Moving Towards no Tailings Dams
BOHOGS – 25 September 2014

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Constraints under which TSFs Must Operate

- Climatic and topographic setting of TSF
- Processing plant tailings production rates
- Need to manage, store, and recycle when possible, supernatant tailings water
- Need to meet discharge water quality licence requirements
- Need to maximise tailings settled dry density, and hence minimise wall raising and tailings storage volume
- Need to facilitate upstream wall raising, where appropriate
- Need to rehabilitate TSF on closure to minimise environmental impacts and achieve some post-closure land use or function

Tailings Continuum (Davies, 2004)

Slurry-like:
No particle/particle interaction
Saturated
No effective stress

Complex water management
Inefficient water recovery
Containment required
Seepage likely
Rehabilitation difficult

Likely low OpEx and CapEx, but high rehabilitation cost

Tailings slurry
(typically segregating)

Thickened tailings
(dewatered, ideally non-segregating)

Paste tailings
(Dewatered, ideally non-bleeding)

Pumpable

Non-pumpable

CONTINUUM

"Wet" filter cake
(near-saturated)

"Dry" filter cake
(85 to 70% saturated)

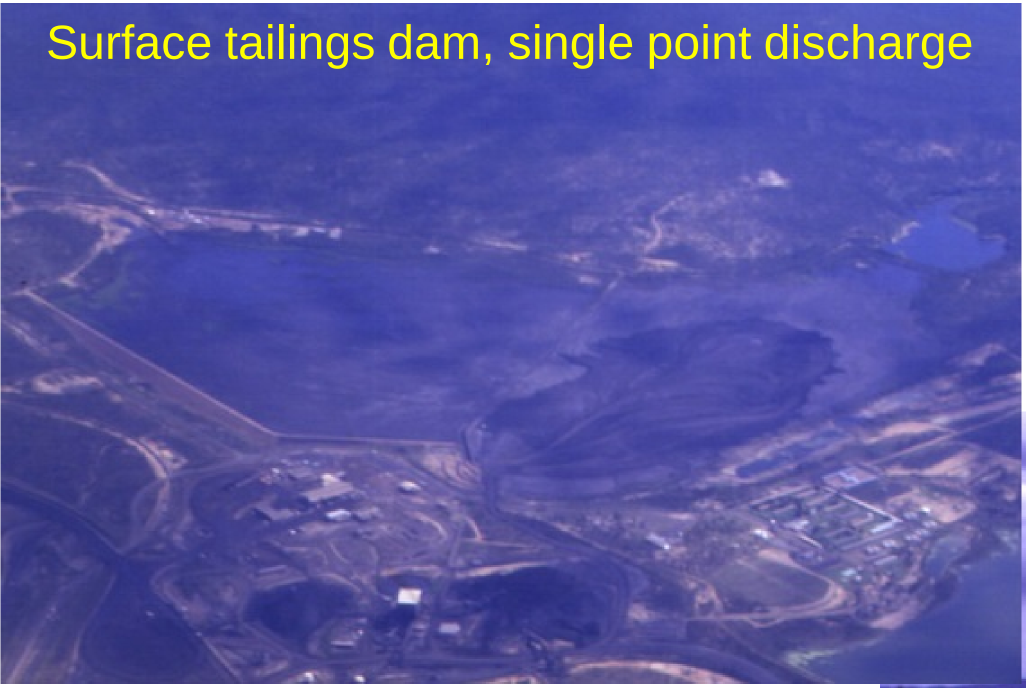
Simple water management
Efficient water recovery
Process chamical recovery
Minimal containment required
Negligible seepage losses
Progressive rehab. possible
Stable tailings mass

High OpEx and CapEx, but low rehabilitation cost

Soil-like:
Particle/particle interaction
Effective stresses and suction
Shear strength

Consistency of Tailings

Conventional Surface Tailings Dam and Pumped Co-Disposal



Issues with Conventional Surface Tailings Dams

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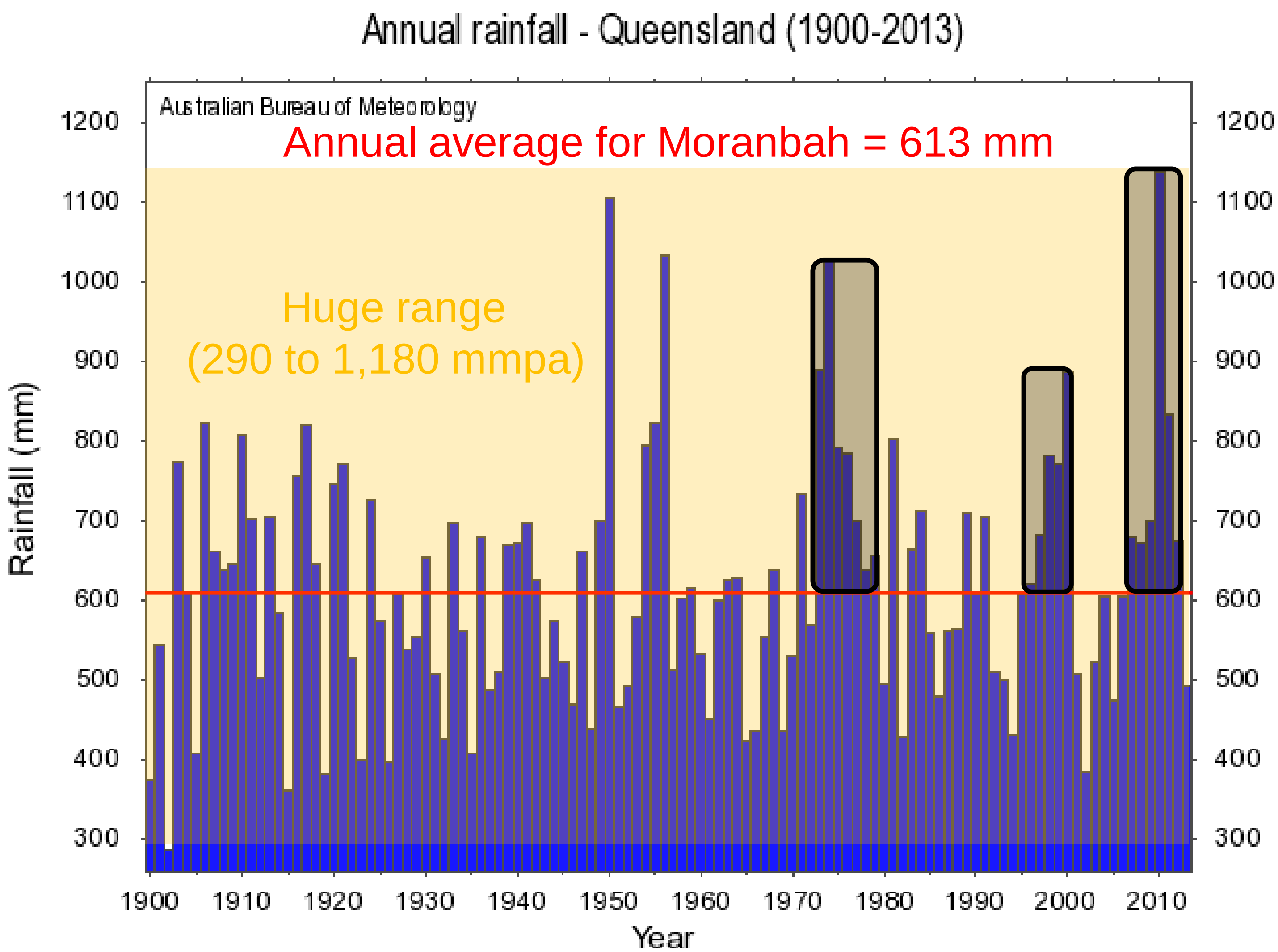
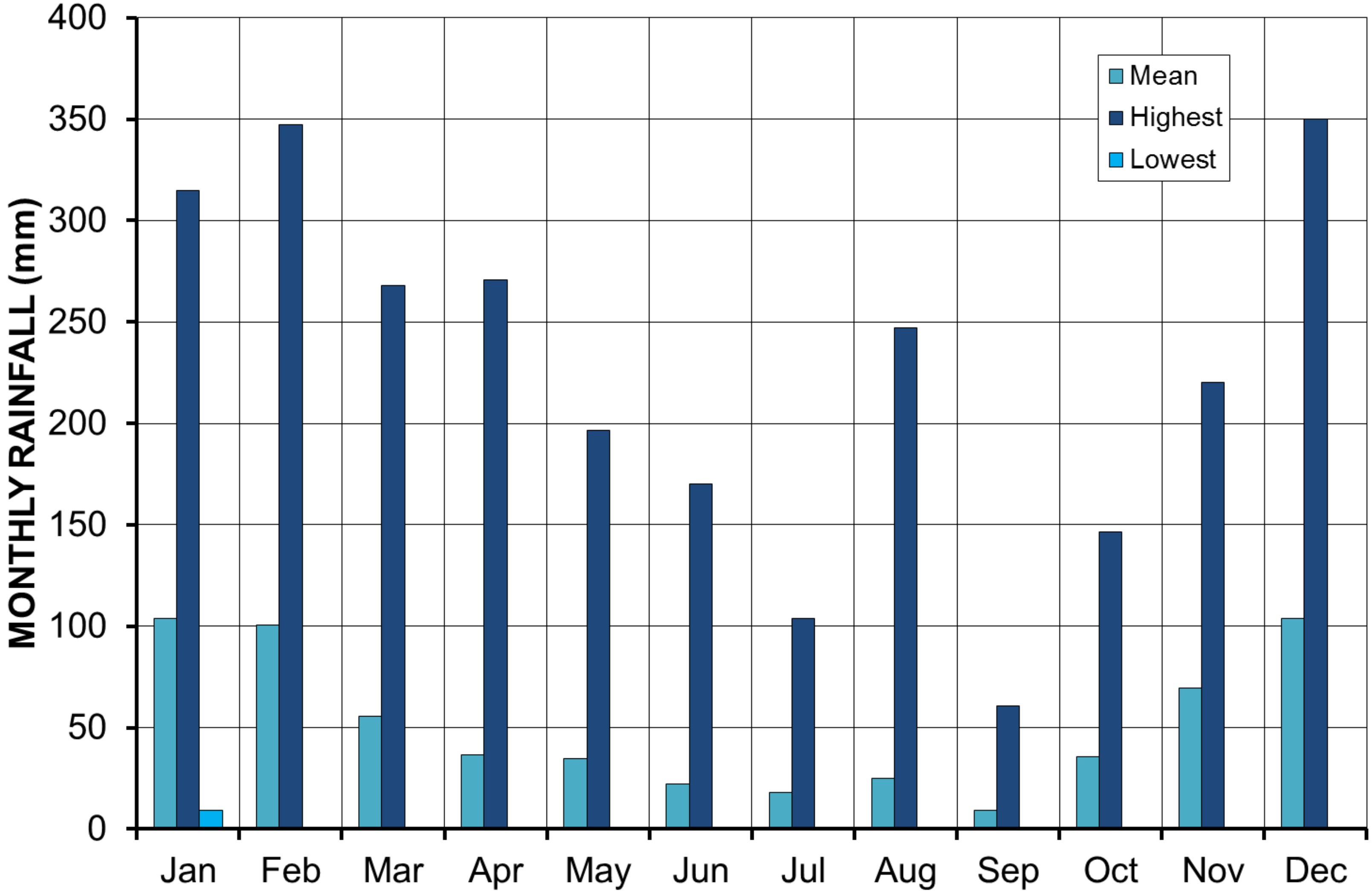
CONVENTIONAL APPROACH	ISSUE
<35% solids by mass (typically 25%)	>80% water by volume discharged, leading to storage mainly of water and water losses to evaporation and seepage
Single point discharge	Poor utilisation of storage volume, and difficulty in directing supernatant water to decant
Beaching and sorting	Low % solids leads to greater segregation, and reverse sorting carries coal-rich tailings to pond
Pumped co-disposal	Low % solids (~25% by mass) and high velocity (~4 m/s) lead to wash-out of fines to a tailings-like beach, requiring containment
Cap and rehabilitate crusted tailings	Soft or poorly-crusted tailings are difficult to cap and rehabilitate

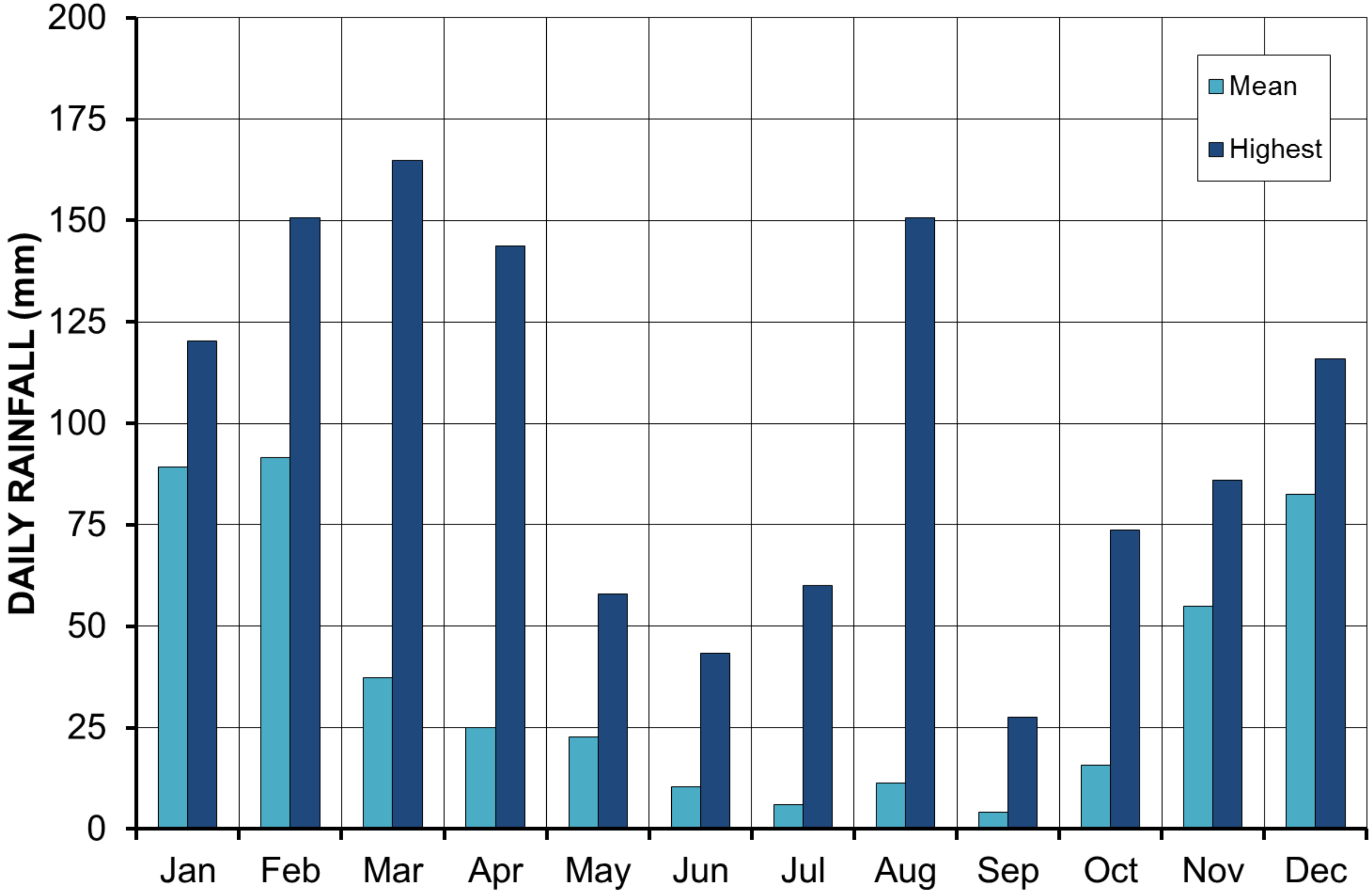
Annual Rainfall Variability



Moranbah Monthly Rainfall



Moranbah Daily Rainfall



Superimposing Tailings Slurry Deposition on Climate

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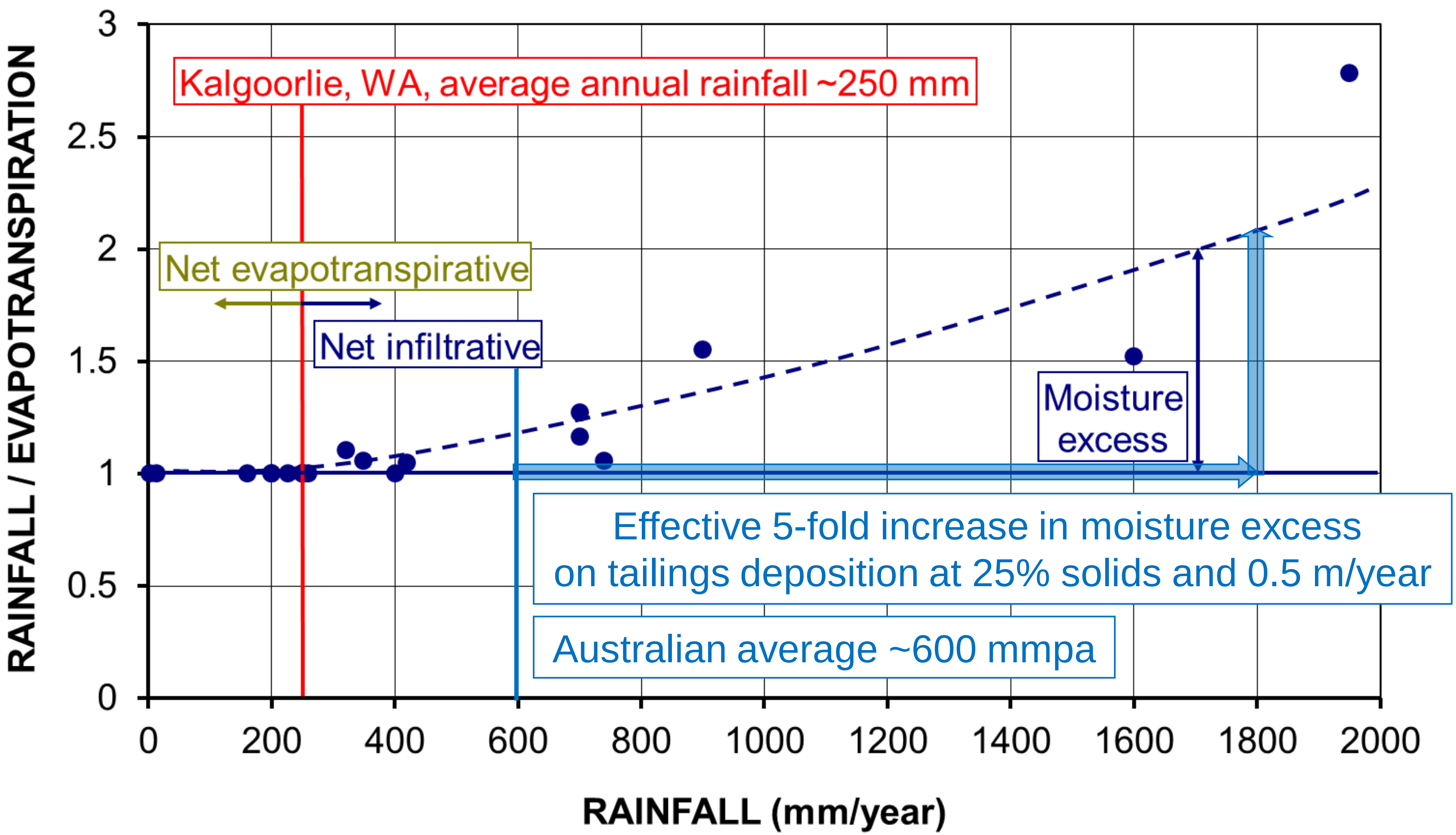

Handling Tailings Water and Rainfall & Runoff

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- While tailings water is >> rainfall and runoff, it is regular and involves relatively small and handleable volumes of supernatant water/day:
  - Tailings water discharged can be 1.5 to 6 x incident rainfall alone (about 3 x on average)
  - Runoff from any additional TSF catchment will reduce this factor
  - Volume of supernatant water/day ~5 mm/m^2/day
  - Volume of water entrained (~40% by volume) ~5 mm/m^2/day, ignoring evaporation and seepage losses
- Rainfall and runoff can be extreme:
  - Rainfall alone can be up to 165 mm/day (33 x supernatant), and a 72-hour storm could amount to 350 mm (70 x supernatant), requiring bigger pumps used for extended periods
  - Runoff from any additional TSF catchment will increase this further

Operational Tailings Water Balance

- Determining water volumes:
  - Best-known water volumes are initial % Solids, rainfall, and possibly evaporation from ponded water
  - Water volumes that can be determined include water entrained within tailings, runoff, input and storage of waste water, and evaporation from wet, desiccating and dry tailings
  - Water volumes that are least well-known are seepage into TSF foundation and through TSF wall
- Operational tailings water balance issues include seepage water quality, and entrainment and evaporation losses:
  - Evaporation dominates in dry climates (20 to 50%)
  - Up to 50% of water discharged with tailings could be available for recycling to plant if water quality is suitable

Operational Tailings Water Balances

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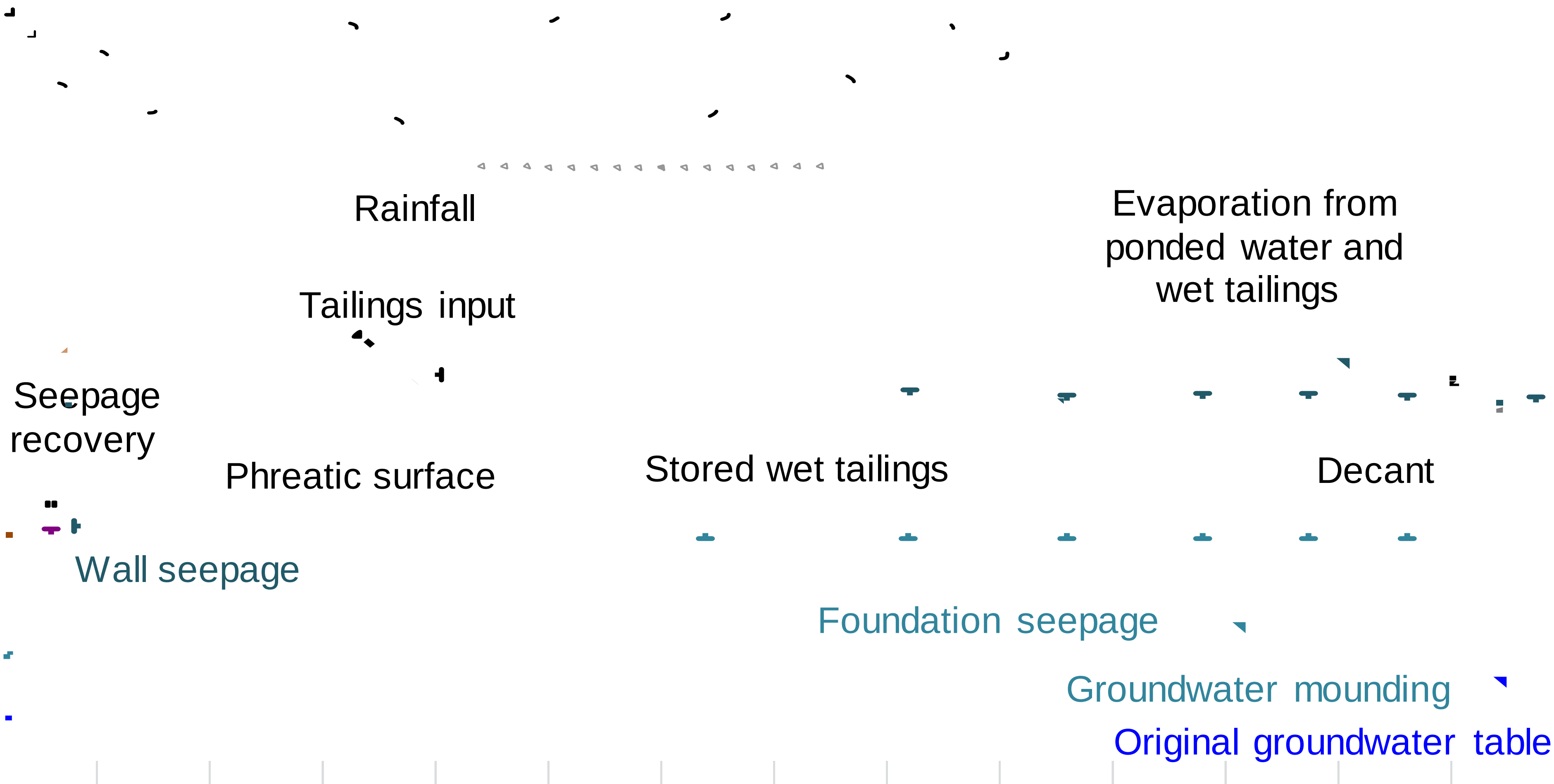

Responses to Issues with Conventional Surface Tailings Dams

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ISSUE	AVAILABLE RESPONSES
>80% water by volume discharged	• Increase % solids discharged – limited scope • Centrifuge tailings – difficult to both pump and truck • Filter tailings (belt press or plate and frame) – expensive
Single point discharge	• Use multiple spigots and cycle – low take-up
Segregation and reverse sorting	• Increase % solids to reduce sorting – limited scope
Fines beach on pumped co-disposal	• Increase % solids and reduce velocity to reduce fines wash-out – reluctance due to potential pipe blockage • Discharge upslope to cover fines – difficult to recover water
Poor beaching and water return	• Inline flocculation has proved effective for clay mineral-rich coal tailings
Poor crusting limiting capping	• Enhance crusting by removing ponded water and cycling tailings discharge

Surface vs. In-Pit Tailings Disposal

SURFACE	IN-PIT
Large area, low height	Small area, greater depth, and hence much faster rate of rise, particularly initially
Relatively easy to remove supernatant water by pumping from decant pond	More difficult to access in-pit pumps to remove supernatant water
Exposure to evaporation by sun and wind, leading to desiccation and increased dry density and shear strength	Greatly reduced exposure to sun and wind due to shadowing by pit walls, reducing potential for desiccation, densification and strengthening
Relatively easy to cap and rehabilitate if allowed to crust	Relatively difficult to cap and rehabilitate due to poor crusting
Not feasible to maintain sulphidic tailings underwater	Potential for flooding of pit and tailings, maintaining sulphidic tailings underwater

In-Plant Recovery of Tailings Water

- In-plant is most effective means of maximising water recovery (reducing raw water demand), but it comes at high financial and management cost
- Overall tailings water recovery as a % of total water used in processing increases from typically:
  - 50 to 60% for tailings disposal as a slurry
  - 60 to 70% for tailings disposal as a high density slurry
  - ~80% for tailings disposal as a high slump paste
  - 85 to 90% for tailings disposal as a low slump paste
- Increasing % solids $\rightarrow$ corresponding improvements in settled dry density and shear strength of tailings
- Paste tailings would require positive displacement pumps
- Filtered tailings would be transportable by truck or conveyor

Water Recovery from TSF

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- Water recovery from TSF is generally limited to recovery of supernatant water, although seepage through wall may be collectable
- Other tailings water is lost to:
  - Entrainment within tailings
  - Evaporation from decant pond and wet tailings
  - Seepage into foundation
- In order to maximise recovery of supernatant water, good design, construction and management of decant system is required, including:
  - Directing supernatant water to decant pond
  - Minimising size of decant pond and rapid recovery
  - Maintaining decant pumps and water return pipelines

Post-Closure Tailings Water Balance Issues

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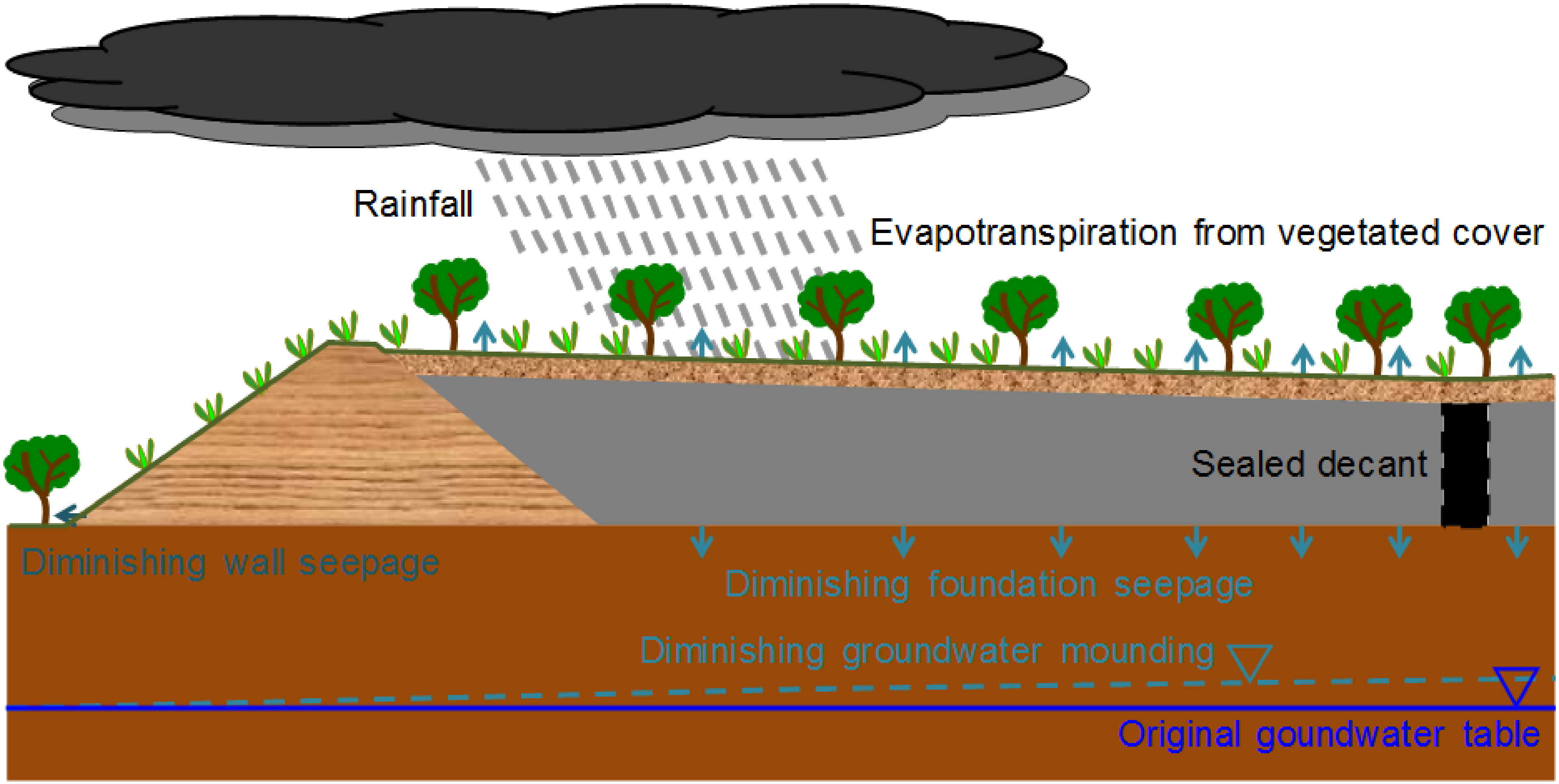
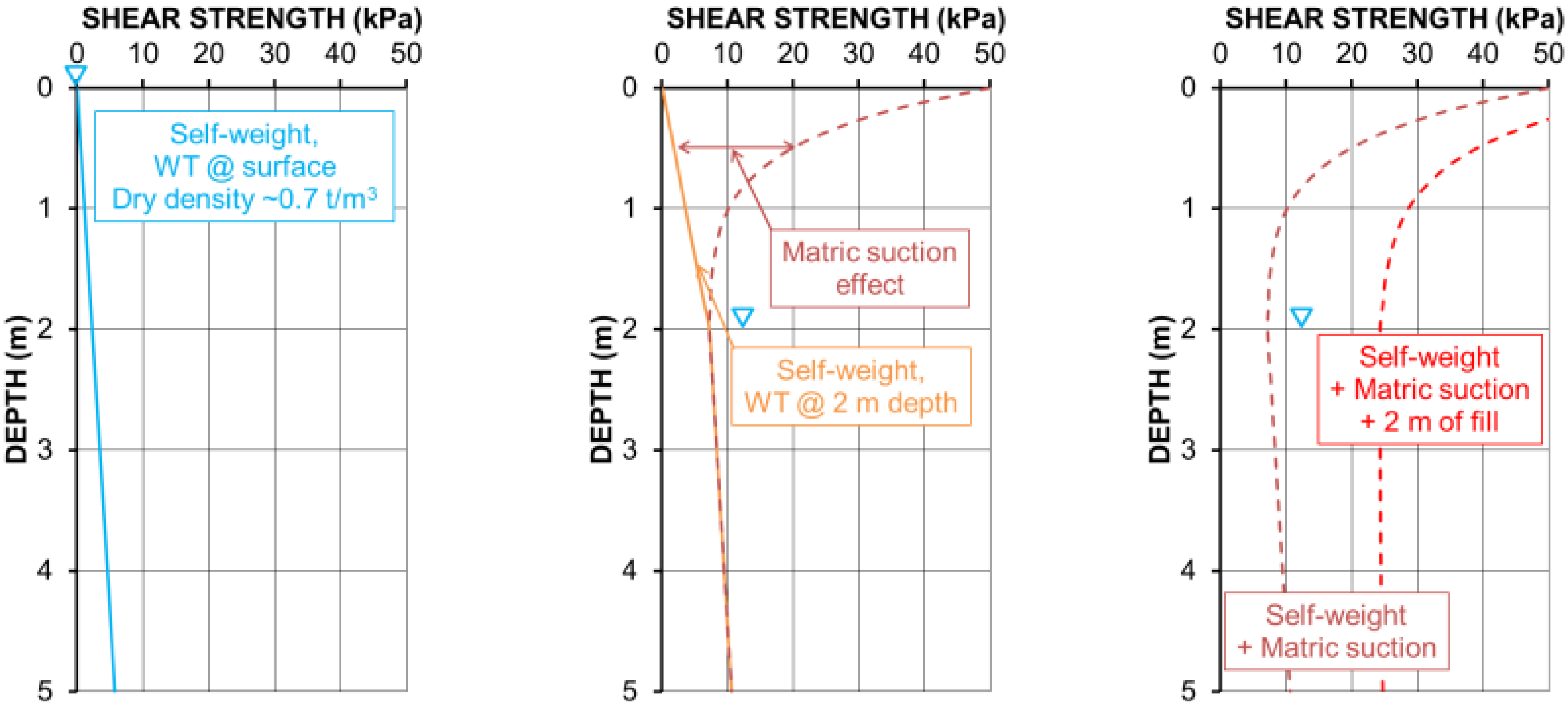
- Water quality, dictating whether or not spillway overflows can be discharged directly to environment or require treatment
- Ongoing seepage, which would be expected to diminish as tailings drain down, but would be recharged by rainfall runoff that is not spilled
- Drain down of tailings would also expose them to oxidation and potential contamination of runoff and seepage

Post-Closure Tailings Water Balance



Schematic Shear Strength Profiles with Depth

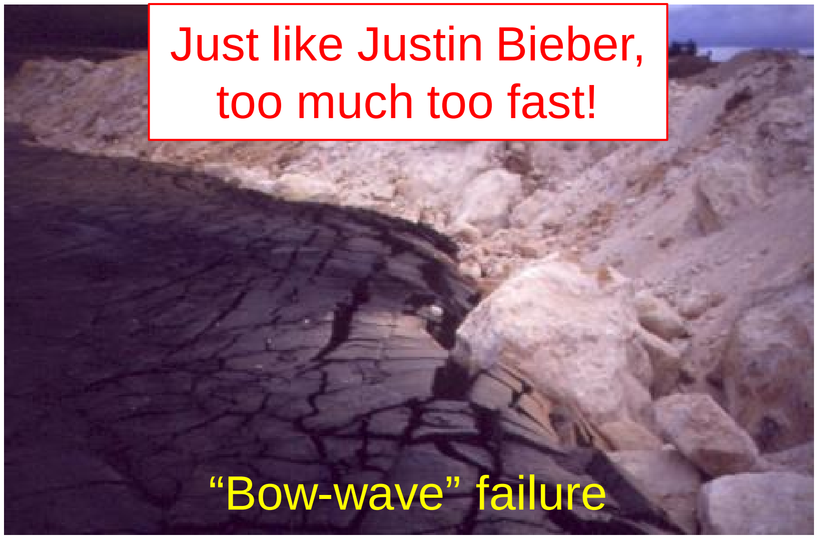


Self-weight + Desiccation +2 m Fill

Desiccation and filling are most effective for consolidation and strengthening

Capping Crusted Tailings (or Hydraulically with Coarse Material)

Just like Justin Bieber, too much too fast!



"Bow-wave" failure

"Bow-wave" failure

Surcharging edge

Pushing shallow fill on a broad front

Moving Towards No Tailings Dams

- Drivers:
  - Ongoing TSF failures (~2/year worldwide)
  - Ever larger TSF footprints as tailings volumes increase exponentially
  - Escalating community concern about mining in general, and tailings dams in particular, despite attempts to label them TSFs
  - Escalating regulator pressure to eliminate surface tailings dams, for new projects
- Industry responses:
  - In-pit disposal – but this is not the answer
  - Filtering tailings (where water is in short supply) and combined disposal with coarse wastes – practiced since 1987, e.g. Howich
  - Shallow, on-off tailings cells, using sun/wind drying, harvesting and disposal with coarse wastes – practiced since 1990, e.g. Charbon

In-Pit Disposal of Tailings and Belt Press Filtering

Co-Disposal of Tailings Filter Cake with Coarse Reject and Spoil

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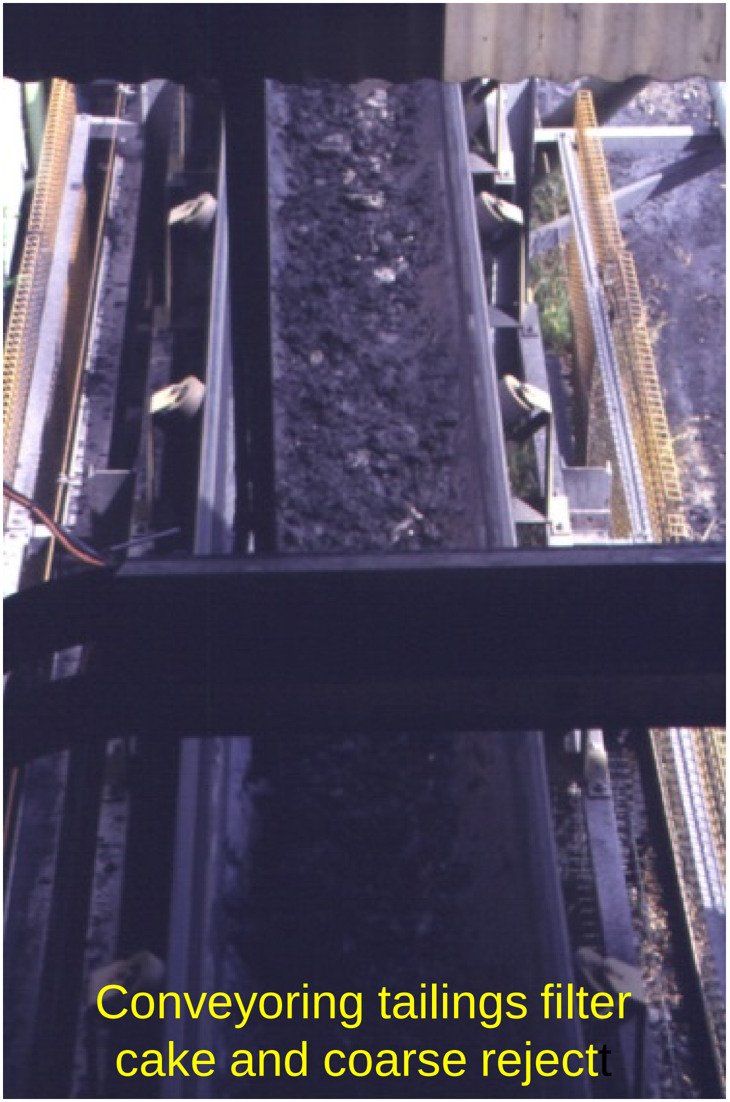
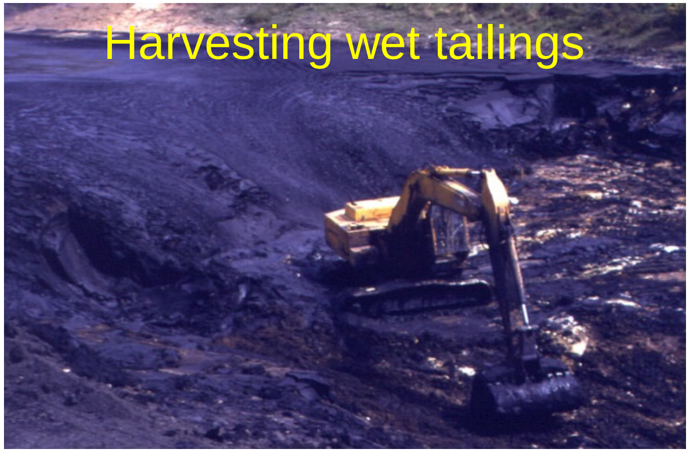

Conveyoring tailings filter cake and coarse reject


Co-disposing tailings filter cake and coarse reject in spoil piles

Shallow On-Off Tailings Cells (Charbon, from 1990)



On-Off Tailings Cells at Charbon – March 2010

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Other Responses

- For higher yield ROM Coal, by-pass washery :
  - Reduces fines production and tailings volume
  - By-passed ROM Coal can be blended with washed ROM Coal to meet Product Coal specifications
- Reduce production of fines:
  - Only over-size ROM coal needs to be crushed for beneficiation
  - Excessive handling of ROM Coal and conventional crushing using hammer mills (which pulverise) produce excessive fines
  - A crushing roller mill crushes over-size while generating less fines (dictated by gap between rollers) than a hammer mill, using about half energy (although they are about an order of magnitude more expensive)