The true cost of groundwater

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Groundwater in mining

Water supply:

- Dry regions - groundwater may be critical to operation e.g. Atacama, Patagonia, Pilbara
- Evaporation losses minimized
- Water “banking”, sharing and trading likely to occur in future

Groundwater in mining

Mine inflows/ dewatering:

- Groundwater inflows dominant factor in some operations
- High inflows not restricted to wet climates – e.g. Nevada gold mines
- Highest inflow mines often associated with carbonates; coal, lignite mines also often high inflows
- What to do with excess water?

Groundwater in mining

10 of the wettest metal mines:

Project	Company	Commodity	Location	Geology	Mine workings	Inflow rate	
						USgpm	L/s
Konkola	Vedanta	Cu	Zambia	Carbonates, sandstone	UG	165,900	5,050
Pomorzany	ZGH	Zn, Pb	Poland	Carbonates	UG	126,000	3,830
Christmas Creek	FMG	Fe	W Australia	Iron Formation, Dolomite	Pit	115,000	3,500
Cloudbreak	FMG	Fe	W Australia	Iron Formation, Dolomite	Pit	95,300	2,900
Grasberg	Freeport	Au, Cu	Indonesia	Carbonates	Pit, UG	72,200	2,200
Leeville	Newmont	Au, Cu, Ag	Nevada	Carbonates, metasediments	UG	51,600	1,570
Vibernum Trend	Doe Run	Pb, Zn, Cu, Ag	Missouri	Carbonates	UG	49,800	1,510
Hope Downs	Rio Tinto	Fe	W Australia	Iron Formation, Dolomite	Pit	39,500	1,200
Konkola North	Lubambe	Cu	Zambia	Metasediments	UG	38,200	1,160
San Vicente	SIMSA	Pb, Zn	Peru	Carbonates	UG	36,100	1,100

Groundwater in mining

Slope stability:

- Pit slope stability influenced by groundwater pore pressure

Generalities:

- High inflows = drained slopes
- Low inflows = undrained slopes
- Low rock strength – slope stability relatively sensitive to pore pressure
- But some notable exceptions!

Groundwater in mining

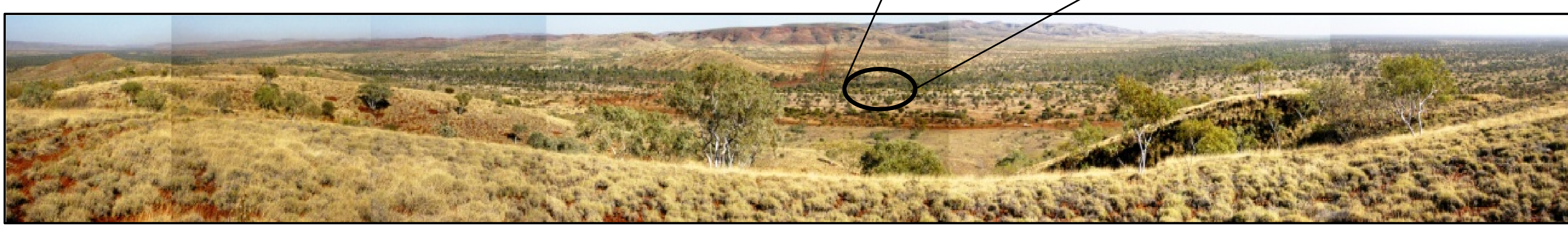
Environmental impacts/ closure:

- Groundwater contacting mine workings often creates AMD; on closure, leaking adits and poor-quality pit lakes – often requires water treatment over long-term – can migrate offsite
- Precipitation contacting mine waste often creates AMD which seeps to the water table
- Mine drawdown of water table can affect supply of neighbouring users and surface water bodies/ ecosystems
- Subsidence from water table drawdown

Groundwater in mining

Groundwater-dependant ecosystems:

- Characterized by biodiverse flora, fauna and cultural significance:
  - Springs, freshwater and brackish marshes and ephemeral rivercourses
  - Forested areas with shallow water tables and largely or partially phreatophytic vegetation
  - Subsurface ecosystems



Groundwater in mining

Mine safety:

- Groundwater plays a role in many mine fatalities, notably:
  - Ground failures in open pit and underground mines
  - Sudden water inrushes
  - Mud rushes
  - Tailings and waste rock pile collapse
  - Sinkhole collapse

How groundwater affects economics

Water supply:

- Lack of available groundwater can sometimes result in large pipeline / water treatment costs (e.g. Escondida)
- Security of supply critical

How groundwater affects economics

Dewatering:

Major direct costs associated with wet pits:

- Delays to production
- Increased haulage and tire maintenance costs
- Increased blasting and explosives costs
- Ore drying – ore moisture

How groundwater affects economics

Dewatering:

Major indirect costs associated with wet pits:

- Loss of production as below water table (BWT) tonnes unavailable - extra haulage to access replacement ore and short-term loss of in-pit dumping sites
- Capital brought forward to open replacement pit or pit expansion as BWT pit is unavailable

How groundwater affects economics

Dewatering/ slope stability:

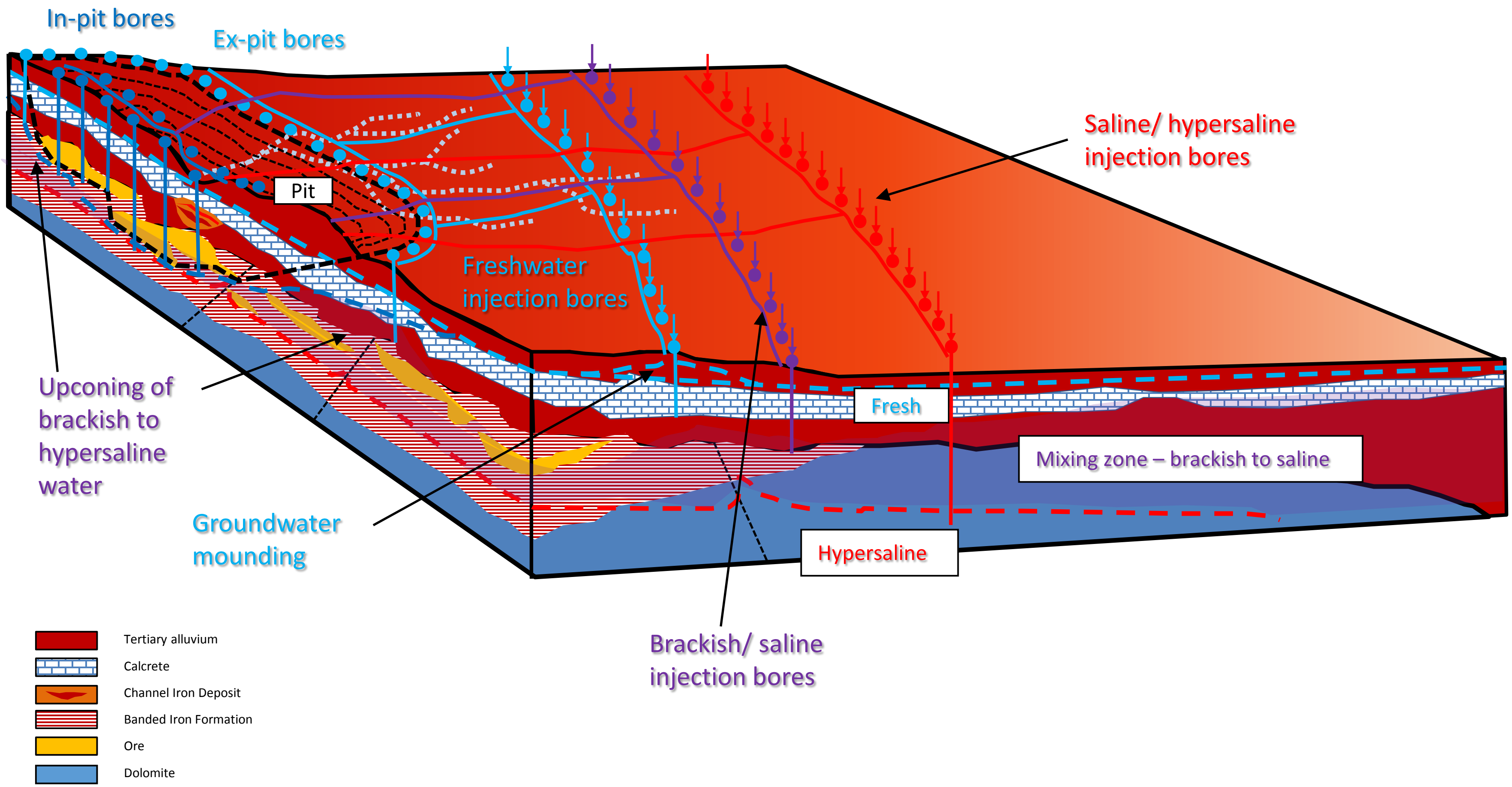
- Strip ratio increased by flatter slopes due to high pore pressure
- Ore lost when depth is limited by slope stability
- Price penalties occur as desired ore becomes unavailable and must be substituted by inferior product
- Costs associated with loss of optionality

How groundwater affects economics

Excess water management – dry areas

- Most excess water discharged to surface, resulting in unsustainable artificial ecosystems; discharges of some mines contributing to inflows at others
- Surface discharge often not favored
- Now:
    - Irrigation – increasingly utilized (e.g. Pilbara (alfalfa), Peru woodlot)
    - Evaporation ponds
    - Piping of water from mines in excess to ones in deficit
    - Reinjection; often best option for brackish to saline water; injection bores and recharge basins used

MAR Schematic – Fortescue Valley



How groundwater affects economics

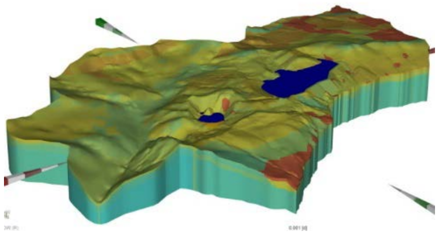
Mine closure:

- Leaking mine adits, leaching from waste rock, tailings and leach piles can result in long-term water treatment legacy delay in handover

How groundwater affects economics

Common dilemmas:

- Groundwater regime often inadequately characterized as project advances to mine; costing often not feasibility-level at feasibility stage
- Principle reason is complexity of groundwater systems, low budgets to characterize and inadequate use of other sources of data
- Result: detailed designs for dewatering systems, pit slopes and water management systems often based on poor understanding of groundwater occurrence and inflows
- Too often results in surprises



Caption/Description

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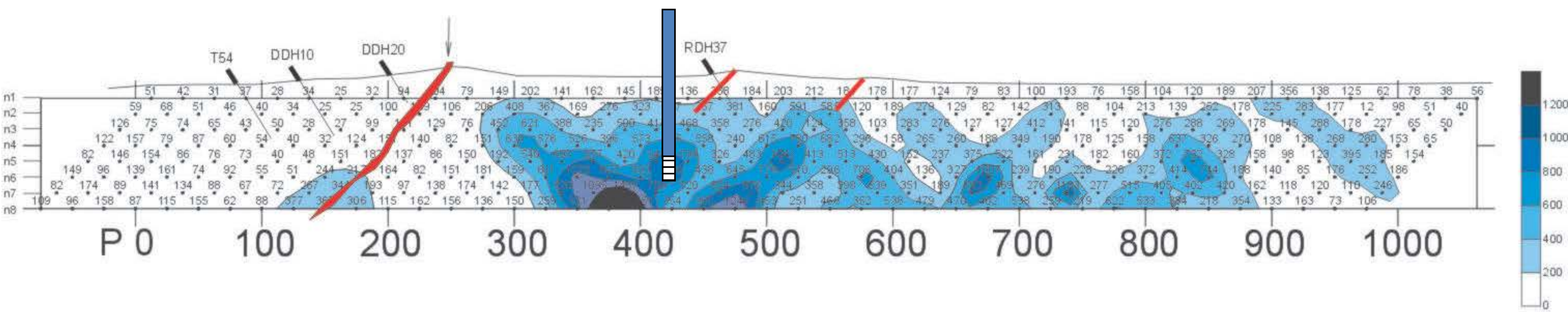
Managing groundwater

Collect good data, early:

A lot of good quality hydrogeological data may be collected at very low cost at drilling exploration stage, including:

Geophysics

- Consider hydrogeological application when running surface and downhole geophysics



Managing groundwater

Collect good data, early (cont'd):

Drilling

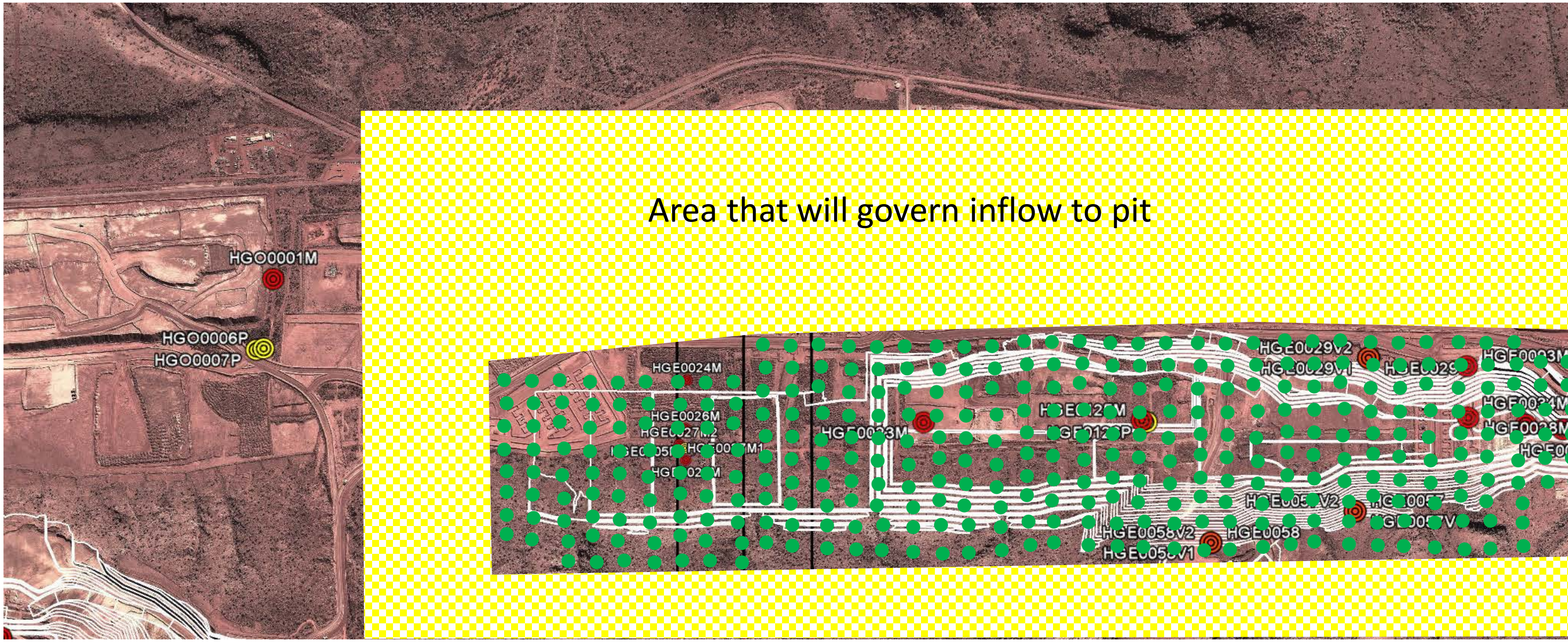
- Diamond drill and mud rotary circulation losses
- Elevated hydraulic pressures encountered
- Air rotary airlift yields
- Document below water table voids closely

Managing groundwater

Utilize exploration, geotechnical, metallurgical holes:

- Packer-based hydraulic testing
- Open hole piezometric monitoring
- Piezometer installations (standpipe and VWP)
- Good quality installations
- Holes in pit slopes where pore pressure may be an issues may act as passive drains, particularly if outfitted with slotted PVC casing after drilling; also permits access for monitoring or installation

Managing groundwater



- Use mineral exploration drilling to define deposit hydrogeology, other drilling to define hydrogeology external to pit

Managing groundwater

Mine dewatering – maintaining production:

- Large scale of mine pits and "ore is aquifer" hydrogeology - dominantly in-pit dewatering. To minimize interference:
  - Maximize production capacity of in-pit bores;
  - Improve survivability of in-pit bores through robust design, blasting ballast and controlled blasting around bores;
  - Ensuring dewatering infrastructure is ready in advance and with adequate capacity;
  - Minimize downtime through blast cycles through rapid removal and re-establishment of pumps;
  - Taking advantage of ex-pit or bench dewatering when opportunities arise.

Thank you

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