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# ***2012 Americas School of Mines***

## **Basics of Mining and Mineral Processing**

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# *Agenda*

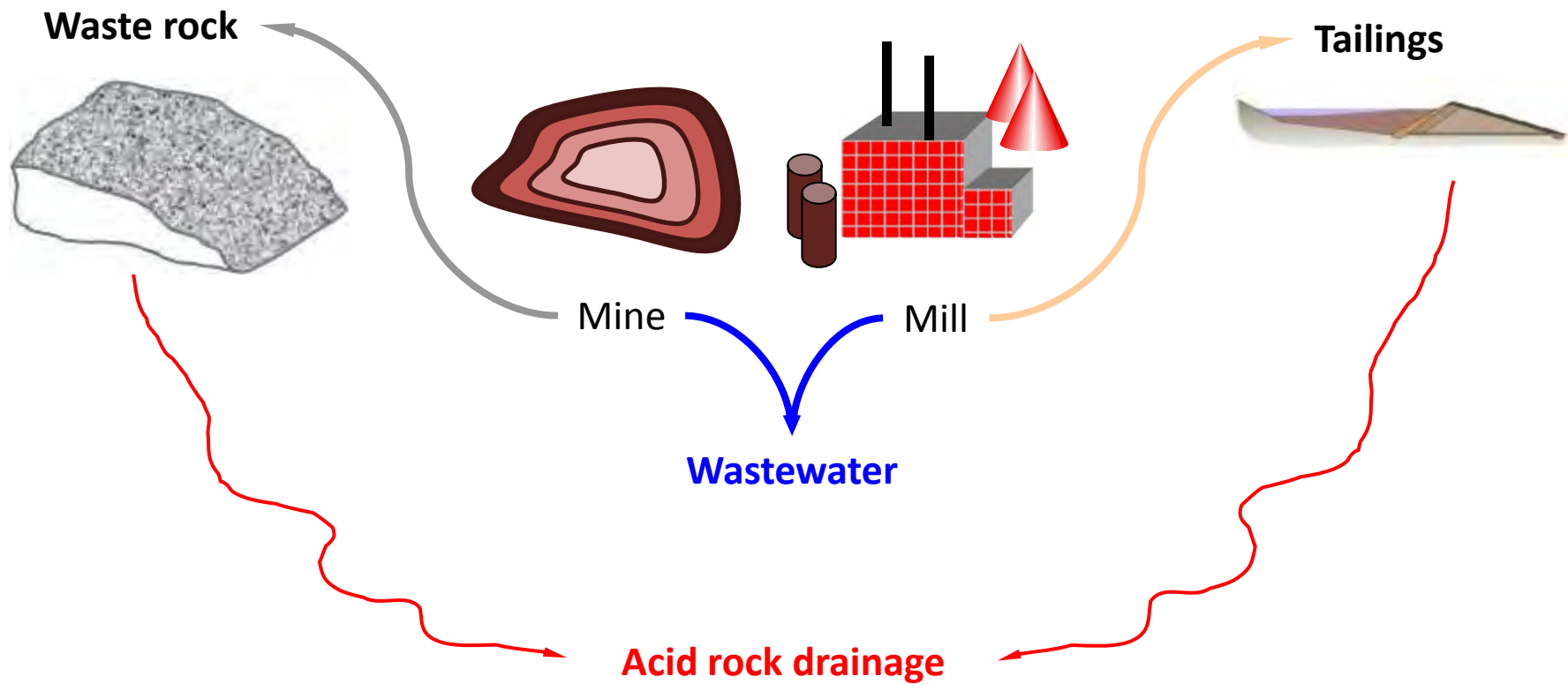
- Geological Concepts
- Mining Methods
- Mineral Processing Methods
- Mine Waste Management
- Mining and Money
- A Future of Mining

# ***Mine Waste Management: The Topics***



[www.edwardburtynsky.com](http://www.edwardburtynsky.com)

# ***Mine Waste Streams***



# ***Tailings***

Finely ground rock from the concentrator/processing plant  
Particles  $\leq 0.1$  mm in diameter (sand and silt)

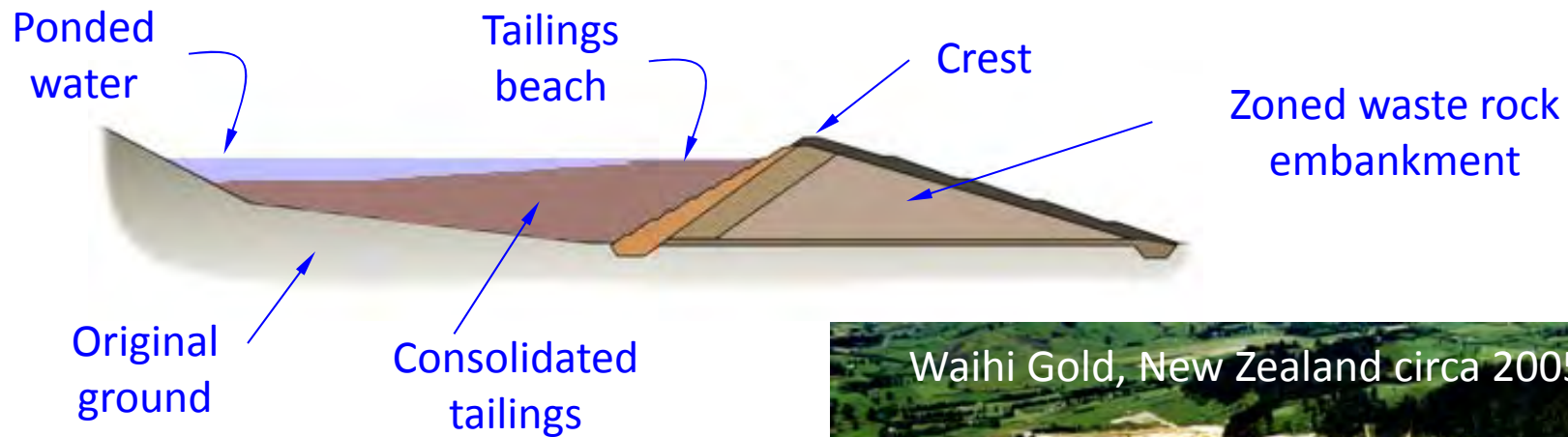
## Three basic forms of disposal

wet tailings in slurry form

thickened tailings

dewatered tailings

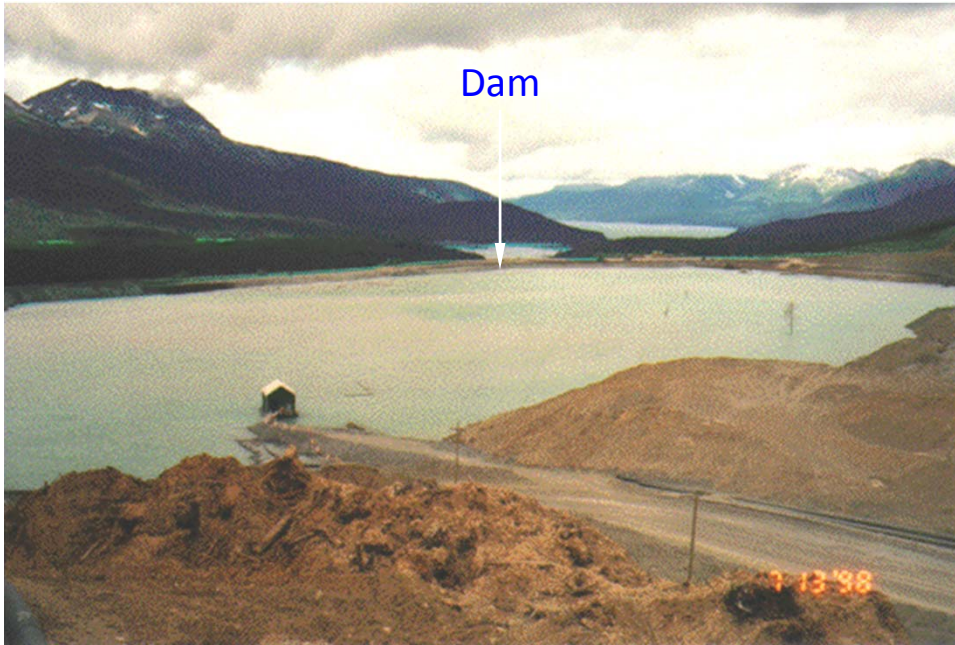
# Wet Tailings Deposition



[www.newmont.com](http://www.newmont.com)



# *Tailings Ponds*

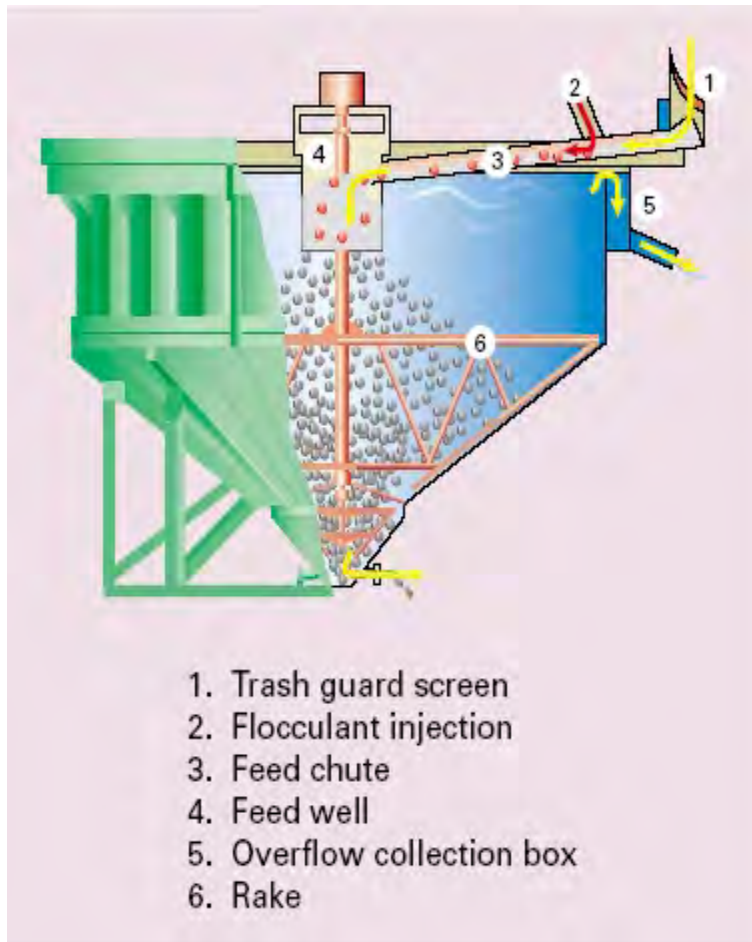


Huckleberry Mine, BC

Subaqueous tailings disposal RPM  
gold mine, Brazil



# *Dewatering by thickener*



[www.mining-technology.com/contractors/separation/cde-global](http://www.mining-technology.com/contractors/separation/cde-global)

Thickener cross-section



# ***Thickened Tailings***



Thickened tailings at Kidd Creek Ontario  
[www.tailings.info/thickened.htm](http://www.tailings.info/thickened.htm)

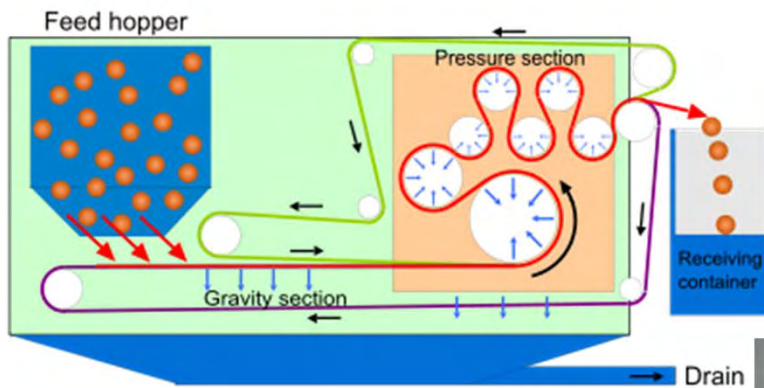
This ...  
thickened, wet enough to pump  
through a pipe, but dry enough to  
minimize flow after discharge  
⇒ smaller footprint



Single point discharge at Glebe Mines UK  
[www.tailings.info/deposition.htm](http://www.tailings.info/deposition.htm)

versus this

# *Dewatering by a belt press*



Slurry in the feed hopper is sandwiched between two filter cloths (shown green and purple). Fluid is extracted initially by gravity, then by squeezing the cloth through rollers. Filtrate exits through a drain, while solids fall into a container.

[http://en.wikipedia.org/wiki/Belt\\_filter](http://en.wikipedia.org/wiki/Belt_filter)

Expensive, but necessary if water is needed especially in a dry climate.

Also used to dry mineral concentrates.



## ***Dry Tailings (La Coipa, Chile)***



Dry climate - need to conserve water for processing ore so tailings are dewatered and deposited dry.



# ***Antamina Tailings Dam, Peru***

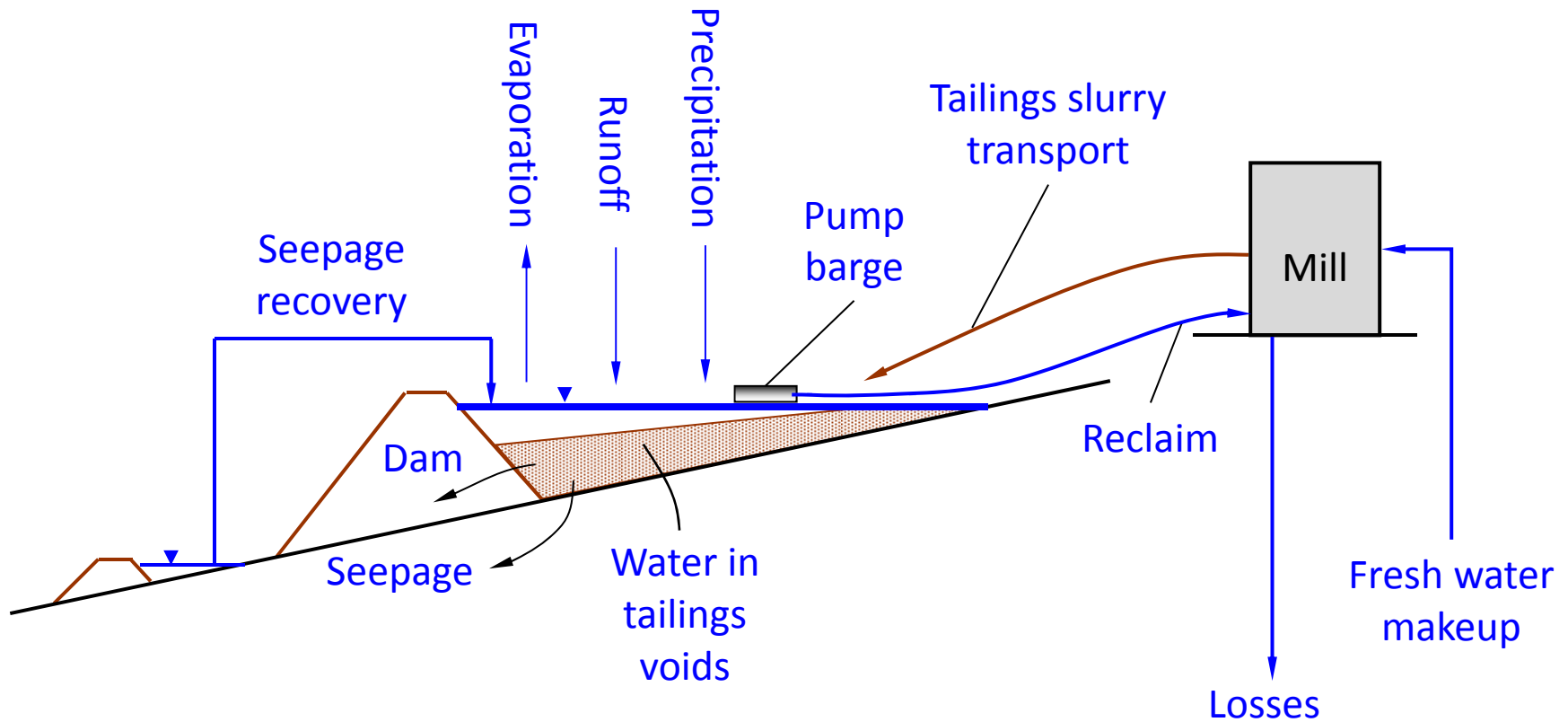
Rockfill dam with upstream concrete face



Capacity: 570 million tonnes  
Ultimate height: 240 m

Source: Golder Associates [www.golder.com/sa](http://www.golder.com/sa)

# ***Tailings Water Balance***



Monitored closely to check for leaks. No tailings pond, no processing.

# ***Oil sands tailings***





## ***Notes: Oil sands tailings***

Fine clay particles derived from processing of oil sands remain suspended in large lagoons near processing plants. Clay slurry retains water that must be re-used in processing. Fines and water can be separated with flocculants, but flocculants in recycled water interfere with oil sand processing.

As of 2008, about 750 million cubic metres of fluid clay tailings exist within the tailings ponds near oil sands operations in Fort McMurray. If there is no change in processing method or tailings management, the amount of fluid tailings is forecast to reach one billion cubic metres in 2014 and two billion in 2034.

# ***Waste Rock Dumps***

Non-mineralized rock and/or low grade ore  
Particle sizes range from clay size to 2m



# ***Morenci mine waste pile***



## ***How much tailings and waste?***

Consider a copper mine with 0.5% grade  
170,000 tonnes per day x 360 days per year x 20 years  
⇒ 1.224 billion tonnes waste + ore

Suppose the strip ratio is waste/ore = 0.5. This gives  
816 million tonnes ore and **408 million tonnes waste**

Suppose 27% copper concentrate is produced, recovery 90%  
This yields 13.6 million tonnes concentrate  
leaving  $816 - 13.6 =$  **802.4 million tonnes tailings**

**8 million tonnes of concrete were used to build the Hoover Dam**



## ***Notes: How much tailings and waste?***

Consider a copper mine with 0.5% grade (That's one part in 200 parts). If the mining rate is 170,000 tonnes per day, 360 days per year over 20 years, 1.224 billion tonnes (Bt) of waste + ore will be produced.

Suppose the strip ratio is waste/ore = 0.5. If waste + ore = 1.224 Bt, then 816 million tonnes ore and **408 million tonnes of waste will be produced.**

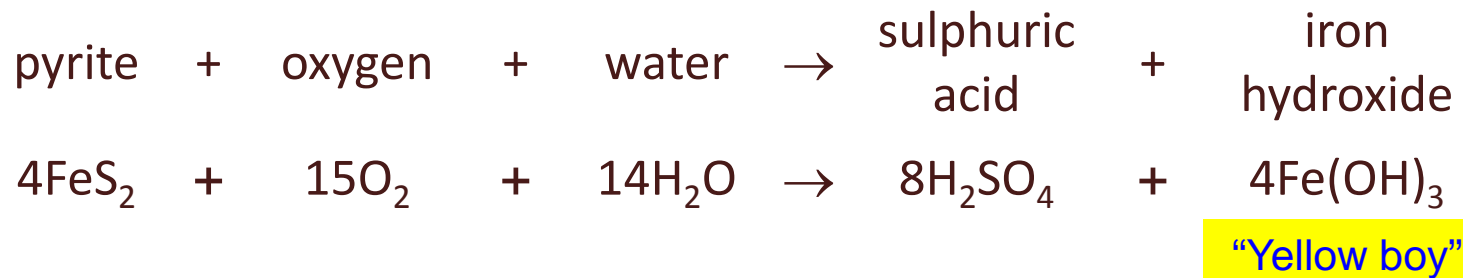
Suppose a concentrate with grade 27% copper is produced and the recovery is 90%. A simple mass balance gives

$$K \text{ tonnes ore} \times 0.005 \times 0.9 = 1 \text{ tonne concentrate} \times 0.27$$

From which  $K = 60$  tonnes ore to produce one tonne of concentrate. Thus from 816 million tonnes of ore  $816/60 = 13.6$  million tonnes concentrate will be produced. This leaves  $816 - 13.6 =$  **802.4 million tonnes of tailings.**

# ***Acid Rock Drainage (ARD)***

Acid produced by exposure of sulfide minerals to air and water (an oxidation reaction). For example, pyrite:



Similar reactions for other metal sulfides  
⇒ metal contaminated water

Treatments:

Add lime to neutralize acid, but does nothing about metal contamination. Also expensive

Prevent by flooding – keeps the oxygen out



# ***Some Examples of ARD***



Some ARD is natural. Acid may be produced from a mineral deposit containing pyrite if exposed to air and natural water flows through it. Nearby creeks or rivers will have high acid concentrations and no plant life.

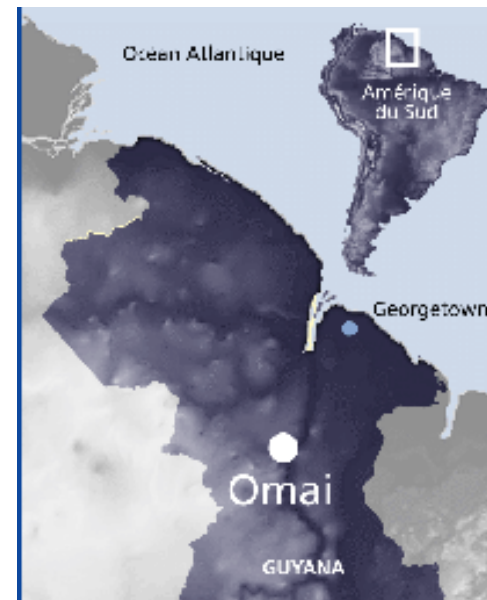
# ***Tailings Incidents***

- Stava, Italy (July 1985)
- Merriespruit, South Africa (Feb 1994)
- Omai, Guyana (Aug 1995)
- Marcopper, Philippines (Mar 1996)
- Los Frailes, Spain (April 25, 1998)
- Ajka, Hungary (October 4, 2010)

# ***Omai, Guyana***

Internal erosion caused crest of tailings dam to drop over 1 m  
Cyanide-laced tailings water released into the Omai river

Internal erosion to be explained



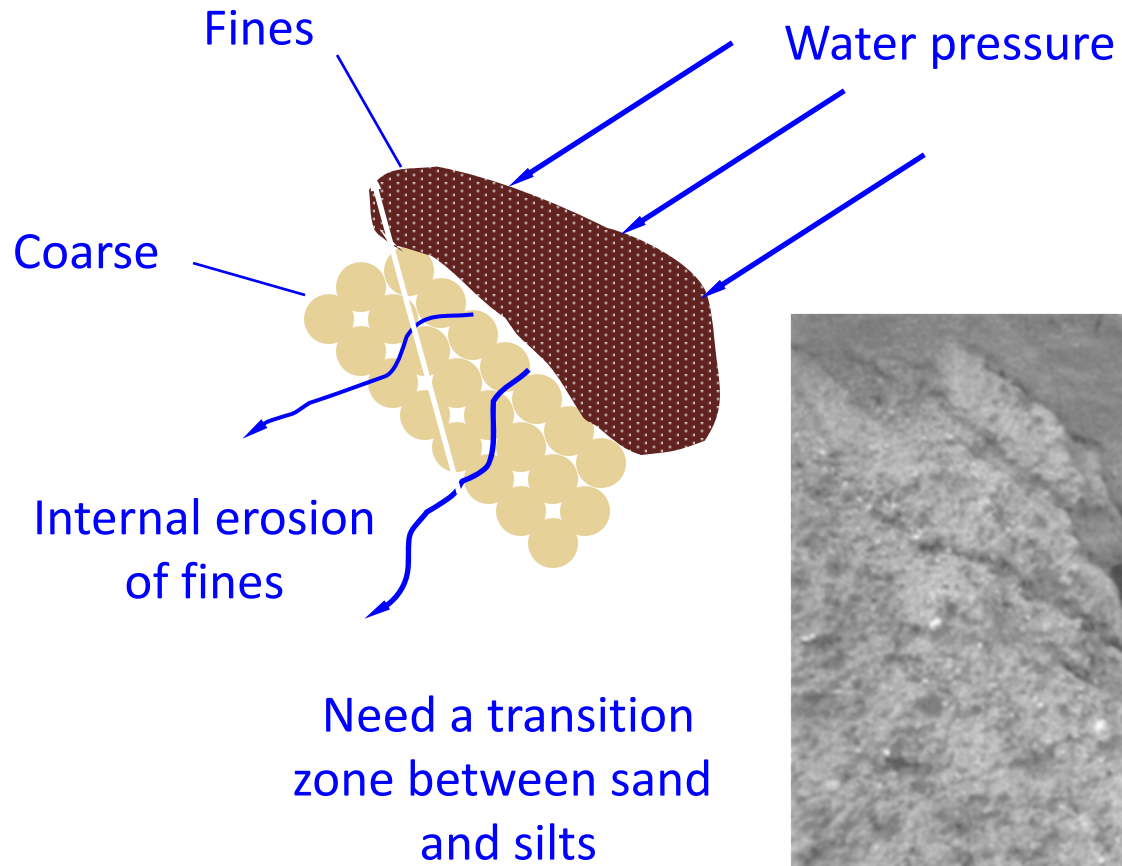
# *The crest slump at Omai*



August 1995

Photo source: Mineral Policy Center

# ***Never let this happen!***



## ***Notes: Never let this happen!***

The story is that suitable material to continue building the dam became unavailable, but production continued. So the cyanide-laced tailings were coming with no dam to contain them. Mine personnel used what was available – crushed waste rock. This was too coarse-grained and the sandy material used to build the dam filtered through it.



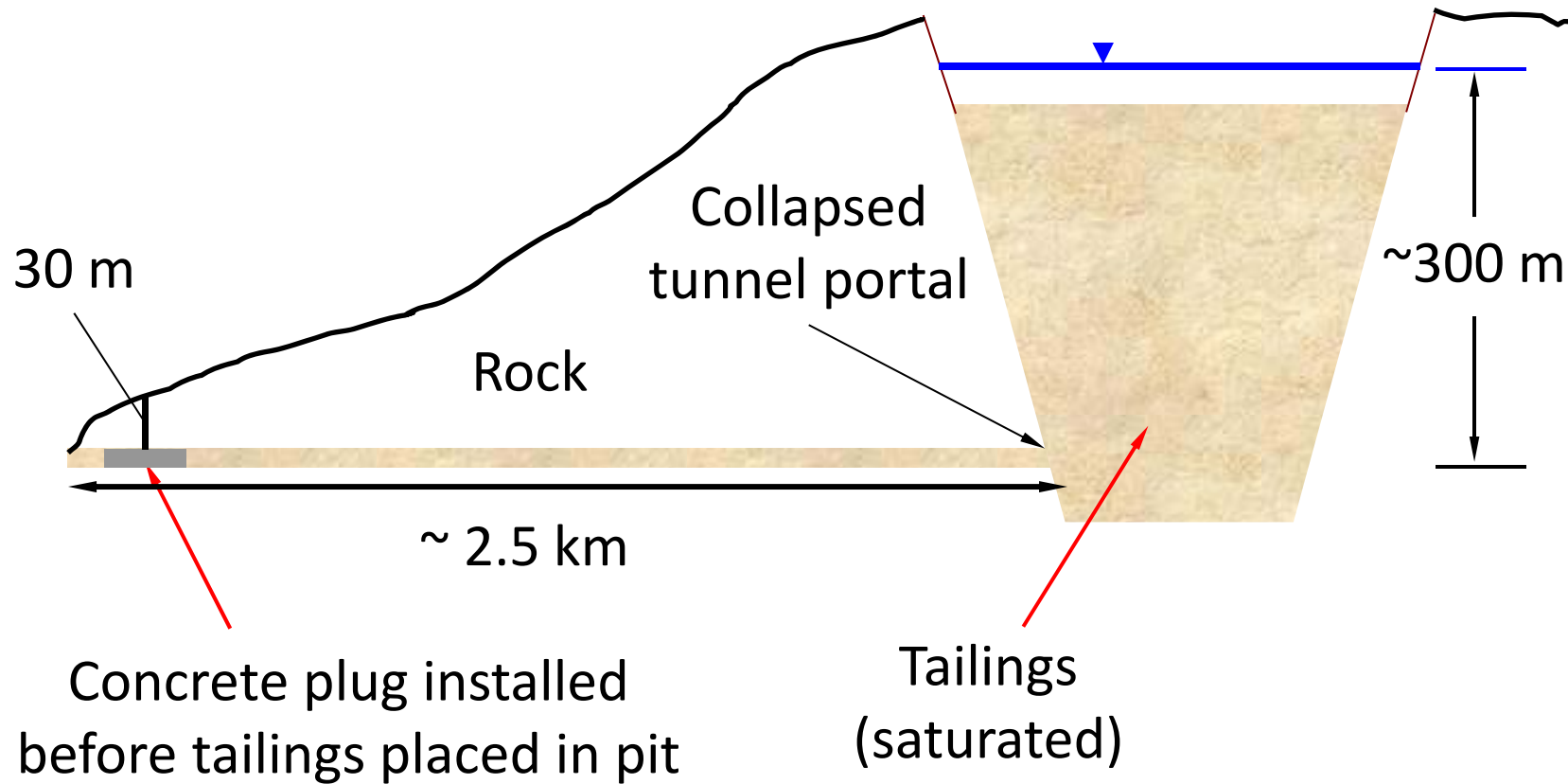
# Marcopper Philippines, Tapian Pit



Catherine Coumans, 1987

Tunnel from pit used to drain the pit when it was in operation

# ***Tapian Pit: Cross-section***



## ***Notes: Tapan Pit Cross-Section***

How much water pressure was on the rock around the plug? That is easily computed:

$$\begin{aligned} P &= \text{density of water} \times \text{acceleration due to gravity} \times \text{height of water} \\ &= 1000 \text{ kg/m}^3 \times 9.8 \text{ m/sec}^2 \times 300 \text{ m} \\ &= 2,940,000 \text{ Pascals} \end{aligned}$$

That's about 426 pounds per square inch (psi). (By way of comparison, your car tire pressure is 40-50 psi.) But what was the pressure in the ground where the rupture occurred? That is also easily computed. The depth of rock over the rupture was about 30 meters. The density of most rock is between 2000 and 2500 kg/m<sup>3</sup>. Let's estimate a range of rock pressure:

$$\begin{aligned} P &= \text{density of rock} \times \text{acceleration due to gravity} \times \text{depth of rock} \\ &= (2000 \text{ to } 2500) \text{ kg/m}^3 \times 9.8 \text{ m/sec}^2 \times 30 \text{ m} \\ &= 588,000 \text{ to } 735,000 \text{ Pascals} \end{aligned}$$

That's a range of 85 psi to 107 psi. So there is 426 psi of water pressure up against 85 to 107 psi of rock pressure. What do you think will win? (Hint: The concrete plug would likely not crack – way too strong.)

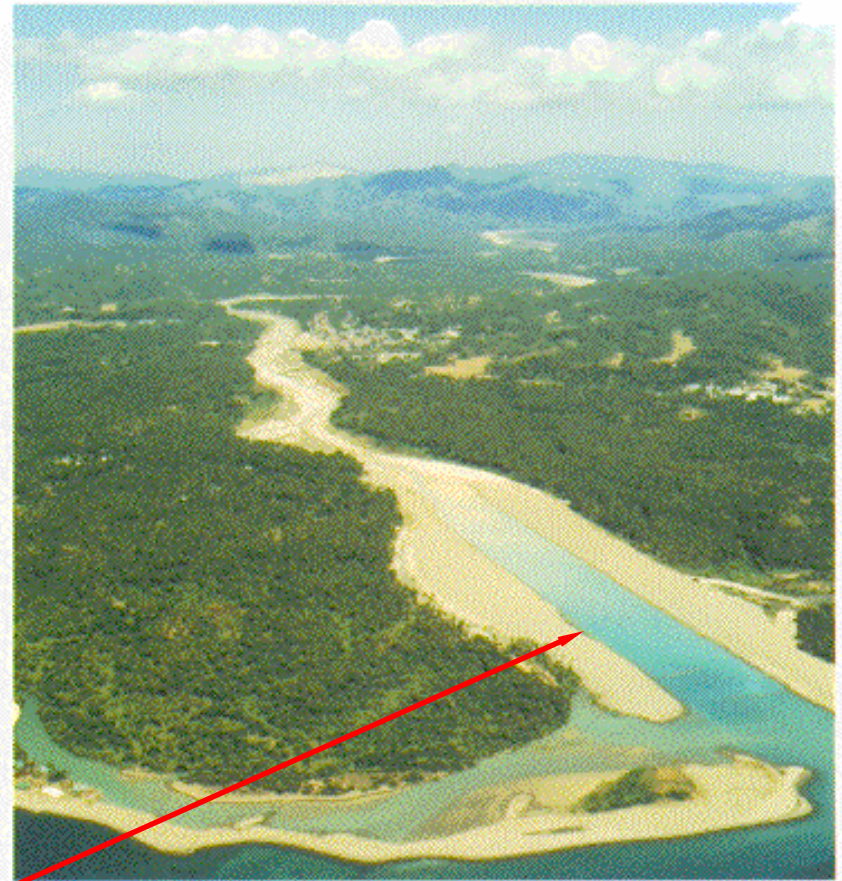


***March 24, 1996***



The physics worked. Rock around the plug fractured causing leaks. 1.6 million m<sup>3</sup> of tailings were released into the 26 km long Boac river.

Dredged channel at mouth of Boac River

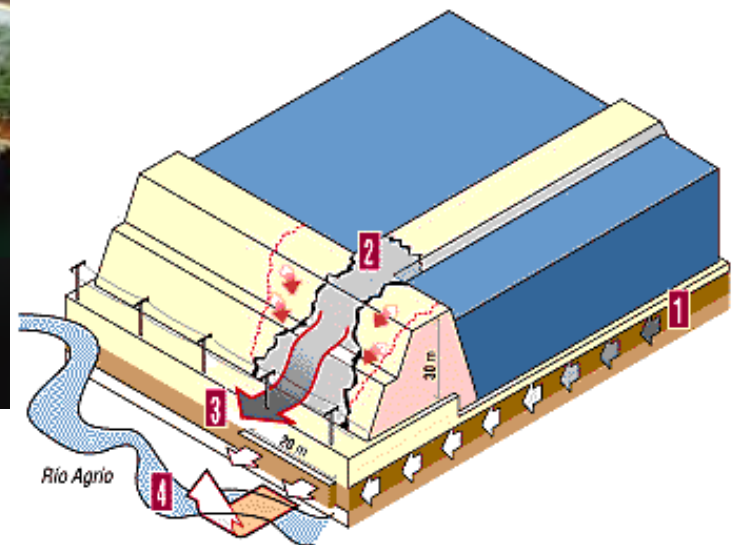


# Los Frailes Spain



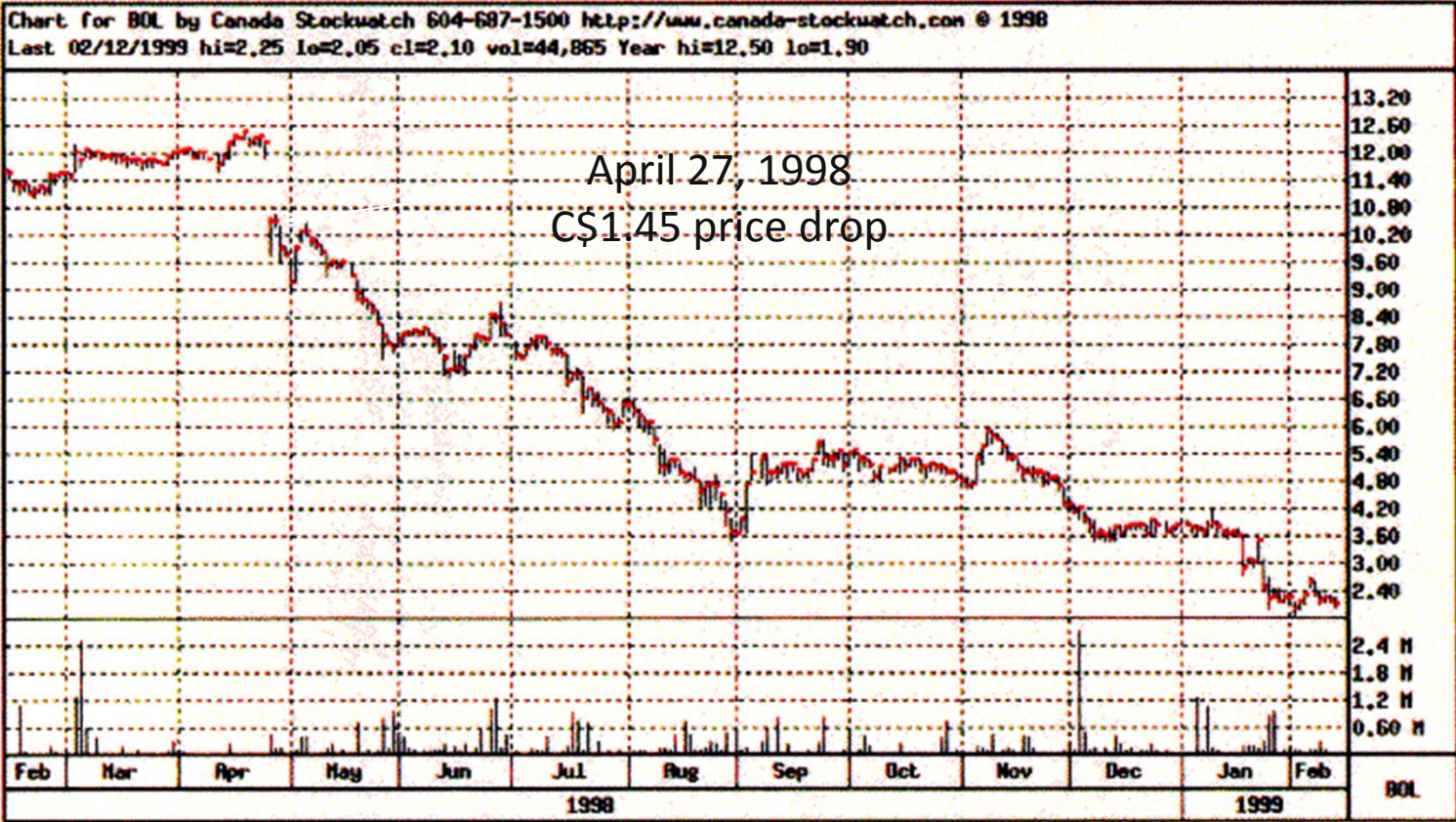
1.3 million m<sup>3</sup> tailings and 5.5 million m<sup>3</sup> acidic tailings water released into Rio Agrio

Deep failure in foundation caused rupture of dam





# *The market clobbers Boliden share price after the Los Frailes incident*





# ***Aluminum plant at Ajka, Hungary***

Untreated waste kept behind large dam which failed

October 4, 2010



# ***A 800,000 m<sup>3</sup> spill***



40-45% iron oxide  
10-15% aluminum oxide  
10-15% silicon oxide  
plus other metal oxides

Seven people killed, 150 injured, 500 displaced

\$100 million in fines imposed on company

Manager of company arrested, company assets seized

Criminal negligence charges being considered

# ***The Real Costs***

- Lives lost
- Environmental damage
- Criminal charges and jail terms
  - mine managers guilty by reason of association
- Lawsuits
  - from locals and interest groups representing locals
- Cleanup costs and liabilities
  - large range: \$500 million to \$4 billion
- Loss of reputation and  
**possible loss of social license**

***Could something as bad as this happen in the mining industry?***

Deepwater Horizon oil spill  
aka the *BP oil spill*, the *Gulf of Mexico oil spill*, the *BP oil disaster*,  
or the *Macondo blowout*  
April 20, 2010



# ***Reclaimed Tailings***

Highland Valley, BC





# ***Reclamation at Waihi Gold, New Zealand***



[www.newmont.com](http://www.newmont.com)



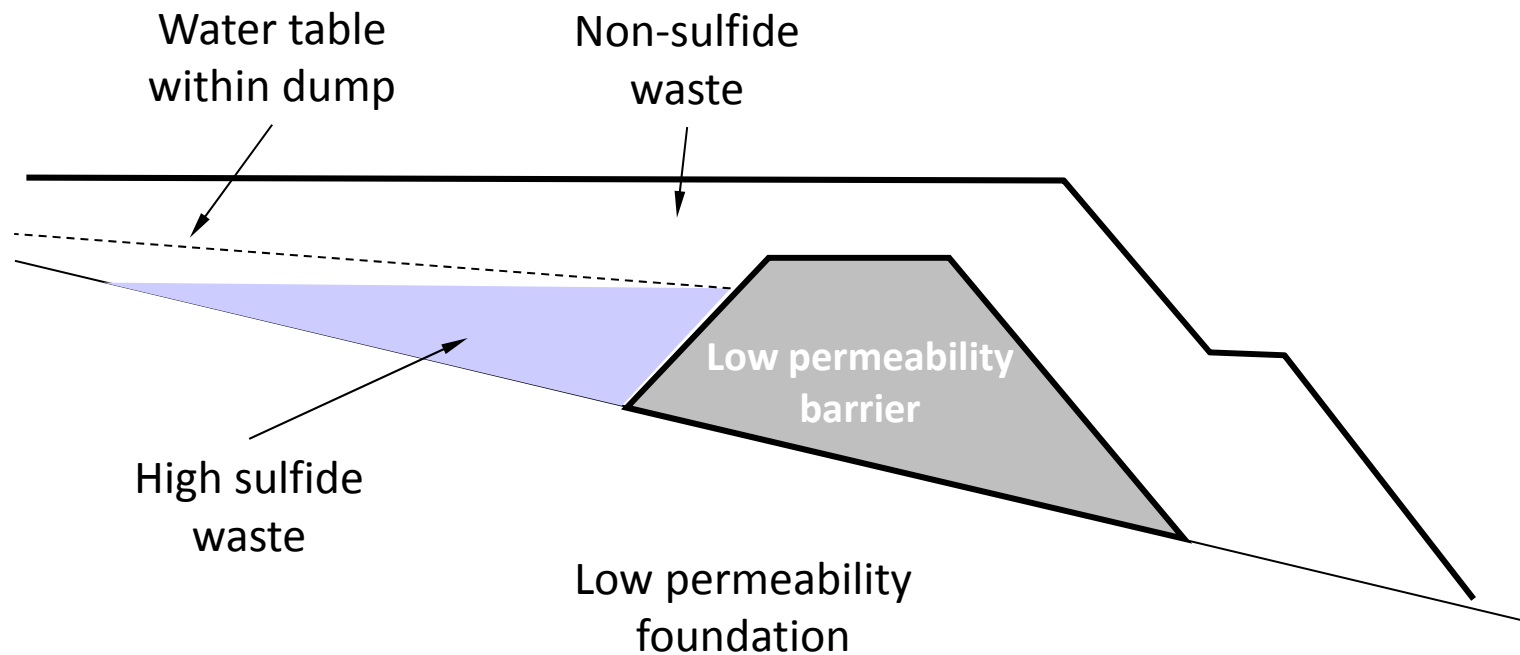
[www.marthamine.co.nz/waste\\_tailings.html](http://www.marthamine.co.nz/waste_tailings.html)

# ***Kidston Gold Mine, Australia***



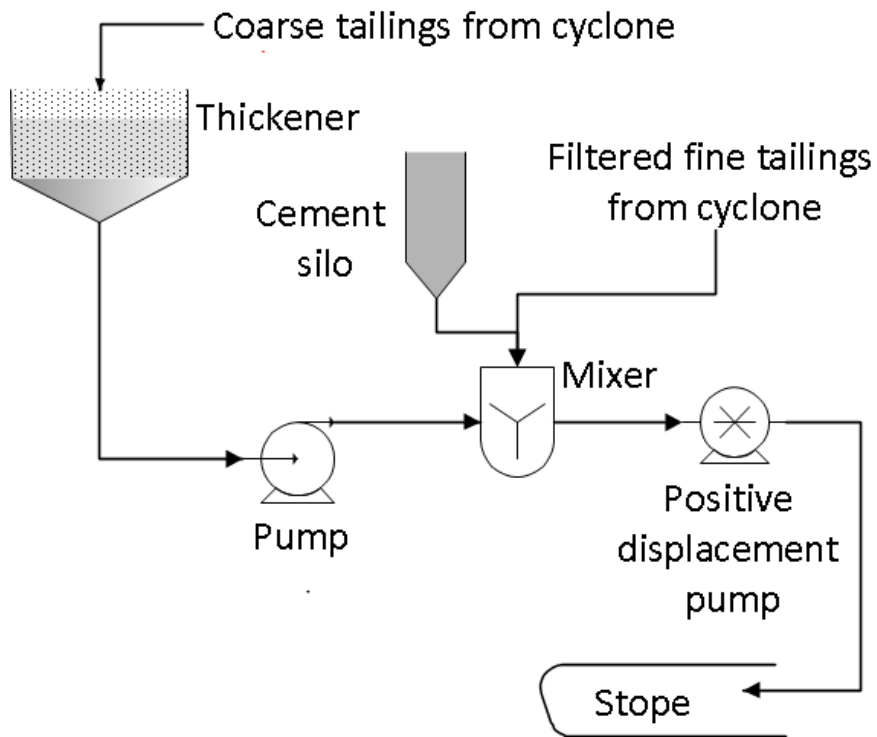
Source: Golder Associates, 2005. Codisposal. Available at: [www.infomine.com/publications/docs/CodisposalPresentation.ppt](http://www.infomine.com/publications/docs/CodisposalPresentation.ppt)

# ***Cover sulfide waste with non-sulfide waste***



Goal is to maintain saturation of high sulfide waste  
Can be designed given disposition of waste types in orebody model

# ***Cemented paste backfill***



Cemented paste poured into stope  
at Lisheen mine, Ireland

[www.lisheenmine.ie/?Backfill](http://www.lisheenmine.ie/?Backfill)





# ***Myra Falls, British Columbia***



www.em.gov.bc.ca

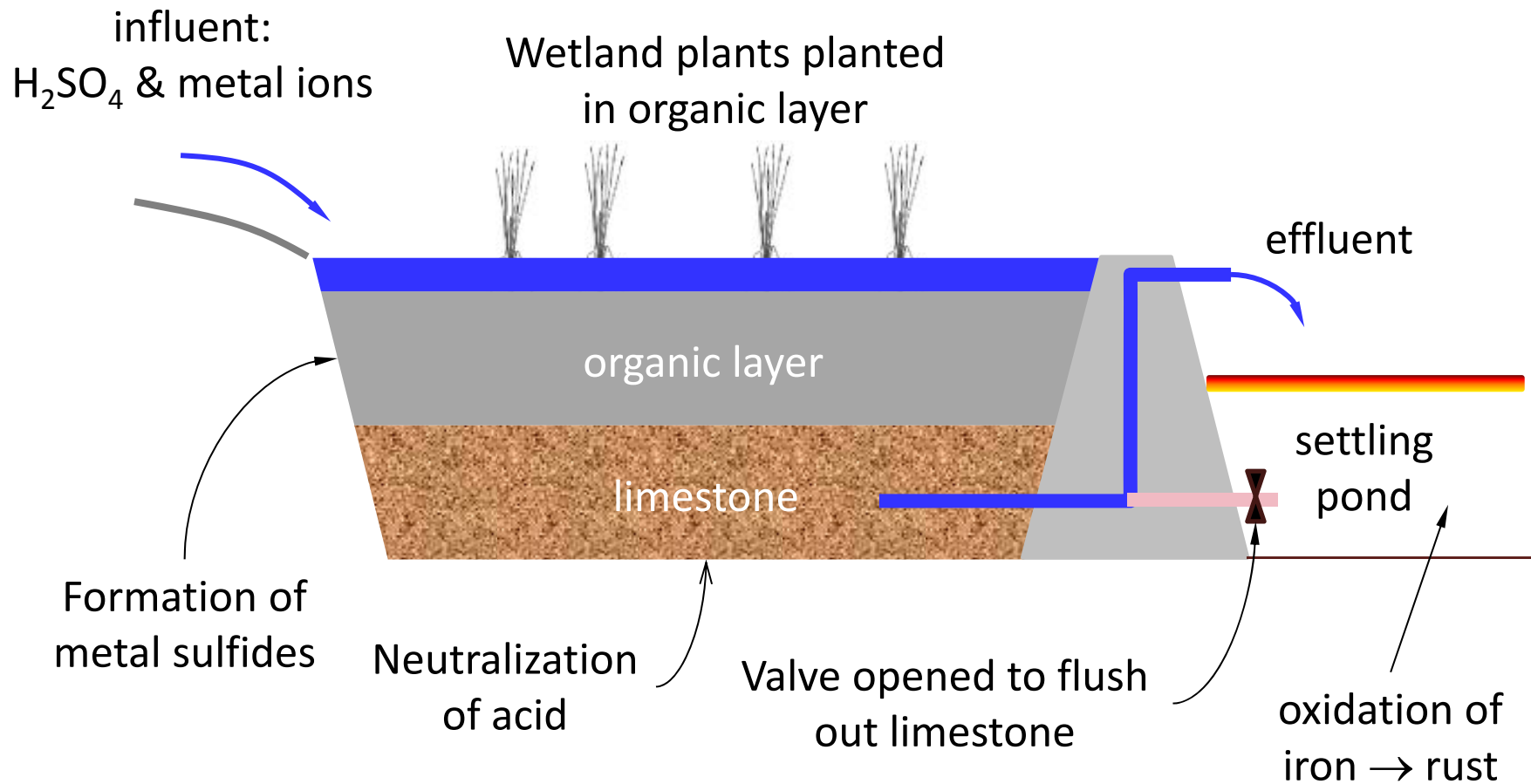
Underground mine:  
Cu, Zn, Pb with Au and Ag

Situated in Strathcona Provincial Park

Tailings pond? This is it and there's no  
more room for coarse tailings  
Must use paste backfill



# ***Passive treatment of ARD***



# ***Treatment of ARD in Pennsylvania***



[www.somersetcountyconservancy.org/restoration.html](http://www.somersetcountyconservancy.org/restoration.html)

# ***Co-disposal***



Dewater tailings, combine with waste rock



# END OF PART 4

