Why do projects go wrong and what systemic risks exist in the current design process?

Tailings

Presenter: David Pearce, General Director - SRK

Location: Webinar

Tailings disasters make dramatic headlines …

- Brumadihno, Brazil, January 2019
- Samarco, Brazil, November 2015
- Mt Polley, Canada, August 2014
- Kolontár, Hungary, October 2010
- Baie Mare, Romainia, 2000
- Aznacollar, Spain, 1999

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… but are the risks just associated with catastrophic failures?

Possible events include:

- Loss of integrity; no loss of material or discharge
    - Potentially reduces production until dam repaired / alternative sites constructed ~3-6 months
- Over-topping during storm event
    - Could erode dam wall leading to failure
    - Release of chemicals into environment
- Material discharge; locally contained
    - Investigation by Rostekhnadzhor could lead to cessation of operations and fines
- Material discharge which affects community
    - Clean-up liabilities
    - Fines
- Catastrophic failure
    - Loss of life
    - Imprisonment for managers
    - Loss of business

All can have a significant impact on the project success and potentially on corporate reputation

- Cadia dam failure in March 2018 did not result in any external discharges but reduced share value by $1 billion

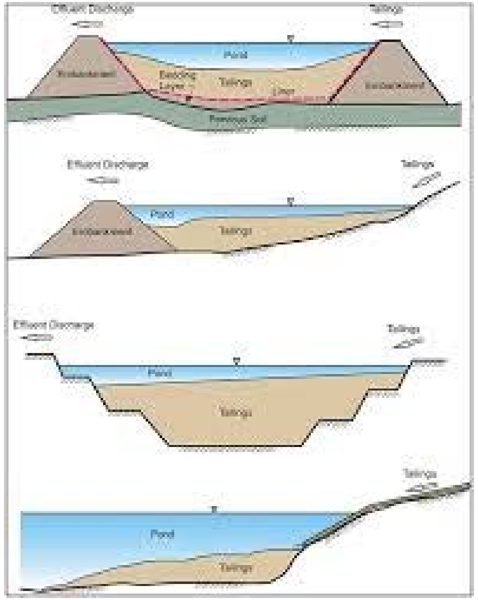
If there have not been any failures in Russia, does that mean all is well?

- We are aware of several major failures, though fortunately they “only” resulted in the tailings dam becoming unusable
- We are also aware of several tailings facilities which have been condemned
  - Excessive water content – operating without a “beach”
  - Rate of lift exceeds design norms

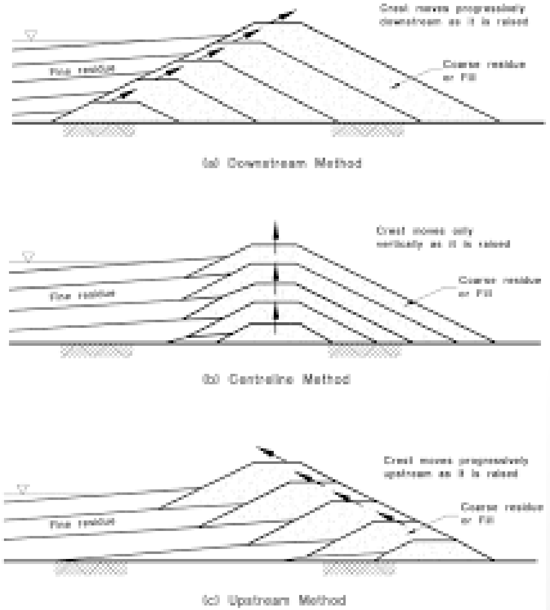
- International best practice has moved on:
  - Russian guidelines consider Effective Stress Analysis (ESA) only.
    - International Guidelines also consider Undrained Stress Analysis (USA) be used in design, particularly for all upstream dams. This assesses the risk of liquefaction which could be triggered by seismic or static loading.
  - International Factor of Safety is higher

	Loading Condition	Shear strength used for evaluation	Minimum FoS (International guidelines)	Minimum FoS (Russian guidelines)
1	Long term drained	Effective strength	1.5	1.25
2	Pseudo-static	Consolidated undrained strength (Loading condition 1, repeated including horizontal acceleration)	1.0	
3	Post-seismic / Liquefaction	Post-seismic shear strength within the tailings mass	1.0-1.3	

- Principal options:
  - Valley fill
  - Ring fill
  - Backfill
  - Subaqueous

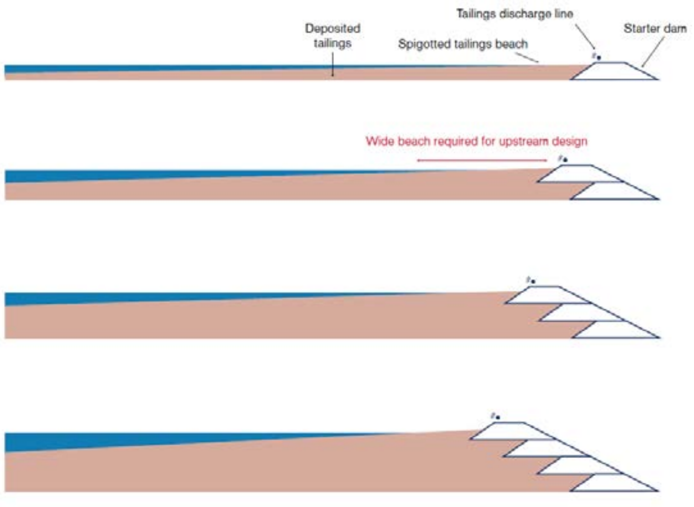


- Three main dam designs:
  - Downstream
  - Centreline
  - Upstream



Key requirements for upstream operations

- Maintain beach to allow coarse tailings to settle and keep phreatic surface from wall
  - Ensures next lift has a firm foundation
  - Cease deposition or move discharge points if heavy rain floods beach
- Ensure drains are working
- Do not increase height faster than the tailings can compact and drain



Courtesy of AngloAmerican

Typical levels of control internationally

- Monitoring – piezometers, inclinometers, pressure gauges, remote sensing
- Inspections
- Annual Dam safety inspections by an external engineer of record
- Third party reviews at least every three years
- Internal governance reviews
- Independent tailings review boards - to conduct a third-party review of design, operation, surveillance and maintenance

Risk assessments - if there was a failure, what could happen?

- Consider potential impact
- Several standards (ICOLD; ANCOLD)
- Ensure controls are appropriate for risk
- Consider redesigning or relocating TSF if necessary

Damage type	Minor	Medium	Major	Catastrophic
Infrastructure (dam, houses, commerce, farms, community) USD$	<$10M	$10M-$100M	$100M-$1B	>$1B
Business importance	Some restrictions	Significant impacts	Severe to crippling	Business dissolution, bankruptcy
Public health	<100 people affected	100-1000 people affected	<1000 people affected for more than one month	>10,000 people affected for over one year
Social dislocation	<100 person months or <20 business months	100-1000 person months or 20-200 business months	>1000 person months or >200 business months	>10,000 person months or numerous business months
Impact area	<1 km²	<5 km²	<20 km²	>20 km²
Impact duration	<1 (wet) year	<5 years	<20 years	>20 years
Impact on natural environment	Damage limited to items of low conservation value. Remediation possible.	Significant effects on rural land and local flora & fauna. Limited effects on: A. Items of local & state natural heritage B. Native flora and fauna within forestry, aquatic and conservation reserves	Extensive rural effects. Significant effects on river system and areas A & B. Limited effects on: C. Items of National or World natural heritage D. Native flora and fauna within national parks. Remediation difficult	Extensively affects areas A & B. Significantly affects areas C & D. Remediation involves significantly altered ecosystems.

Population at Risk	Severity of Damage and Loss			
	Minor	Medium	Major	Catastrophic
<1	Very Low	Low	Significant	High C
>1 to 10	Significant (note 2)	Significant (note 2)	High C	High B
>10 to 100	High C	High C	High B	High A
>100 to 1,000	Note 1	High B	High A	Extreme
>1,000		Note 1	Extreme	Extreme

Why do failures happen?

- Key design issues behind disasters:
  - Design overlooked weak foundation
  - Water balance not verified / insufficient allowance for peak events
  - Lack of emergency spillway
  - Insufficient drainage installed
  - Inappropriate design

- Key operational issues behind disasters:
  - Beach allowed to be flooded or smaller than designed resulting in fine tailings being deposited near crest
  - Rate of rise is excessive
  - Drains not maintained / not identified as being inadequate
  - Not reacting when phreatic surface is noted as being too high

Why do failures still happen?

- Legacy issues
  - TSF constructed many years ago when standards were less strict and techniques less detailed
- Familiarity
  - Routine activity allows complacency to develop
- Production pressures
  - Temporarily allow beaches to be flooded
- Lack of internal expertise / awareness
  - TSF managed by processing specialists, not TSF specialists
- Budget & time constraints during design process
  - Insufficient data collected / analysis done

Systemic risk with TSF design in Russia

- Strength parameters used in some locations are not consistent with expected properties for similar materials and require verification.
  - SRK recommends resampling and retesting with ASTM and/or BS standards
- Stability analysis does not include all loading scenarios included in international guidelines.
  - Pseudo-static and post-seismic/liquefaction stability loading scenarios have not been analyzed
- Preference is for upstream dams
- Lower Factor of Safety permitted in Russia
- Many sites now much larger than was typical when the regulations were developed
- Lack of emergency spillway at most sites
  - Emergency spillways are used for emergency situations, not for discharging supernatant during regular operations. Should be capable of handling a 1-in-1000 year, 72 hour flood event
- The TSFs are not lined and therefore there is potential for seepage of tailings effluent water.
- The standard of monitoring has fallen behind current best practice – stand pipes vs vibrating-wire piezometers; no slope inclinometers; etc. - which reduces the depth of analysis possible.
  - Monitoring is focused on collecting data for compliance; not for proactive investigation
- No independent reviews
  - Annual review typically done by designers

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Recommendations

Design stage

- Ensure design is independently reviewed by specialists familiar with international standards
- Verify material parameters to ASTM and/or BS standards
- Review risks and Factor of Safety using both ESA and USA methods
- Independent reviews

Operations

- Upgrade monitoring system and provide internal reports which focus on risk potential
  - Record beach width, continuous monitoring with piezometers
- Third party reviews at least every three years
- Internal governance reviews or Independent tailings review boards depending on risk

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