Towards a Global Research Consortium on Tailings

Workshop Report

First Consultation Workshop, Santiago, Chile

Tuesday 9 July, 2019

SMI-International Centre of Excellence in Chile, Las Condes

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INTRODUCTION

- This report provides a summary of the proceedings of the First Consultation Workshop of the Global Research Consortium on Tailings. The Workshop was held in Santiago, Chile on the 9th of July, 2019, prior to the 6th International Seminar on Tailings Management – Tailings 2019.
- The purpose of the workshop was to solicit feedback on the proposed Global Research Consortium on Tailings and to use this feedback to develop a prospectus for further discussion and support.
- The workshop was held with the support of the SMI-ICE-Chile and CORFO and was attended by 29 participants.
- Strong support and enthusiasm was expressed by attendees to further develop the concept and present a full prospectus for consideration at a subsequent consultation forum held prior to the Tailings and Mine Waste 2019 Conference, in mid-November 2019, in Vancouver, Canada.

BACKGROUND (i)

- On the 25th of January 2019 tailings Dam 1 at the Córrego do Feijão iron ore mine, near the town of Brumadinho, in Minas Gerais, Brazil, suffered a catastrophic and fatal failure. The failure followed a similar event in Minas Gerais, the Fundão tailings dam disaster in 2015. The 2019 failure caused an estimated 270 deaths and widespread and serious damage to mine facilities, and downstream ecosystems.
- In late February, 2019 the Sustainable Minerals Institute (SMI) at The University of Queensland prepared a concept note for discussion *'Towards a Global Research Consortium on Tailings*.' The concept note was shared with the CEO Council of the International Council on Mining and Metals, who met in Miami to discuss the industry's response to the Brumadinho failure. The concept note was released widely.
- SMI received wide interest and strong positive feedback on the concept note.

BACKGROUND (ii)

- The outcome statement of the Miami meeting of the ICMM CEO Council committed the industry to: (i) define technical guidance for the safe design, construction, operation, and closure of tailings facilities, by drawing upon existing technical best practice; (ii) develop capacity and a database to facilitate learning and knowledge sharing across the industry; and (iii) <u>consider ways to leverage member resources to enhance and optimise the industry's existing research and training initiatives.</u>

- The ICMM is partnering with the United Nations Environment Programme and Principles on Responsible Investment to develop an independent consequence-based tailings management standard and has convened an expert panel to support the process led by Professor Bruno Oberle from the École polytechnique fédérale de Lausanne, Switzerland.

BACKGROUND (iii)

- In June 2019, Professor Neville Plint, Director of the SMI, wrote to 37 research institutions involved in tailings research from around the world inviting them to express interest in the Consortium and be part of a series of consultation workshops to establish the initiative.
- Twenty-two research groups have expressed interest in being involved (see Table 1).

BACKGROUND (iv)

Table 1. Expressions of Interest from Research Groups

Camborne School of Mines, University of Exeter, United Kingdom	Norman B Keevil Institute of Mining Engineering, The University of British Columbia, Canada	Sustainable Minerals Institute & Geotechnical Engineering Centre, The University of Queensland, Australia
UCL Hazard Centre, University College London, United Kingdom	Oil Sands Tailings Research Facility, Faculty of Engineering, The University of Alberta, Canada	Department of Environmental Engineering, RMIT, Australia
Irish Centre for Research in Applied Geosciences, University College Dublin, Ireland	Department of Geological Sciences and Geological Engineering, Queens University, Canada	Faculty of Engineering and Mathematical Sciences, The University of Western Australia
Department of Civil, Environmental and Natural Resources Engineering, Luleå University of Technology, Sweden	Namibia University of Science and Technology	School of Molecular and Life Sciences, Curtin University, Australia
Computational Hydraulics Group, Universidad Zaragoza, Spain	School of Civil and Environmental Engineering, University of the Witwatersrand, South Africa	Centro Universitário da Fundação Educacional Inaciana, Brazil
Institute of Mineral Resources Engineering, Aachen University, Germany	Department of Chemical Engineering, University of Cape Town, South Africa	Escola Politecnica, University of Sao Paulo, Brazil
Institut für Bergbau und Spezialtiefbau, TU Bergakademie Freiberg, Germany	Department of Mining Engineering, University of Jos, Nigeria	Advanced Mining Technology Center, Universidad de Chile
		Instituto Geologia Economica Aplicada, Universidad de Concepción, Chile

KEY FEATURES OF THE CONSORTIUM (i)

- The proposition of the Consortium is that with renewed, coordinated and dedicated action a dramatic scale-up of global efforts can develop the knowledge-solutions necessary to address the technical, social, environmental and economic risks of tailings.
- The Consortium would bring together the world's leading thinkers in tailings and mine waste management: researchers, practitioners, industry professionals, regulators, civil society and community representatives to develop transdisciplinary knowledge-solutions (science, technology and practices).

KEY FEATURES OF THE CONSORTIUM (ii)

- The Consortium will: extract value from existing knowledge; prioritise research in areas that require collective effort; support evidence-based policy-making and practice; contribute to increased education and communication between all stakeholders; support the implementation of existing and new initiatives (e.g. ICMM/UNEP/PRI tailings review & standard; Global Mineral Professionals Alliance)

- Activities could include: facilitating dialogue between researchers, practitioners and those impacted by tailings; collating the state of the art of global research and practice; defining an agreed program of applied research with consortium members addressing the critical knowledge gaps; creating a forum for knowledge exchange and research translation with industry, government and civil society; incubating innovations and ideas, seed research and undertake feasibility studies to implement innovations; and growing a portfolio of research solutions.

KEY FEATURES OF THE CONSORTIUM (iii)

The Consortium will not:

- duplicate or compete with the work of individual research groups
- promote one research group over another
- create additional silos or barriers to the uptake of innovative research and practice.

The structure of the Consortium could be modelled on the successful and long-lived Large Open Pit Project, where the Sponsors identify and prioritise research topics, assisted by Research Providers and a Consortium Manager. The Sponsors, Researchers and Consortium Manager meet 6-monthly worldwide to engage, report on the progress of current research, and plan future projects. The aim is to cost-effectively allocate sponsors' funds to research and training to achieve the vision of the Consortium.

KEY FEATURES OF THE CONSORTIUM (iv)

Potential areas of focus could include:

Tailings Production

- Dewatering of wet tailings by thickening or filtration
- Coarse-grained processing and the reduced production of tailings
- Dry-processing
- De-sulphurisation and the removal of environmentally sensitive elements and compounds
- Cost and other drivers of tailings production
- Optimisation of rheology, mineral recovery, water and energy inputs, economics, AMD prevention, rehabilitation and the social outcomes of tailings
- Reprocessing and re-use of tailings

Tailings Storage

- Cost and other drivers of tailings slurry deposition (full life-cycle accounting)
- Safety and stability of future, existing and decommissioned tailings storage facilities
- Monitoring, control and rehabilitation practices
- Co-disposal of mining waste streams and in-situ water recovery

KEY FEATURES OF THE CONSORTIUM (v)

Potential areas of focus could include:

Tailings Consequences

- Downstream environmental, social and economic risks of tailings from chronic and catastrophic events
- Community involvement and engagement

Tailings Governance and Practice

- Policy, capacity-building, training and practice
- Governance and regulation
- Involvement of non-traditional actors in research and practice e.g. environmental and engineering consultancies, technology and equipment providers, at-risk communities, regulators, civil society, unions etc.

WORKSHOP FEEDBACK (i)

Overall

- Enthusiasm and support for the Consortium and it's potential
- 'Failure is not an option'
- Public good, non-competitive, outputs/activities public/shared
- Strong role for capacity building, research translation and training
- The current performance of the industry in tailings management is simultaneously a major driver of societal distrust, and investor concern in the sector.
- Additional consultation workshops, especially in Europe would be welcomed

Focus

- Research directions/topics can be identified and progressed in 6 monthly meetings
- Not repeating the same or similar existing research or technology development
- Increased physical/geotechnical stability though dewatering and improved containment
- Geochemical as well as geotechnical stability

WORKSHOP FEEDBACK (ii)

Activities (i)

- Opportunity to demonstrate links between research and practice e.g. Bingham Canyon dewatering LOP project; first used monitoring data to calibrate models and will use the system as a huge experimental laboratory.
- Need for a ‘competent persons’ to design and operate tailings dams, similar to JORC and NI 43-101 Reporting, but more so – required to define and uphold the ‘design intent’ and to achieve and maintain very high performance standards.
- Postgraduate projects may not be ideal given the duration of academic milestones compared to industry timelines, however postgraduate apprenticeships (3-6 months) on mine sites could be a practical way to exchange knowledge and practice.
- The Consortium could help with a global program of knowledge exchange and research work to help raise the capabilities and then capacities of tailings practitioners and regulatory organisations worldwide.

WORKSHOP FEEDBACK (iii)

Activities (ii)

- The Consortium could help build toward the establishment of an organization similar to those in the maritime and aviation industries – e.g. International Maritime Organization (IMO) and International Civil Aviation Organization (ICAO) – for regulating all aspects of tailings management, which would inform national and provincial regulatory bodies worldwide.
- Role in public education about mineral use as well as hear public concerns about addressing the environmental and social aspects of mining.
- The Consortium could ‘road test’ the international standards on tailings storage facilities being developed by ICMM, UNEP and PRI to identify gaps, practical application issues and enabling initiatives that would ultimately strengthen the standards, improve the resilience and robustness of the tailings storage facilities and build greater confidence with civil society.

WORKSHOP FEEDBACK (iv)

Structure

- Multi-stakeholder
- Facilitated by a Consortium Manager or Coordinator
- Should take a staged approach to establish the Consortium.
- Industry supports a multi-stakeholder model that involves governments, civil society, affected communities, consultancies, technology and service providers. A necessity to rebuild public trust.
- What can we learn in developing the Consortium from the INAP model, which was led by industry and connected in with MEND (Mine Environment Neutral Drainage program)? Might (probably) not want an industry-led model for the Tailings Consortium but there could still be good learnings or aspects of the model that would be helpful to replicate.

WORKSHOP FEEDBACK (v)

Funding

- Industry Sponsors
- Potential for Government Sponsors
- Other sources of funding include foundations, multilaterals, and bilateral development funders (both through direct contribution and a membership model)
- Sponsors should be actively involved in the Consortium, identifying and prioritising research topics, and monitoring progress
- Need to align researcher salaries with what is acceptable by industry, in other words manage the overhead issue
- Industry may wish to be selective in assigning projects to their preferred research providers

NEXT STEPS

- Conduct individual consultations with interested partners and funders
- Hold additional Consultation Workshops:
  - Goldschmidt Conference, 18-23 August, 2019, Barcelona, Spain.
  - Society for Geology Applied to Mineral Deposits Conference, 27-30 August, 2019, Glasgow, Scotland.
  - International Mining and Resources Conference, 28-31 October, 2019, Melbourne, Australia.
  - Tailings and Mine Waste, 17-20 November, 2019 Vancouver, Canada.
  - EU Raw Materials Week (TBC), 18-22 November, 2019, Brussels.
- Prepare draft prospectus to be presented at Vancouver Consultation Workshop
- Finalise prospectus following Vancouver Workshop
- Invite partners, establish Consortium structure and secure funding

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Annex A – Agenda

CONSULTATION WORKSHOP AGENDA	
TIME	**ACTIVITY**
2:15 – 2:30pm	**Registration**
2:30 – 2:35pm	**Welcome:** David Mulligan, Executive Director, SMI-ICE, Chile
SESSION 1 – Perspectives on the Global Tailings Challenge **Moderator:** David Williams, Director Geotechnical Engineering Centre, UQ	
2:35 – 2:45pm	**Industry Tailings Practice:** Mike Davies, Senior Advisor Tailings and Mine Waste, Teck Resources
2:45 – 3:05pm	**Challenges in Tailings Management:** David Williams
3:05 – 3:20pm	**Evolution of Tailings Dam Construction in Chile:** Luis Valenzuela, Geotechnical Consultant, Chile
3:20 – 3:45pm	**Geochemical Perspectives:** Mansour Edraki, CMLR, SMI, UQ
3:45 – 4:15pm	**Afternoon Tea**
SESSION 2 – Advancing the Global Research Consortium on Tailings (GRCT) **Moderator:** Daniel Franks, Program Lead, Governance and Leadership in Mining, SMI, UQ	
4:15 – 4:35pm	**Overview of the Consortium:** Daniel Franks
4:35 – 5:30pm	**Discussion**
5:30 – 6:00pm	**Networking and Drinks**

Annex B – Presentation by Dr Mike Davies, Senior Advisor Tailings and Mine Waste, Teck Resources

Towards a Global Research Consortium on Tailings

Industry Tailings Practice

9 July 2019

Dr. Michael Davies

Teck

Industry Tailings Practice - The Landscape

FACTS

- Historically high production rates
- Historically low returns on investment
- Societal demand for products misaligned with commodity pricing
- Societal/Regulatory expectations and requirements increasing at a significant pace
- Global shortage of experienced/qualified:
  - Design Professionals
  - Operators
  - Regulators
  - Pragmatic Academics

Industry Tailings Practice – The Landscape cont.

- Sufficient governance and technical guidance exists
- Adherence to the guidance insufficient
- Global Standard and supporting guidance pending

- Myth – dewatered tailings are a panacea
- Fact – a continuum of tailings products are needed by the industry

- Myth – mining industry's inability to spend on tailings has led to the failures
- Fact – sufficient governance with similar spend in all cases would prevent the failures that have occurred. Selection of proper technology is part of good governance.

Industry Tailings Practice – Keys to Research

Tailings Research Initiatives – Keys for Mining Industry

- Embrace the facts and dispel the myths
- Understand site-specific nature/challenges of tailings management (e.g. one size does NOT fit all)
- Do not isolate technology from very real human resource challenges
- Provide educators with balanced information

Essentials for Research Framework(s)

- Clarity on how to design (concept through closure)
- Clarity on how to regulate
- Clarity on comparative costs (life cycle)

Annex C – Presentation by Prof. David Williams, Director Geotechnical Engineering Centre, The University of Queensland

Global Research Consortium on Tailings
Challenges in Tailings Management
Santiago, Chile – 9 July 2019

Professor David Williams

The University of Queensland, Brisbane, Australia

Email: *D.Williams@uq.edu.au*

Constraints Under Which Surface TSFs Must Operate

- Climatic, topographic and seismic settings
- Nature of tailings, particularly sulfidic minerals and presence of clay minerals
- Tailings production rate and % solids on deposition
- Dam foundation conditions and borrow materials
- Need to maximise tailings settled dry density and strength
- Risk of a (sudden) spill of water and/or tailings
- Need to manage, store, and recycle process water
- Need to meet discharge water quality licence conditions
- Need to rehabilitate TSF in perpetuity

People, infrastructure & environment downstream are key risks

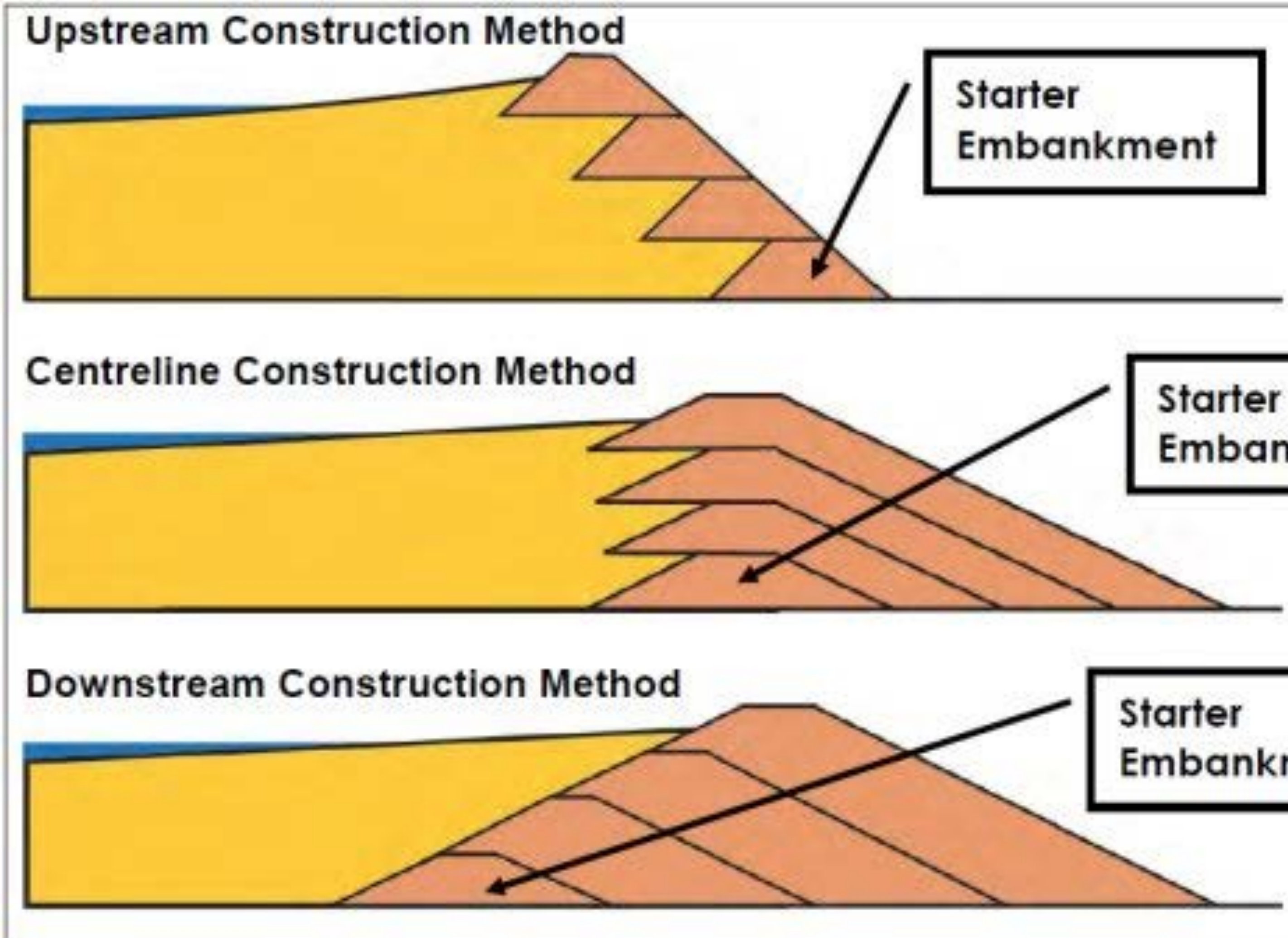
Conventional Tailings Disposal and Storage

The University of Queensland
AUSTRALIA
Create change

Commonly held perception, supported by NPV approach, is that transporting tailings as a slurry to a dam is most economic

- Dewatering tailings is perceived to be too expensive
- Reduced storage volume occupied by dry tailings, and relative ease of capping are discounted, as is potential for a higher level future land use
- Cost of rehabilitating resulting soft and wet tailings is discounted and not considered to be significant
- Few TSFs have been rehabilitated, due to difficulty and expense of capping "slurry-like" tailings, particularly at a time when mine is no longer producing revenue

Conventional Tailings Dam Construction Methods



Less borrow, but dependent on tailings beach for support

Intermediate

More material, higher cost, but more stable

Ongoing Tailings Dam Failures

- Average tailings dam failure rate over last 100 years is 1.2% or 2.2/year, >2 orders of magnitude higher than that for water retention dams of 0.01% ***– Unacceptable***
- Focus is on failures that occur in developed countries (e.g., Mount Polley, Canada in 2014; Cadia, Australia in 2018) or that involve global mining companies (e.g., Samarco [BHP Billiton/Vale joint ownership], Brazil in 2015; Brumadinho [Vale], Brazil in 2019)
- Tailings dams **can fail in seconds and catastrophically**

Recent, high profile tailings dam failures are threatening mining industry's financial and "social licences to operate" and threatening industry's control of its destiny!

Media Reports on Tailings Dam Failures

WORLD MINE TAILINGS FAILURES FROM 1915

MINING [DOT] COM

29 August 2016 – Why Samarco tailings dam failed

MINING TECHNOLOGY

27 March 2019 – Time to talk about tailings dams

The Guardian

27 January 2019 – Brazil dam collapse: 10 bodies found and hundreds missing

Mining Magazine

20 February 2019 – Tailings dams: we need to start 'failing forwards'

AUSTRALASIAN MINE SAFETY JOURNAL

April 2019 – Newcrest report into Cadia tailings dam failure released

COSMOS THE SCIENCE OF EVERYTHING

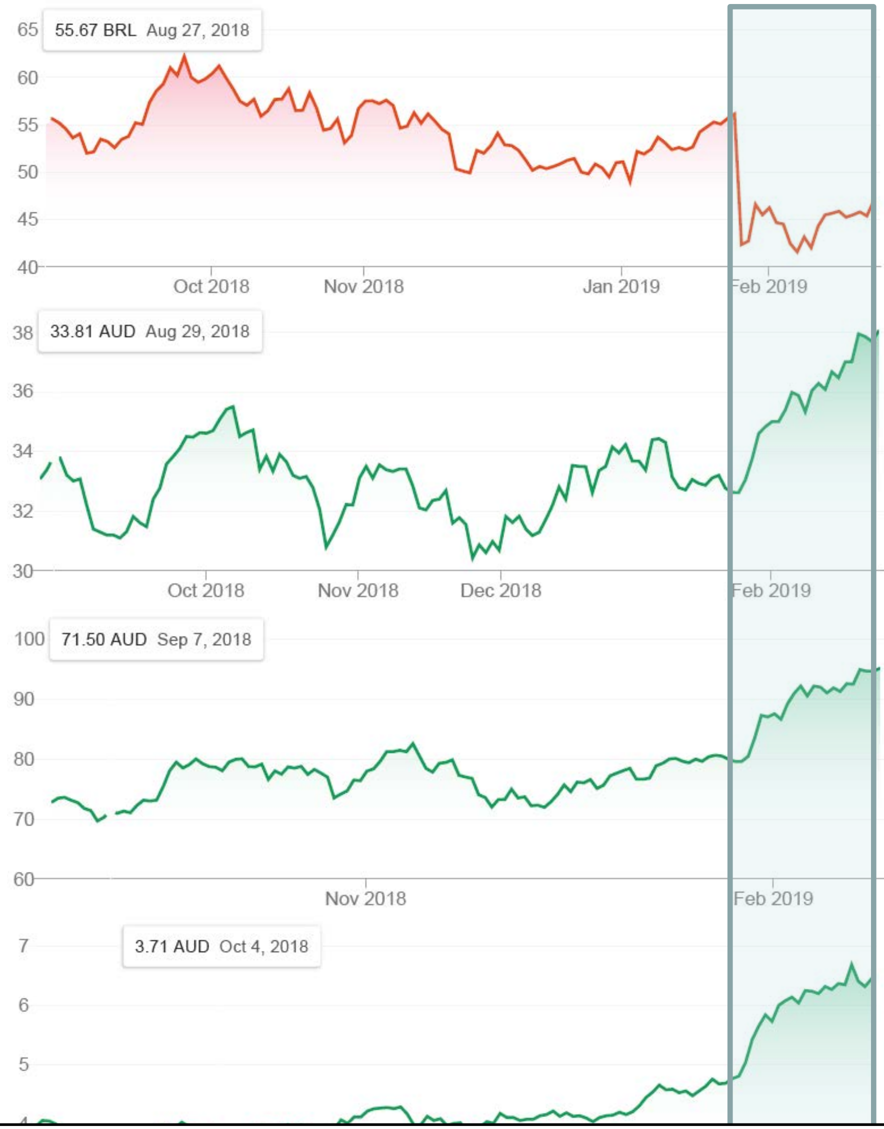
10 May 2019 – Why do dams collapse? The answer is both obvious and unclear

ABC

20 June 2019 – Tailings dams failure risks range from high to extreme in audits by Australian mining giants

A Moment of Reflection

Early Impact of Brumadinho Tailings Dam Failure on Share Prices



Vale down initially 25.9%, recovering to 16.3% down

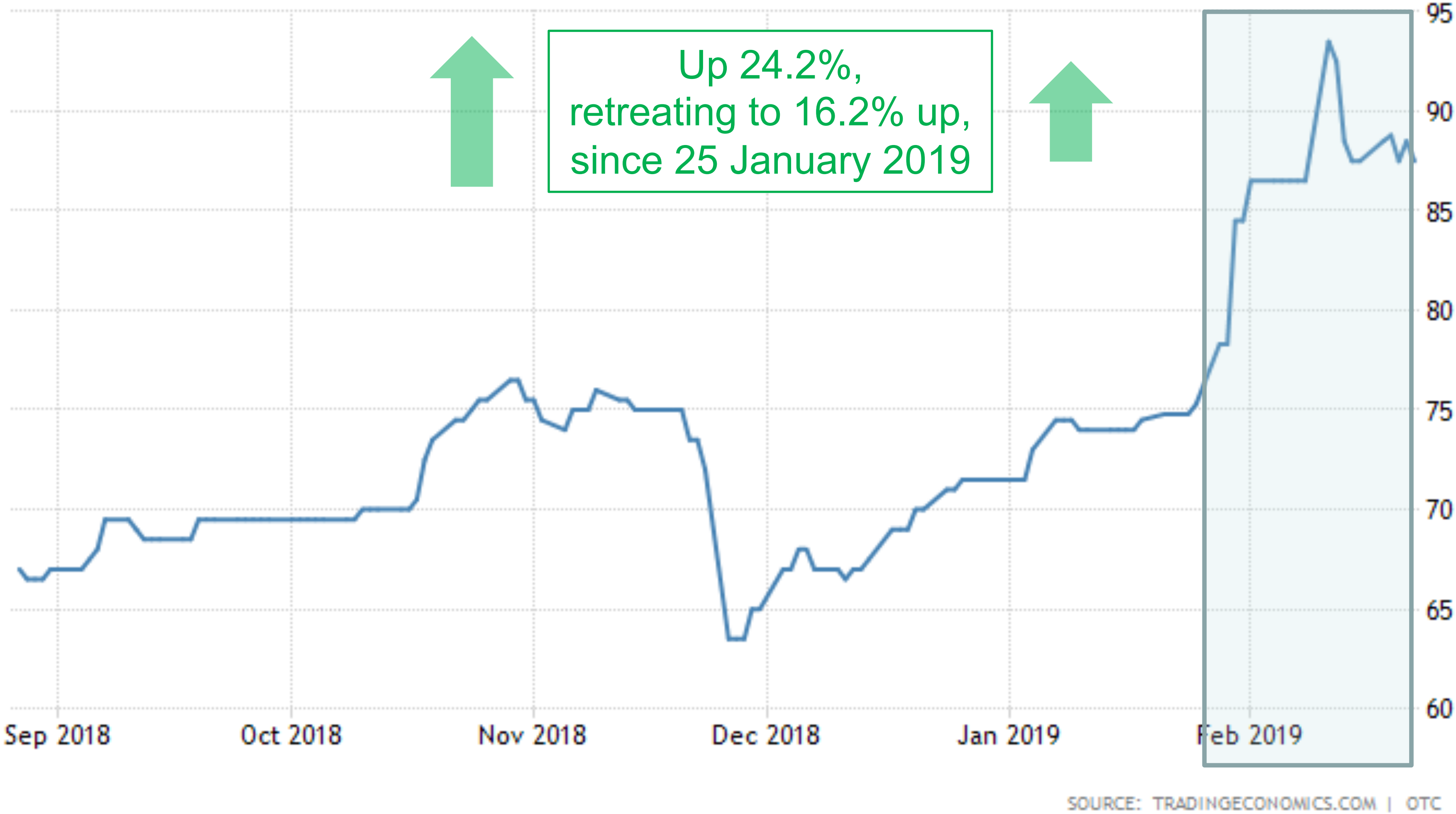
BHP up 15.1% since 25 January 2019

Rio Tinto up 18.2% since 25 January 2019

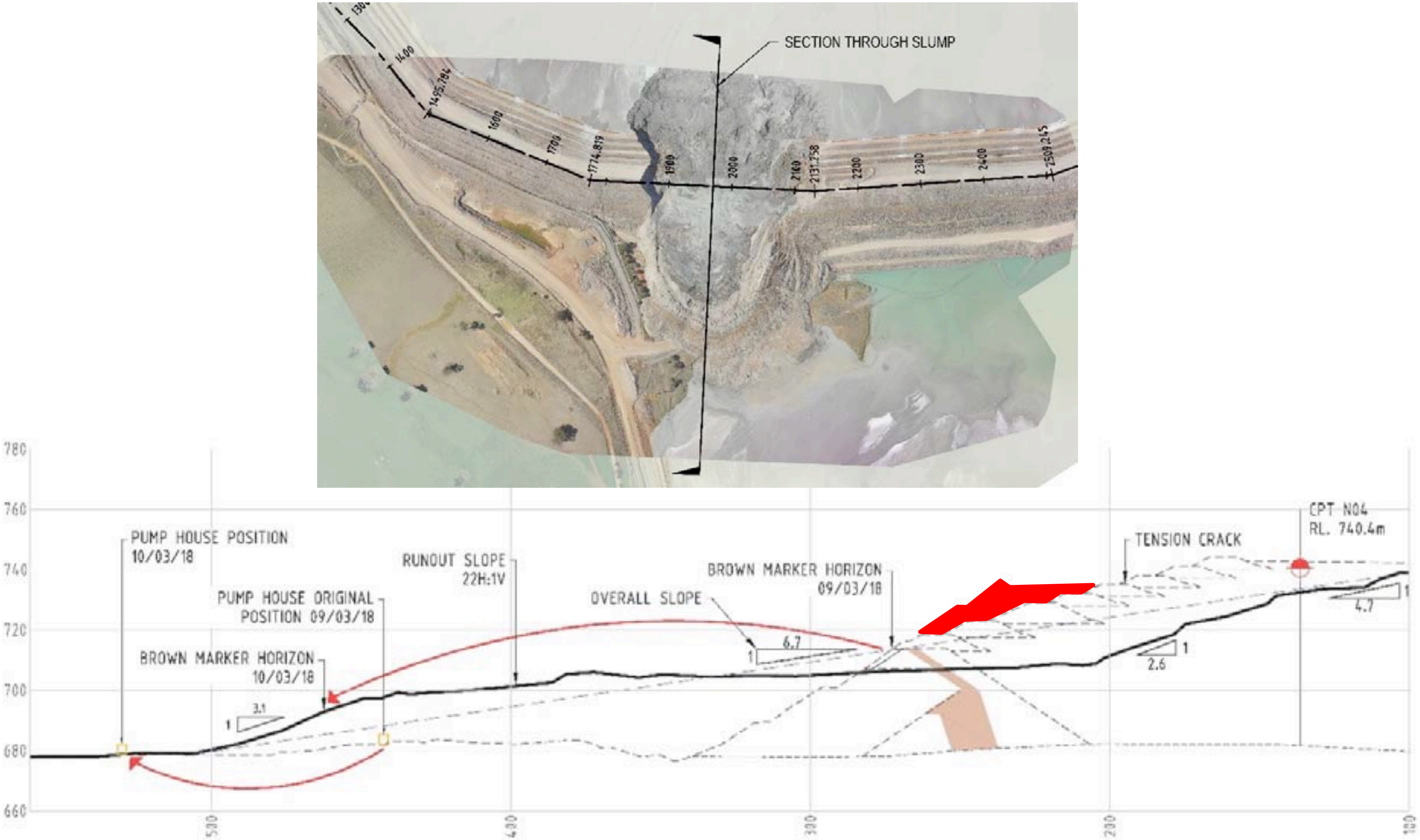
Fortescue up 34.4% since 25 January 2019

Market Capitalisation of all Iron Ore producers remained about same!

Impact on Iron Ore Price (62% Fe in USD)



Cadia Tailings Dam Failure
9 March 2018



Exposed Foundation Beneath Toe of Future Slump

Key Causes of Tailings Dam Failures and Industry Threats

- Most tailings dam failures involve "water" as one of prime causes, making drainage, clay cores and water management key
- Another cause can be a weak (often unidentified, possibly moving from over to normally-consolidated) foundation layer
- Industry threats motivated in particular by recent catastrophic tailings dam failures are coming from:
  - Investors; e.g., Church of England
  - Insurers
  - Regulators; e.g., outlawing upstream construction, which happened in Chile following earthquake-induced failures in 1965, and will follow in Brazil (wet climate and failures)

Risk of Tailings Liquefaction

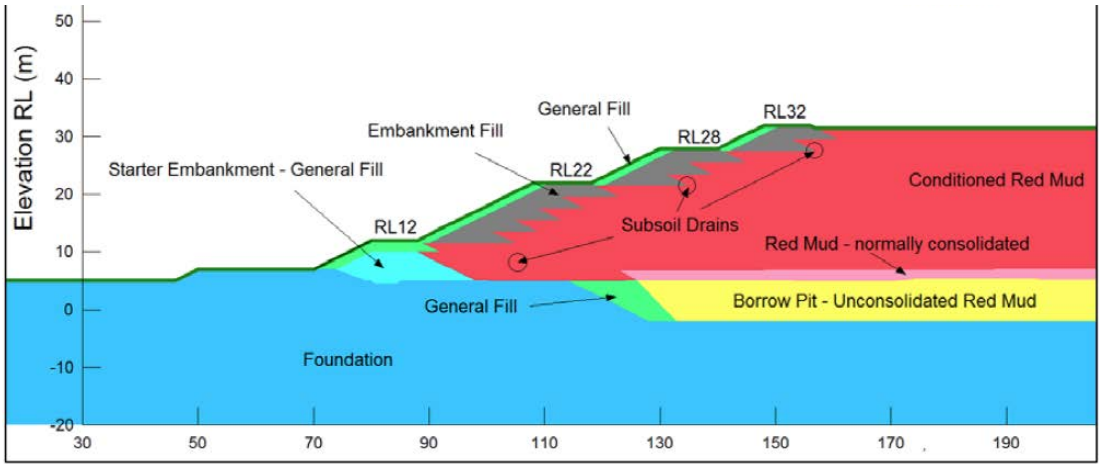
- Risk of earthquake-induced liquefaction:
  - Fine-grained sandy or silty sand tailings – √
  - Loose (contractive, brittle) state – √
  - Near-saturated – √
  - Earthquake magnitude > 5.5 and peak ground acceleration >0.13g – ?
- Risk of static or flow liquefaction, triggered by:
  - Loss of containment due to dam instability
  - Overtopping and erosion of dam
  - Pore water pressure increase due to dam raise
  - Rise in phreatic surface due to heavy rainfall or fresh tailings

Susceptible tailings can behave in an undrained, contractive, strain-softening manner, and liquefy or flow

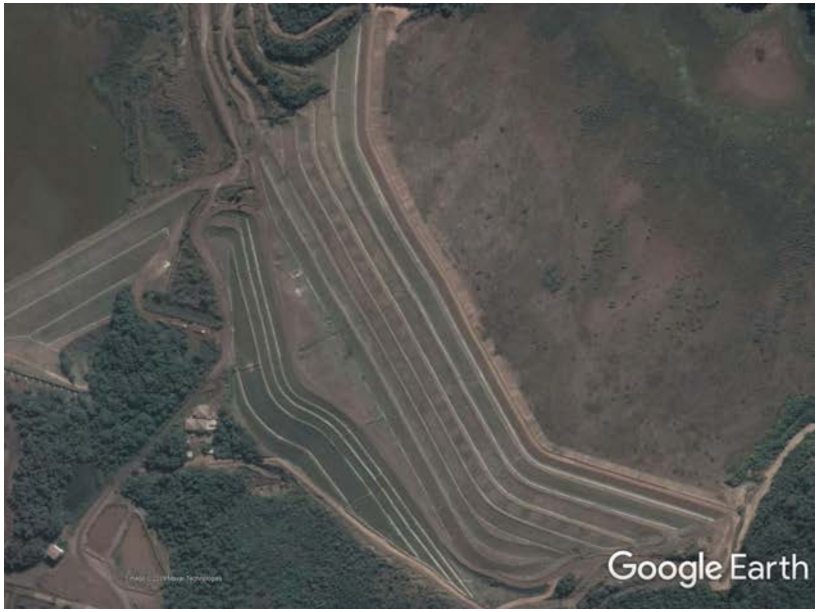
Upstream Construction – Australia versus Brazil

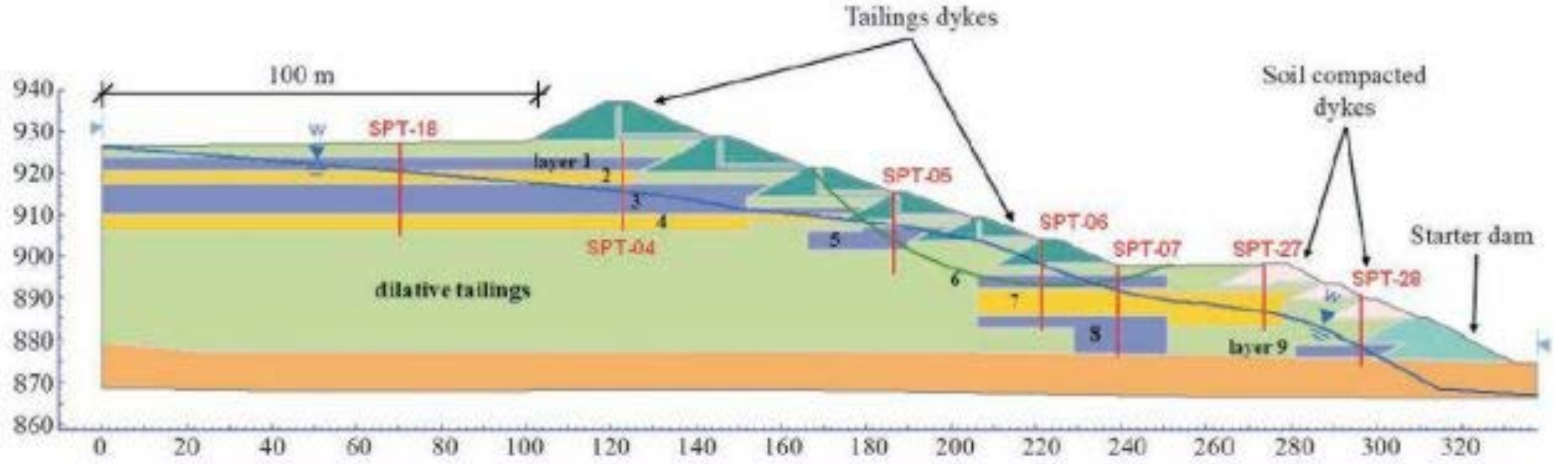
AUSTRALIA	BRAZIL
• Dry climate	• Seasonally wet climate
• Minimum FoS = 1.3 to 1.5 for peak strength, 1.0 to 1.2 for seismic	• Minimum FoS = 1.3 to 1.5 for peak (Nov 2017), previously set by designer (> 1.05)
• Rate of rise < 1-2 m/year	• Rate of rise can be order of magnitude higher
• Deposition in thin layers and cycled to facilitate consolidation and desiccation	• Deposition can be rapid and in thick layers (<< desiccation)
• Possible to avoid liquefaction-prone tailings foundation	• Potentially liquefiable tailings foundation
• Possible to have a wide wall raise on an adequate foundation	• Typically a narrow wall raise possibly on a wet foundation (marginal stability)

Typical Upstream Construction in Australia



Typical Upstream Construction in Brazil





Emerging Tailings Dam Surveillance Methods

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

Create change

METHOD	COMMENTS
Drone surveillance	Aiding visual inspection
Nested VW Piezometers	Recorded/analysed in real-time
V-notch weirs	Recorded/analysed in real-time
Settlement monuments	For correlation with radar and remote monitoring
LiDAR (above water) and bathymetry (below water)	For density estimation and water/wet/dry tailings proportions
Radar	"Noise" issues, affecting analysis period
Satellite	Weekly fly-over
Future "Smart" geofabrics	Within tailings beach

Above all, ensure an acceptable Factor of Safety and maintain vigilant surveillance

Resilient Tailings Dam Design, Construction, Operation and Closure

The University of Queensland
Australia
Create change

Clear understanding and achievement of "design intent"

- Company – Onsite Tailings Manager
- Independent Engineer-of-Record, interacting with:
  - Onsite Tailings Manager (up to monthly contact, up to quarterly face-to-face on site, with authority to stop operation)
  - Designers (could be Engineer-of-Record)
  - Dam Safety Inspector
  - Independent Technical Review Board (essential for High and Extreme Dam Failure Consequence Category)
- Two levels of Dam Safety Reviews:
  - Annually by Engineer of Record (detailed)
  - Periodic External Independent Technical Review at critical points (overview, drawing on experience of reviewers)

Innovations in Tailings Management

- Thickening, paste disposal and dry stacking of filtered tailings (e.g., La Coipa)
- "Co-disposal" of tailings and coarse-grained wastes, such as pumped co-disposal of coal washery wastes in Australian Eastern Coalfields from 1990s
- Integrated Waste Landforms have been instituted at some projects; e.g., Kidston in-pit, Fortescue, and been proposed for numerous new projects
- "Paste rock", patented by Golder Associates, has been trialled in Canada for mine waste covers
- "GeoWaste", patented by Goldcorp, incorporates filtered tailings and screened or crushed waste rock

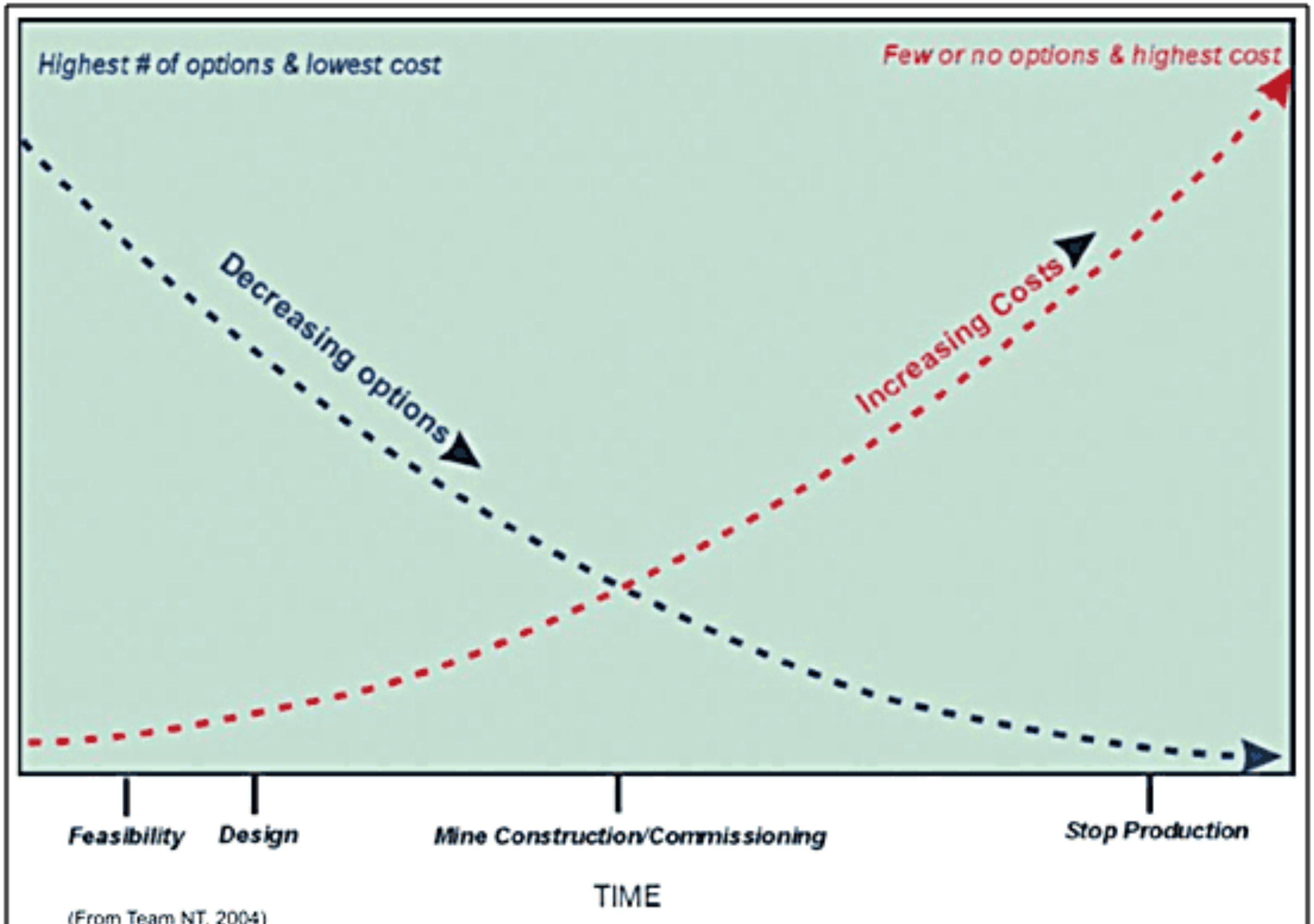
Limited take-up due to perceived costs

Geotechnical Closure Risks and Challenges for TSFs

- Dam geotechnical instability – Tailings are expected to drain down on cessation of deposition, but may be recharged by high rainfall (in absence of a spillway)
- Dam erosional instability, particularly in a dry climate if slope is flattened and topsoiled
- Differential settlement, affecting slope profile and drainage
- Poor water quality (saline, and/or acidic, or alkaline), after a lag:
  - Ponded water, and runoff leading to ponding below dump
  - Emerging at low points around toe and from face
  - Infiltrating to groundwater resource

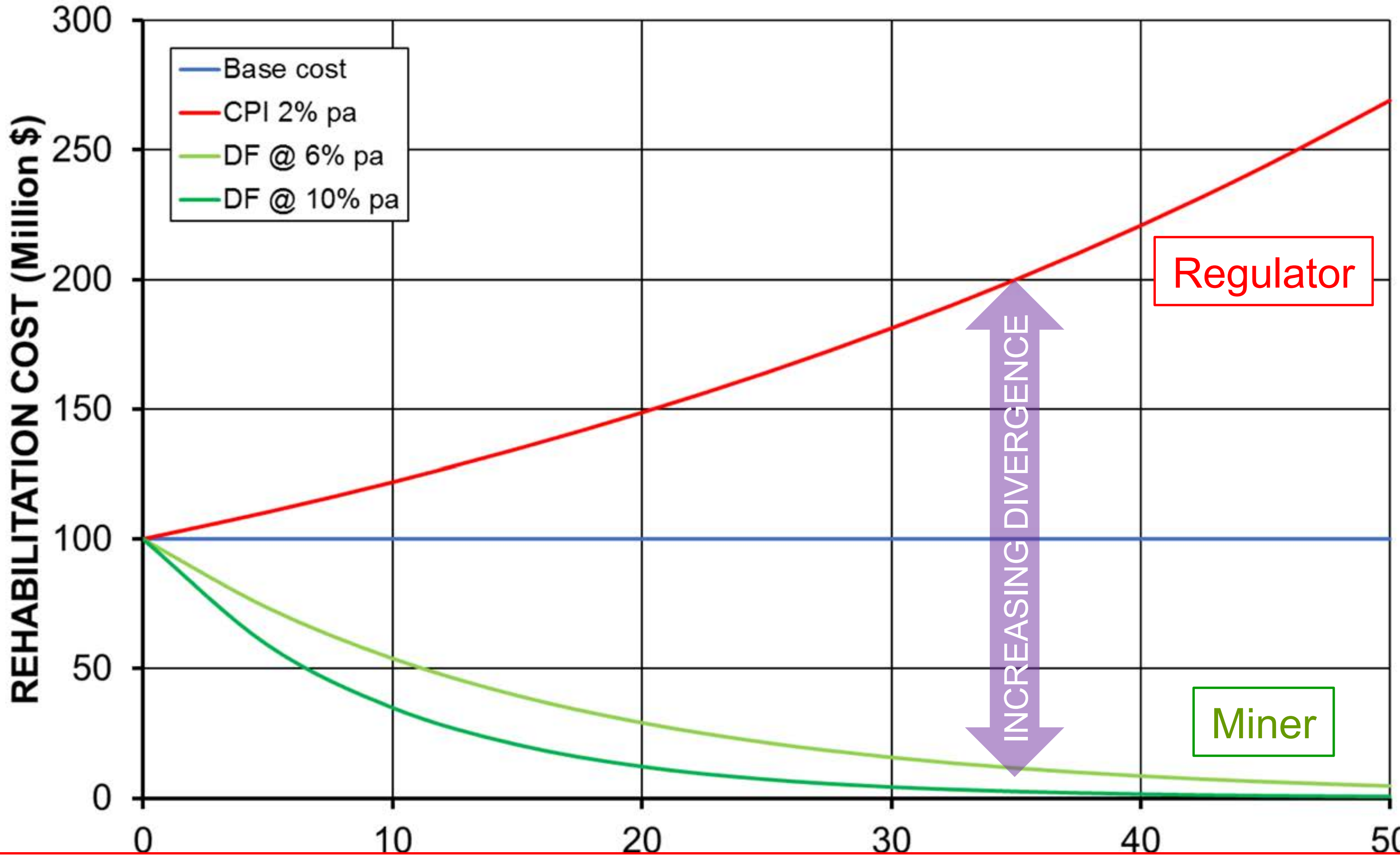
Few TSFs have been successfully rehabilitated, with reprocessing and in-pit disposal being considered

Closure Options Decrease and Costs Increase with Time (GARD, 2009)



This is somewhat counter to NPV Accounting with a high Discount Factor (10%)

Divergent Perceptions of Rehab. Cost over Time ($100 M Base Cost)



Which approach is more realistic of actual rehabilitation costs delayed over time?

We need a **new narrative focussed on opportunity for adding value** to site post-mining, which sets budget, resulting in wins for Company, Community and Government

“Cost” versus “Value” Approach to TSF Rehabilitation

The University of Queensland
Australia
Create change

CONVENTIONAL CLOSURE	VALUE-ADDED CLOSURE
• Mine production rules • Rehabilitation is seen by miner and regulator as a “cost” • Miner discounts cost over time, discouraging rehabilitation • Infrastructure such as power lines are stripped • Rehabilitation is limited to “smoothing” and “greening” • Post-closure land use and function are limited • Miner loses social and financial licences to operate	• Post-closure “value” is identified upfront • Examples include: – Renewable energy (NIMBY) – solar, wind and pumped storage, delivered to grid via mine transmission lines – Agriculture and/or fishery using mine dams – Tourism and mining heritage (older the better) • “Value” sets rehabilitation budget • Wins for miner, future land user and Government!

Annex D – Presentation by Luis Valenzuela, Geotechnical Consultant, Chile

Towards a Global Research Consortium on Tailings
Consultation Workshop – Santiago – July 9, 2019

Evolution of Tailings Dams Construction in Chile

Luis Valenzuela
Geotechnical Consultant

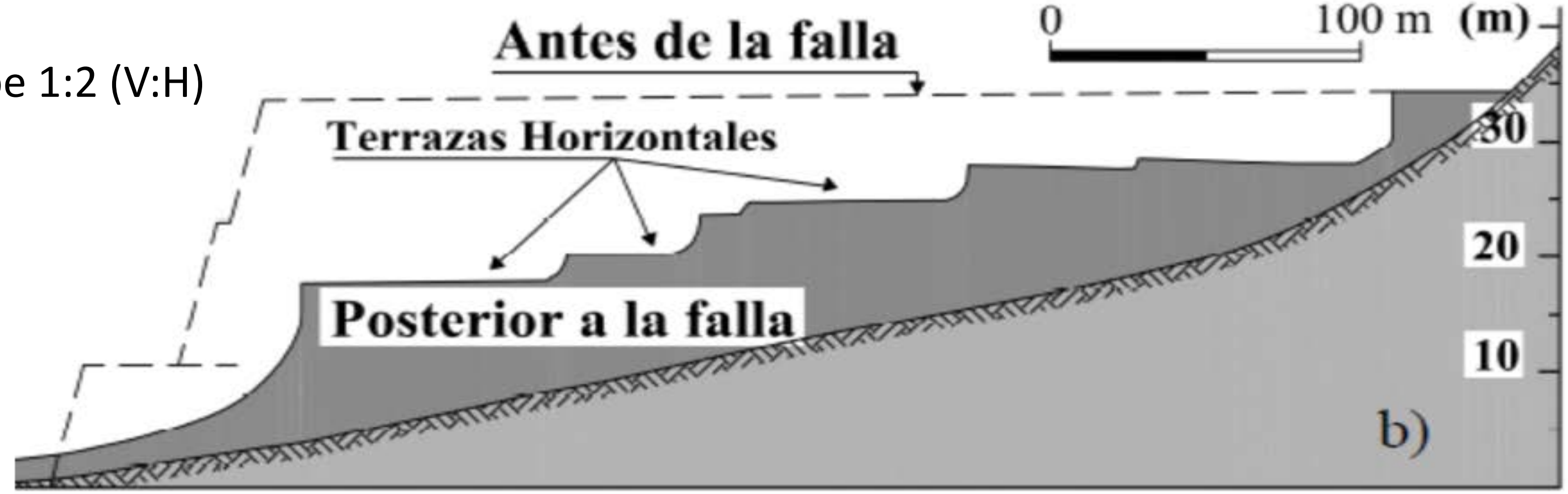
Failure El Cobre tailings dam (Soldado mine)

TERREMOTO DE LA LIGUA:

Fecha:	**28 de Marzo de 1965**
Hora local:	**12:33**
Magnitud:	**M_W = 7.4**
Profundidad:	**68 km**

FALLA TRANQUE DE RELAVES
SEPULTA PUEBLO EL COBRE
VICTIMAS FATALES: 200 - 350 ?

DS slope 1:2 (V:H)



R. Dobry and L. Alvarez, Seismic Failure of Chilean tailings Dams, *J. of the Soil M. & Found.D.*, ASCE, **SM6** (1967), 237-259.

Summary evolution tailings dams in Chile 1/2

- Before 1965 tailings dams constructed upstream were a majority.
- El Cobre tailings dam failure in 1965 - with more than 200 fatalities - occurred in a decade when world copper production particularly in Chile started to increase significantly.
- El Cobre disaster originated the review of the existing legislation and new Government Decree 86 (1970, replaced in 2007) was approved:

  > Forbidding upstream construction unless exceptional approval.

  > Introducing the concept of "dangerous distance" (DP).

  > DP to be used in seismic analysis to determine seismic coefficient **a**.

  > **a = 0,05 log (100+ h)** **h** being number of people in "danger"

  > Compaction was required for all dams.

Summary evolution tailings dams in Chile 2/2

- Even before Decree 86 was put in place, mining companies reacted designing downstream construction of different types of dams.
- These new dams were; compacted embankment dams, compacted waste rock fill dams and compacted sand dams.
- Most of new dams are downstream construction although center line construction is not forbidden and it has been used in some dams.
- In 2007 a new Decree 284 replaced Decree 86 introducing new restrictions such as:

> Maximum percentage of fines of 20% (<mesh 200) in sand dams.

> Dynamic seismic analysis required under certain conditions.

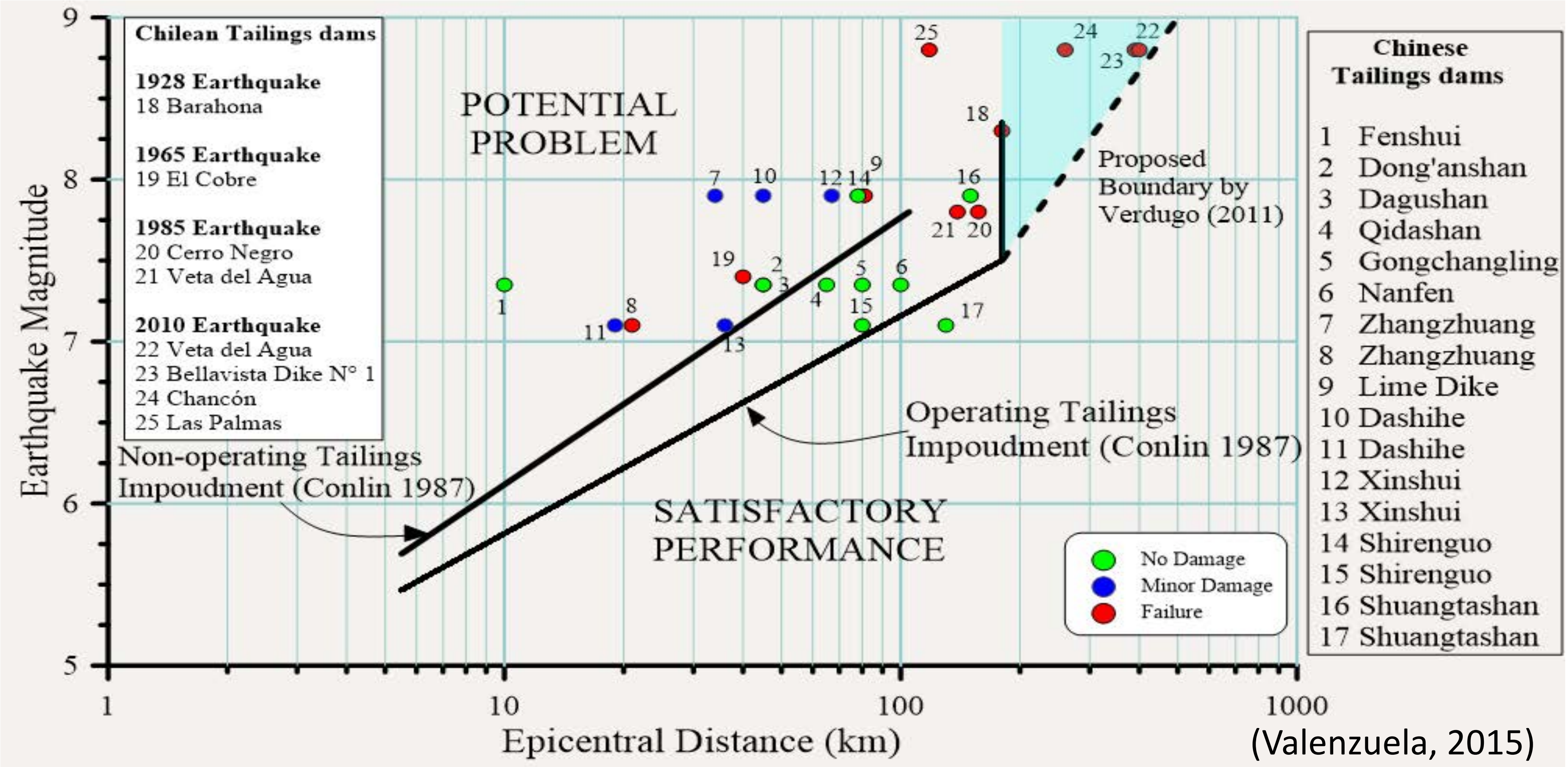
> Closure design at conceptual level.

> Dam break analysis required (still named as "dangerous distance").

Main failures of sand tailings dams in Chile

Sand tailings dams (US and DS)		Year	Fatalities	EQ Magnitude
Presa de Relaves Barahona	US	1928	54	Ms = 8,3
Presa de Relaves El Cobre N° 1, N° 2 y N° 3	US	1965	>200	Ms = 7,4
Presa de Relaves Veta del Agua N° 2	US	1981		Ms = 6,5
Presa de Relaves Cerro Negro	US	1985		Ms = 7,8
Presa de Relaves Veta del Agua N° 1	US	1985		Ms = 7,8
Presa de Relaves Planta Chacón	US?	2010		Ms = 8,8
Presa de Relaves N° 1 Planta Bellavista (DS)		2010		Ms = 8,8
Presa de Relaves N° 5 Veta del Agua	US	2010		Ms = 8,8
Presa de Relaves Adosado Planta Alhue (DS?)		2010		Ms = 8,8
Presa las Palmas	US	2010	4	Ms = 8,8

Failure upstream tailings dams after major EQ



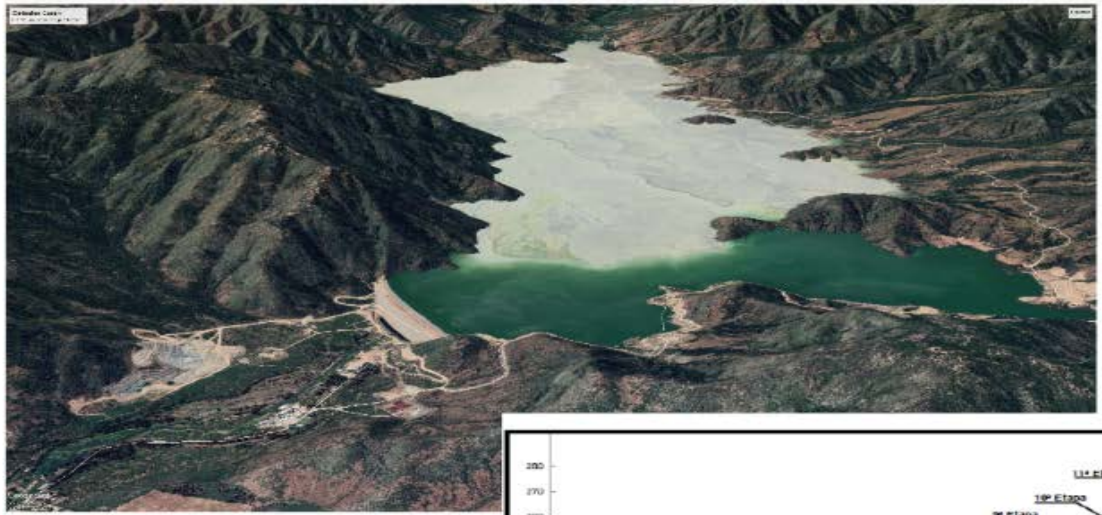
(Valenzuela, 2015)

Main tailings dams built after 1965 in Chile

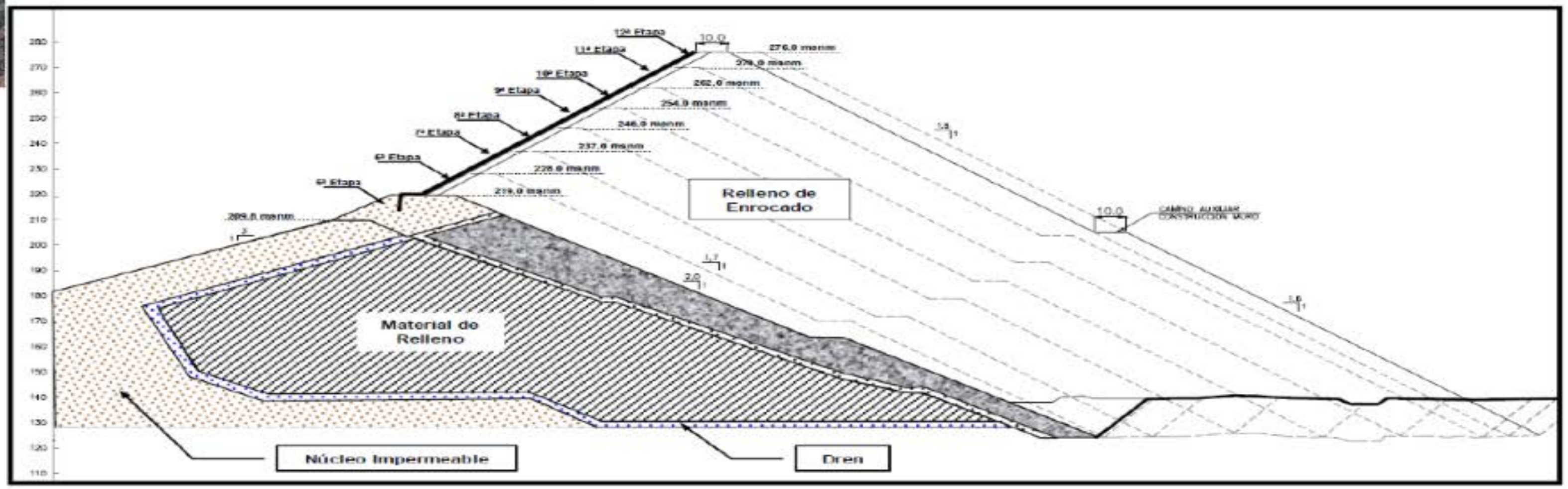
Name	Max height (m)	Dam length (m)	Capacity (Mm^3)(+)	Operation start	Type	Operation end
El Cobre 4	68	1,140	31	1969	DS	1992
Pérez C. 2	115-135 (§)	500	84	1978	DS	1992
El Chinche	110	470	14.5	1992	DS	1999
Las Tórtolas	150-170	1.700 (-)	1996	1992	DS	OP
Torito	78	2,190	122	1992	DS/CL	OP
Quillayes	175-198	1.600 (+)	360	1999	DS	2008
Ovejería	58-120	3.600 (+)	235	1999	DS	OP
El Mauro	237	1,450	1088	2008	DS	OP
Piuquenes	58	500	20.5	1970	DS	1980
P. Pabellón	90 (§)	4.500 (+)	2400	1998	RF	OP
Pampa Austral	29	700	100	1989	EF	OP
El Indio	79	290	42	1987	EF	1999
Los Leones	160	500	140	1980	RF	1999
Talabre	40	5,300	1200	1985	EF/DS	OP
Colihues A	83	1,200	160	1981	EF	1986
Candelaria	163	2,400	260	1995	RF	OP
Carén	54	950	300	1986	EF	OP

DS: Downstream Sand Dam; CL: Centerline Sand Dam; RF: Rock-fill; EF: Earth-fill

Caren tailings embankment dam (Teniente)

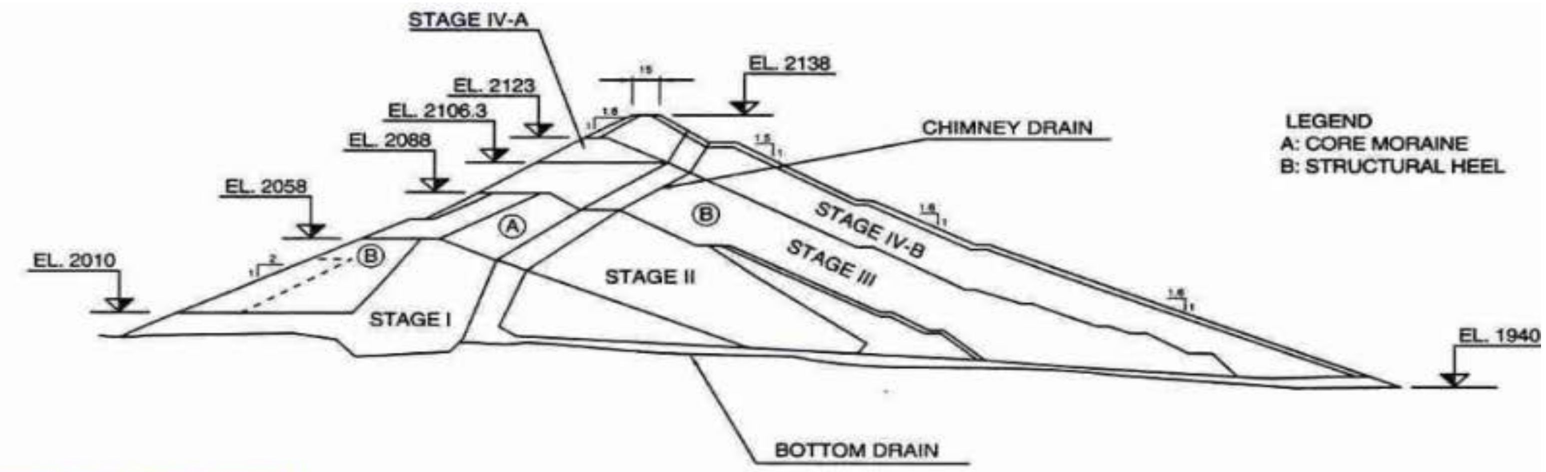


Caren



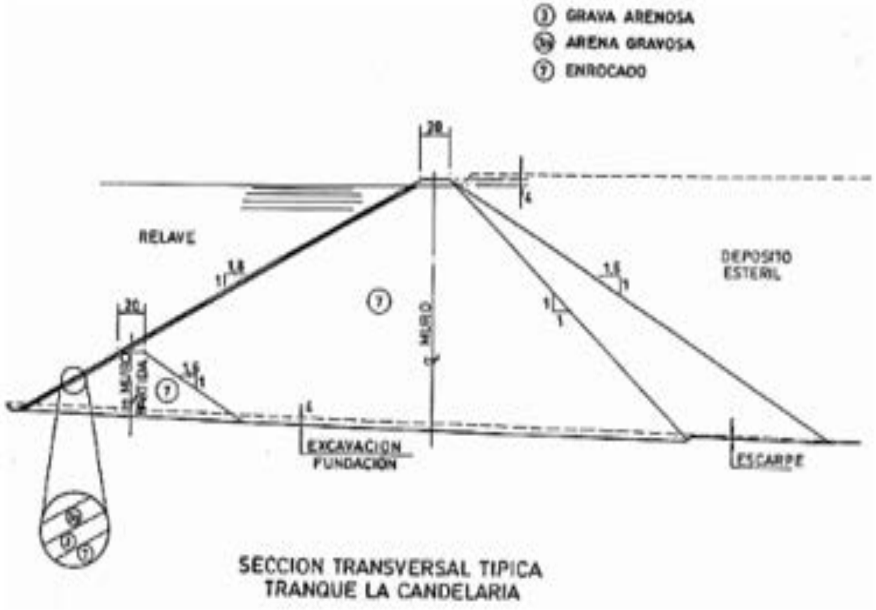
Los Leones rock fill tailings dam (Andina)

LOS LEONES

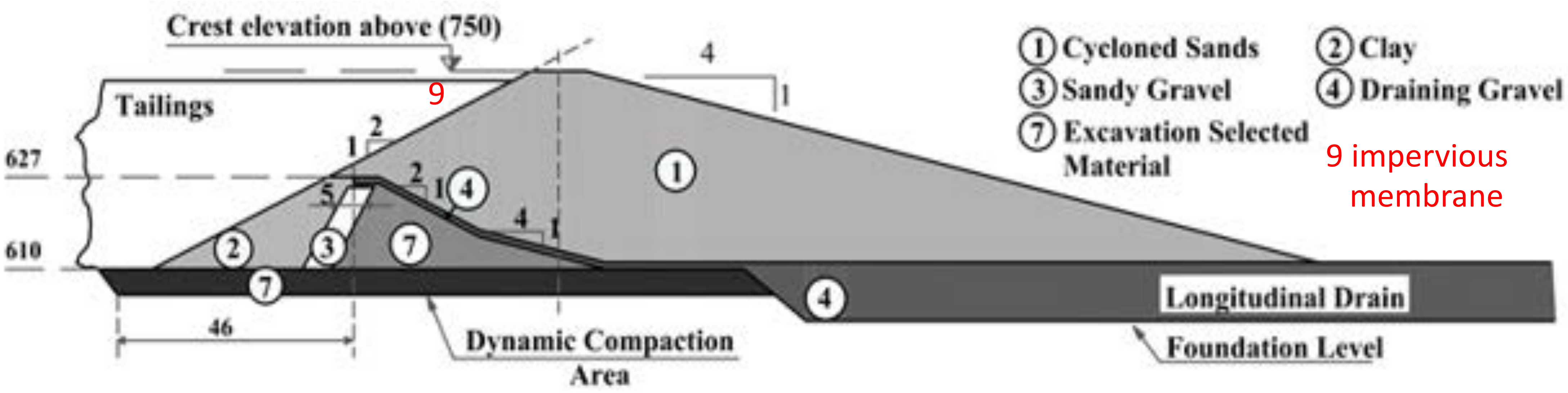


UBICACIÓN: CORDILLERA, EN LA ZONA CENTRAL
ALTURA TOTAL = 198 m

Candelaria waste rock tailings dam (Lundin)



Las Tortolas sand DS tailings dam (170 m high)



Downstream sand tailings dams in Chile

- Downstream sand tailings dams are the type of dams that are generally recognized as the characteristic tailings dams of Chile.
- Some of them designed for significant heights (200m – 300m high)
- Despite their heights and country seismicity their performance has been very positive.
- Some of their distinctive characteristics are:

> They are associated with a highly seismic environment.

> The Chilean practice considers industrialized cyclone plants.

> Strict control on percentage of fines – usually << 20% (< mesh 200).

> Strict compaction control.

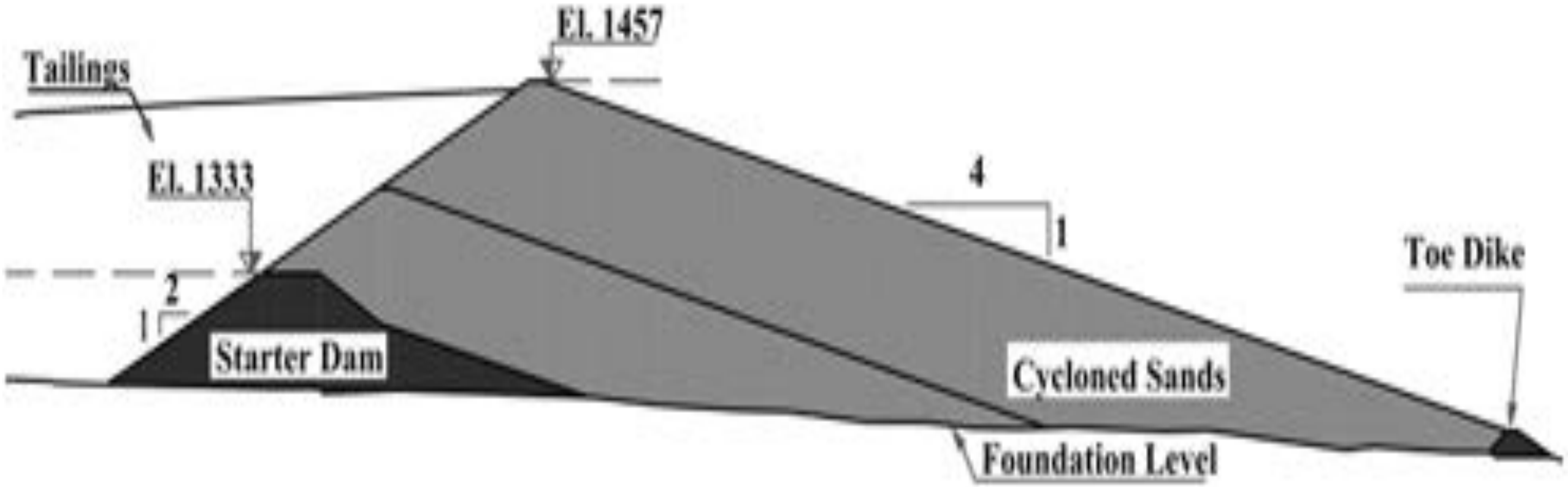
> Generous basal drainage (central and lateral).

Typical sand DS tailings dam (Quillayes dam)

Industrial cyclone station (Quillayes dam)

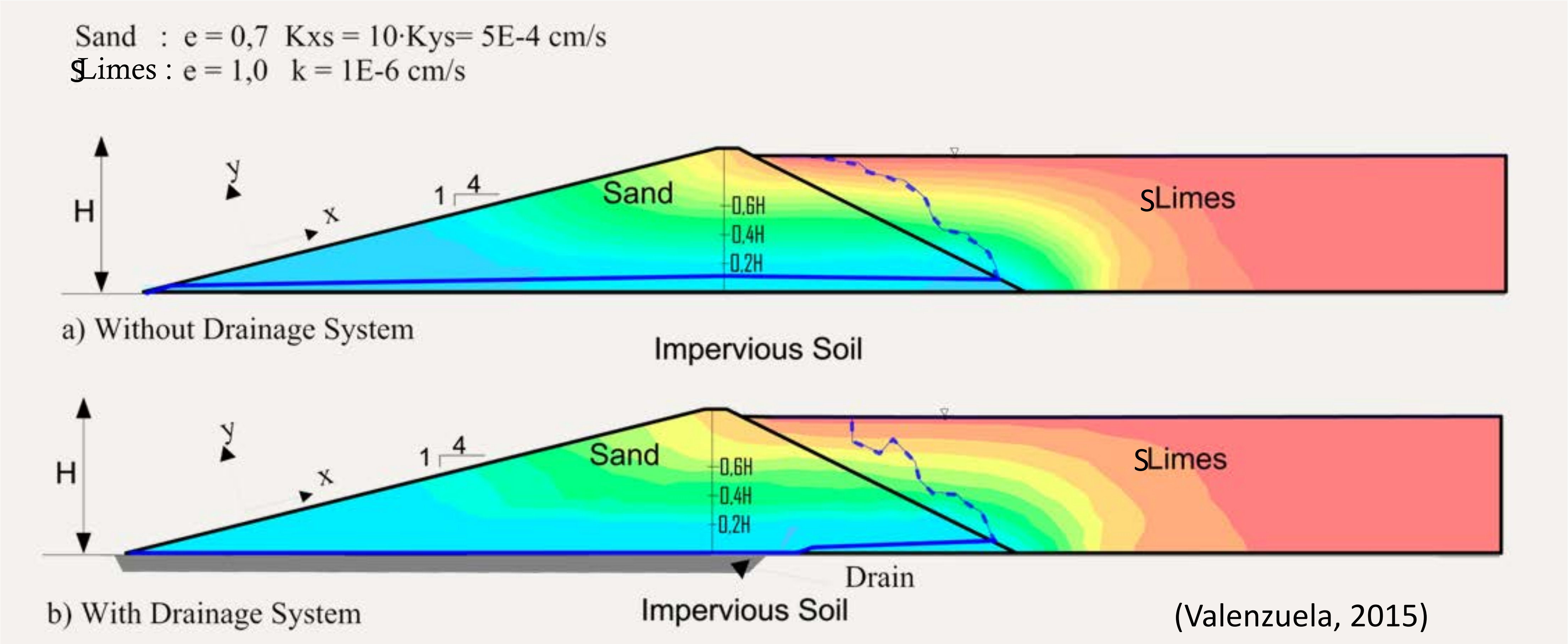
Compaction of DS slope (Quillayes dam)

Typical cross section sand DS dam (Quillayes)



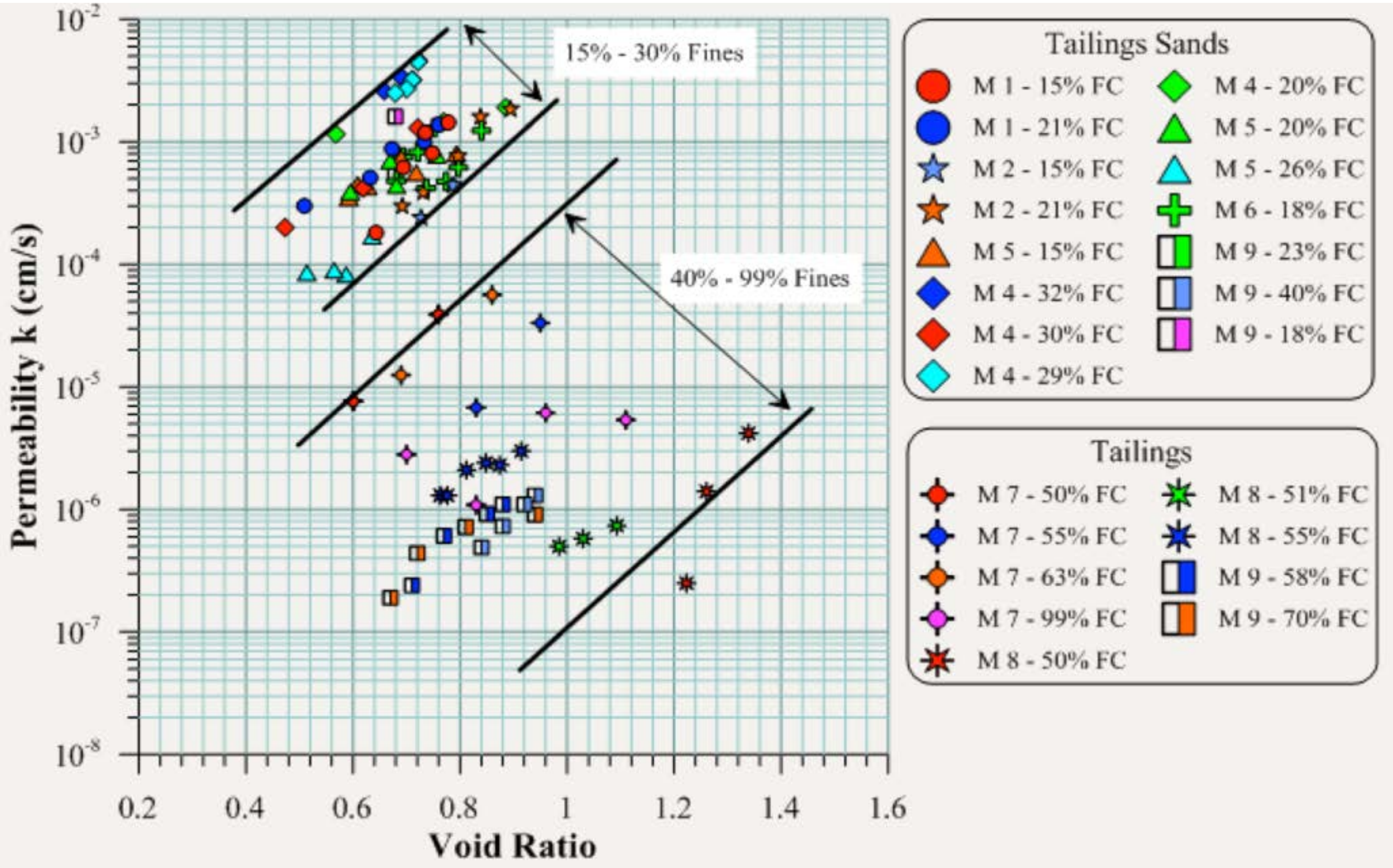
Parameter	Original Design	Revision
Relative Density (%)	59	60
Friction Angle (°)	35-35.7	35
CRR	0.21	0.24
FC (% below#200)	15%	16%
Permeability (cm/s)	$10^{-3} - 10^{-4}$	$10^{-3} - 10^{-4}$
Phreatic level (m)	10	< 10

Permeability contrast slimes-sand in DS dams



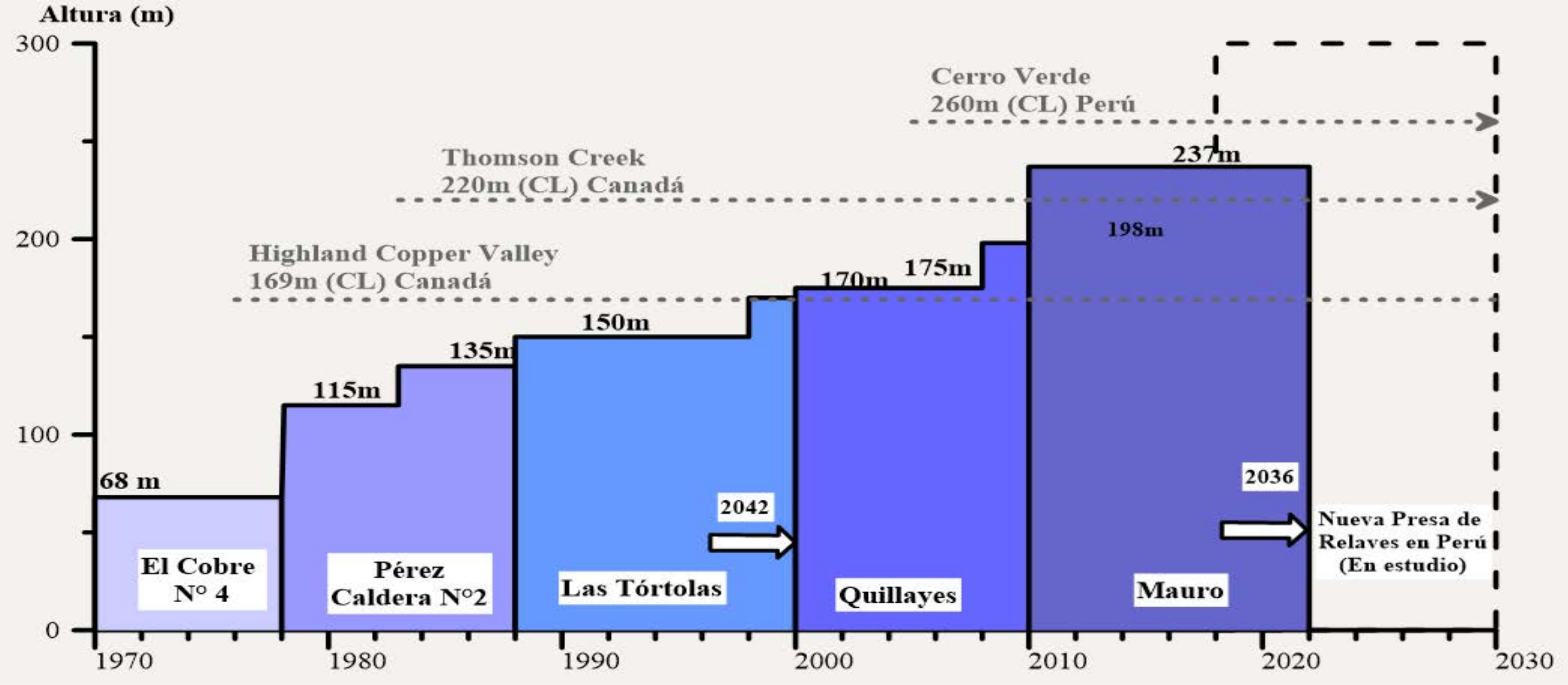
(Valenzuela, 2015)

Tailings sand permeabity vs fines content (FC)

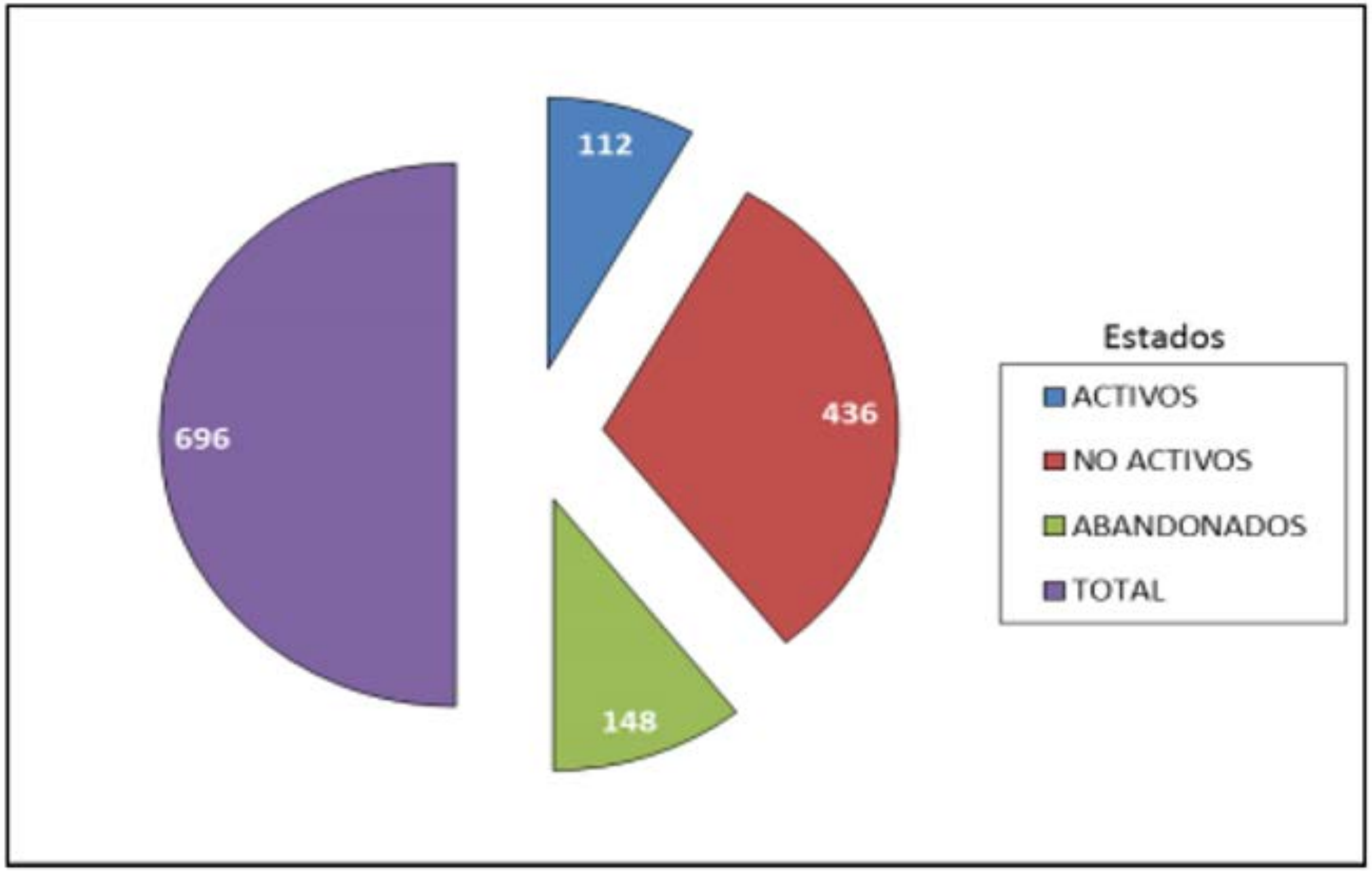


Sand permeability under high confining pressures.
Campaña et al. 2015
Valenzuela, 2015

Evolution (height) in sand DS tailings dams



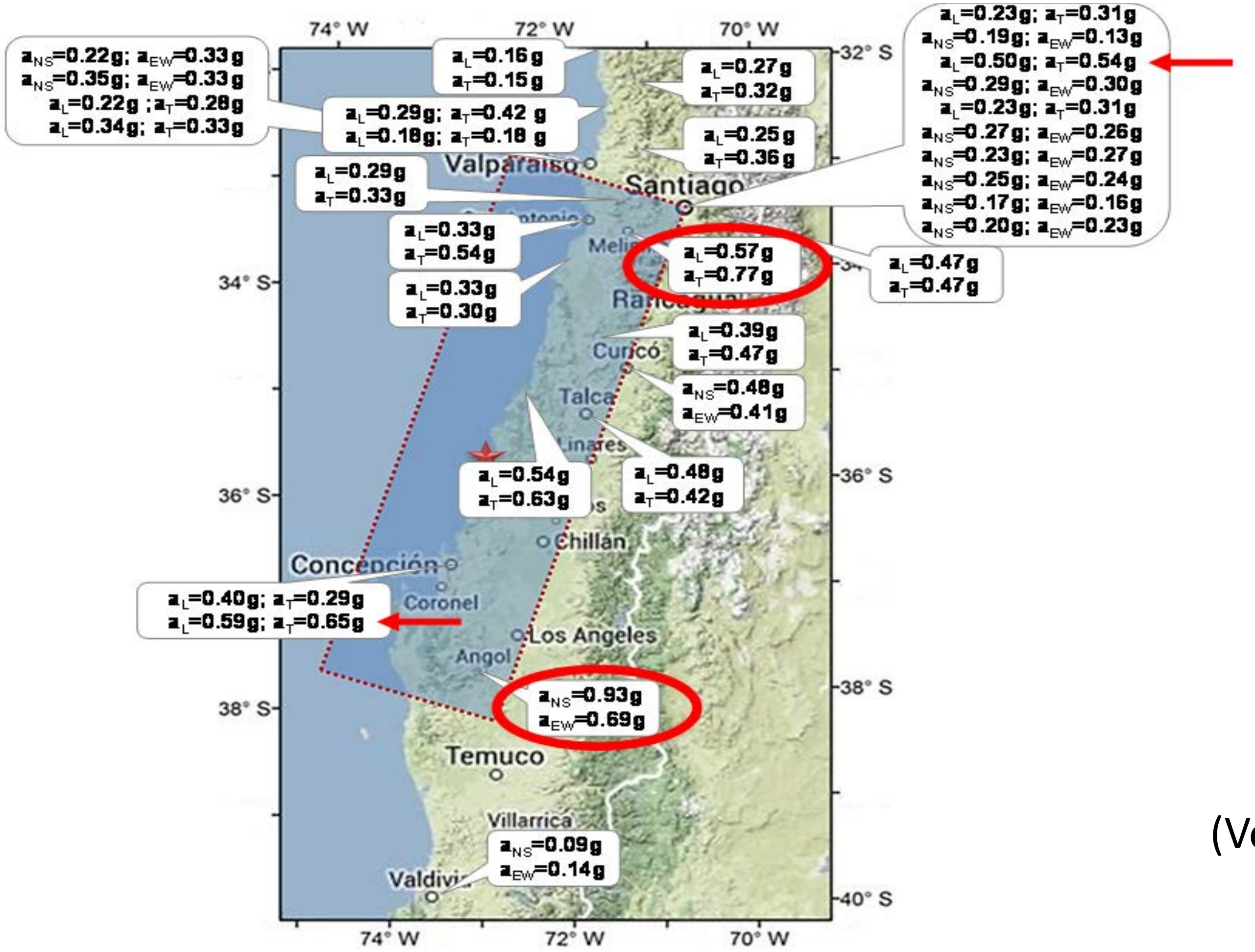
Total number tailings deposits in Chile (2018)



Sernageomin, 2018

Seismic performance tailings dams in Chile

PGA (hor.) soil deposits - 2010 EQ Mw 8.8



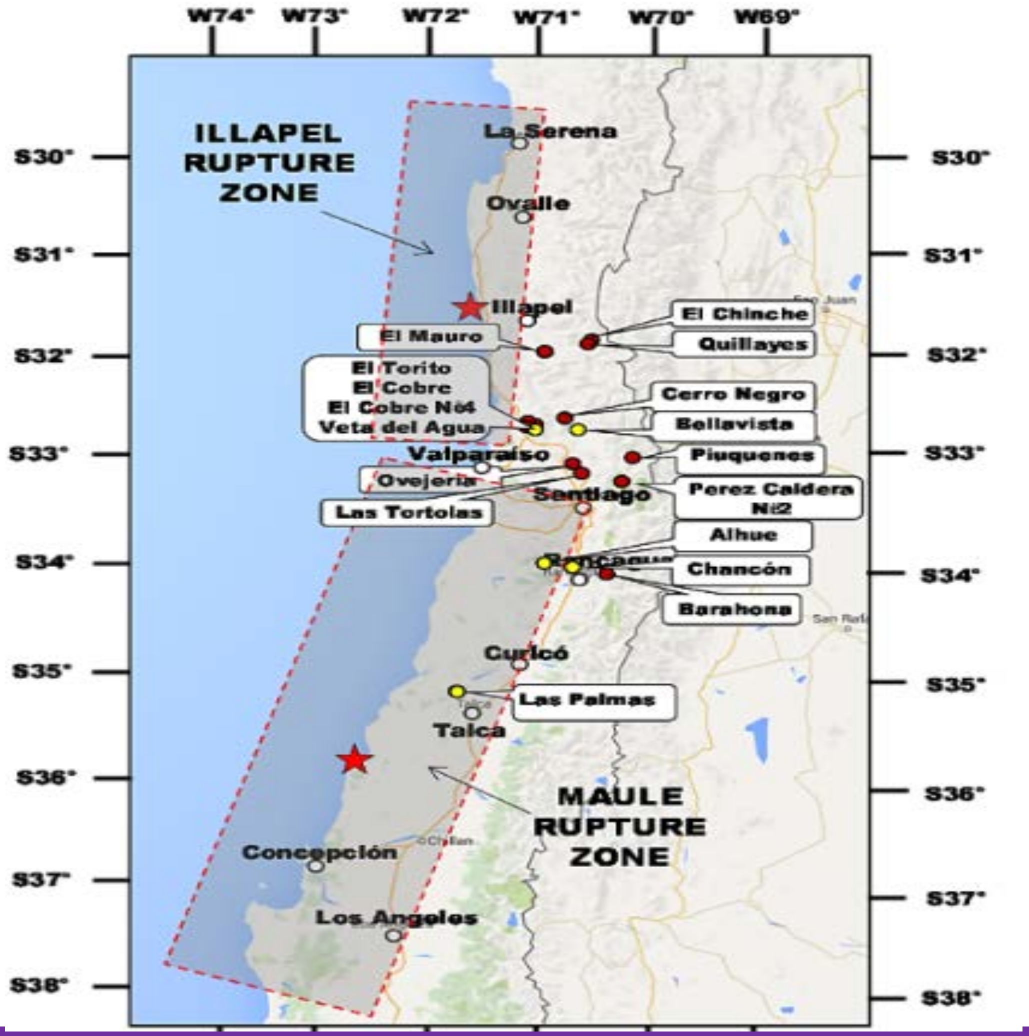
(Verdugo et al., 2017)

Maule 2010 EQ Mw 8.8-Tailings dams location

2015 Illapel EQ (Mw 8.4) and dams location

(Verdugo et al., 2017)

Tailings dams - rupture zones 2010 &2015 EQ



(Verdugo et al., 2017)

Back up slides: Risk and probability of failure

Probability tailings dam failure > other dams

Where	When (decade)	p_f	Approx p_f
World-wide	Around '79	44/(3,500*10)	10^{-3}
World-wide	Around '99	7/35,000	$2*10^{-4}$
US	Around '79 & Around '99	7 or 8/(1,000*10)	7 or $8*10^{-4}$

Ref. Oboni & Oboni, 2013

Frequency of failure of "civil" water dams is in the order of 1:10.000 or even lower (1:100.000 ?). Frequency of failure in tailings dams is around 1:1.000 (meaning "lesser quality" than hydro dams). This is a fact that stakeholders are considering unacceptable → **risk of loosing social license to operate.**

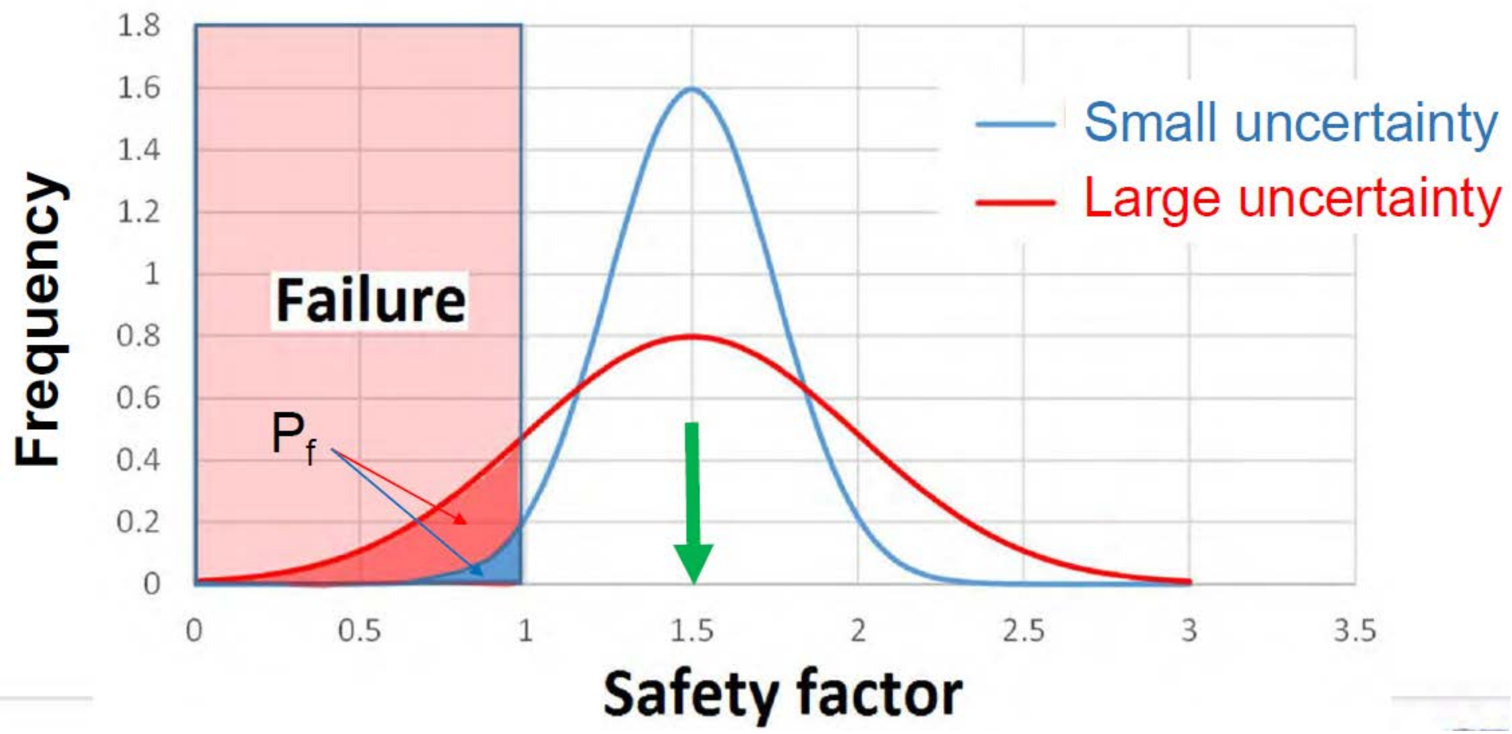
6th Victor de Mello Lecture (Brazil, 2018)

Professor Norbert R. Morgenstern (University of Alberta):

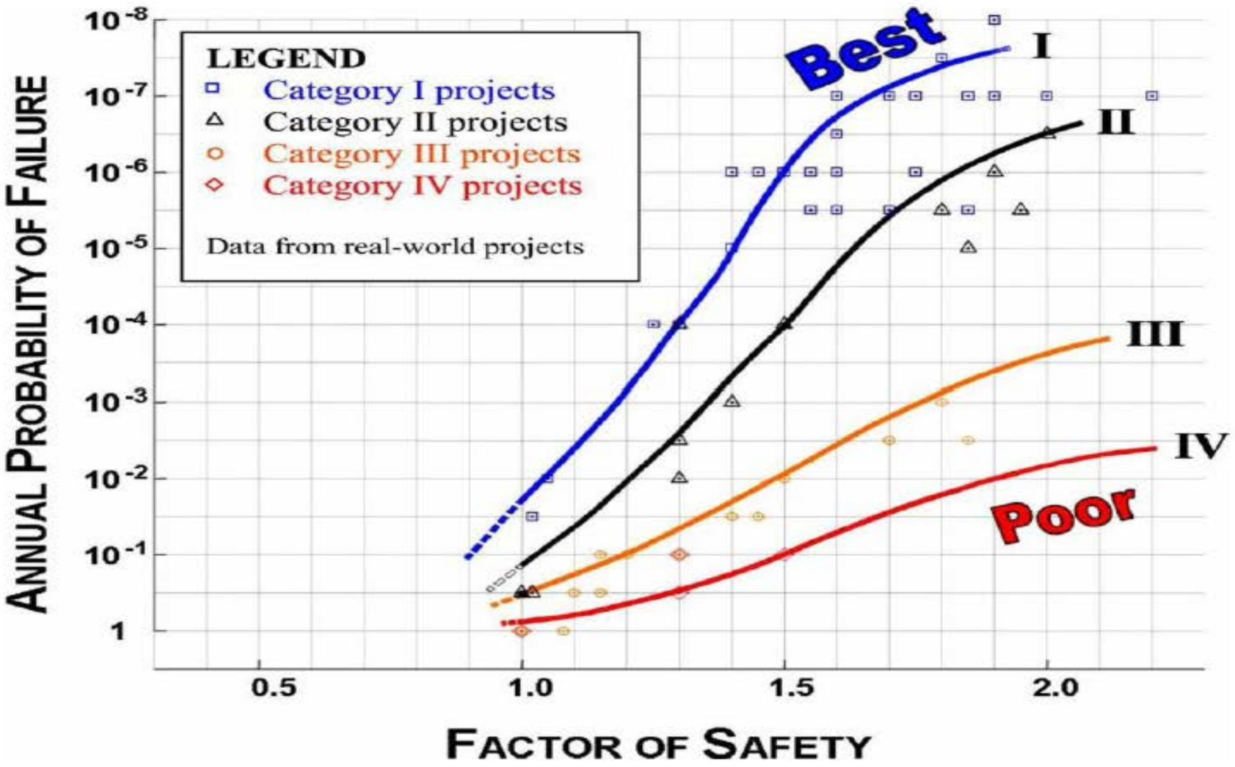
"At this time, there is a crisis associated with concern over the safety of tailings dams and lack of trust in their design and performance."

Factor of safety FS and failure probabilities Pf

Very different safety margins and failure probabilities

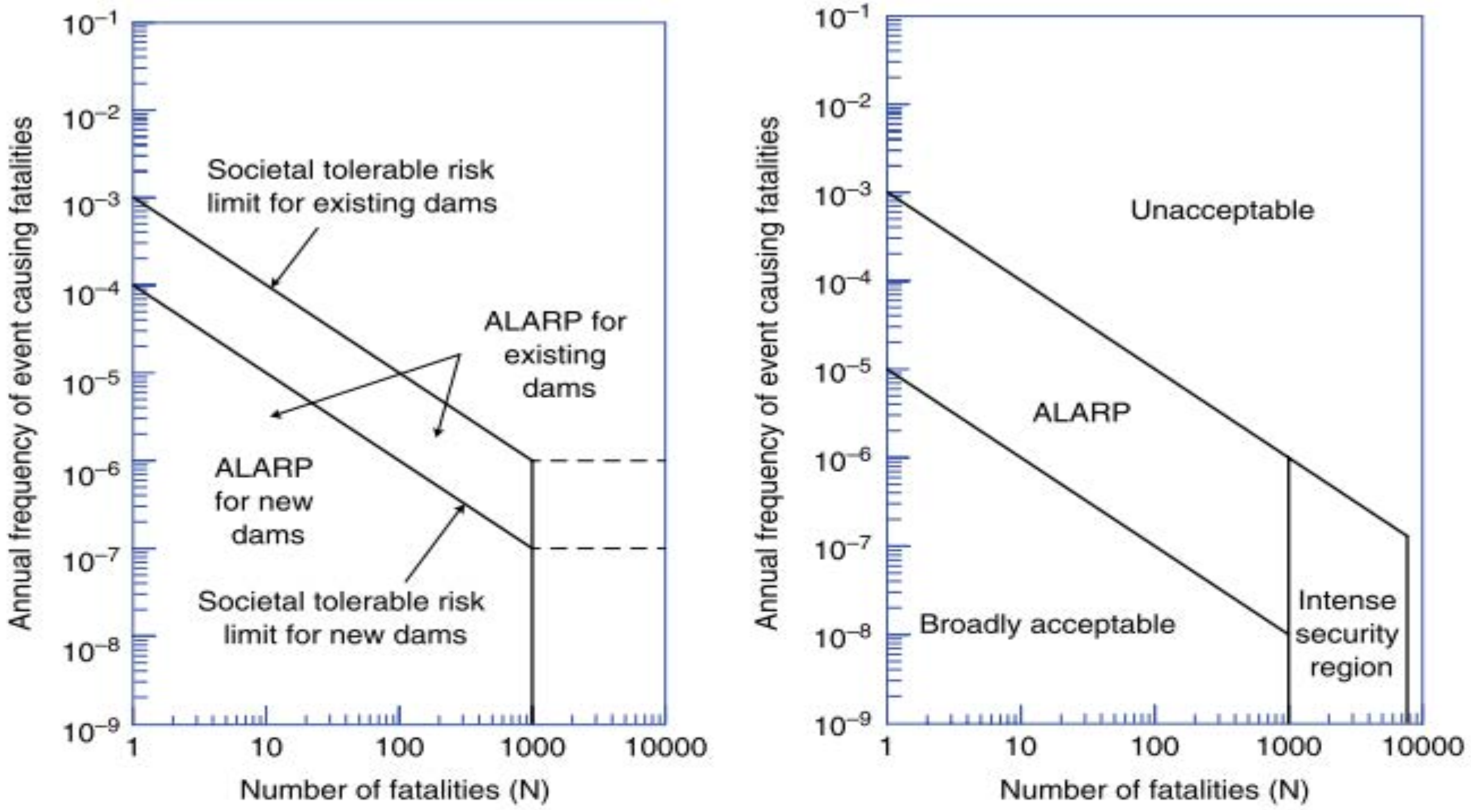


FS and Pf→depending on design & operation



ig. 2 Annual Probability of Failure vs. Factor of Safety following Silva, Lambe, Marr (SLM) (F. Silva, W. Lambe, W.A. Marr, 2008) methodology.

Tolerable risk for lives losses, dams and slopes



A cultural shift in tailings management ?

Hazard	→	Consequence
Response	→	Preparedness and risk reduction
Reactive	→	Proactive
Science-driven	→	Multi-disciplinary
Response management	→	Risk management
Planning for people/society	→	Planning with people and society

S. Lacasse and K.Hoeg, ICOLD, 2019

Annex E – Presentation by Associate Professor Mansour Edraki, Centre for Mined Land Rehabilitation, SMI, UQ

Knowledge gaps and opportunities for using geochemical data in tailings management

Mansour Edraki

m.edraki@cmlr.uq.edu.au

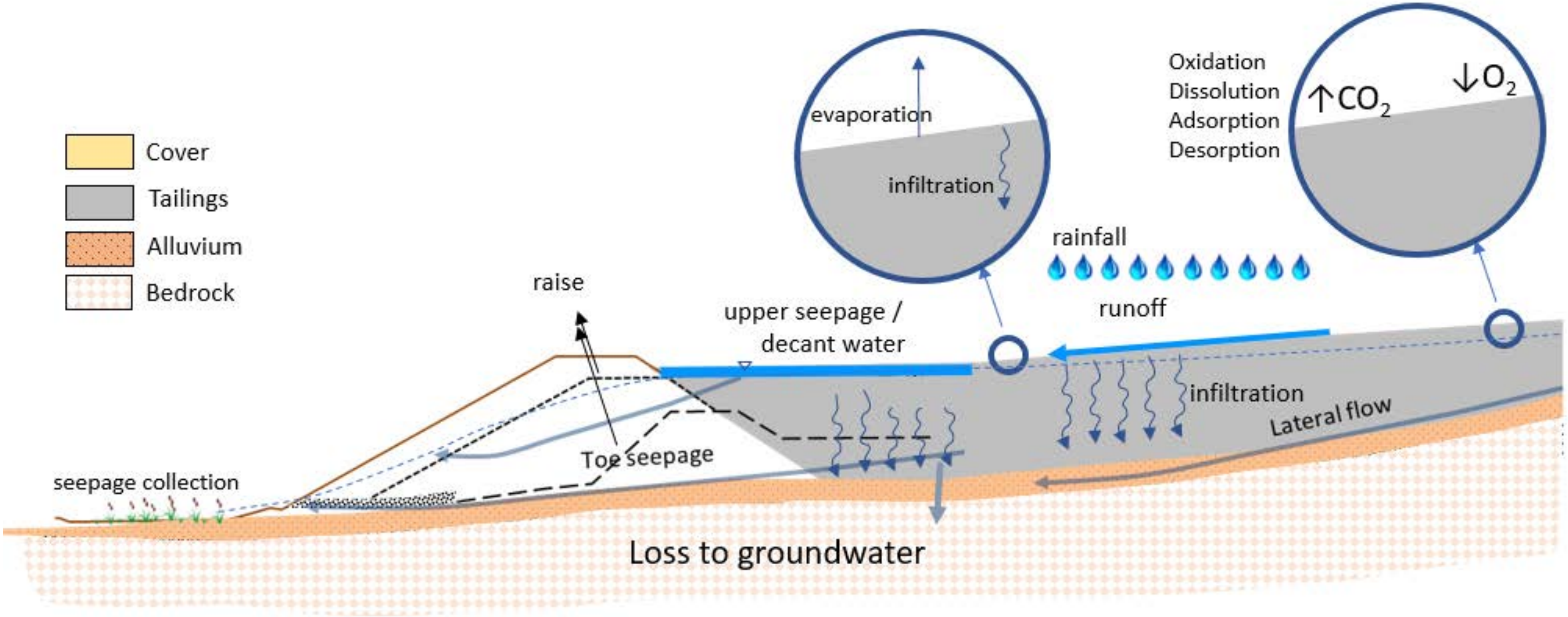
Towards a Global Research Consortium on Tailings - Santiago 9 July 2019

Ludden et al (2015):

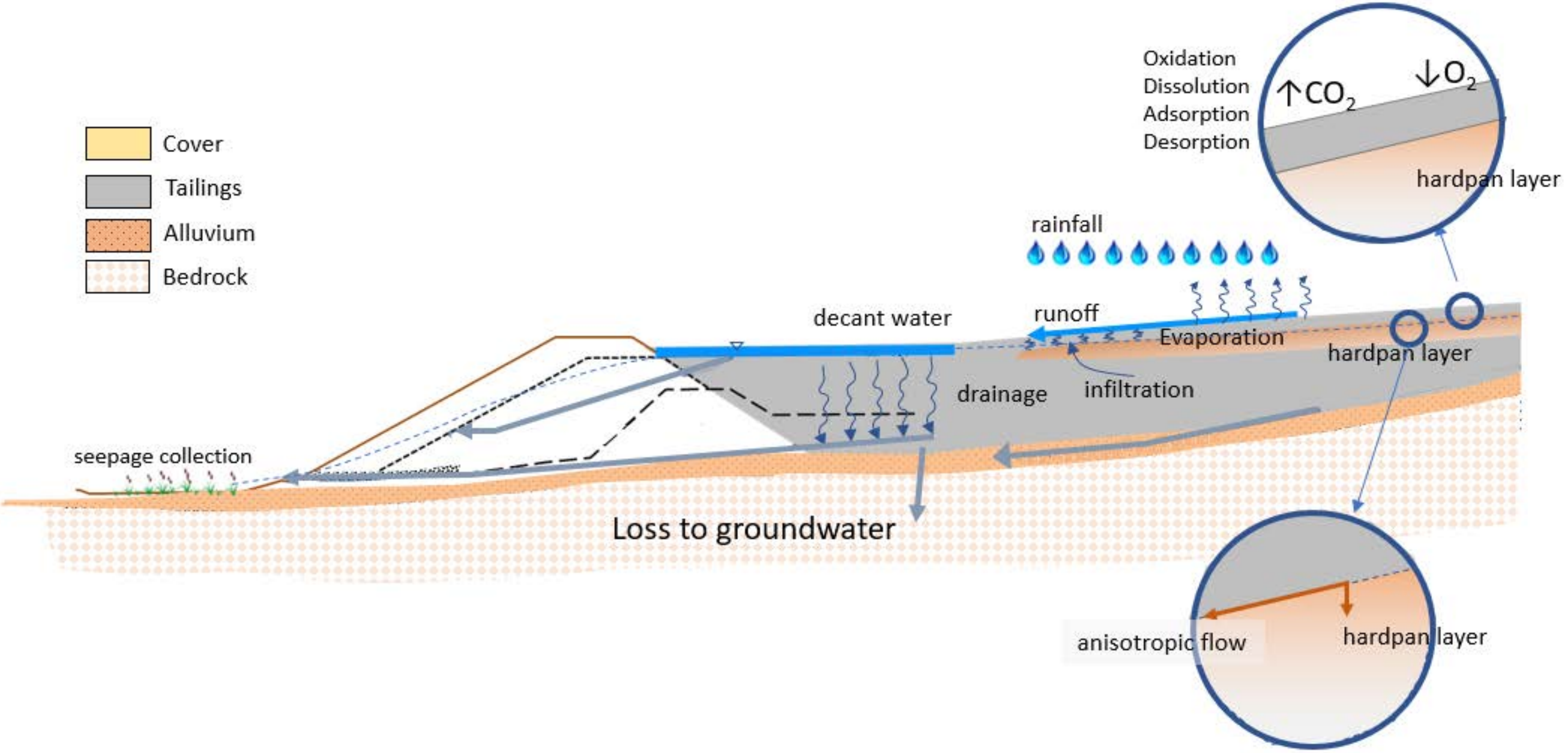
"Our ability to move from the provision of evidence to describing a solution, and then convincing politicians and implementing agencies to put this solution into practice, is in question.

Geochemists should not simply move onto the next interesting problem until we have found a way to move the results into innovation".

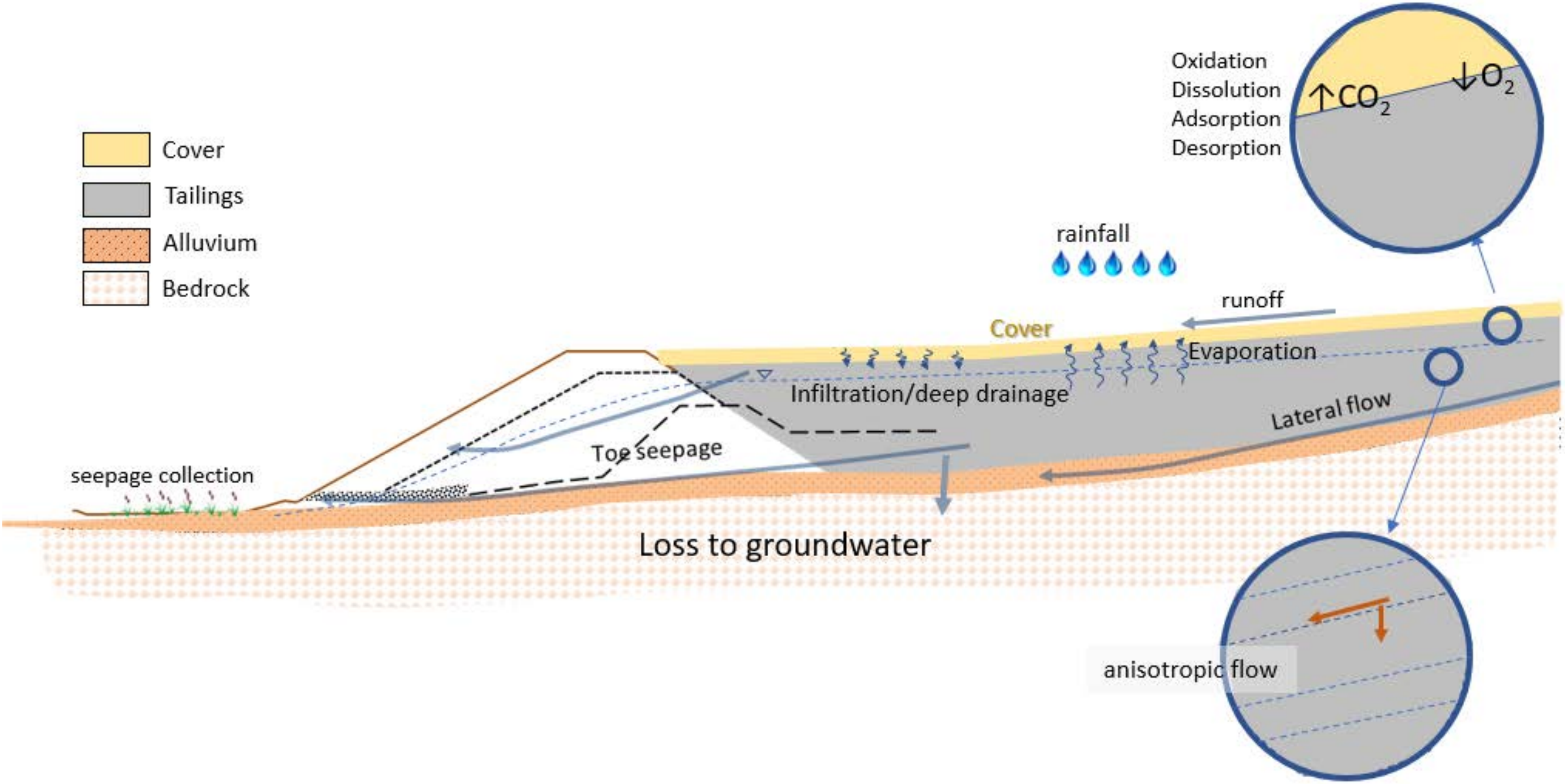
Background –
Evolution of tailings seepage geochemistry

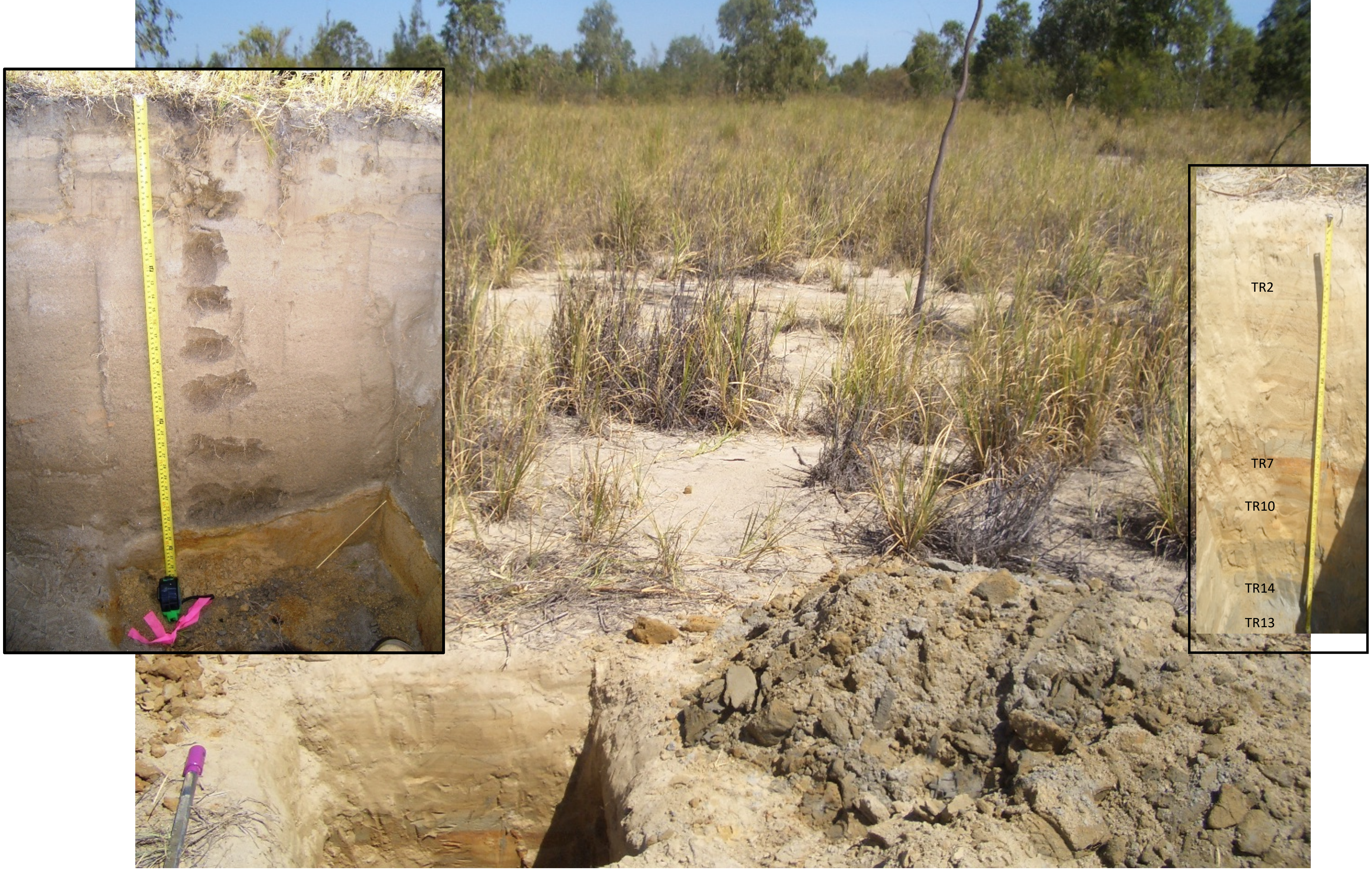


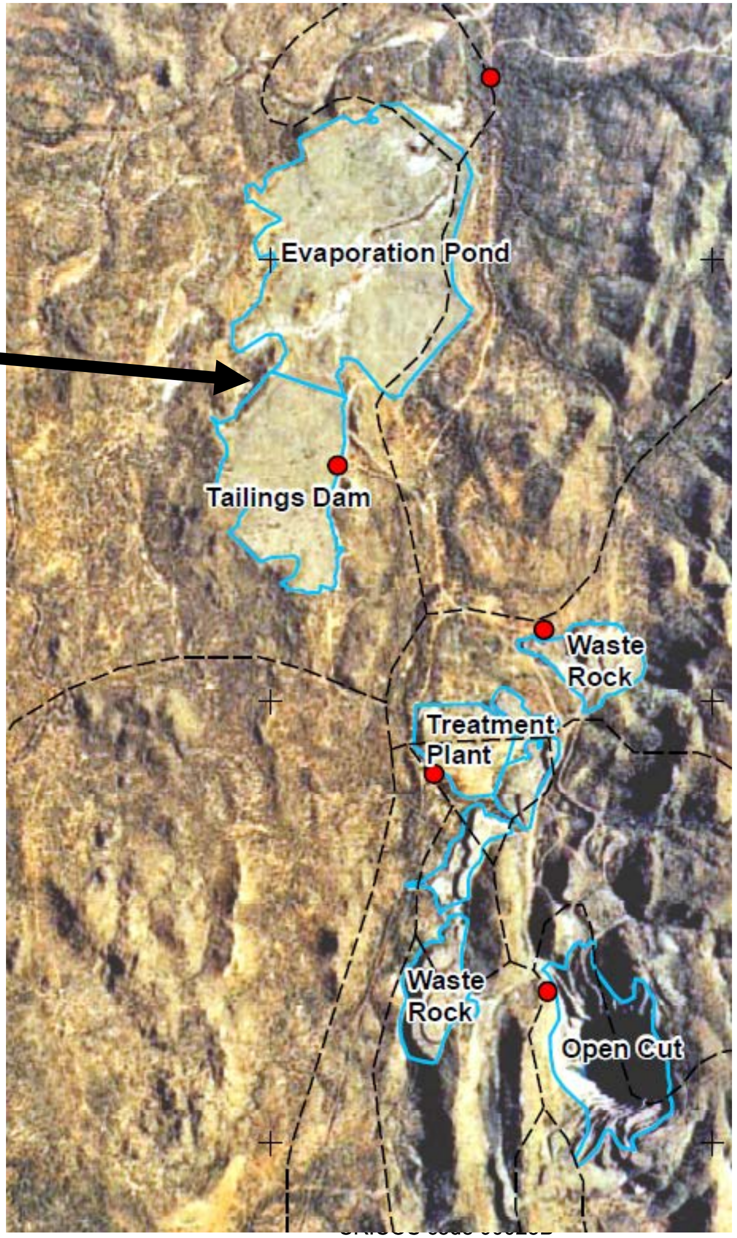
Evolution of tailings seepage geochemistry



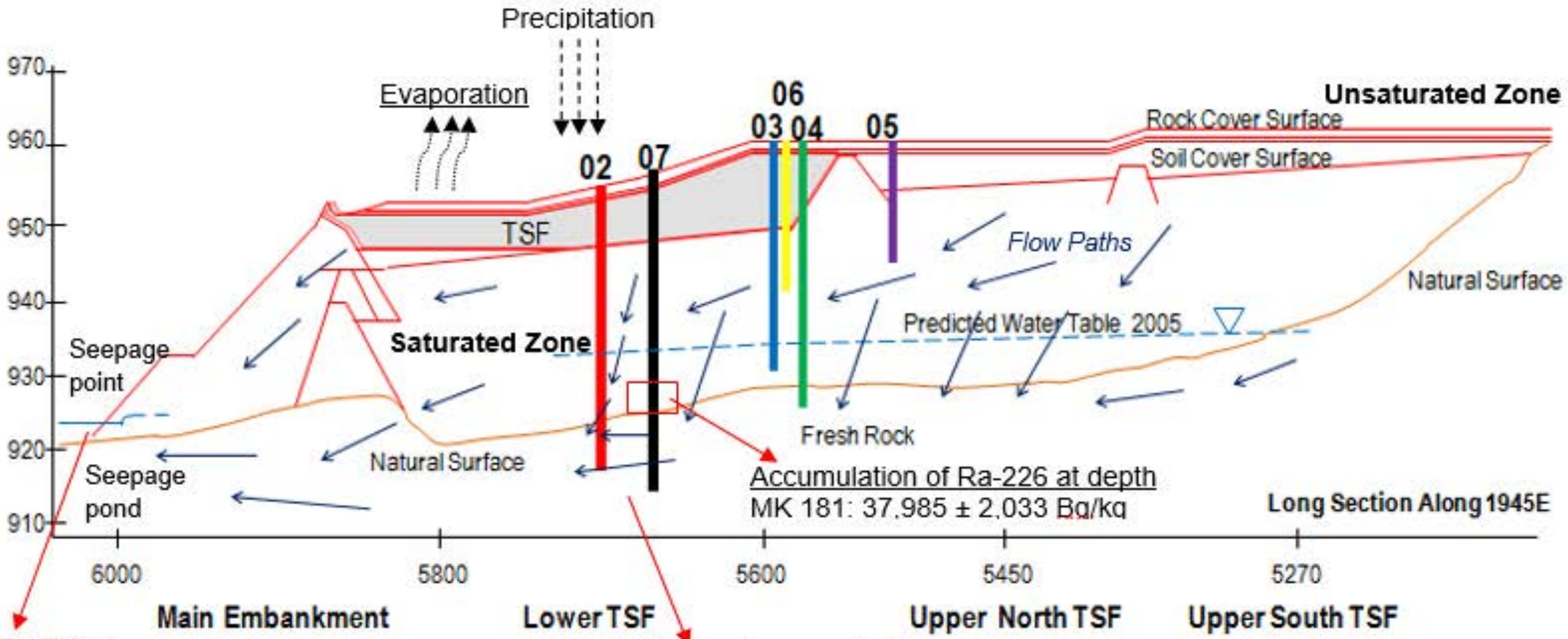
Evolution of tailings seepage geochemistry




TR2
TR7
TR10
TR14
TR13



Tailings seepage at Mary Kathleen mine north Queensland



Acid Mine Drainage
MKWS12 (Seepage point)
pH : 5.1 – 7.6
EC : 4,900 – 12,100 µS/cm
SO_4^{2-} : 3,900 – 9,200 mg/L

Ba	: 0.01 – 0.04 mg/L	**Mg**	: 248 – 1,800 mg/L
Ca	: 490 – 1,036 mg/L	**Mn**	: 5.2 – 120 mg/L
Cd	: 0.002 – 0.05 mg/L	**Na**	: 170 – 710 mg/L
Cu	: 0.001 – 0.009 mg/L	**U**	: 0.17 – 1.0 mg/L
K	: 11 – 86 mg/L	**Zn**	: 0.03 – 0.05 mg/L

Infiltration to groundwater
MKPZ 42 (downstream of evaporation pond)
pH : 6.8 – 7.7
EC : 6,094 – 8,800 µS/cm
SO_4^{2-} : 4,600 – 5,900 mg/L

Ba	: 0.01 – 0.03 mg/L	**Mg**	: 610 – 870 mg/L
Ca	: 380 – 470 mg/L	**Mn**	: 10 - 21 mg/L
Cd	: < 0.003 mg/L	**Na**	: 690 – 1100 mg/L
Cu	: 0.008 – 0.01 mg/L	**U**	: 0.02 – 3.0 mg/L
K	: 8 – 16 mg/L	**Zn**	: 0.02 – 0.07 mg/L

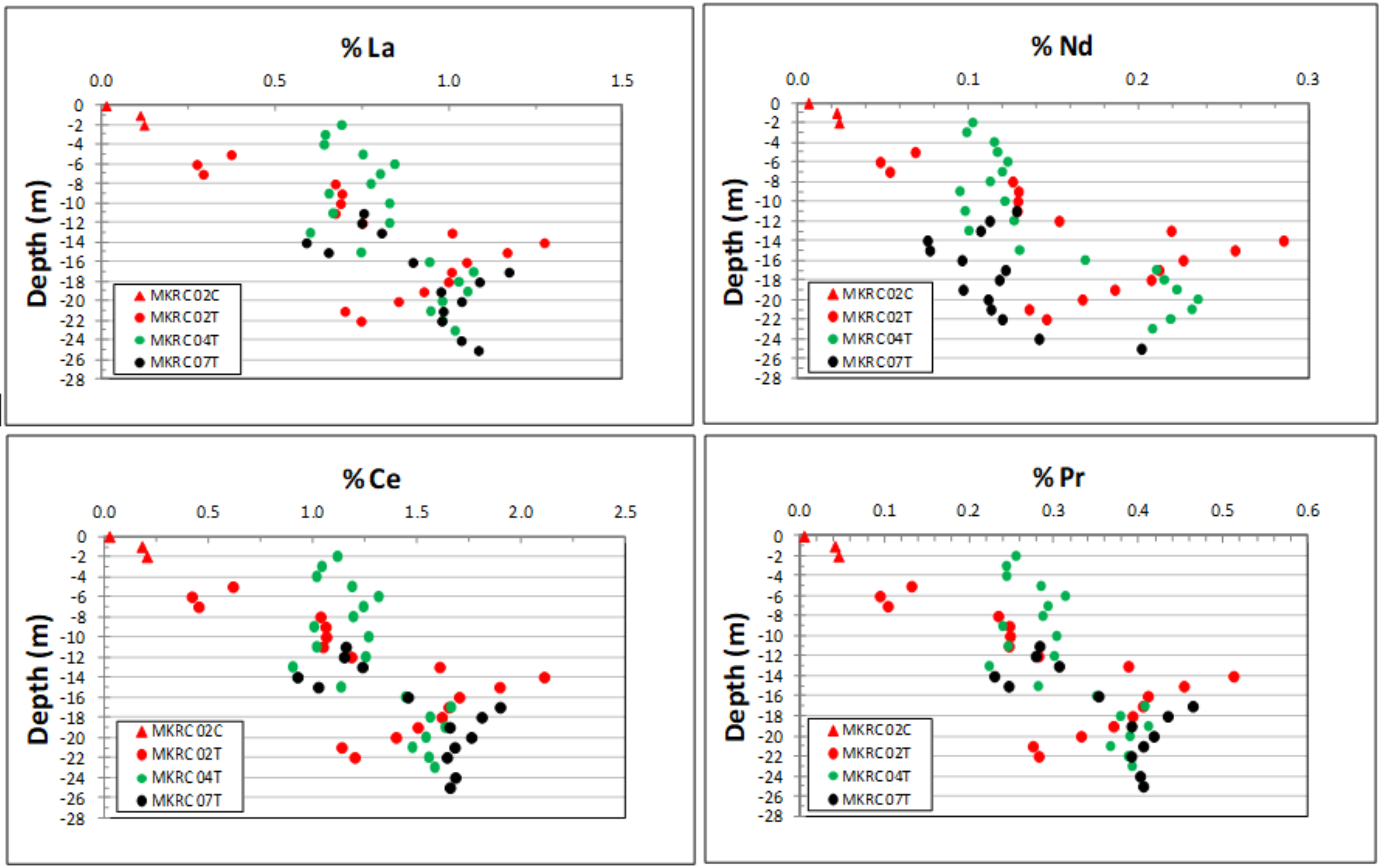
Geochemical Processes
Neutralisation (dissolution of magnesium silicates)
Exchange Reactions
Pyrite oxidation
Dissolution of Ca-sulfate

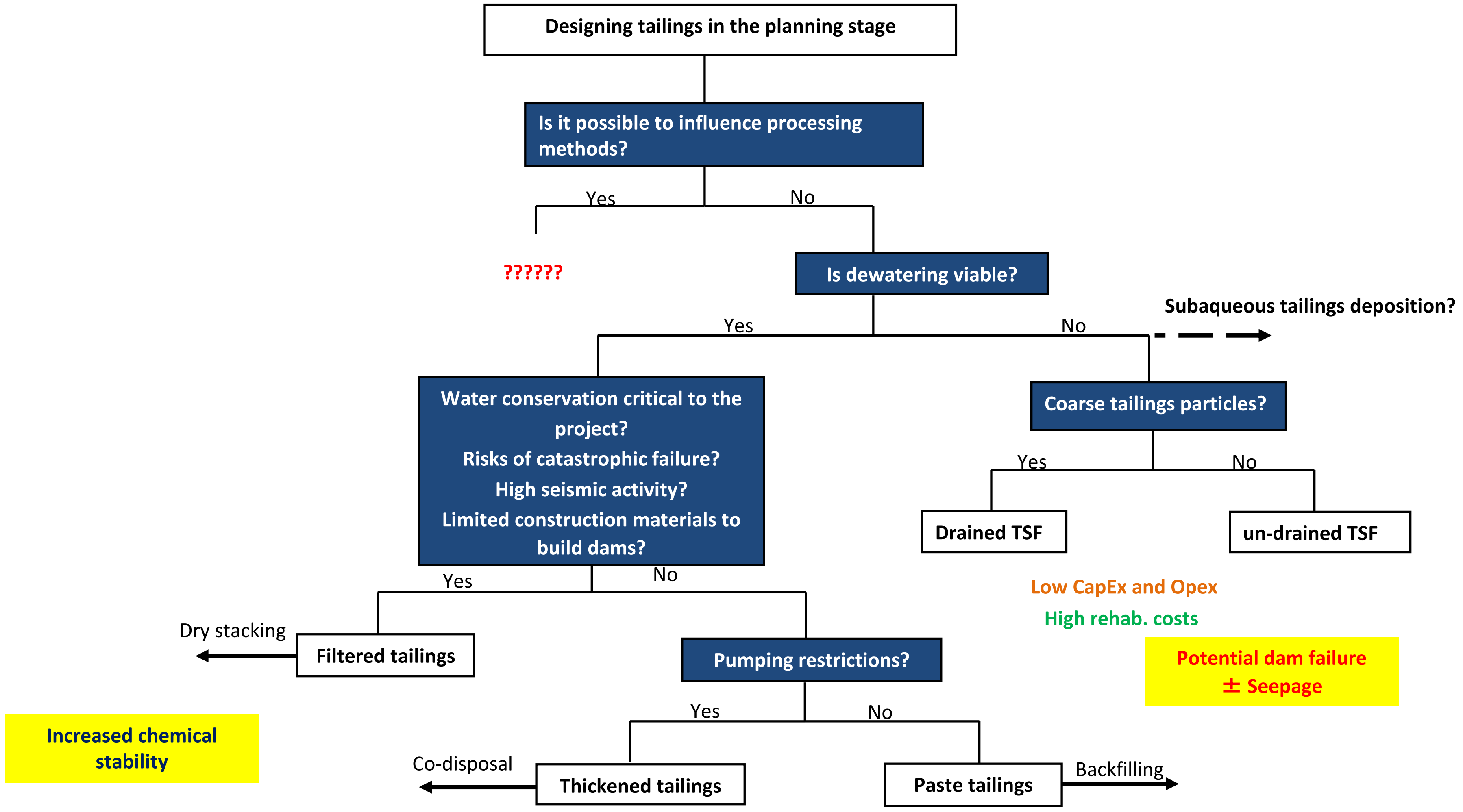
Source: Tina Vegafria's PhD Thesis

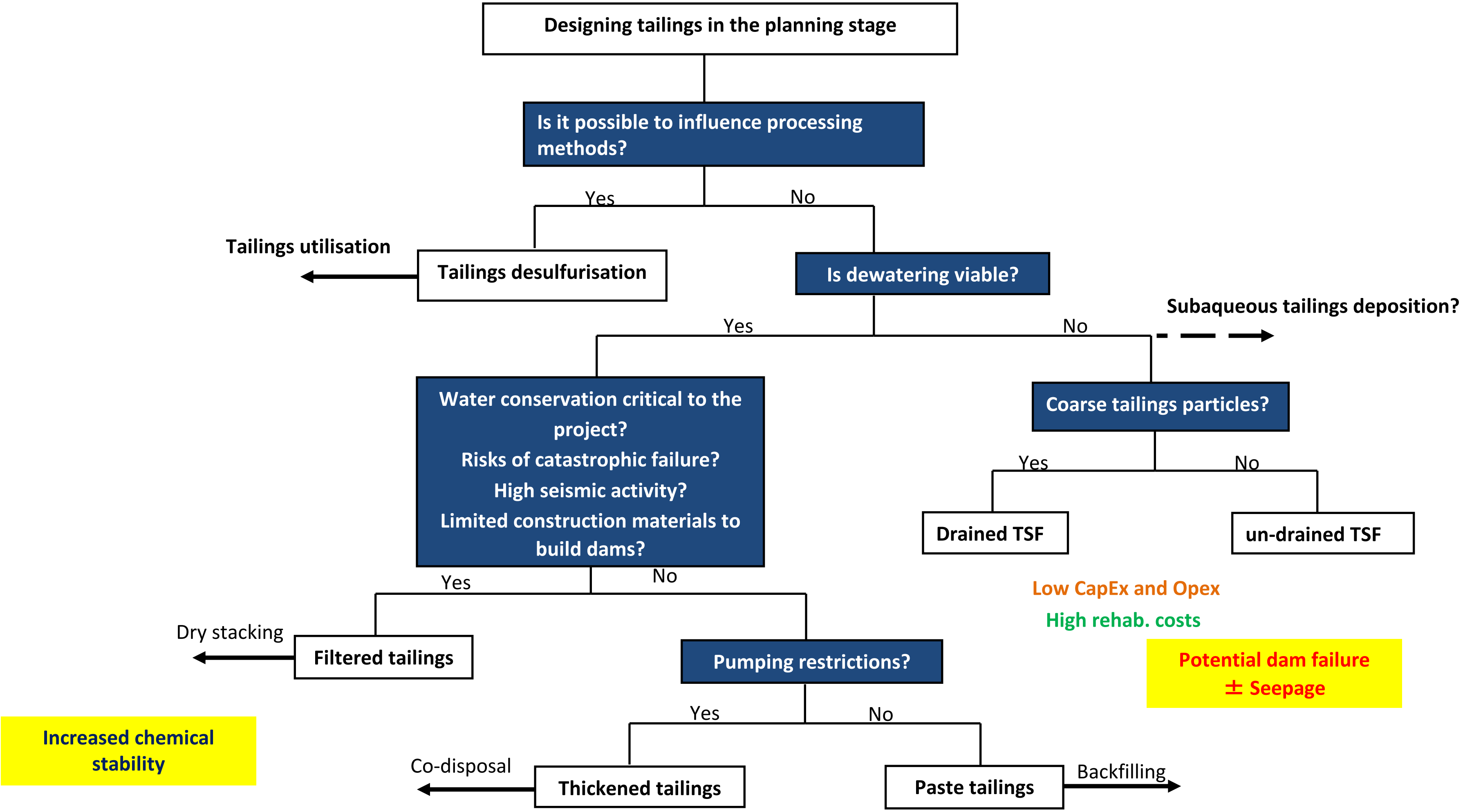
Scale up issues

- Water contact - fraction of tailings flushed by unsaturated flow
- Moisture content effect on oxidation rate
- Particle size effect on oxidation rate
- Specific mineral concentration
- Surface area of minerals - passivation effects
- Temperature
- Oxygen and CO_2 concentrations in tailings
- Bacterial activity

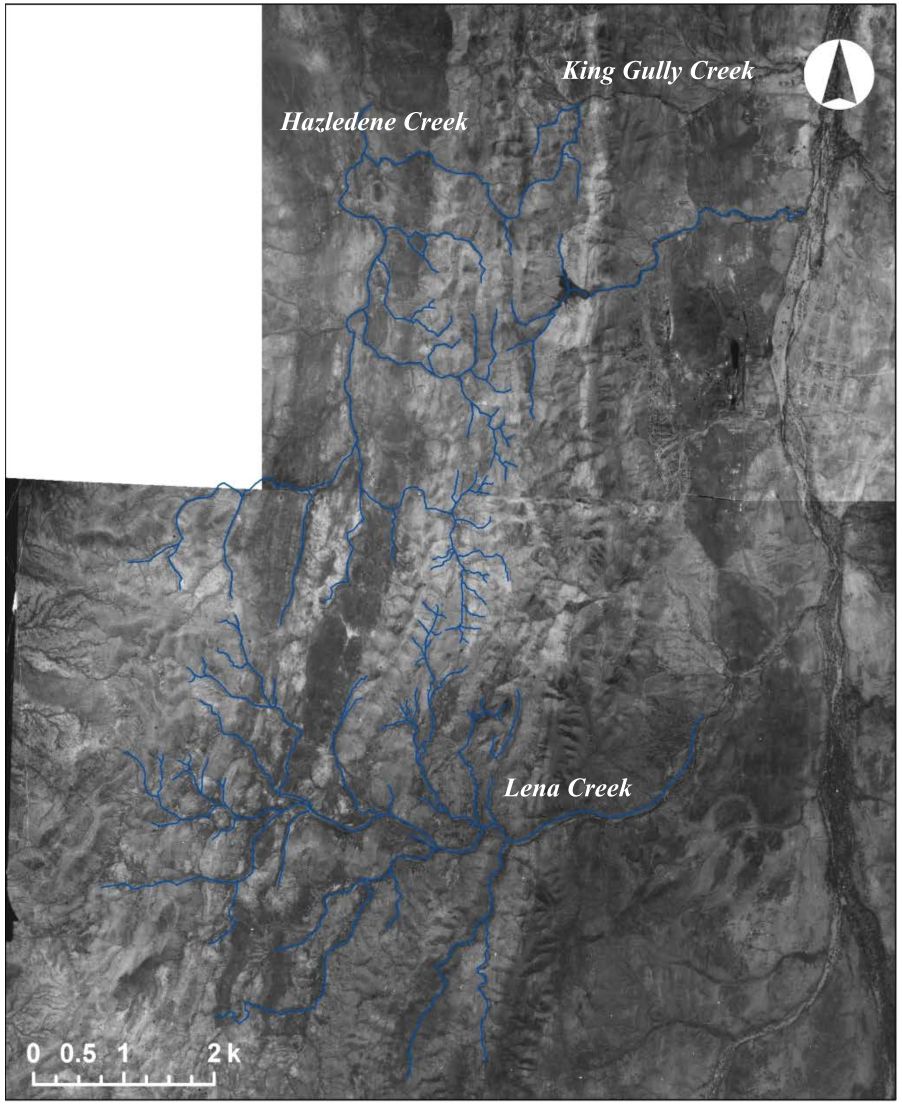
Dispersion of elements: REE



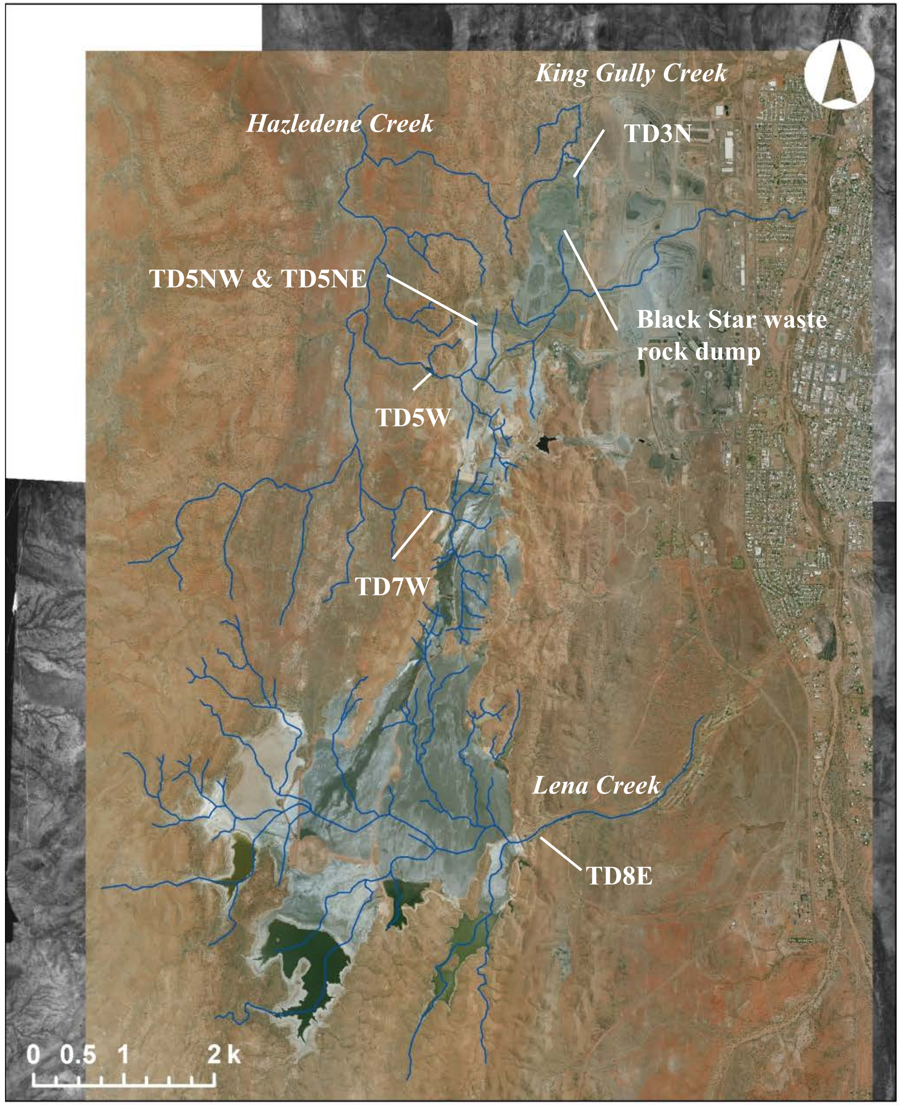

Designing tailings in the planning stage
Is it possible to influence processing methods?
Yes
No
??????
Is dewatering viable?
Subaqueous tailings deposition?
Yes
No
Water conservation critical to the project?
Risks of catastrophic failure?
High seismic activity?
Limited construction materials to build dams?
Coarse tailings particles?
Yes
No
Drained TSF
un-drained TSF
Low CapEx and Opex
High rehab. costs
Potential dam failure
± Seepage
Yes
No
Dry stacking
Filtered tailings
Pumping restrictions?
Increased chemical stability
Yes
No
Co-disposal
Thickened tailings
Paste tailings
Backfilling


Designing tailings in the planning stage
Is it possible to influence processing methods?
Yes
No
Tailings utilisation
Tailings desulfurisation
Is dewatering viable?
Subaqueous tailings deposition?
Yes
No
Water conservation critical to the project?
Risks of catastrophic failure?
High seismic activity?
Limited construction materials to build dams?
Coarse tailings particles?
Yes
No
Drained TSF
un-drained TSF
Low CapEx and Opex
High rehab. costs
Potential dam failure
± Seepage
Yes
No
Dry stacking
Filtered tailings
Pumping restrictions?
Increased chemical stability
Yes
No
Co-disposal
Thickened tailings
Paste tailings
Backfilling

1947

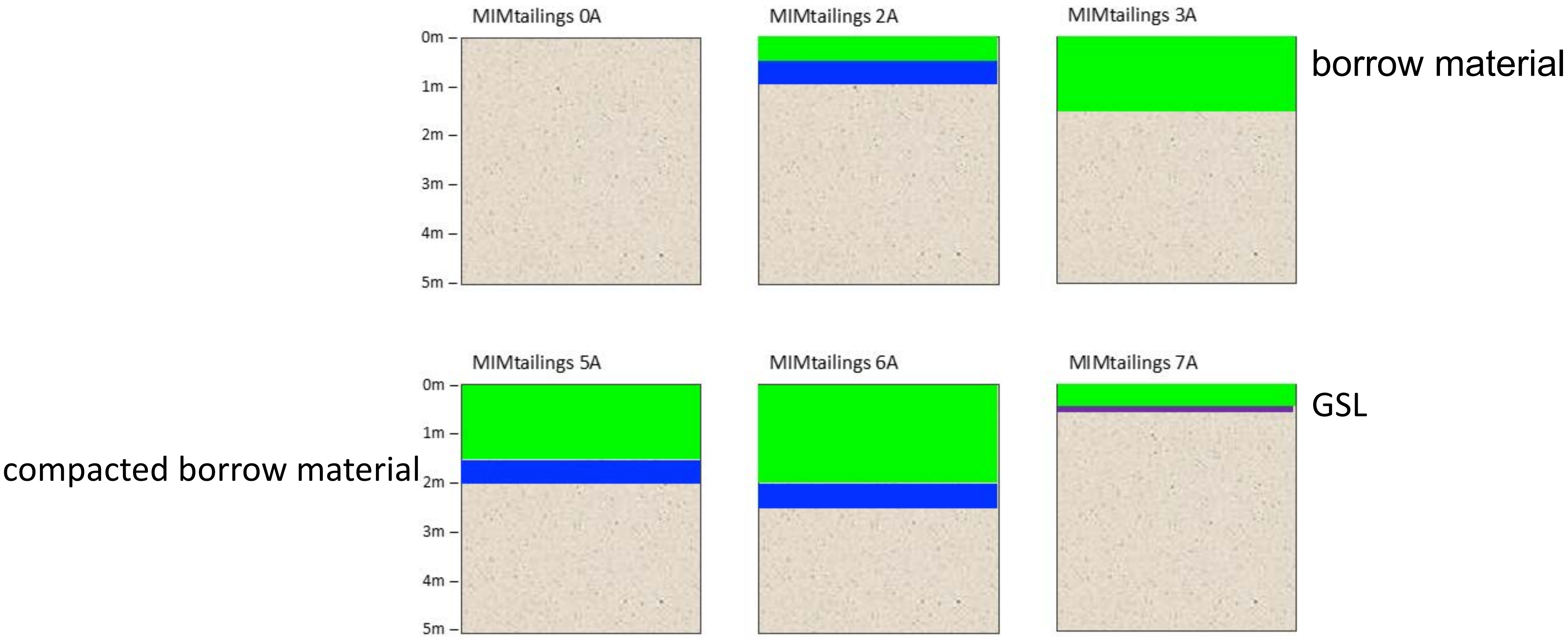

King Gully Creek
Hazledene Creek
Lena Creek
0 0.5 1 2 k

2008


King Gully Creek
Hazledene Creek
TD3N
TD5NW & TD5NE
Black Star waste rock dump
TD5W
TD7W
Lena Creek
TD8E
0 0.5 1 2 k


Evaporation
Incident Rainfall
Upper seepage
Toe seepage
Toe seepage loss to groundwater
Tailings dam seepage (drainage water)
244 m
© 2013 Whereis® Sensis Pty Ltd
Image © 2013 Aerometrex Pty Ltd
Google earth

Cover scenarios - 20 million m^3 material required



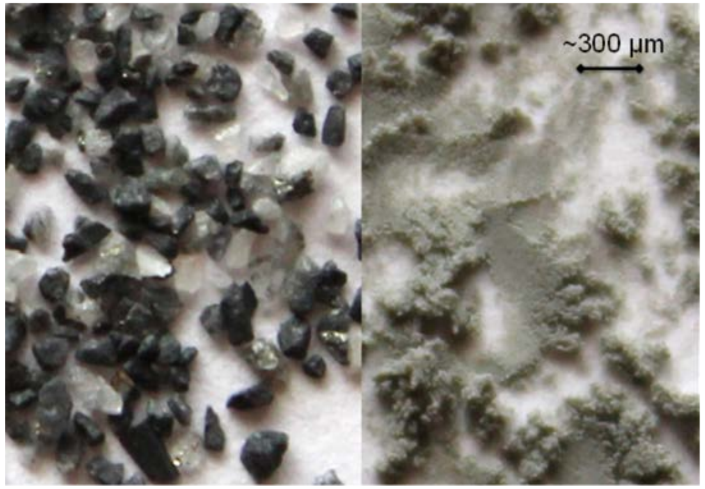
Tailings desulfurisation and land rehabilitation

Tailings desulfurisation for mined land rehabilitation: the case of copper tailings from Mount Isa Mines

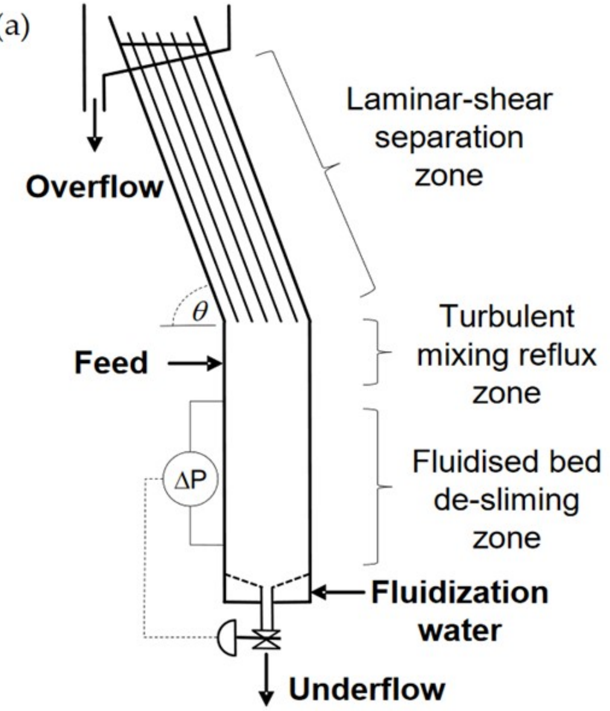
Artem Golev[1*], Mansour Edraki[1], Glen Corder[1], Kristian Mandaran[2], Paul Radulovic[3]

[1] *Sustainable Minerals Institute, The University of Queensland, St Lucia, QLD 4072, Australia*
[2] *Mount Isa Mines, Mount Isa, QLD 4825, Australia*
[3] *Glencore Technology, Brisbane, QLD 4000, Australia*
[*] Corresponding author. *E-mail address:* a.golev@uq.edu.au (A. Golev).

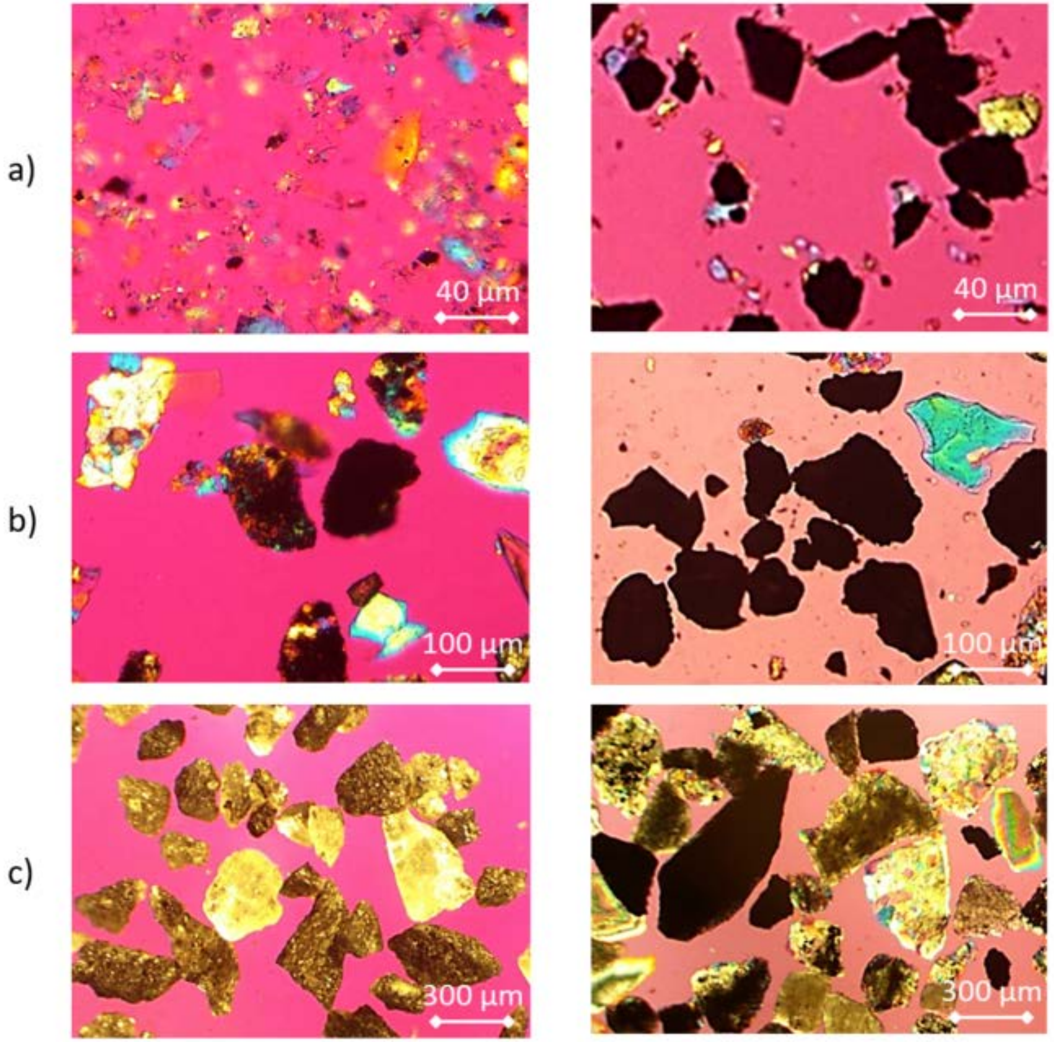
Underflow (~12-28 wt.%) **Overflow (~72-88 wt.%)**



(a)



(b)

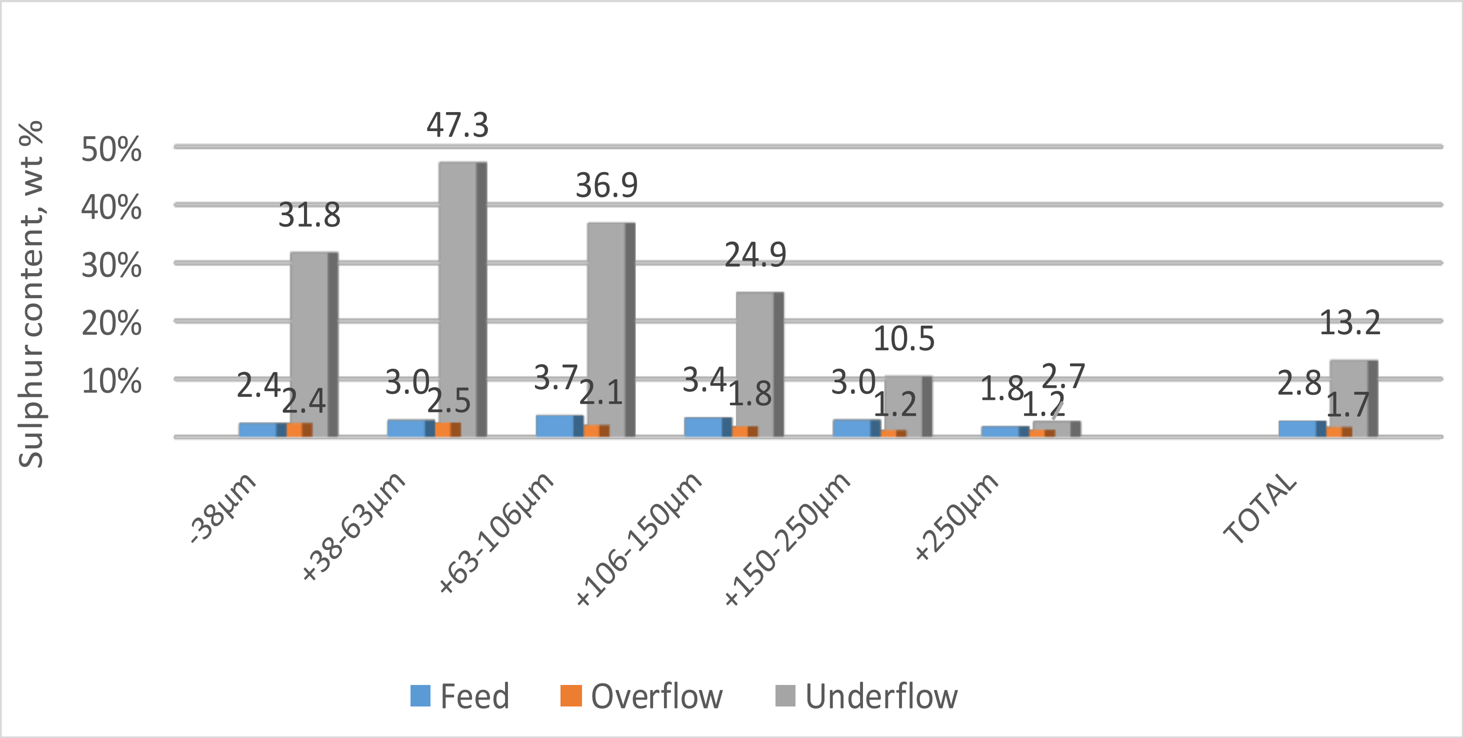


-38 µm

+38-106 µm

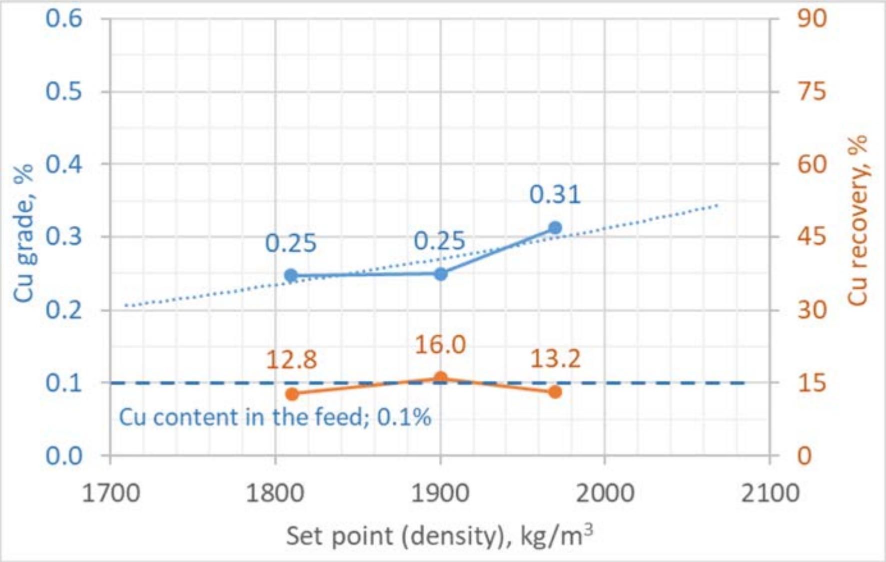
+106 µm

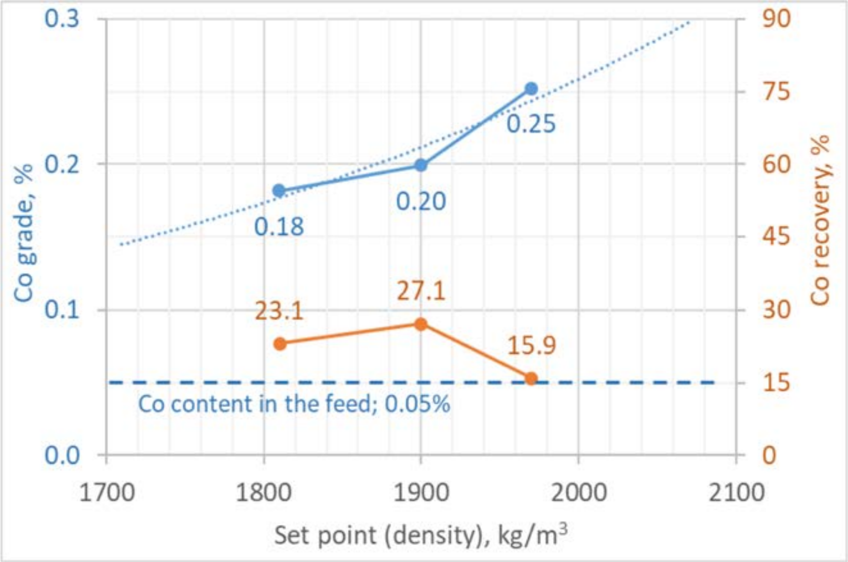
Sulfur content across different particle size fractions (trial #3)



The decrease in sulfur content: ~40 wt. % on average, with the best results achieved for the +106-250 µm particle size range – up to 65 wt. %.

Minerals recovery +0-150 µm fraction

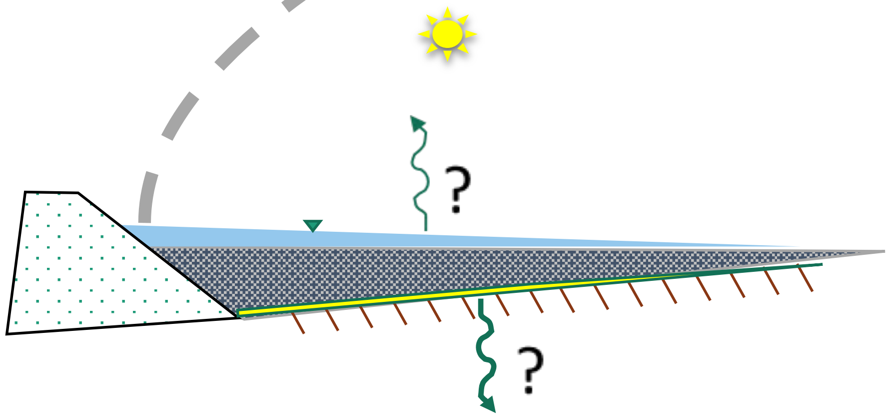




The valuable metals content in the sulfide concentrates was upgraded 2-3 times with up to 50% recovery rates, containing up to 0.40% wt. % Cu and 0.14 wt. % Co.

Processing Plant

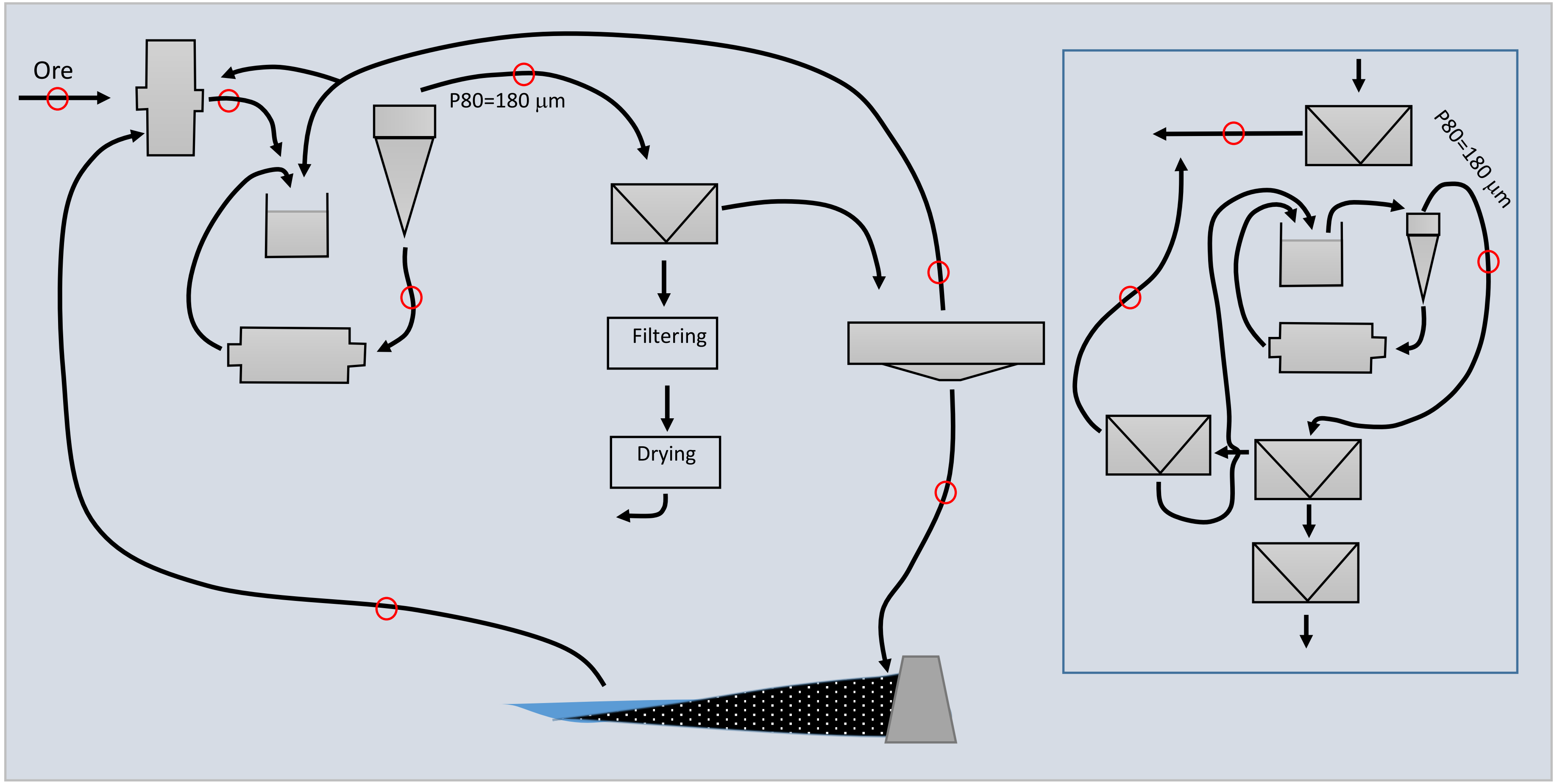
- Alternative processing options
    - Coarse flotation
    - Removal of pyrite
    - Managing clay mineralogy
    - Engineering stable aggregates



- Effect of dewatering on transport
    - Geochemical behavior (surface chemical reactivity)
    - Effect of tailings water chemistry/salinity on transport
- Fate of flocculants/coagulants

- Effect of coarse materials on seepage chemistry
- How to engineer the bottom tailings
- The effect of old liquids and change of chemistry with time

Real-time monitoring



In-line monitoring points

Conclusions

- Geochemistry is not black magic and there is no silver bullet solution for the management of current and future tailings

- The opportunity is embedded in the integration of tailings production with tailings deposition and rehabilitation

- Improving the geochemical stability of tailings can be achieved by altering the mineralogical, and physico-chemical properties of tailings (solids and water)

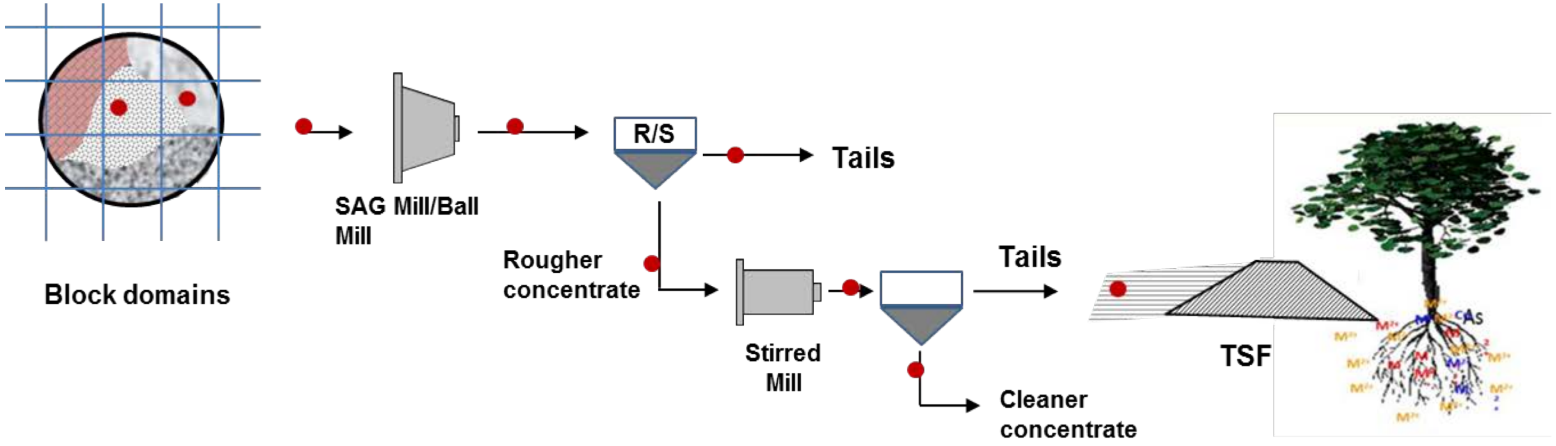
- This requires and understanding of how tailings will behave (geochemically) over time through:

  - Predictive methods or tools that cope with scale up issues and
  - Real-time field monitoring systems

Designer Tailings

Aim:

Identification of potential focus areas in the entire operation that could contribute to improved or alternative tailings (and water) management practices.



Annex F – Consultation Session, Overview of Consortium by Prof. Daniel Franks, Sustainable Minerals Institute, UQ

Towards a Global Research Consortium on Tailings

Overview of the Consortium

Professor Daniel Franks & Professor Anna Littleboy

Sustainable Minerals Institute
The University of Queensland

PROPOSITION

- To bring together the world's leading thinkers in tailings and mine waste management: researchers, practitioners, industry professionals, regulators, civil society and community representatives to develop transdisciplinary knowledge-solutions (science, technology and practices) to address the social, environmental and economic risks of tailings.

WHAT ARE THE POTENTIAL BENEFITS?

A consortium would:

- extract value from existing knowledge
- prioritise research in areas that require collective effort
- support evidence-based policy-making and practice
- contribute to increased education and communication between all stakeholders
- support the implementation of existing initiatives (e.g. ICMM/UNEP/PRI tailings review & standard; Global Mineral Professionals Alliance)

WHAT WILL THE CONSORTIUM DO?

- Facilitate dialogue between researchers, practitioners and those impacted by tailings.
- Collate the state of the art of global research and practice
- Define an agreed program of applied research with consortium members addressing the critical knowledge gaps
- Create a forum for knowledge exchange and research translation with industry, government and civil society.
- Incubate innovations and ideas, seed research and undertake feasibility studies to implement innovations.
- Grow a portfolio of research solutions.

WHAT THE CONSORTIUM WILL NOT DO?

The consortium will not:

- duplicate or compete with the work of individual research groups
- promote one research group over another
- create additional silos or barriers to the uptake of innovative research and practice.

POTENTIAL AREAS OF FOCUS

Tailings Production

- Alternatives to wet tailings and production of benign tailings
- Filtration, paste and thickened tailings, including operational and economic barriers
- Production that optimises rheology, mineral recovery, water and energy inputs, economics, AMD, rehabilitation and the social outcomes of tailings
- Reprocessing and re-use

Tailings Storage

- Safety and stability of future, existing and decommissioned tailings storage facilities
- Monitoring, control and rehabilitation practices

Tailings Consequences

- Downstream environmental, social and economic risks of tailings from chronic and catastrophic events

Tailings Governance and Practice

- Policy, capacity-building, training and practice
- Involvement of non-traditional actors in research e.g. technology and equipment providers, at-risk communities, unions and environmental and engineering consultancies

WHO HAS EXPRESSED INTEREST

NORMAN B. KEEVIL INSTITUTE OF MINING ENGINEERING
THE UNIVERSITY OF BRITISH COLUMBIA

UNIVERSITY OF ALBERTA

Queen's UNIVERSITY

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

NAMIBIA UNIVERSITY OF SCIENCE AND TECHNOLOGY

USP Universidade de São Paulo

Universidad de Concepción CHILE

UNIVERSIDAD DE CHILE

Curtin University

THE UNIVERSITY OF WESTERN AUSTRALIA

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

iCRAG IRISH CENTRE FOR RESEARCH IN APPLIED GEOSCIENCES

UNIVERSITY OF EXETER

RWTH AACHEN UNIVERSITY

LULEÅ TEKNISKA UNIVERSITET

TU BERGAKADEMIE FREIBERG

UCL

HOW COULD THE CONSORTIUM BE STRUCTURED?

- Secretariat
- Management Committee
- Membership
- Engagement

NEXT STEPS

- Consultation Workshop 2 – International Mining and Resources Conference, 28-31 October 2019, Melbourne, Australia.
- Consultation Workshop 3 – Tailings and Mine Waste 2019 Vancouver, Canada.
- Finalise detailed prospectus
- Invite partners and secure funding

YOUR VIEWS

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Annex G – Possible Models
Prof. David Williams

Global Research Consortium on Tailings

Possible Model for GRCT

Santiago, Chile – 9 July 2019

Professor David Williams

The University of Queensland, Brisbane, Australia

Email: *D.Williams@uq.edu.au*

Past and Ongoing Tailings Initiatives

- From 1960: Chronology of major tailings dam failures (https://www.wise-uranium.org/mdaf.html)
- 2000 – 2002: Mining, Minerals and Sustainable Development Project (MMSD) project – Final Report on Breaking New Ground: Mining, Minerals and Sustainable Development (https://www.iied.org/mmsd-final-report)
- World Mine Tailings Failures—from 1915 (https://worldminetailingsfailures.org/)

These initiatives focus on documentation of tailings dam failures, with MMSD short-lived

Responses to Fatal Samarco and Brumadinho Tailings Dam Failures

- Following Samarco in Nov 2015, ICMM commissioned:
  - Position statement on preventing catastrophic failure of tailings storage facilities, Dec 2016 (https://www.icmm.com/tailings-ps)
  - Tailings management guidelines and recommendations for improvement, Dec 2016 (https://www.icmm.com/tailings-report)
- Following Brumadinho in Jan 2019, ICMM committed to:
  - Creating an international standard for tailings dams (https://www.icmm.com/en-gb/news/2019/international-standard-for-tailings-dams)
  - Joining with UN Environment Programme and Principles for Responsible Investment to co-convene a mine tailings storage facilities review (https://www.icmm.com/en-gb/news/2019/tailings-review)

Responses to Fatal Samarco and Brumadinho Tailings Dam Failures

- The Church of England launched an Investor Mining and Tailings Safety Initiative, seeking data on tailings dams from ICMM's 27 Member Companies, and many other mining companies, seeking assurances about stability of their tailings dams, including certification as to their stability (https://www.churchofengland.org/investor-mining-tailings-safety-initiative)
- Insurers became wary of insuring tailings dams
- Global Mineral Professionals Alliance launched tailings initiative (https://www.mining.com/global-mineral-professionals-alliance-launches-tailings-initiative/)

Initiatives would be given support & longevity by GRCT

Possible GRCT Model – Large Open Pit Project Funded Since 2005

- Large Open Pit (LOP) Project is an industry-sponsored international research and technology transfer project, initiated in 2005 and managed by Dr John Read of CSIRO, managed by UQ since 2017, and funded to at least 2022
- LOP's sponsors have comprised a diverse group of multinational mining companies – Sponsors decide research priorities and CSIRO/UQ managed/manage projects and 6-monthly meetings worldwide
- LOP's objectives are to develop and transfer of skills to manage geotechnical risk of large open pits, and address critical gaps in knowledge and understanding
- See: www.lopproject.com

LOP Industry Sponsorship – Ongoing from 2005

- LOP I:
  - 2005 to 2015
  - USD100,000/year/Sponsor – 10 to 14 sponsoring companies
  - Total LOP I funding over 9 years > USD10 million
  - Sponsors included: Anglo American, AngloGold Ashanti, Barrick, BHP Chile, BHP Billiton, Codelco, Collahuasi, De Beers, Debswana, Newcrest, Newmont Australia, Ok Tedi, Rio Tinto, Teck, Vale and Xstrata Copper
- LOP II:
  - Mid-2016 to Mid-2019
  - USD60,000/year/Sponsor – 8 sponsoring companies
  - Total LOP II funding over 3 years > USD1.4 million
  - Sponsors: AngloGold Ashanti, Barrick, BHP, De Beers, Debswana, Newcrest, Rio Tinto and Vale

LOP Industry Sponsorship – Ongoing from 2005

- LOP III – Open Pit of the Future:
  - Mid-2019 to Mid-2022
  - USD100,000/year/Sponsor – At least 10 sponsoring companies expected
  - Total LOP III funding over 3 years > USD3 million
  - Expected Sponsors: AngloGold Ashanti, Anglo American, Barrick, BHP, Debswana, Fortescue, Glencore Zinc, Newcrest, Rio Tinto and Vale
- LOP Project has operated since 2005, and will continue to 2022 and beyond (over 18 years)

Some LOP Deliverables to Date

- Valued Guidelines, which are regularly referenced and are becoming Industry Standards:
  - Open Pit Design – 2009
  - Evaluating Water in Pit Slope Stability – 2014
  - Mine Waste Dump and Stockpile Design – 2017
  - Open Pit Slope Design in Weak Rocks – 2018
  - Slope performance Monitoring – 2019
- Delivery on numerous Research Projects
- LOP Website – www.lopproject.com

Annex H – Enlisting Industry Support
Dr Michael Davies

Towards a Global Research Consortium on Tailings

Enlisting Industry Support

9 July 2019

Dr. Michael Davies

Teck

Enlisting Industry Support

- Understand the industry's need to see the value proposition
- Never over-promise or over-simplify any given technology
- Avoid proprietary technologies
- Avoid addressing a geotechnical issue by creating a geochemical issue (and vice versa)
- Avoid Provincial behaviours (the "better than" discussions)

Enlisting Industry Support

- Look for leveraged funding models where society (e.g. governments/academia) and industry can risk share
- Embrace the life-cycle approach so that closure is included
- Guidance on where NOT applicable as valuable as where applicable with newer technologies

Annex I – Participants and Registrations

Table 2. Workshop Registrations

First Name	Last Name	Organisation	Attendance Confirmed
Marcelo	Llano	KCB	Yes
Joe	Carr	Inmarsat	Yes
Nick	Prevost	Inmarsat	Yes
Valmir	Martins de Oliveira	Universidad Autónoma de Chile - Facultad Adm Negocios	Yes
Jacques	Wiertz	Universidad de Chile - Department of Mining Engineering	Yes
Eric	Medel	Plusmining	Yes
Felipe	Saavedra	SMI-ICE-CHILE	Yes
Doug	Aitken	SMI-ICE-Chile	Yes
David	Mulligan	SMI-ICE-Chile	Yes
Jaime	Gonzalez	MC Inversiones Ltda.	Yes
Ursula	Kelm	Universidad de Concepcion, Instituto GEA	Yes
Michael	Davies	Teck Resources	Yes
Cristian	Avendaño	SG scm	No
Elizabeth	Alarcón	BHP Chile	Yes
Claudia	Velasquez	NuevaUnión	No
Luis	Gutierrez	NuevaUnion SpA	No
Nigel	Wight	SMI-ICE-Chile	No
Anita	Parbhakar-Fox	BRC-SMI	Yes
Glen	Corder	SMI	Yes
Wernher	Brevis	Pontificia Universidad Católica de Chile	Yes
David	Rubinos	SMI-ICE Chile. The University of Queensland	Yes
Daniel	Franks	SMI, The University of Queensland	Yes
Margaret	Armstrong	Universidad Adolfo Ibanez	Yes
Hernán	Cifuentes	The University of Queensland	Yes
Luis	Valenzuela	Geotechnical Consultant	Yes
René	Orellana	Codelco - Chile	Yes
David	Williams	The University of Queensland	Yes
Gloria	Ramos-Fuentes	Ministerio de Relaciones Exteriores de Chile	No
Patrici	Masbernat	Universidad Autonoma de Chile	No
Rodrigo	Moya	Antofagasta Minerals	No
Cristian	Garrido	Fluor Chile	Yes
Manuel	Caraballo	Mining Dept. and AMTC, University of Chile	Yes
Marcos	Pinto	Codice Ingenieria y Construccion SA	Yes
Michel	Julien	Agnico Eagle Mines	Yes
Katherine	Viveros	Arcadis	No
Ward	Wilson	University of Alberta	Yes
Mansour	Edraki	CMLR-SMI	Yes