatic, hammering column)



General measurement principle of the Panda, components, and penetrogram curve log of qd as a function of depth (z) obtained during a characterization test

- Measures tip resistance (not shaft friction)
- Over-sized cone reduces rod friction effects
- Friction can be measured and corrected for
- Provides high-resolution penetrograms (qd vs depth)
- Enables identification of:
  - Weak layers
  - Slip surfaces
  - Material transitions

- Correlations with key soil parameters:
  - Undrained shear strength (su)
  - Friction angle (φ’)
  - Relative density (Dr)
  - Void ratio (e)
- Relationship with CPT:
  - qd ↔ qc strong correlation
- Enables transformation of field data into design inputs

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LANDSLIDE RISK LIFECYCLE APPLICATIONS

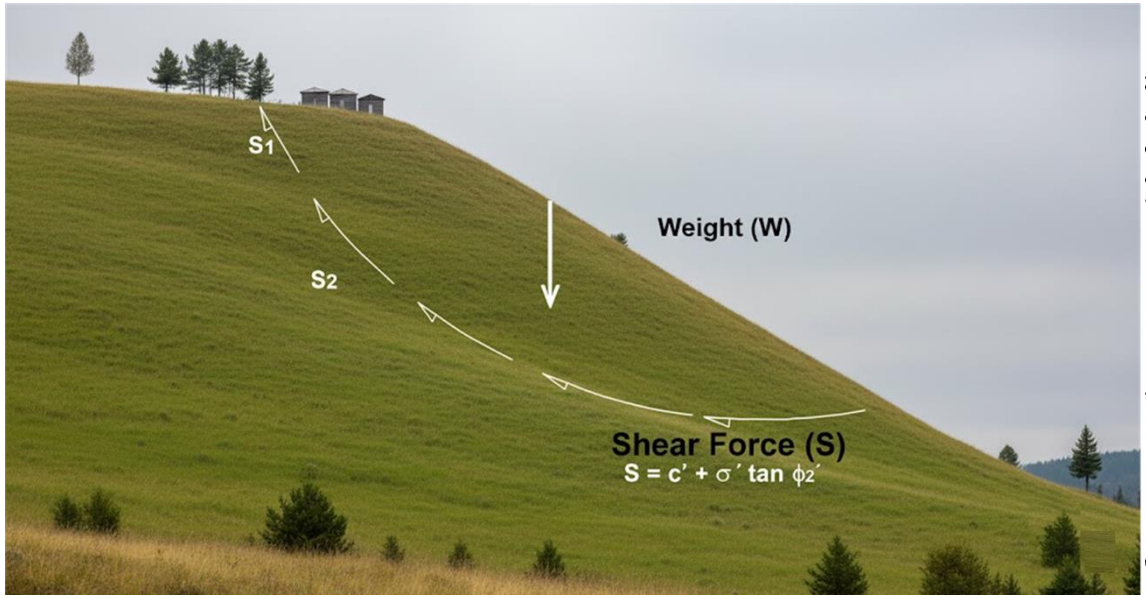
KEY ADVANTAGES

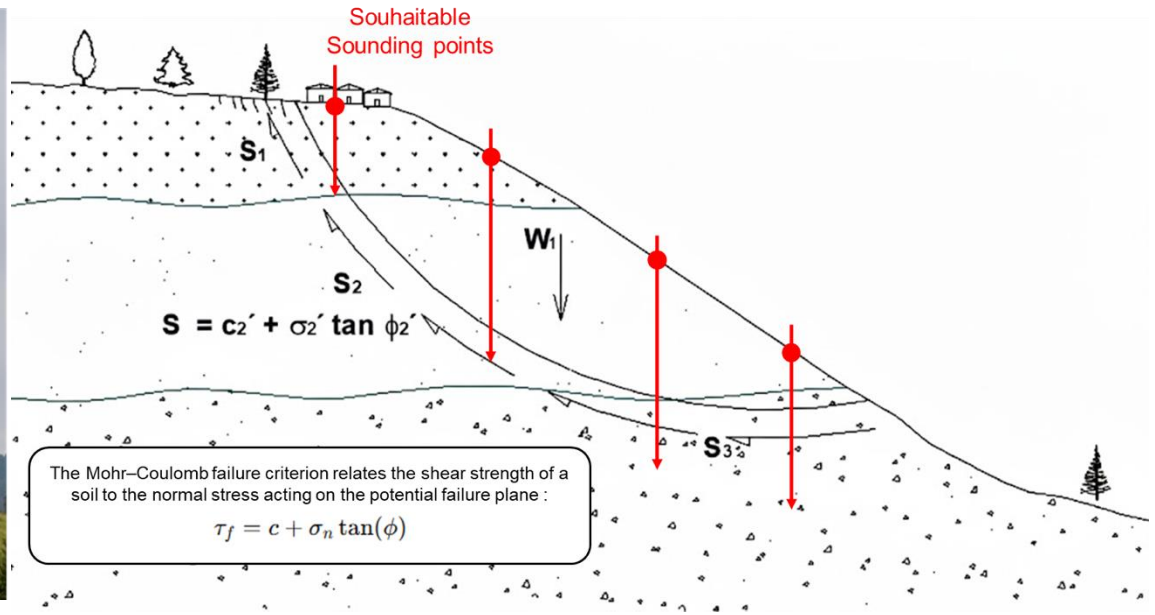
PRACTI

Phase	Objective	PANDA Contribution
Screening & Mapping	• Identify potentially unstable zones in broad reconnaissance	• Rapid profiling of near-surface stiffness variability
Emergency Response	• Determine safe access, assess residual strength	• Triage - quick tests guiding road closures or machinery movement
Design Investigation	• Characterise soil parameters for modelling	• Quantitative E and c inputs for limit-equilibrium or FEM
Construction Support	• Verify compaction or drainage efficiency	• Compare pre- and post-works Qd profiles
Long-Term Monitoring	• Assess progressive changes or softening	• Repeat testing for trend analysis

- Lightweight (≈20 kg total) - transportable by foot or rope descent.
- Safe deployment
- Continuous profiling (high resolution)
- Material Variability
- Testing at angles
- Real-time-data – supports rapid decision making
- Correlation capability

PRACTICAL CORRELATIONS AND SLOPE STABILITY

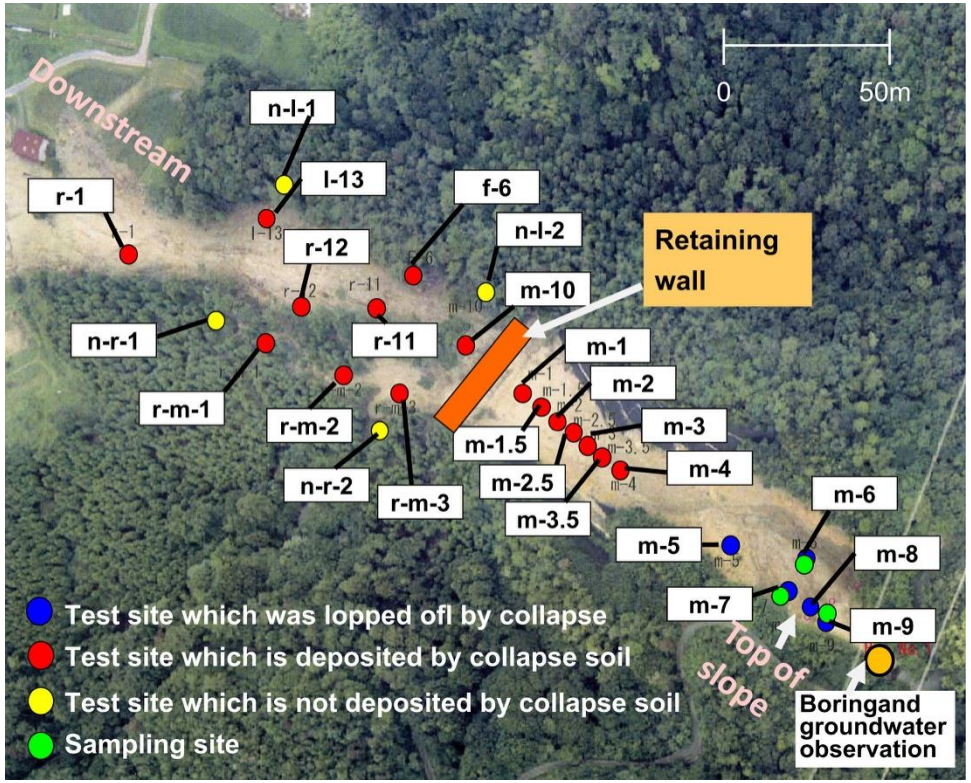


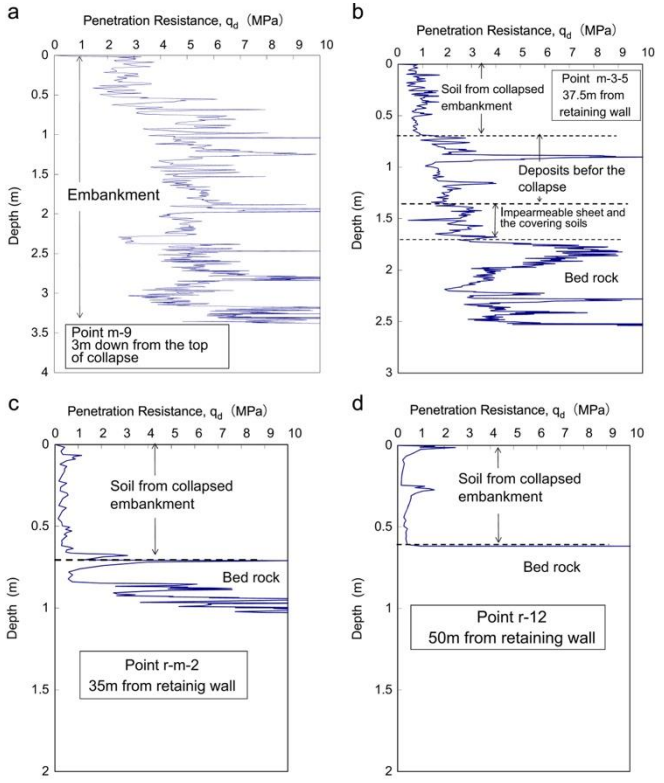


Schema for main principle of slope stability - The resistance to sliding and the overall stability of a slope are primarily governed by the Mohr–Coulomb failure criterion, which depends on soil cohesion, the vertical stress (and therefore the soil density), and the friction angle. These parameters can be expressed in terms of either effective or total stresses (elaborated with AI Gemini).

Stability Assessment of Natural Slopes at Risk of Failure - Japan

- Rainfall-induced failures common in weathered granite slopes
- Panda VEDP used for landslide hazard assessment
- Based on qd measurements + correlations (friction angle, cohesion, void ratio)
- Identifies response patterns for slope behaviour
- Widely applied and validated over 10+ years

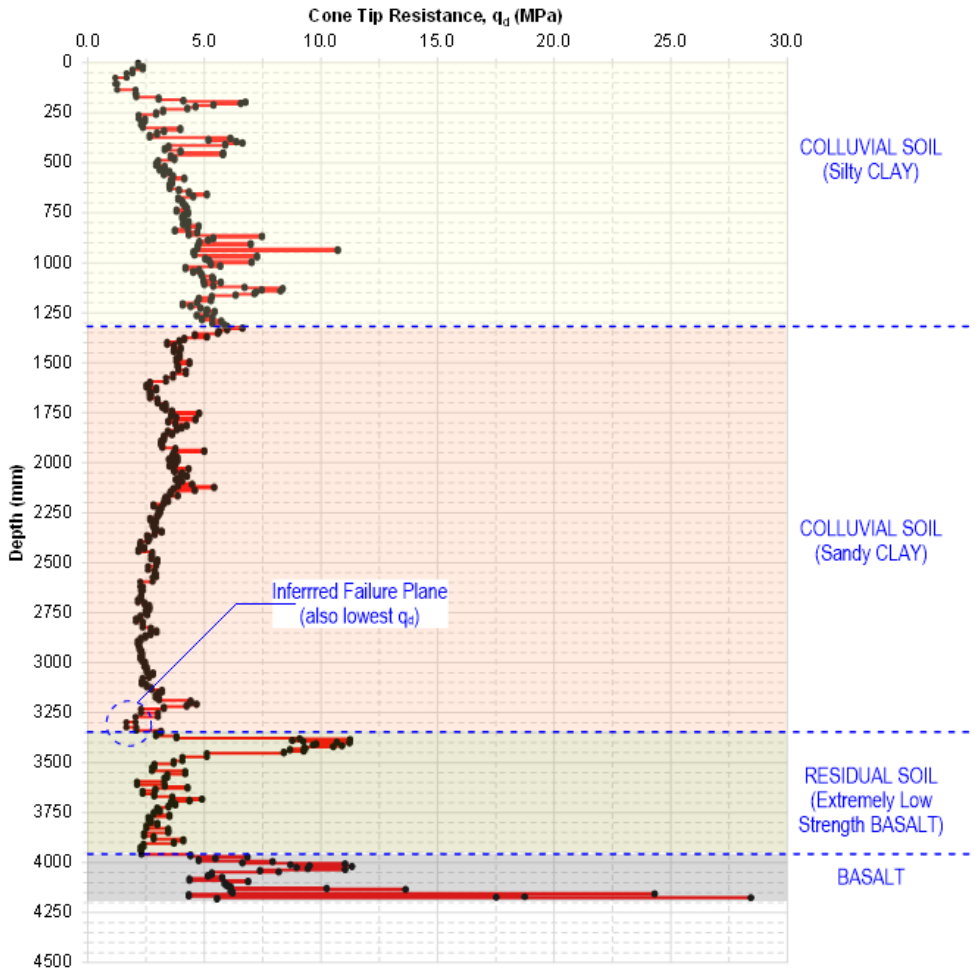




Stability Assessment of Natural Slopes at Risk of Failure assessment by means of geotechnical test and its analysis (Athapaththu et al., 2007, 2015, 2016; Hanaoka et al., 2011; Tsuchida et al., 2011, 2015)

Site Characterisation and Mapping of Extents of Landslide Footprint – Australia

- Slope failure after extreme rainfall; slip plane unknown
- Panda VEDP used for rapid site investigation (13 tests, 2 days)
- Identified soil layers + weak slip zones
- Enabled geological model and design verification



Annotated Panda DCPT profile as interpreted for Naughton's Gap Road site.

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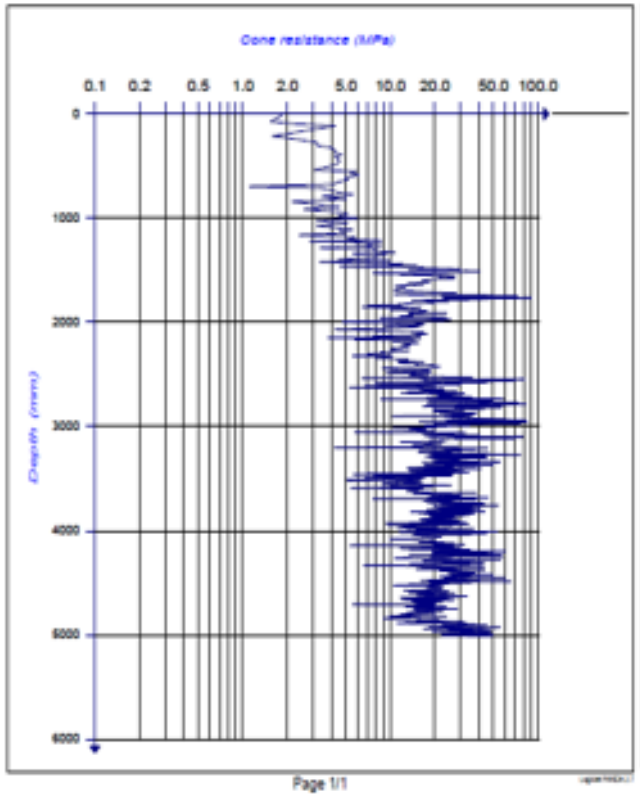
Design Inputs for Landslide Detailed Remedial Designs - UK

- Landslide in weathered mantle, risk to site users
- Panda VEDP mapped mantle thickness + rockhead
- Found mantle thins downslope
- Result: enabled fast, cost-effective design

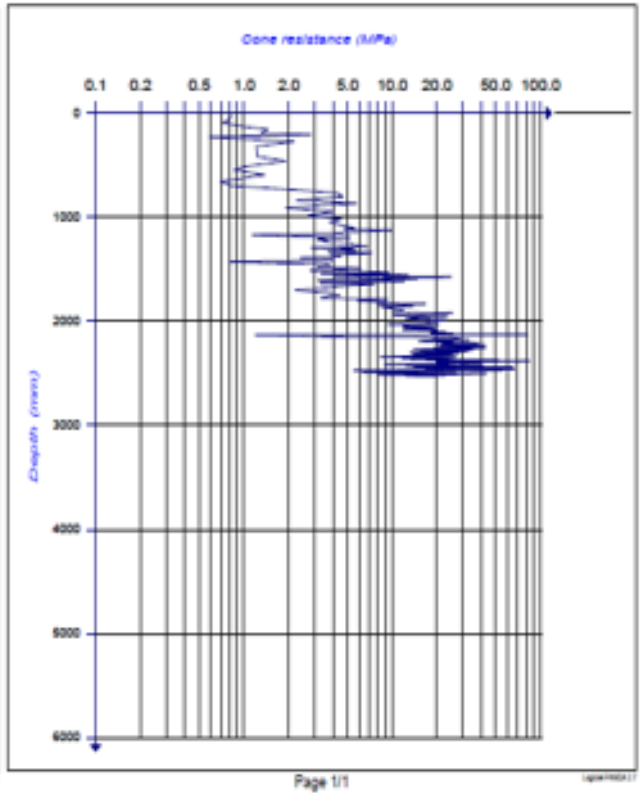
Section of visible rock beneath recent mantle failure

Visible mantle profile on slope

Transect 6-A



Transect 6-B



Transect 6 - Panda Probe Profiles

ALUE

CONCLUSIONS

- Panda VEDP is an effective rapid geotechnical investigation tool
- Enables fast, quantitative slope assessment in crisis conditions
- Identifies slip surfaces, weak zones, and supports geological modelling
- Improves accuracy of slope stability analysis
- Reduces investigation time and cost
- Supports safer, faster decision-making in emergency operations
- Enhances safety and infrastructure resilience
- Applicable through the entire landslide lifecycle

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QUESTIONS?

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