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Mud rush Day of learning

Mud rushes and water inflows in underground mines – a call to save lives

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- MSc Hydrogeology, University College, London
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- Chartered Geologist UK
- Fellow of Geological Society UK, S Africa and Southern African Institute of Mining and Metallurgy (SAIMM)
- Advisor to Global Action on Tailings (GAT), Global Mining Professionals Alliance, Pure Earth and Ramsar convention
- Editor of the International Mine Water Association Journal (MWEN) and Quarterly Journal Engineering Geology and Hydrogeology (QJEGH)
- Committee member SAIMM, International Mine Water Association (IMWA)
- 45 years' experience in mining hydrology and has worked on over 300 mines
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Contents

- Summary of incidents
- Causes and factors behind mud and inrushes
- Water is predictable
- Need for a guideline
- Way forward

Baselining: What we Know

Different types of mud rush

A) Ore pass rush – covered by bow tie workshop

B) Massive mud rush from cave or drawpoints

Summary of fatalities from 1815

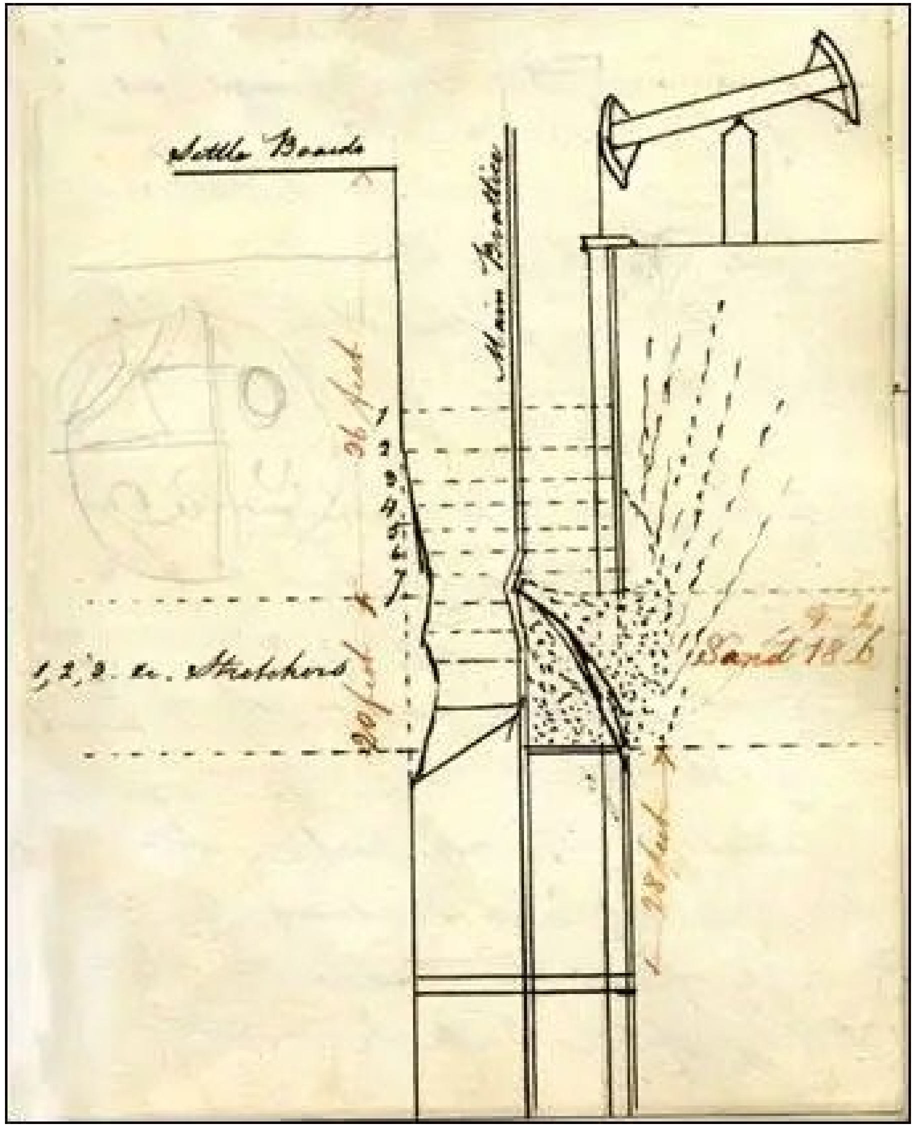
(snap shot data, needs verification)

- 1420 people killed from mud/water inrushes
- Australia, Burkina Fasso, Canada, Chile, China, England, India, Mozambique, Namibia, Russia, Scotland, South Africa, Ukraine, USA, Zambia, India
- Anthracite, Coal, Copper, Diamonds, Gold, Iron ore, Platinum, Potash, Silver , Zinc
- Mostly contractors killed – no voice

Examples of mud rushes

Heaton Colliery Disaster (Flooding) 1815

- May 3rd 1815
- Seventy-five (41 men and 34 boys) lost their lives.



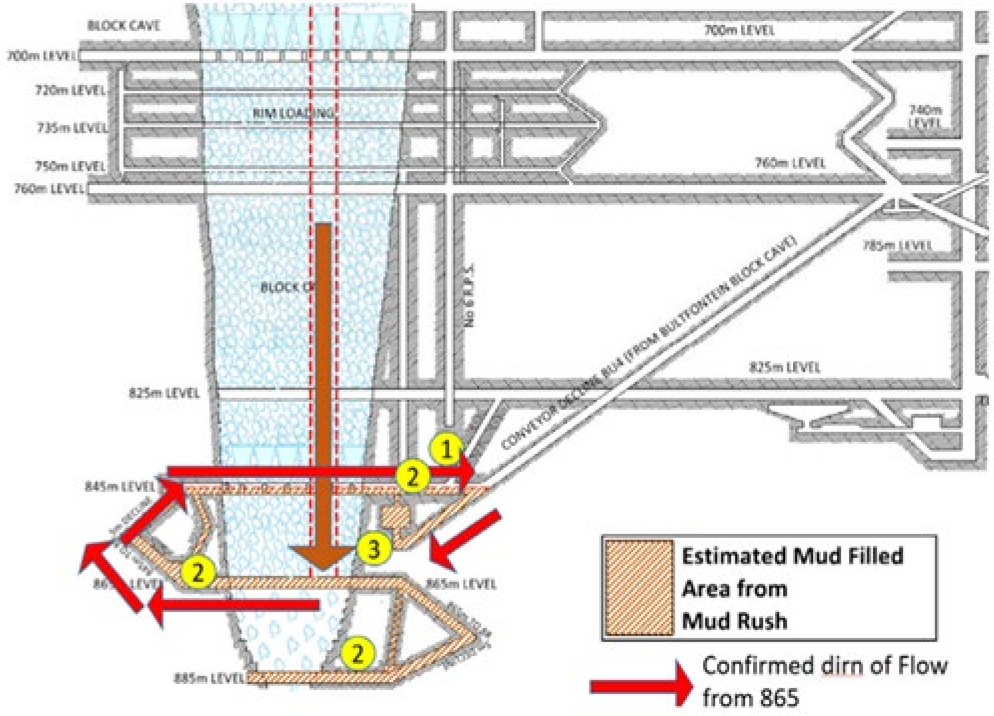
Mufulira (25th September 1970) **89 dead**

Figure 1: Aerial view of the sinkhole at Mufulira No. 3 Dam (Source: *Times of Zambia*, 24 October 1970.)

Ekapa Bultfontein diamond mine mud rush - South Africa 5 dead (7th May 2018)

Bultfontein Mine

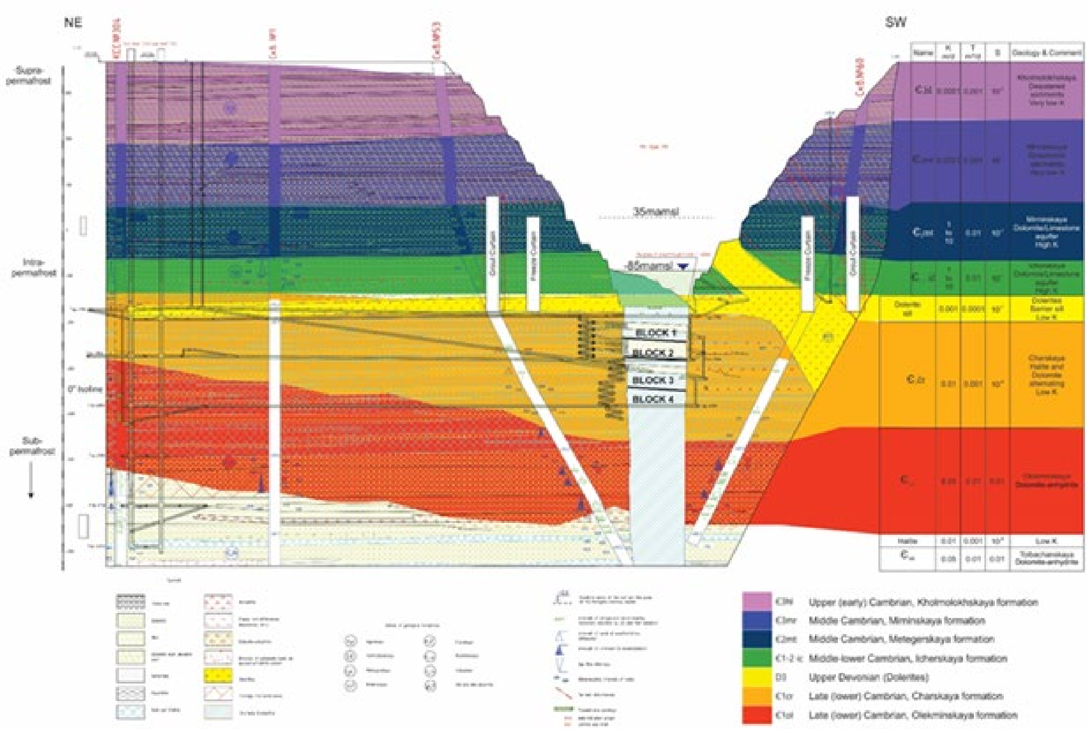
Cross section



Mir diamond mine Siberia (4th August 2017) 11 dead

Open pit

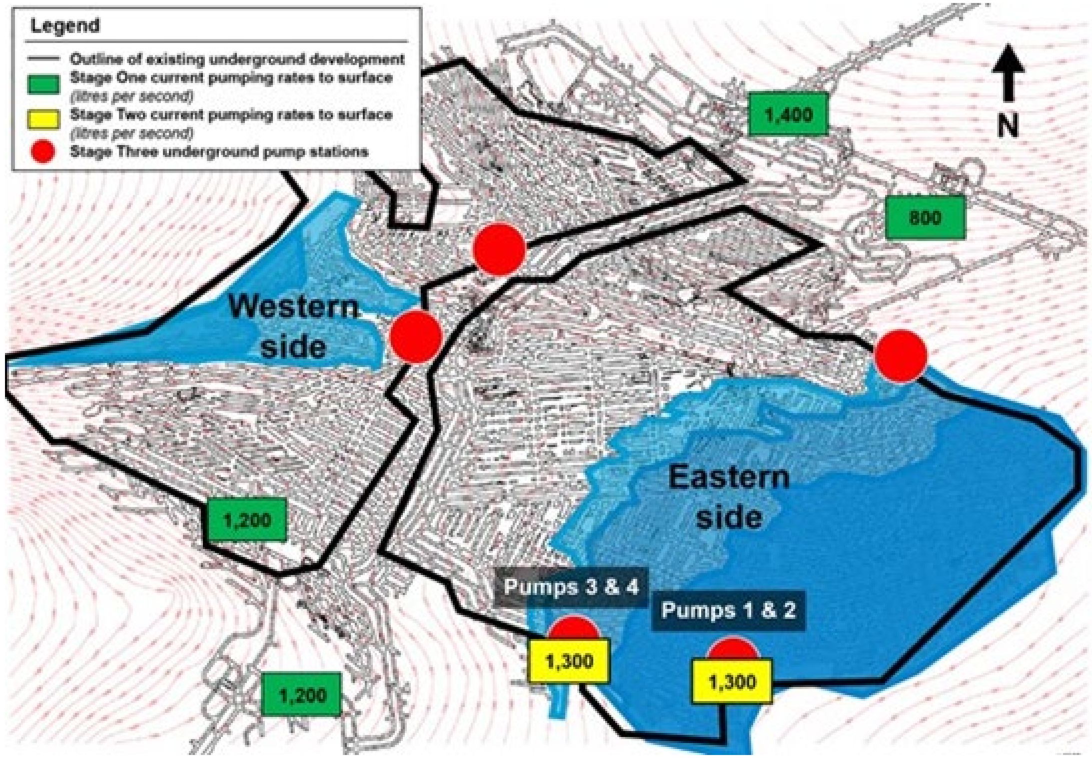
Cross section of block cave



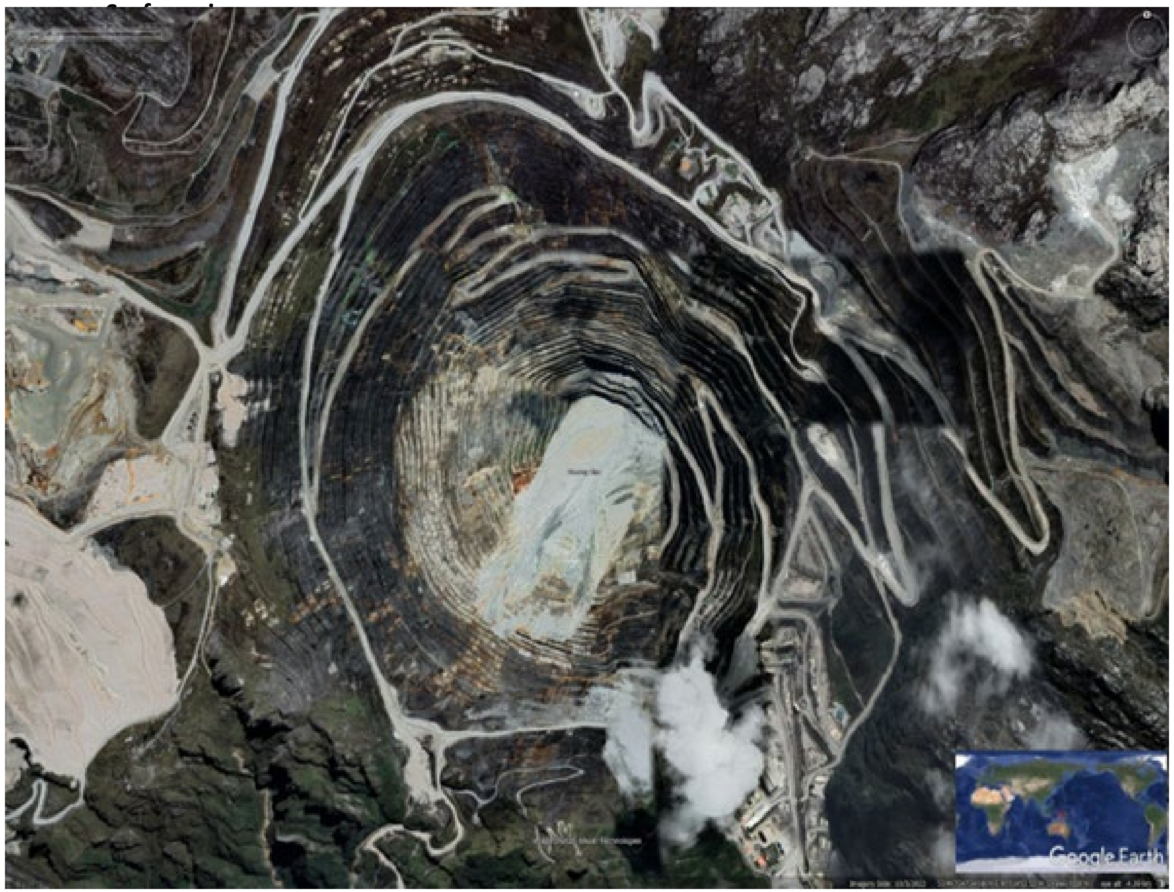
Kamoa Kakula DRC Flooding 2025 – East of mine lost

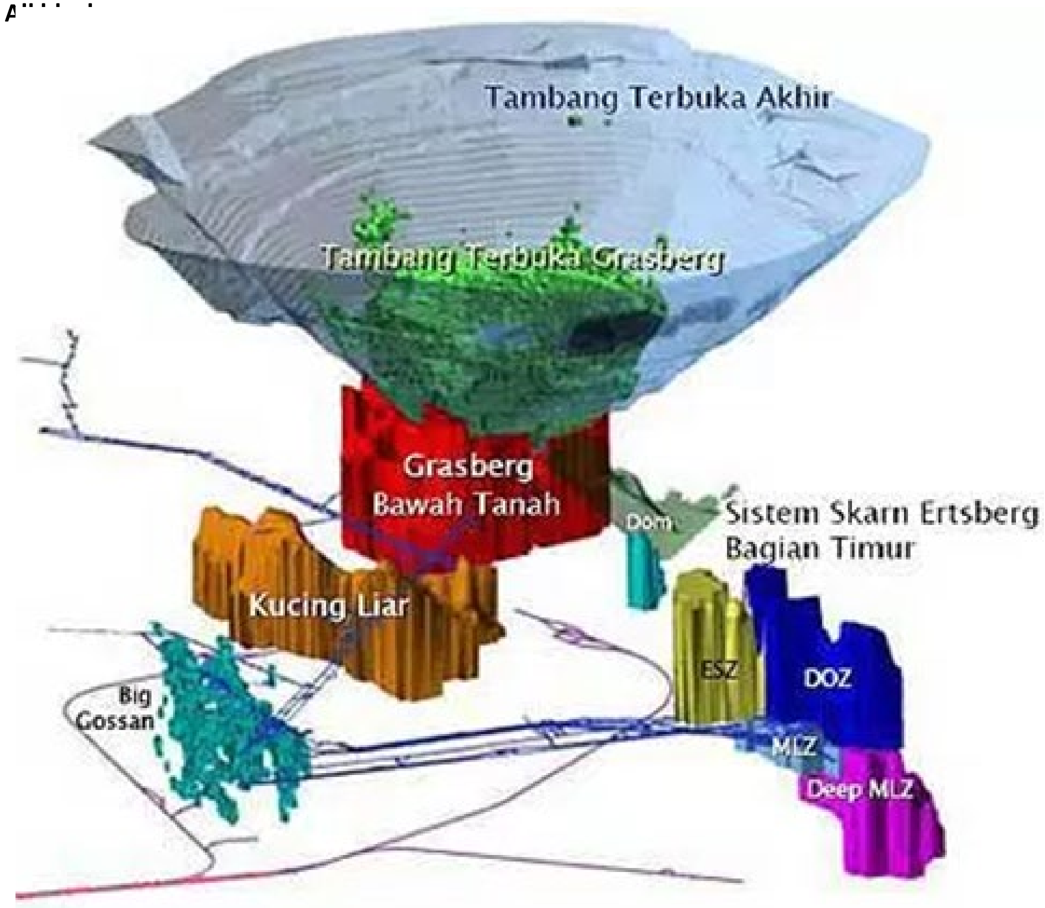
Surface operations

Underground operations

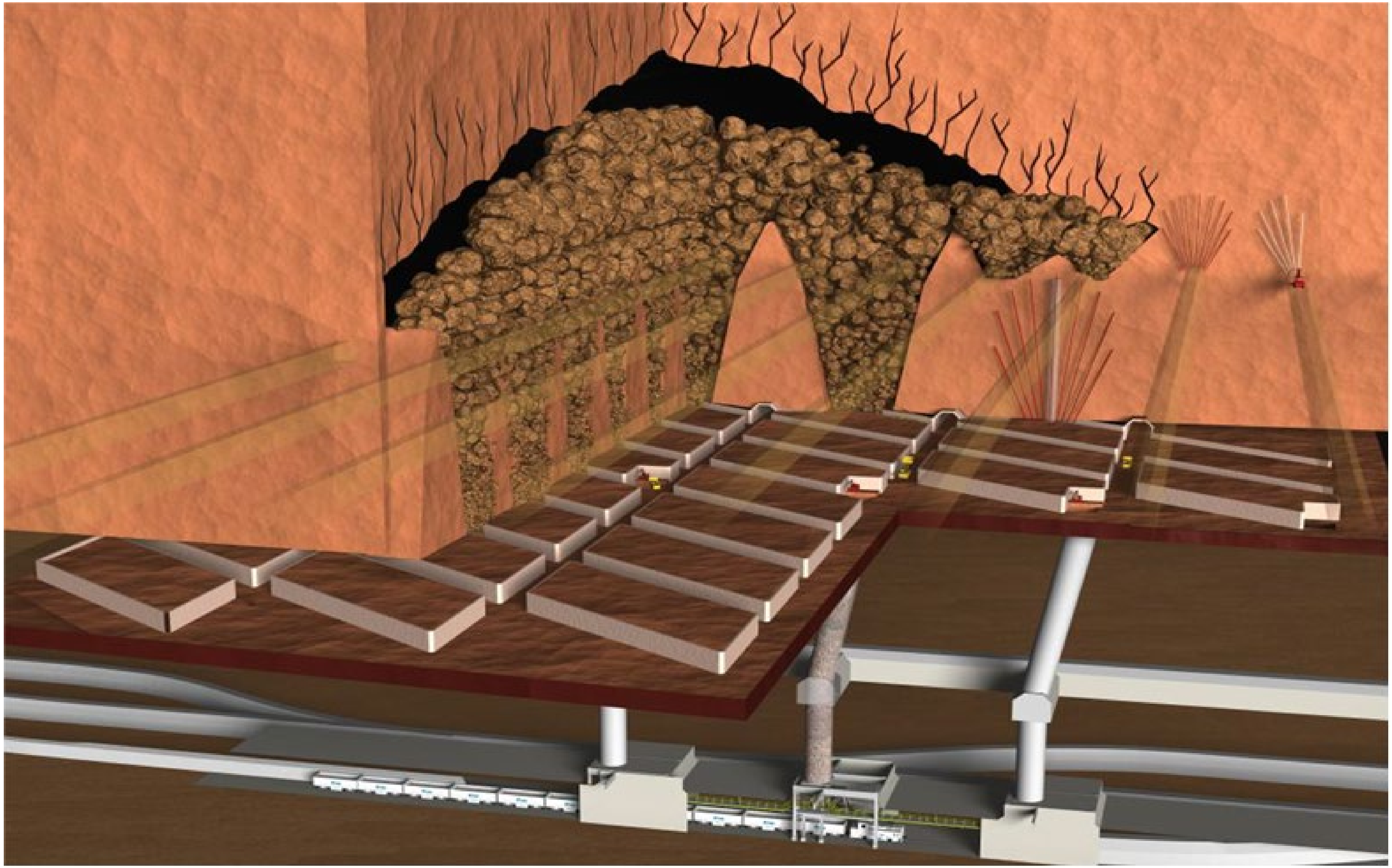


Grasberg (9th September 2025) 7 dead



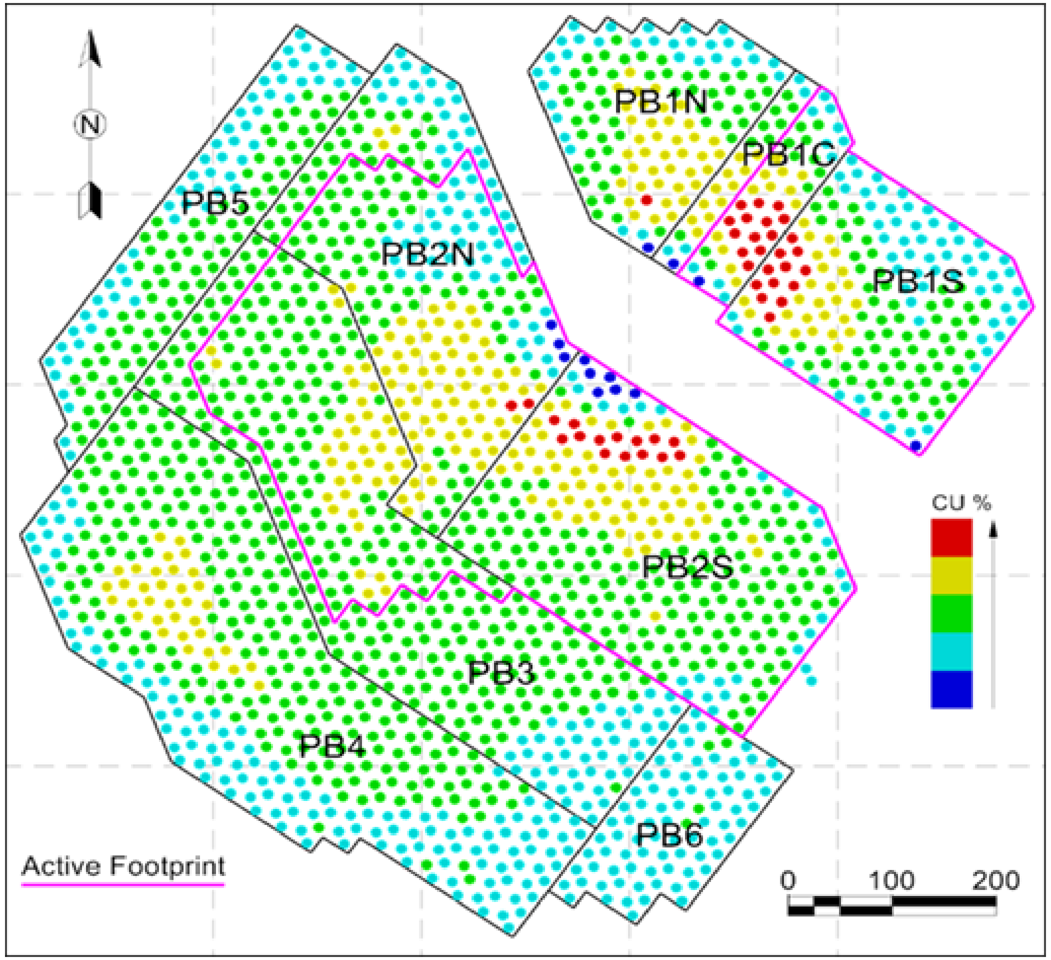


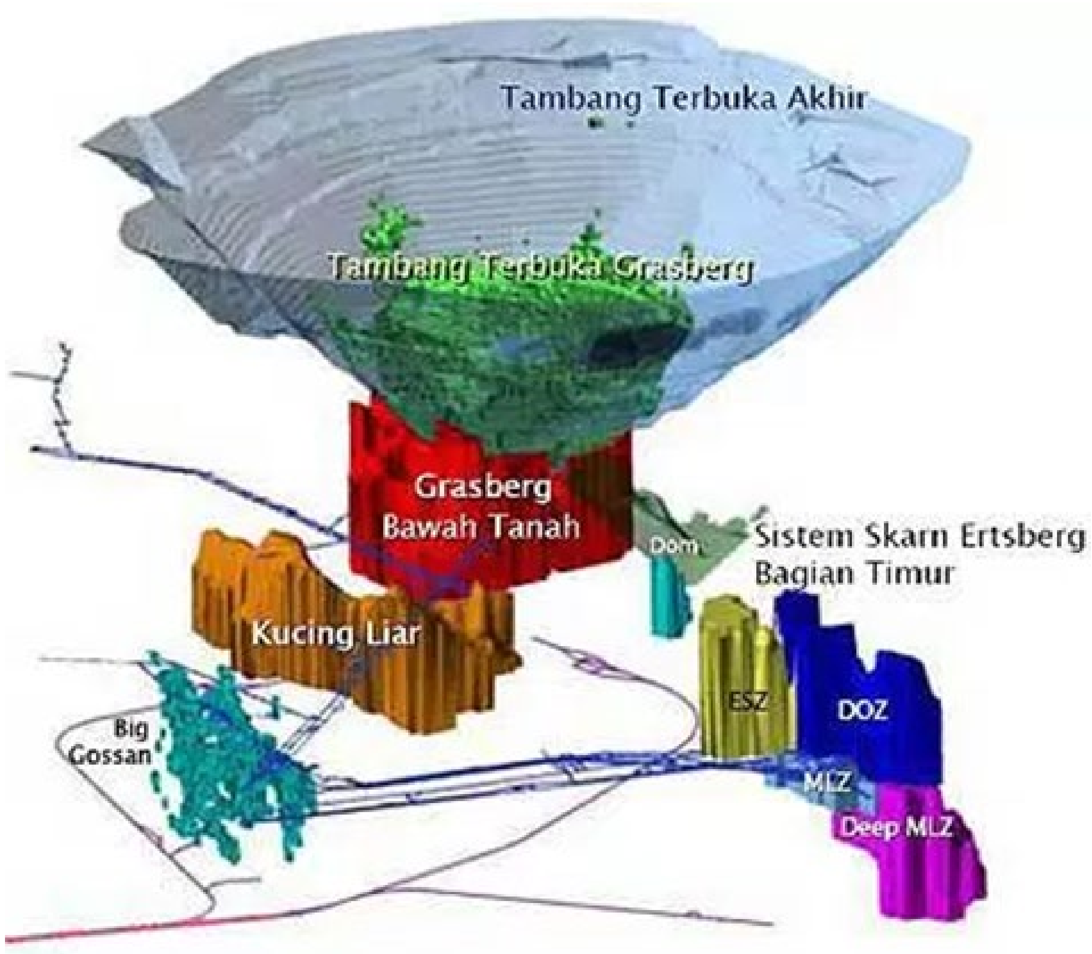
Block cave method



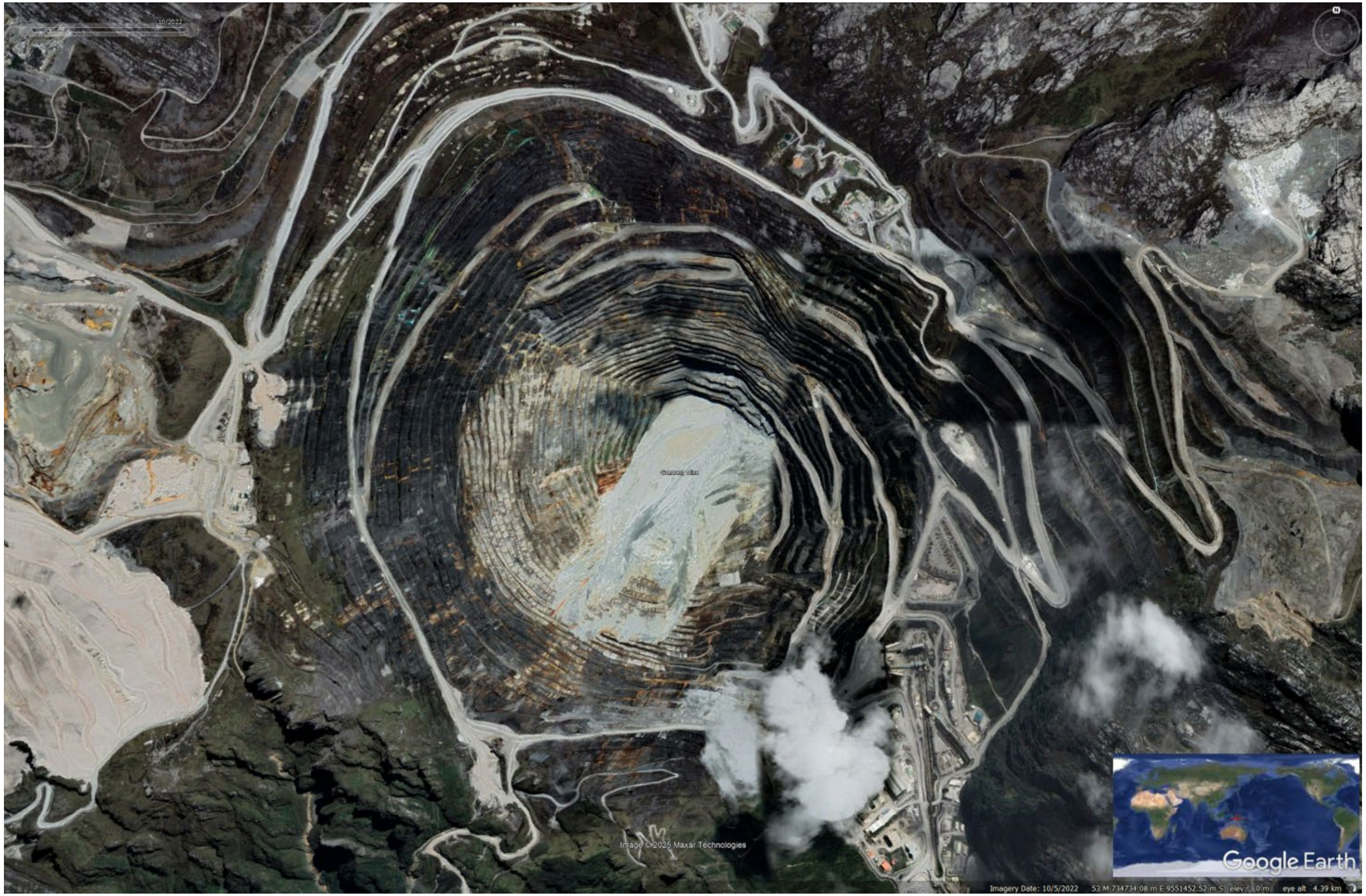
Grasberg Block cave

Block cave layout PB1C inrush





Grasberg location – note sponge at pit bottom



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Inrushes – mine flooding – 8 dead Perkoa

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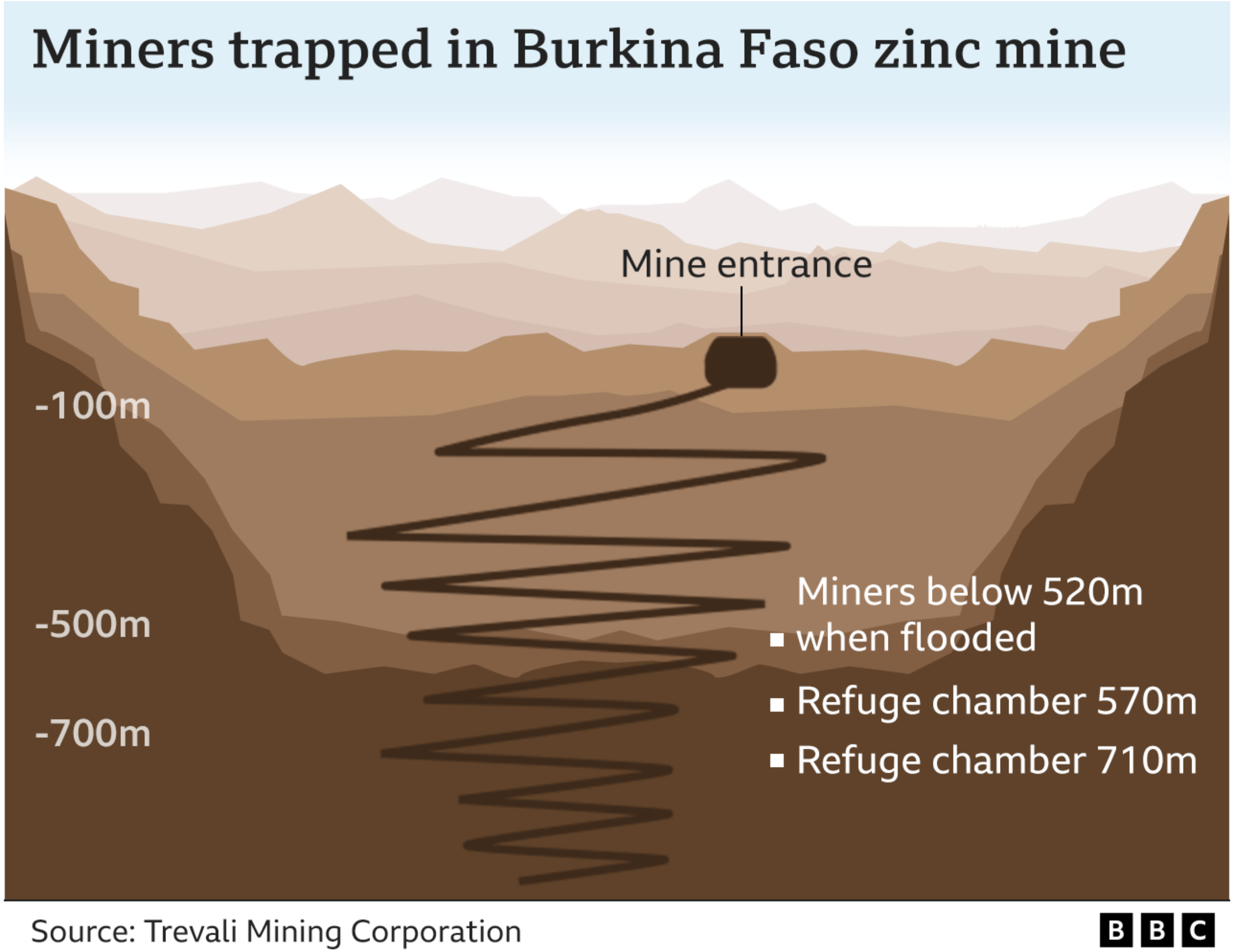

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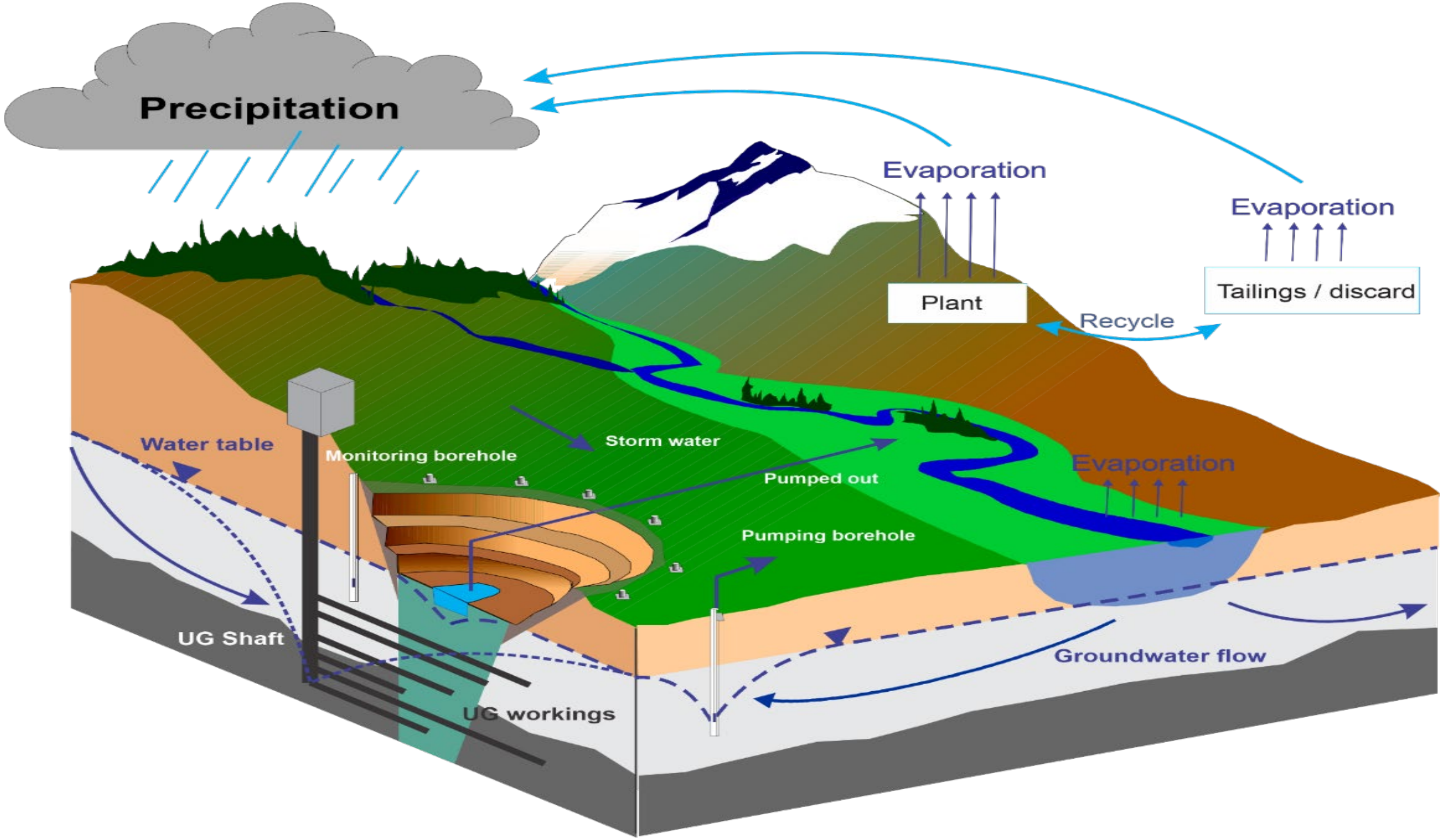
Mud and Flood risk

- Need to be tackled together
- Mud rush is where mud enters the mine and engulfs people and machinery- needs water to drive it
- Flood – inrush is where water enters from surface or underground pockets/neighbours.
- Water and mud need to be tackled together

Water inrush and mud flow prevention

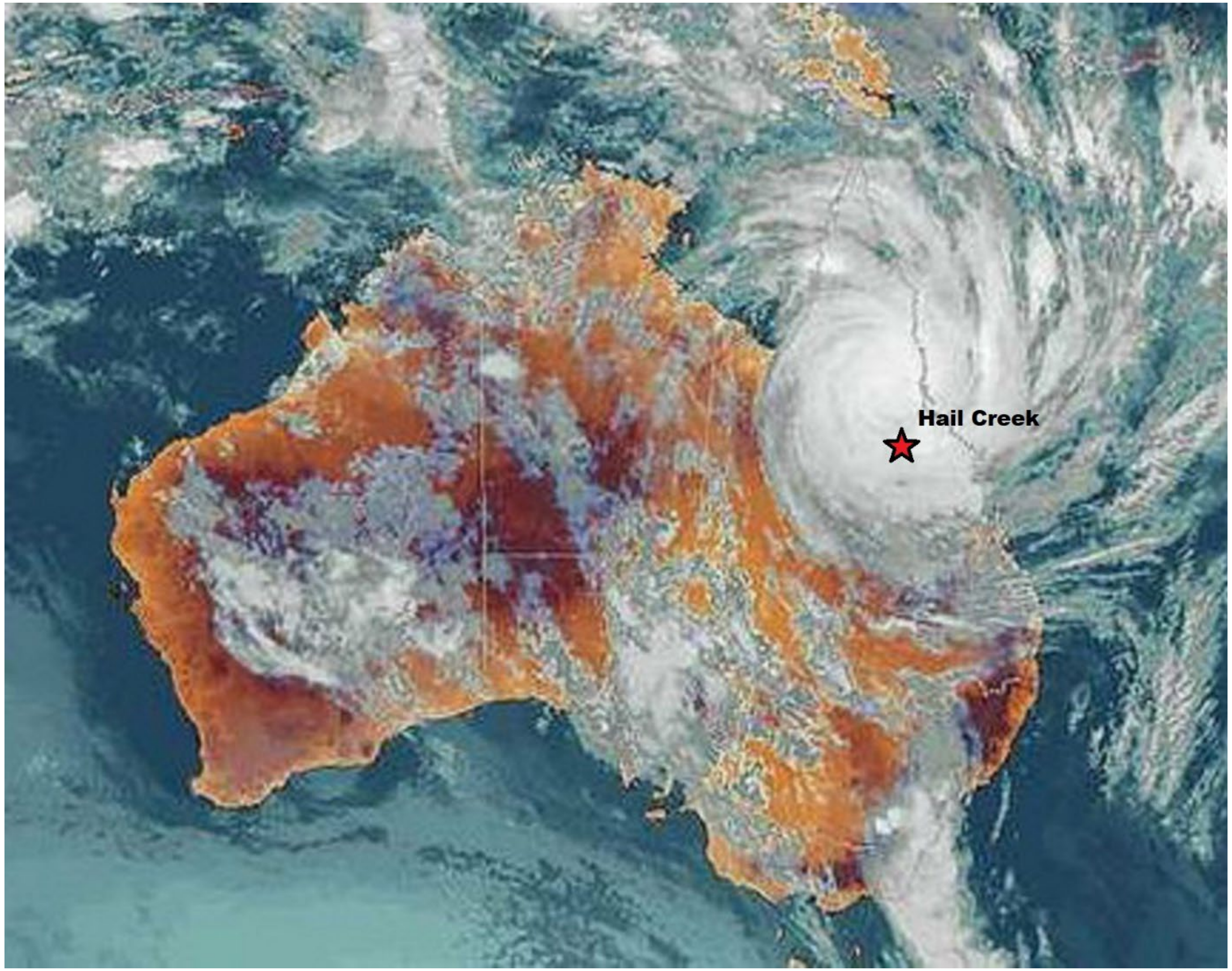
Requires Excellent DEWATERING DESIGN and implementation – understand the hydrological cycle



Water is measurable and predictable

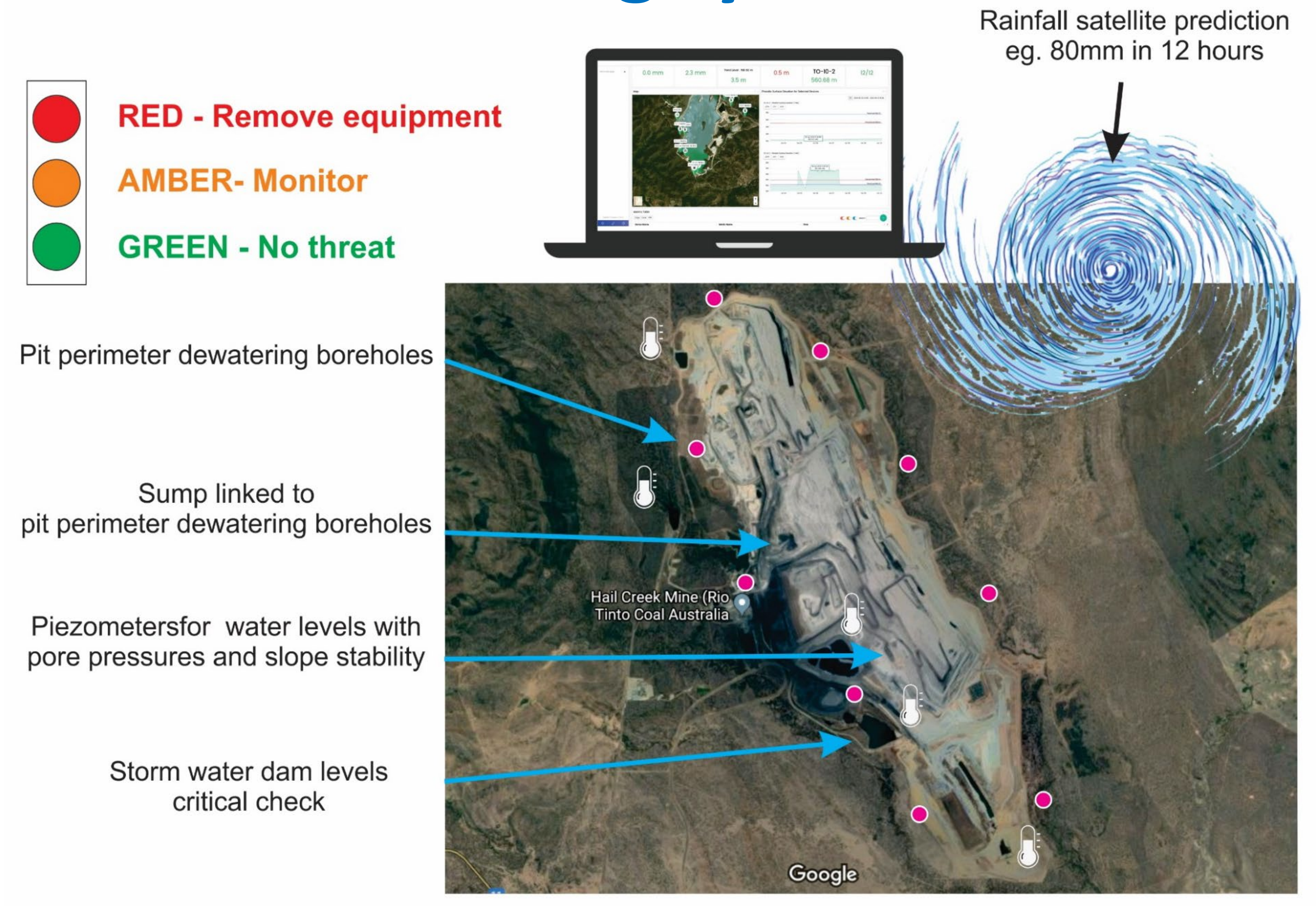
Incoming cyclonic rainfall

NASA moisture content files NOAA Predict rainfall dump

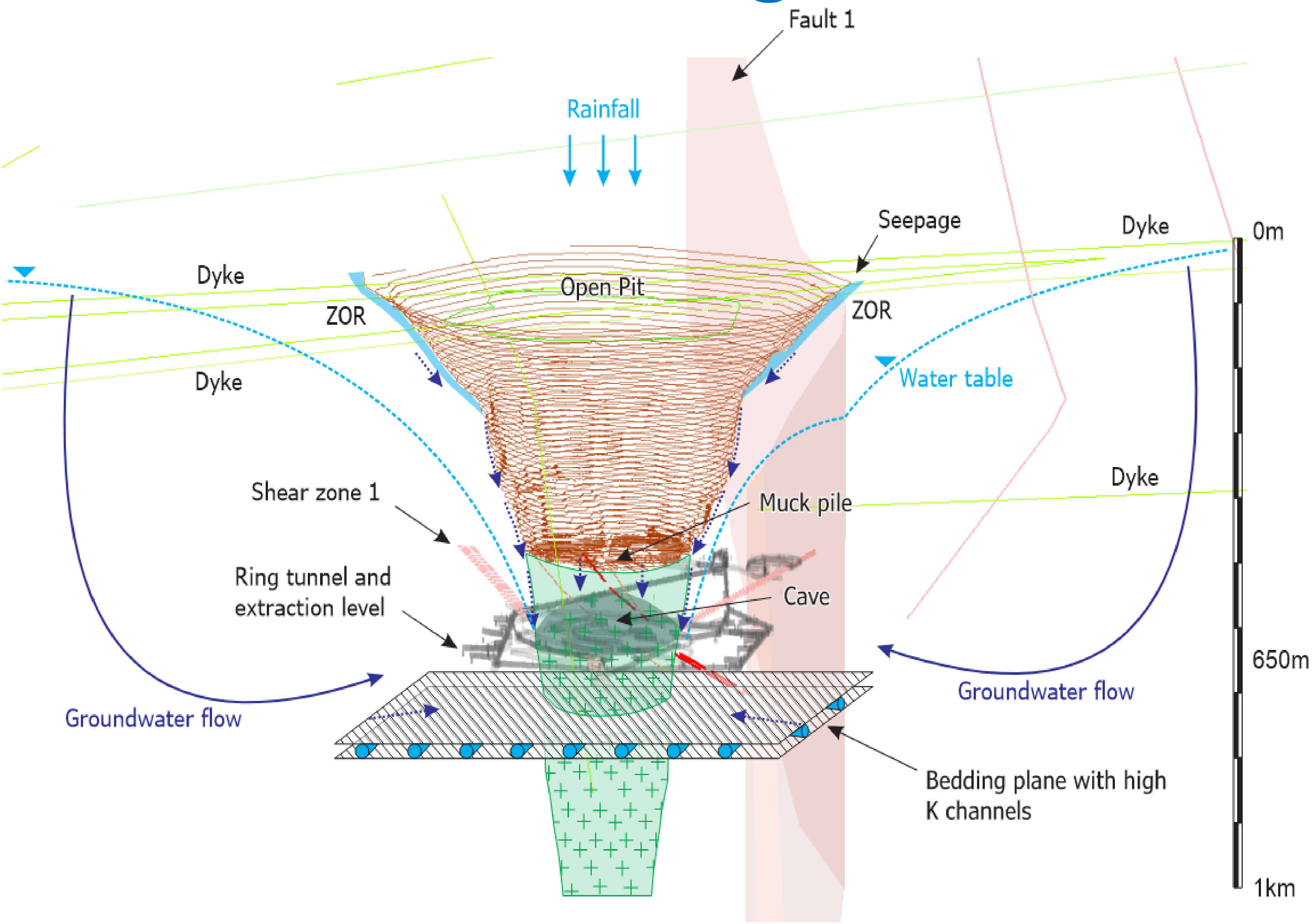


Hail Creek Storm water control

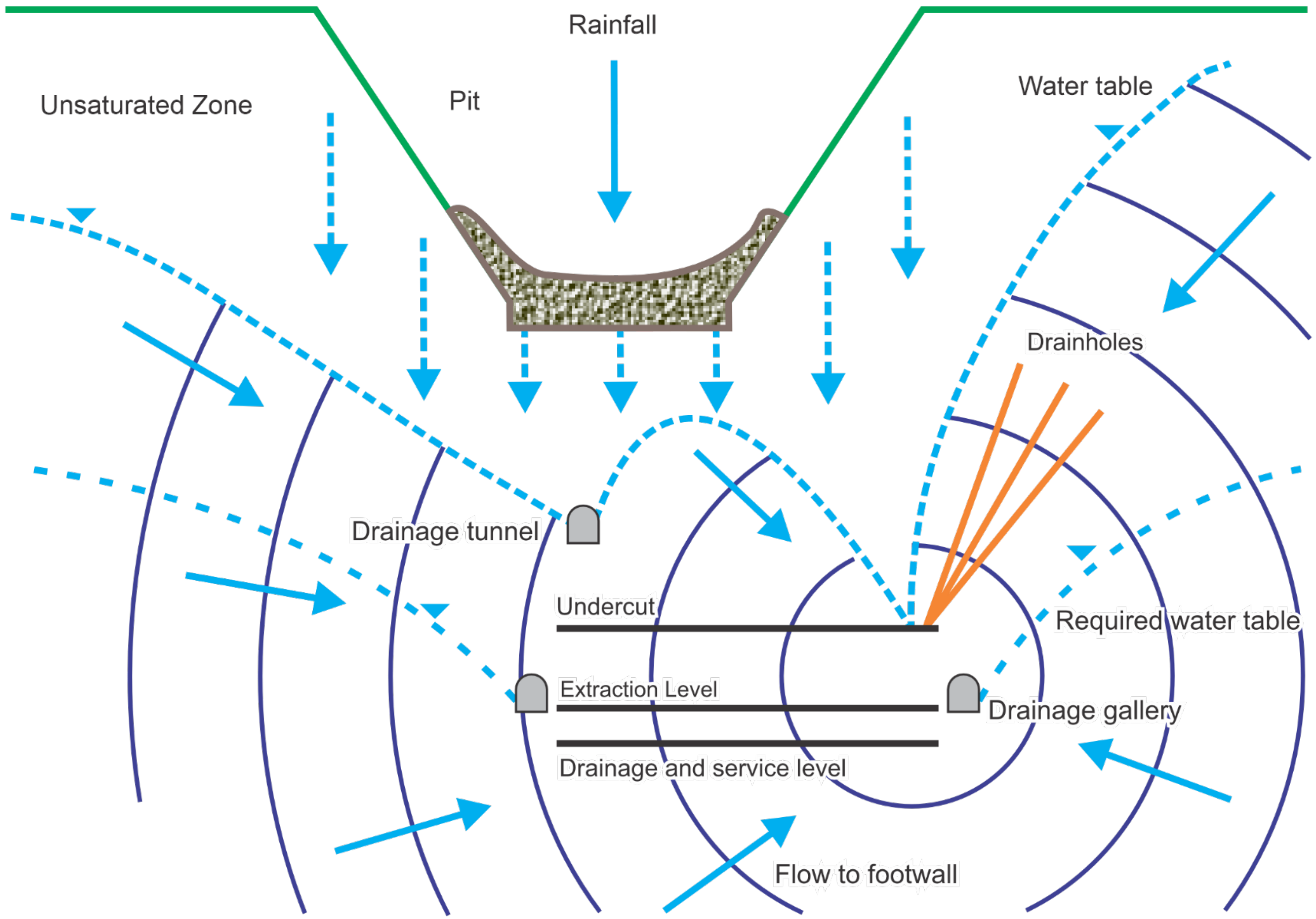
Hail Creek monitoring system



Water flow to an underground mine



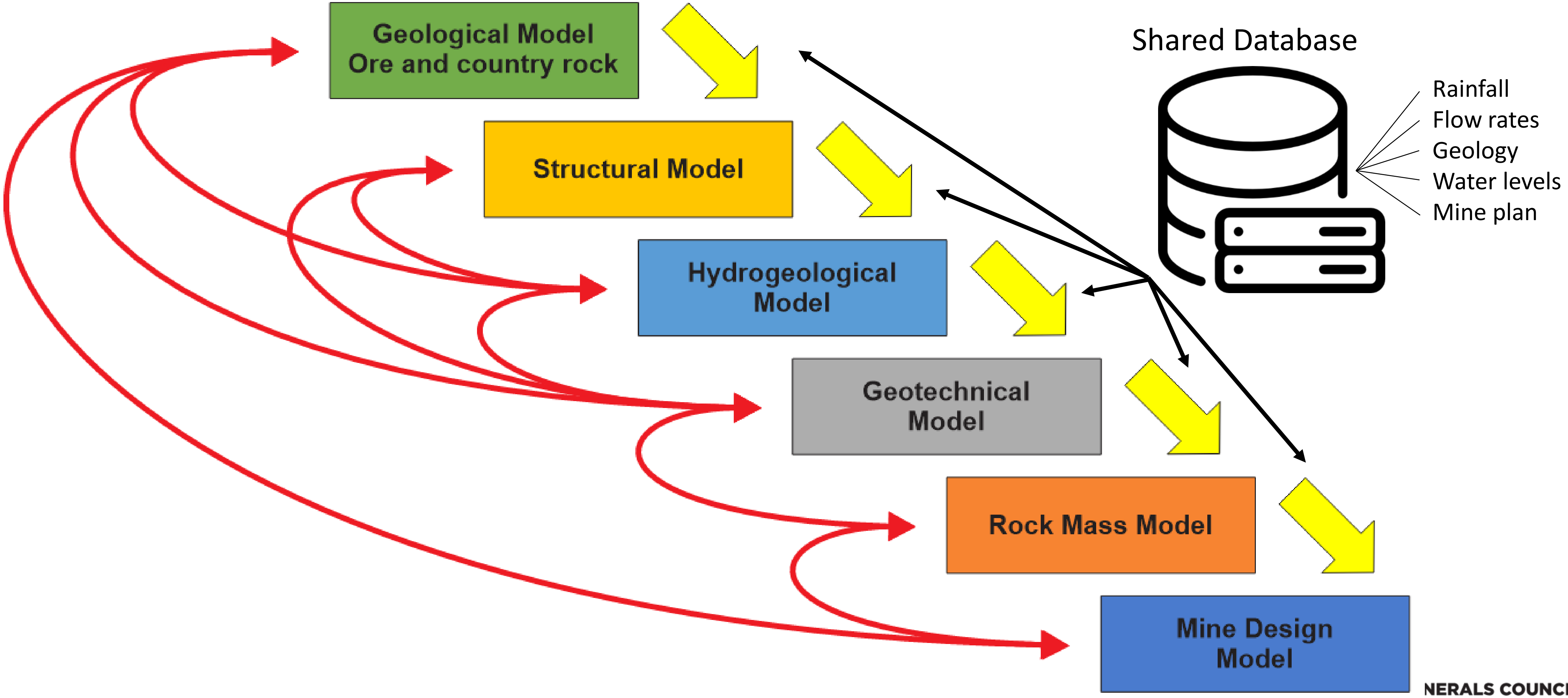
Schematic hypothetical mine head distribution after pit closure above block cave using drainholes vs drainage gallery



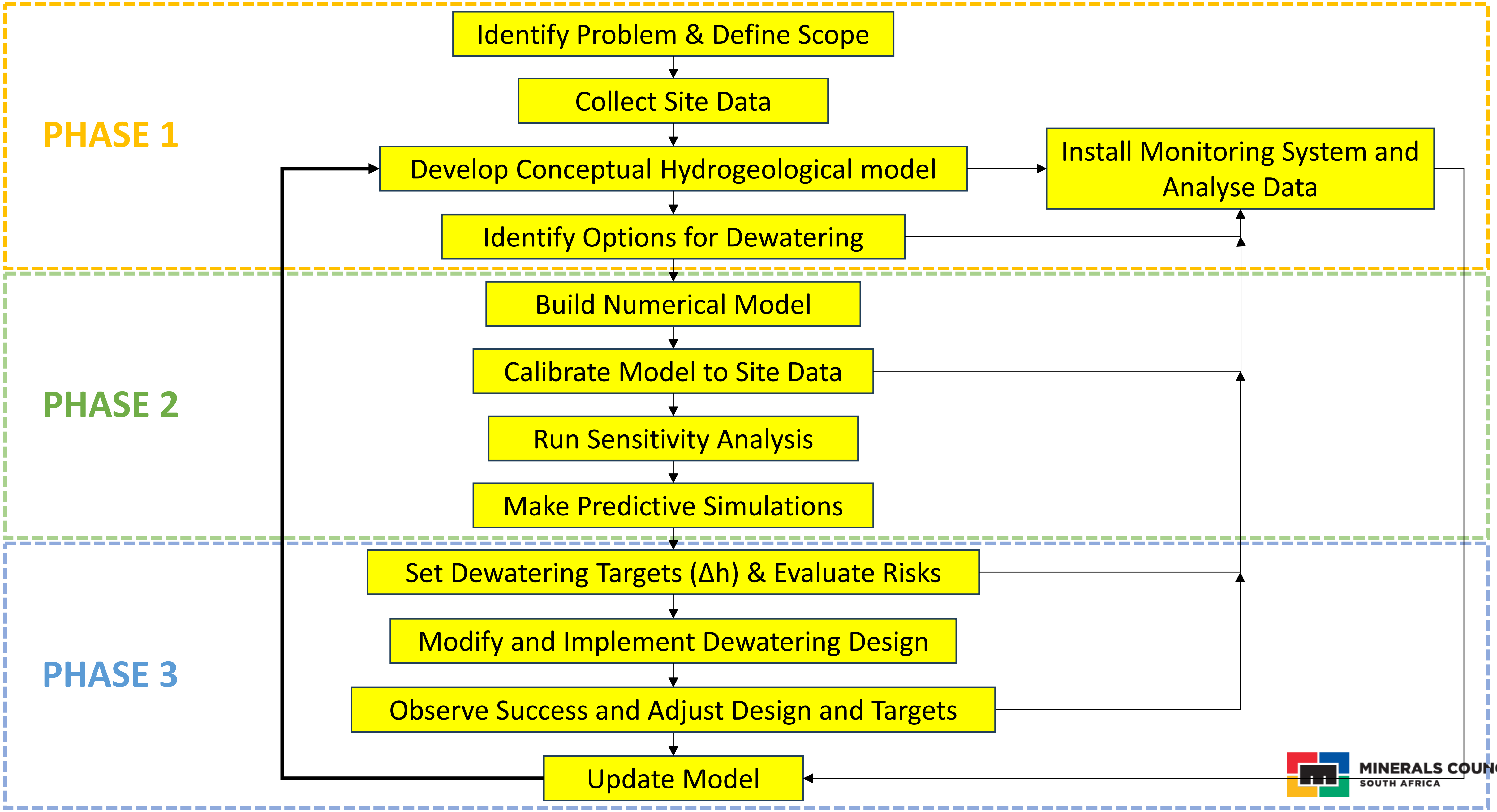
Accurate dewatering requires quantitative understanding of:

- Sources of water (integrate with surface designs)
- Flow-paths (conduits) natural and man made (Hydro-structural model)
- Storage
- Pressures and pressure distribution (head)

FLOW DIAGRAM SHOWING CONTRIBUTION OF EACH MODEL TO FINAL DEWATERING DESIGN MODEL (After A.R. Guest 2005)



A PHASED APPROACH TO MINE DEWATERING DESIGN



Dewatering Success - ESSENTIALS

1. CUT OFF RECHARGE
2. EXPLOIT PERMEABILITY
3. START EARLY
4. SET WATER LEVEL TARGETS
5. MONITOR LEVELS and FLOWS

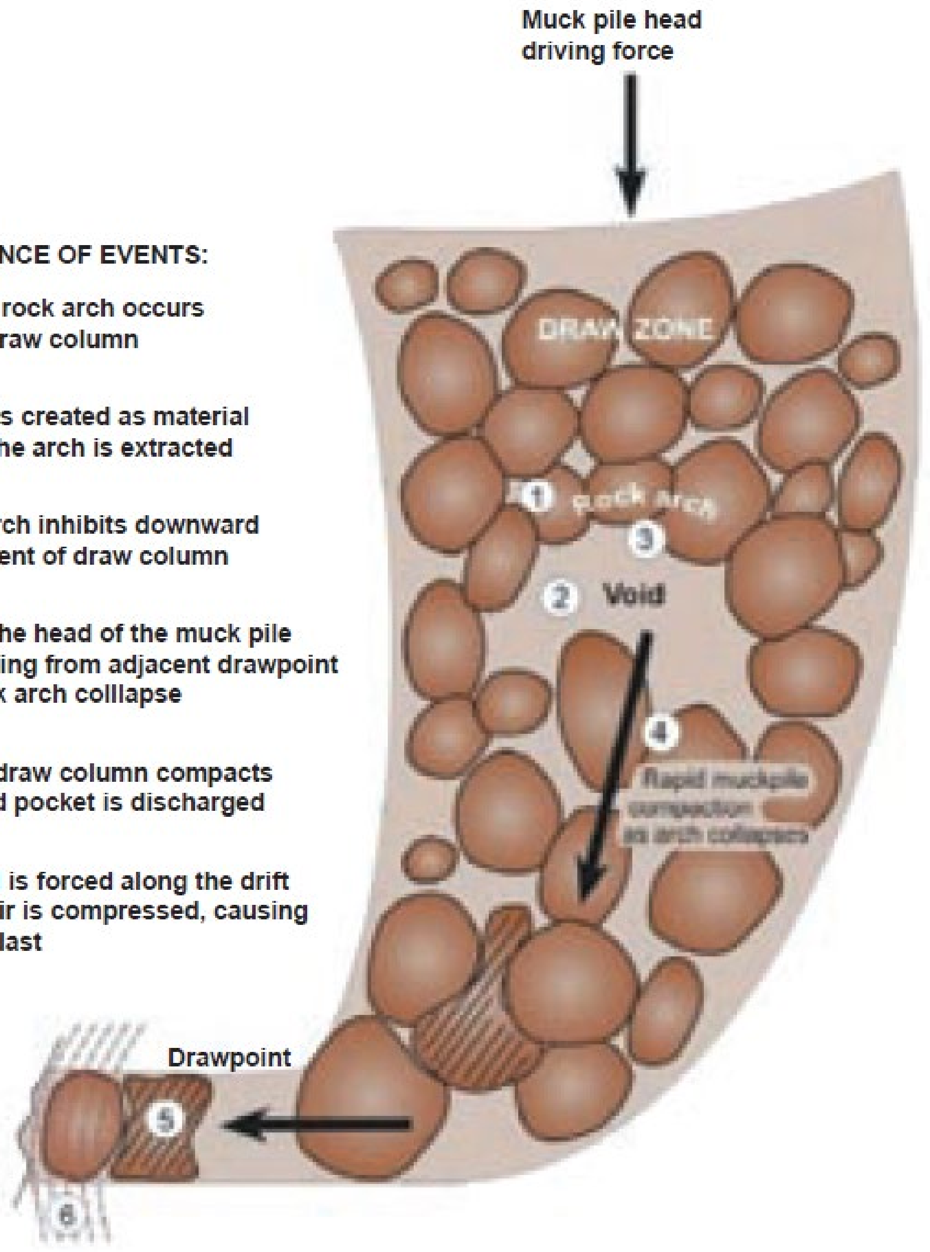
Causes of mud rushes – 4 factors

1. Mud present (slippery rocks)
2. Driving head of water
3. Outlet – draw point
4. Trigger
    1. Seismic (man made or quake)
    2. Increase in head (uncontrolled water)
    3. Over draw/ blasting

Mud rush mechanism (SIMRAC 2000)

SEQUENCE OF EVENTS:

1. A large rock arch occurs in the draw column
2. A void is created as material below the arch is extracted
3. Rock arch inhibits downward movement of draw column
4. Under the head of the muck pile or drawing from adjacent drawpoint the rock arch colllapse
5. As the draw column compacts the mud pocket is discharged
6. As mud is forced along the drift miner air is compressed, causing an air blast



Mudrush risk assessment process 2018

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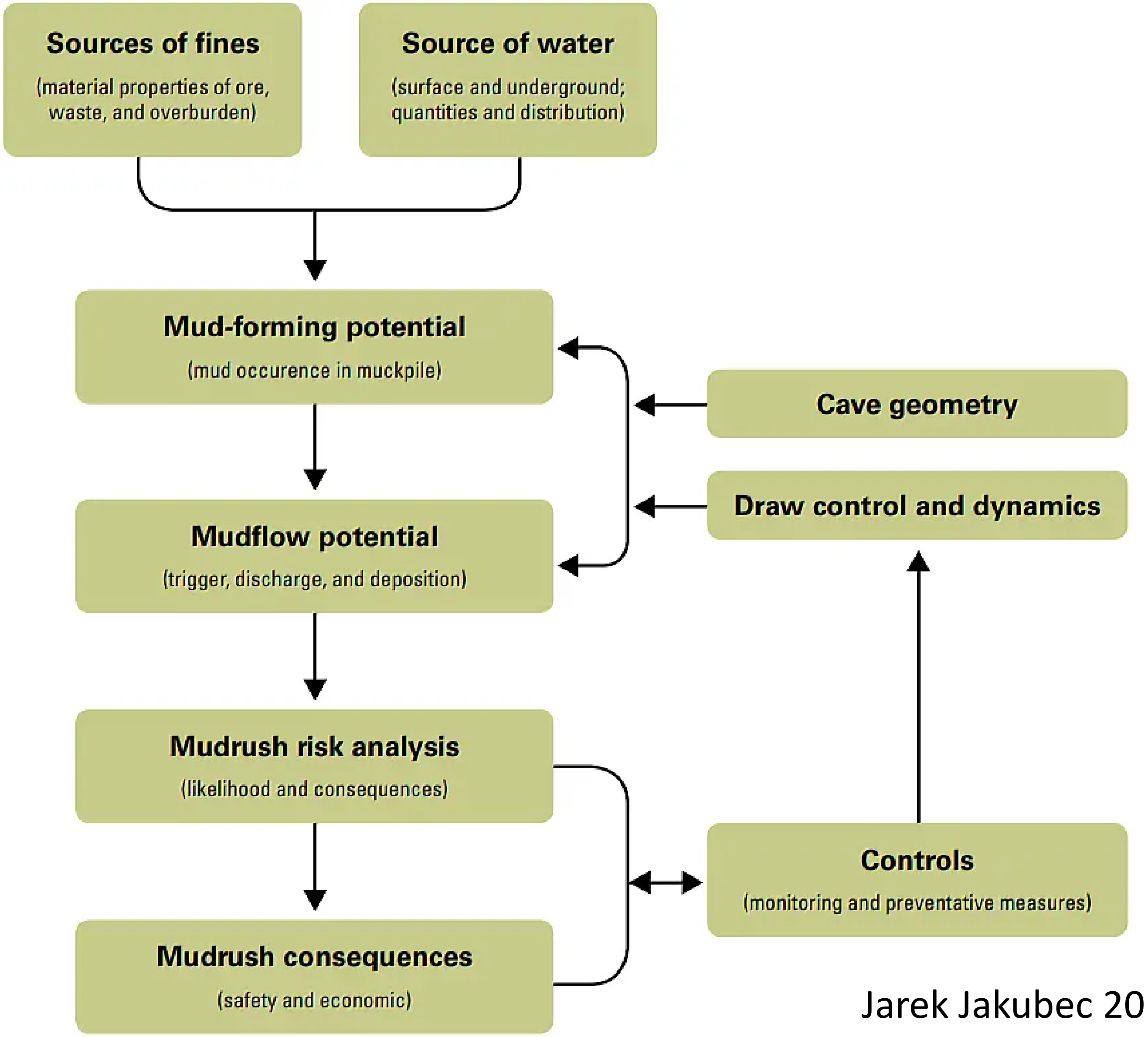

Jarek Jakubec 2018

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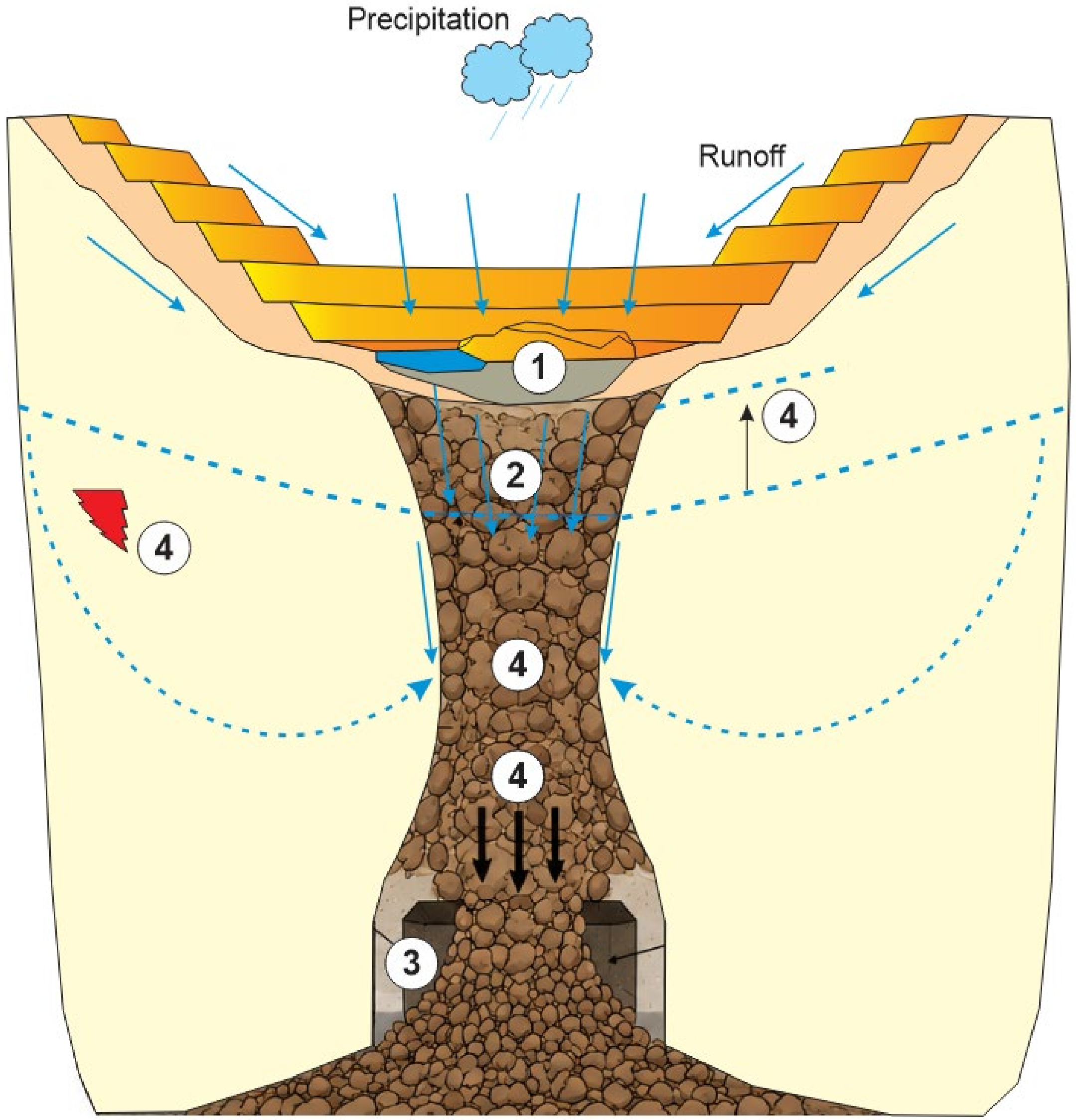
CAUSES of a mud rush 2026 - UPDATED



1. **Presence of mud-forming materials ('low-friction resistance' rock or fines**
2. **Head of water (phreatic surface above a specific maximum level)**
3. **Discharge points (drawpoints)**
4. **Triggers include:**

- **Over draw**
- **Seismic event (natural or man-made)**
- **Increase in head of water (natural or man-made)**

Elements of a mud rush and their control

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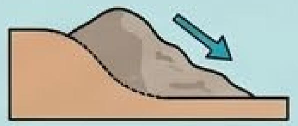
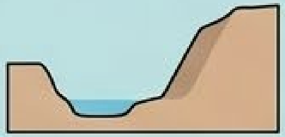
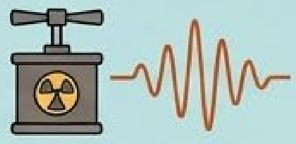
1 PRESENCE OF MUD-FORMING MATERIALS

Presence of mud-forming materials ('low-friction resistance' rock or fines)


Reduce muck pile

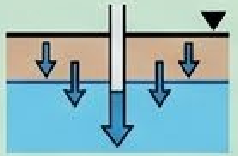

Reduce pit slope failure

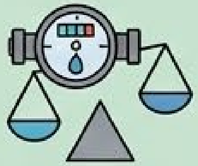

Adapt blasting

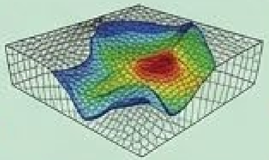
Reduce contact time with water

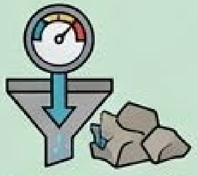
2 HEAD OF WATER

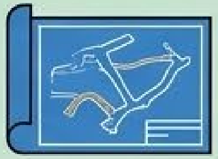
Head of water (phreatic surface above a specific maximum level)

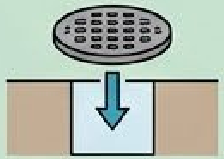

Keep phreatic surface below extraction level


Maintain a detailed water balance


Monitor head distribution in 3D (VWP & dashboards)

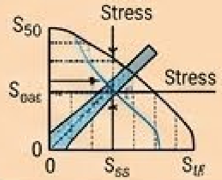

Measure water ingress at drawpoints


Improve mine design to divert water


Ensure good drainage of closed areas

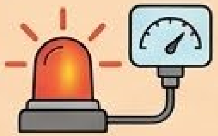
3 DISCHARGE POINTS

Discharge points (drawpoints)



Best practice geotechnical design


Mapping of water ingress


Early warning system of water pressure build-up

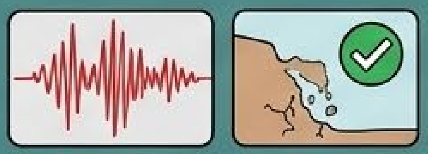
4 TRIGGERS INCLUDE:

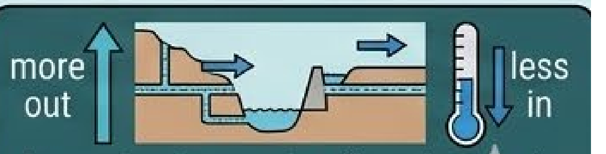
Over draw

Seismic event (natural or man-made)

Increase in head of water (natural or man-made)

Manage draw


Use 'quake prediction tools, adapt caving design



Accurate stormwater diversion, drain upper levels, control pit drainage, ensure water out > water in

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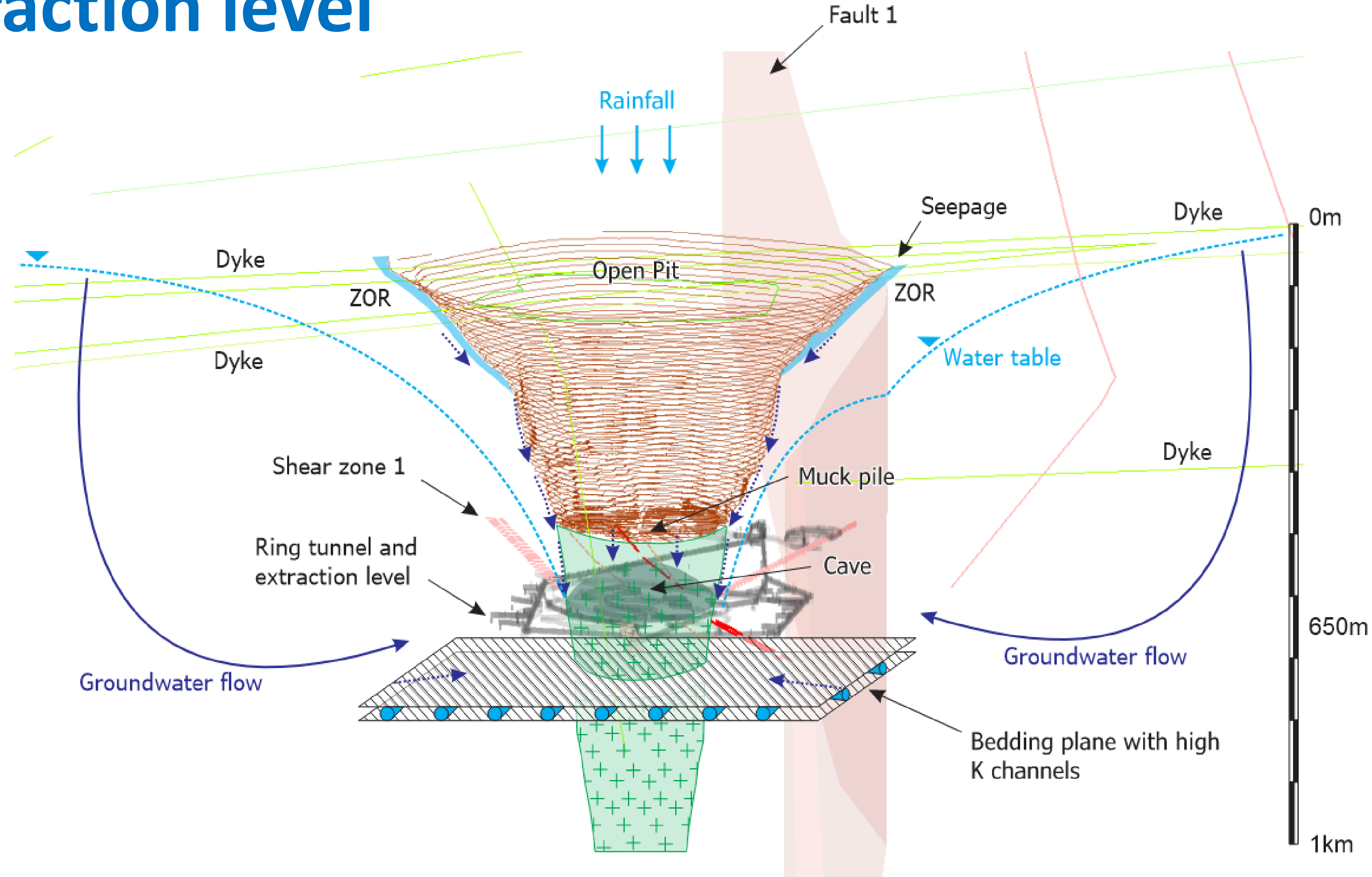
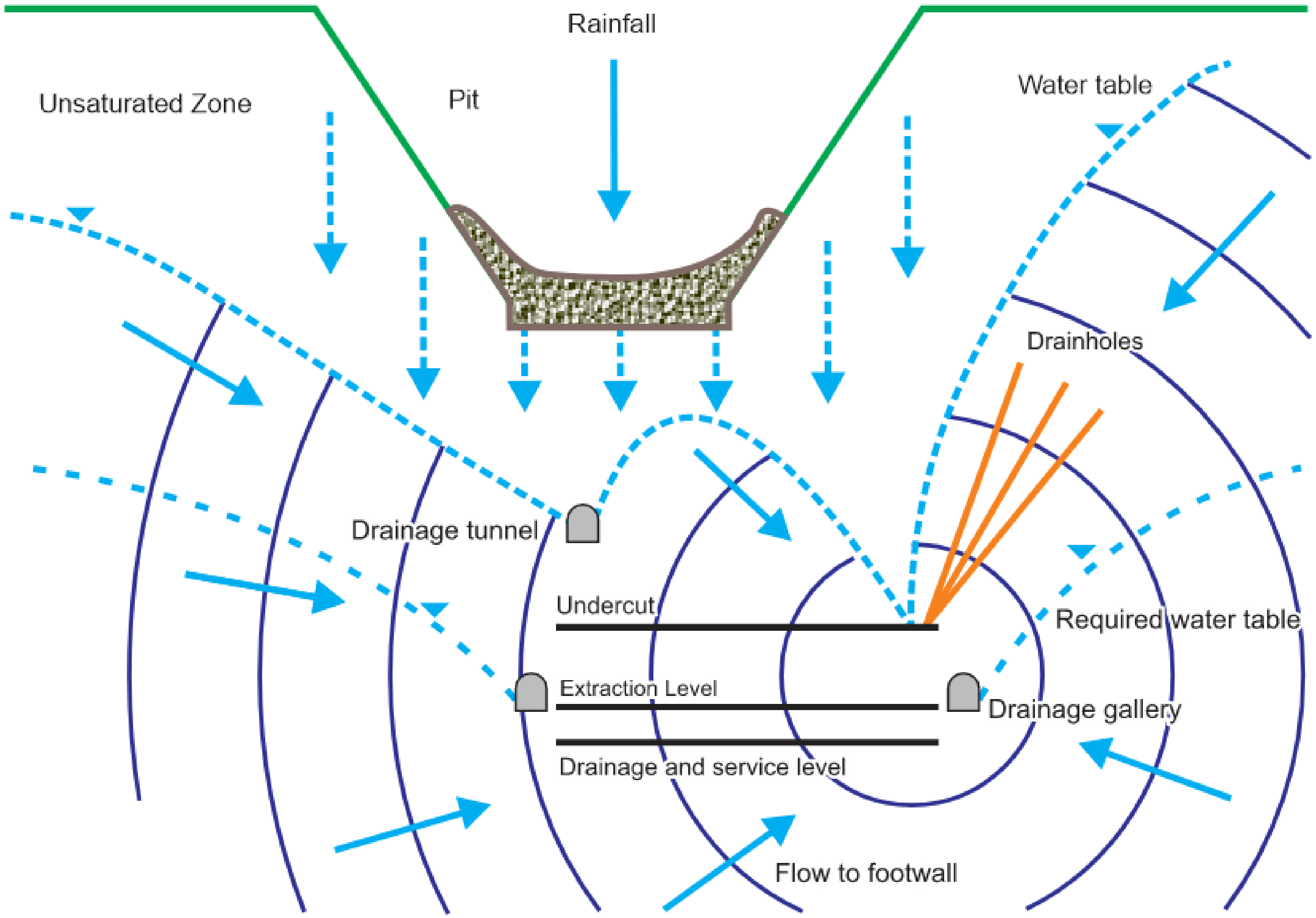
Conceptualisation of a block cave showing flow paths for groundwater moving into the muck pile and extraction level



Schematic head distribution of a hypothetical underground mine



New strategy

- **MONITOR CAUSE NOT SYMPTOM**
- **PREVENTION NOT MITIGATION**
- **INTERNATIONAL GUIDELINE**

Causes of Water and Mudrushes Can Be Monitored, Predicted, and Prevented

Monitoring

- Real-time groundwater level monitoring
- Piezometers and observation boreholes
- Flow measurements and pressure monitoring
- Water balance audits

Prediction

- Rainfall/topography modelling
- Groundwater level modelling
- Risk mapping of water-bearing structures
- Early warning thresholds and trigger levels

Prevention

- Controlled integrated dewatering programmes
- Measurement of head and flowlines
- Drainage drives and pressure relief systems
- Satellite image interpretation and early warning
- Early warning dashboards for trigger levels
- Operational risk management procedures
- Integration of water management

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Strategy to combat mud and water inflows

TASK 1

- Establish comprehensive list of all occurrences
- Obtain all regulations worldwide on water inrush and mud rush prevention
- Evaluate causes of historic mudrushes and categorise

TASK 2

- Draw up guidelines to monitor, predict and prevent water inrushes and mud inrushes for each mine and climate type

TASK 3

- Distribute guidelines
- Work with stakeholders to ensure implementation

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Accurate management of the water drainage for the whole mine using:

1. Regularly (quarterly) updated water balance that ensures water out > water in
2. Annually reviewed, detailed hydrogeological conceptual model based on a detailed hydro-structural model
3. Seasonally updated and accurate surface water control to prevent water entering the pit and underground mine through open holes and the ZOR

Accurate management of the water drainage for the whole mine using:

4. Detailed pro-active dewatering designs for each sector of the mine using dewatering galleries and large diameter drains or pumping wells which keep the phreatic surface below the extraction level
5. Annually updated monitoring network (heads and volumes) that reports on the location of the phreatic surface in 3D.

Key Takeways

- Water balance must ensure water out > water in
- Divert water from the workings and maintain head below extraction level (avoid plugs)
- Monitor head distribution around the cave and create gradient away from workings

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Don’t let water OR MUD surprise you — drown risk, not your mine

Measure → Control → PREVENT

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Thank you

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