Yankee Doodle Tailings Impoundment Risk Assessment

STAKEHOLDER PRESENTATION

Dr. P. K. Robertson

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What is Risk?

Risk = Likelihood x Consequence

Risk combines the probability and severity of an adverse event

To identify risk, three questions must be addressed:

1. *What can happen?*
2. *How likely is it that it will happen?*
3. *If it does happen, what are the consequences?*

Risk is higher when the likelihood and consequence of failure is higher, and risk is lower when the likelihood and consequence is lower

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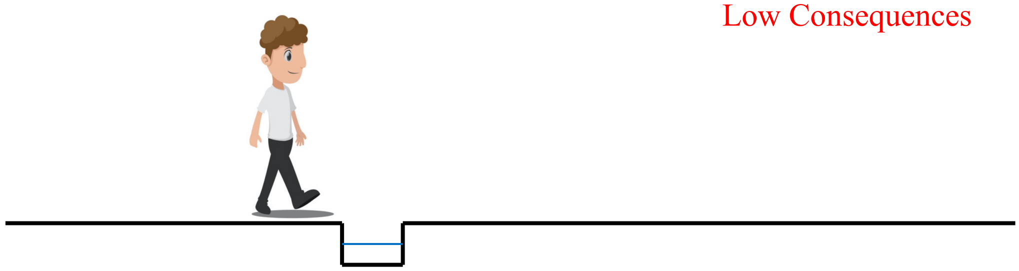
Simple Examples of Risk

Example A

Low likelihood
Low Consequences



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Simple Examples of Risk

Example B

High likelihood
Low Consequences

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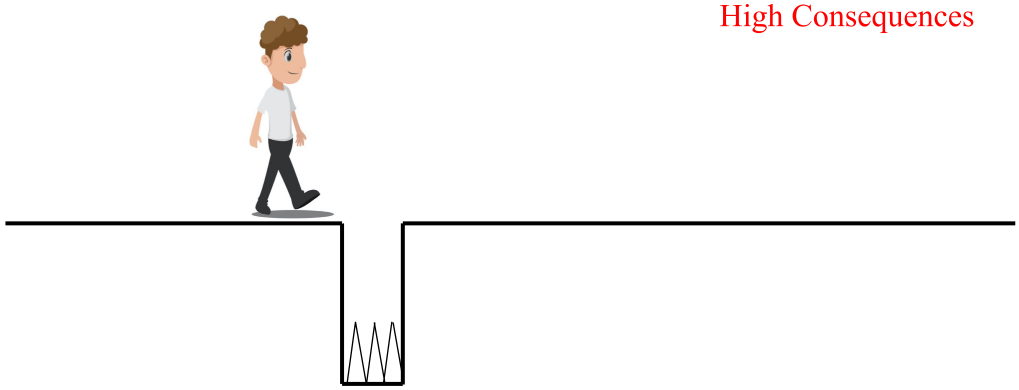
Simple Examples of Risk

Example C

Low likelihood
High Consequences



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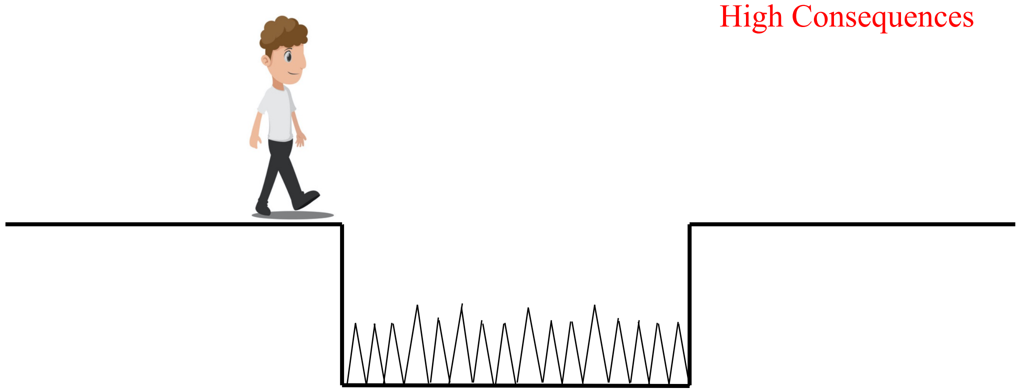
Simple Examples of Risk

Example D

High likelihood
High Consequences



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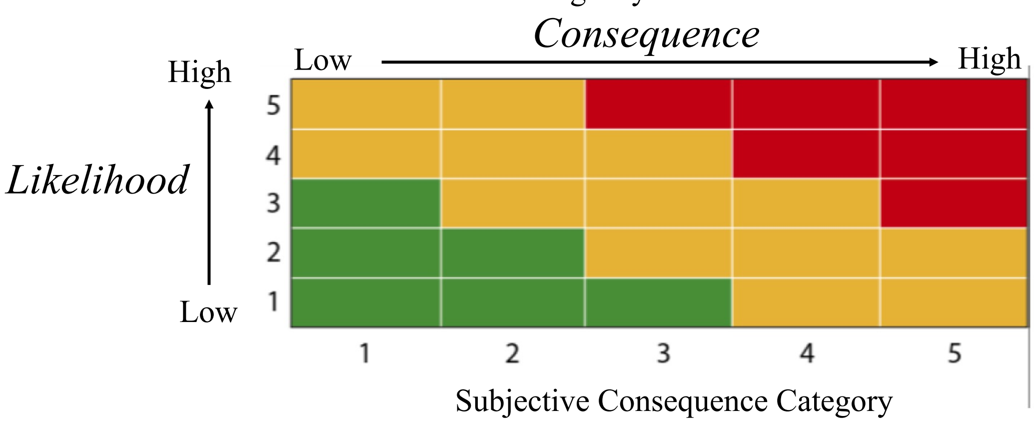
Communication of Risk

Traffic-light system common



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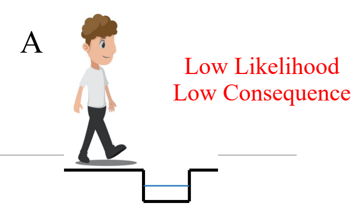
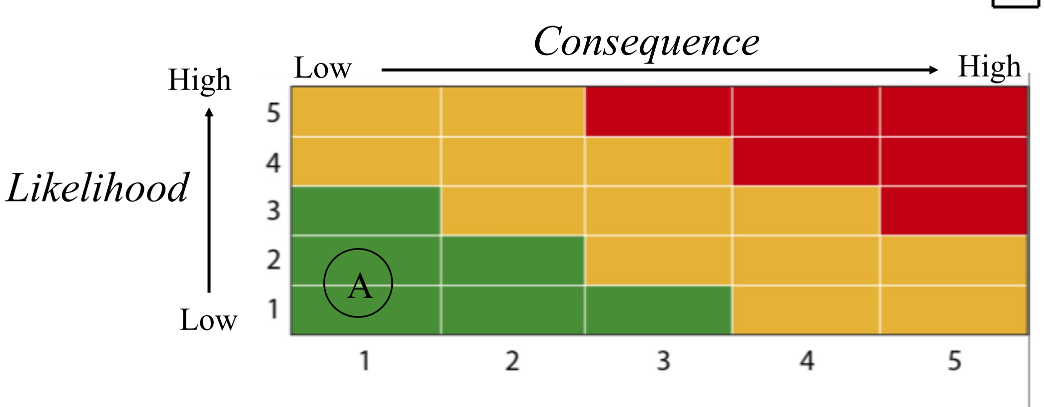
Communication of Risk





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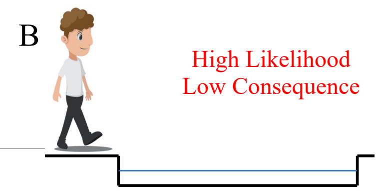
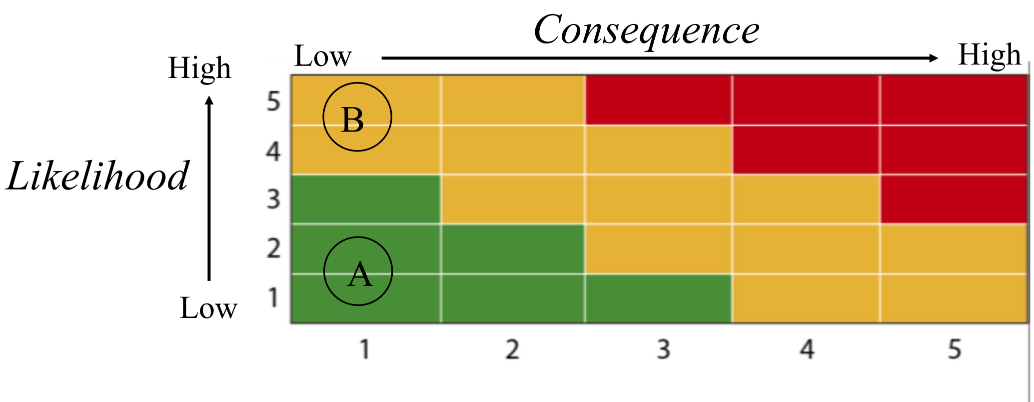
Communication of Risk





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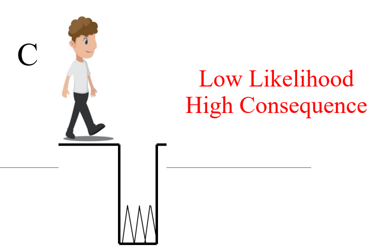
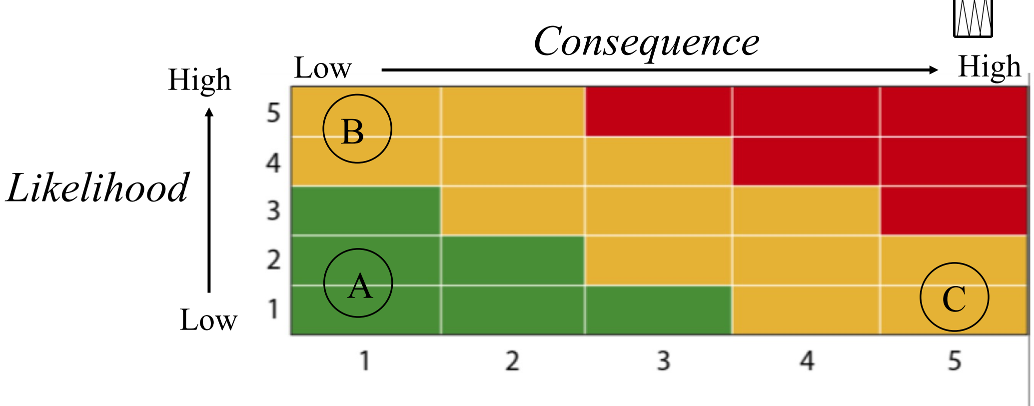
Communication of Risk





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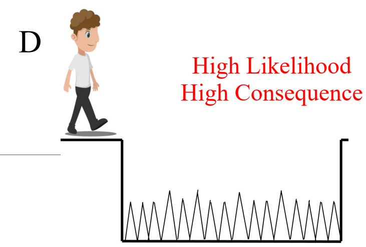
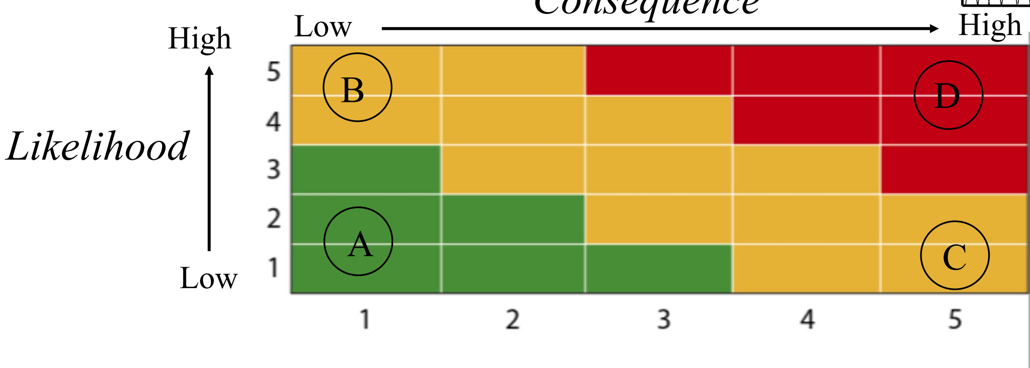
Communication of Risk





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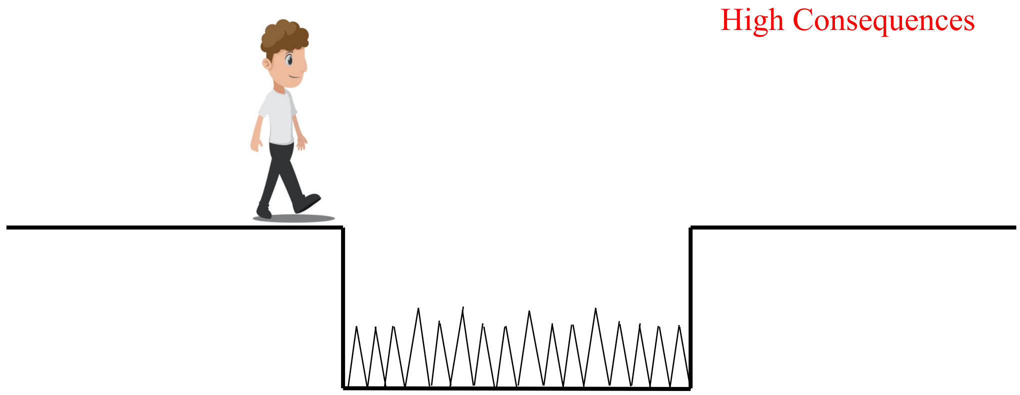
Risk Mitigation (Risk Reduction)

Example D

High likelihood
High Consequences



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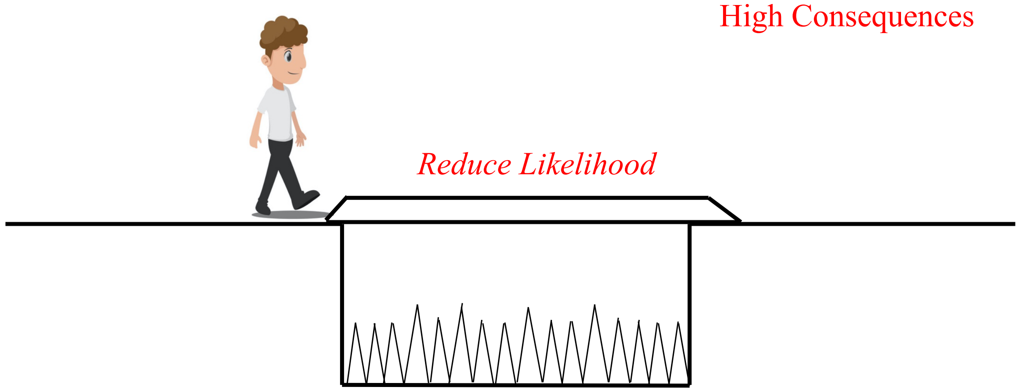
Risk Mitigation (Risk Reduction)

Example D

Low likelihood
High Consequences



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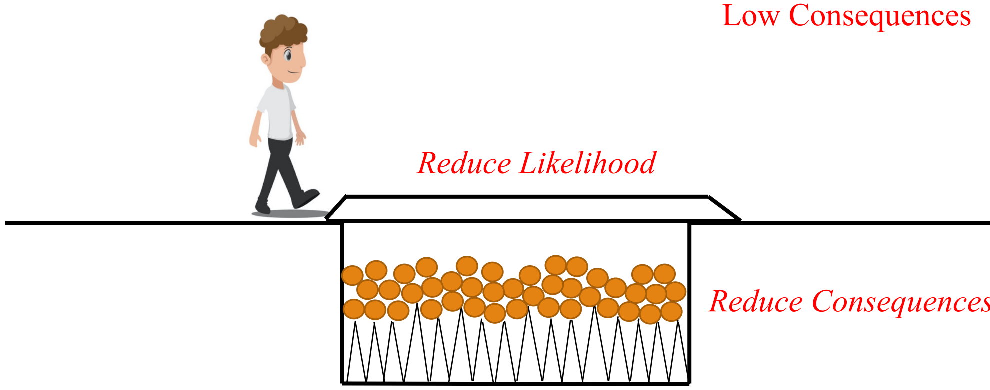
Risk Mitigation (Risk Reduction)

Example D

Low likelihood
Low Consequences



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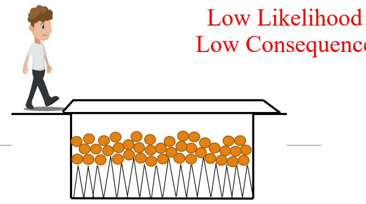
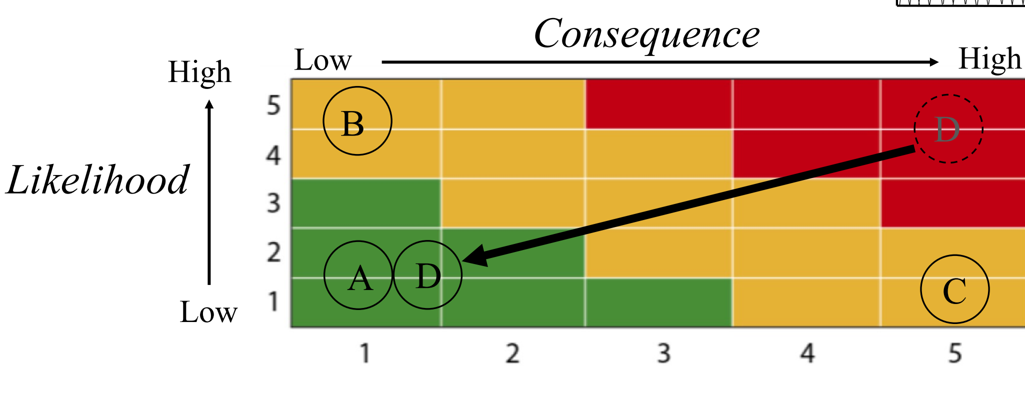
Risk Mitigation





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What are Acceptable Risks?

Likelihood is often presented in terms of Probability

Examples:

High Likelihood would be probability of 1 in 10 (10^{-1}) – once every 10 years
Low Likelihood would be probability of 1 in 1,000 (10^{-3}) – once every 1,000 years
Very Low Likelihood would be probability of 1 in 1,000,000 (10^{-6}) – once every million years

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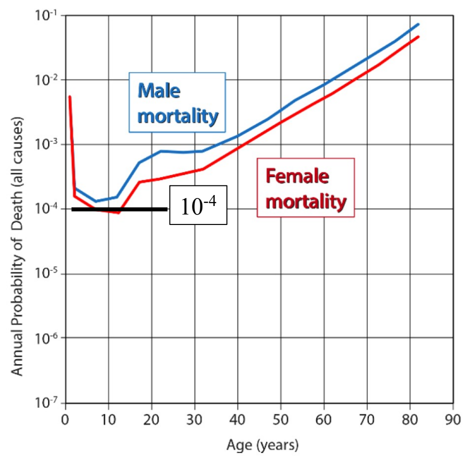
What are Acceptable Risks?

Likelihood of death in N. America

Annual Probability of Death (all cases)

Child under 10 years of age:
10^{-4} Probability
(i.e., 1 in 10,000)



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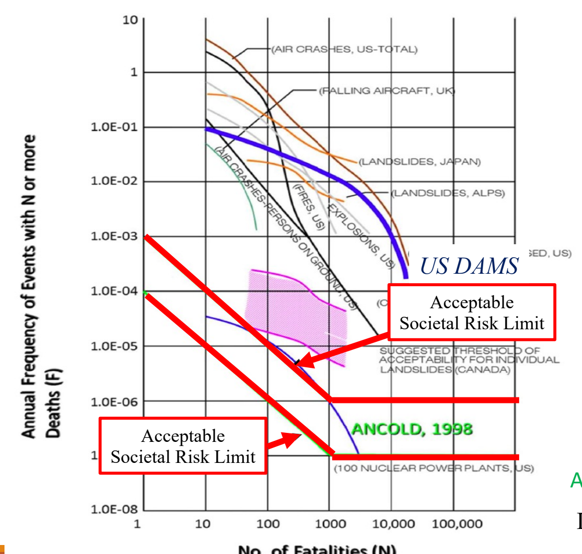
What are Acceptable Risks?



Frequency-Consequence (F-N) Chart

Defines '*acceptable societal*' risks based on historical data

ANCOLD – Australian National Committee on Large Dams

Davidson, 2015 adapted from Whitman, 1984

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Benefits of Risk Assessment

- Transparent and collaborative process
- Identifies and quantifies risk
- Guides mitigation measures to reduce risk

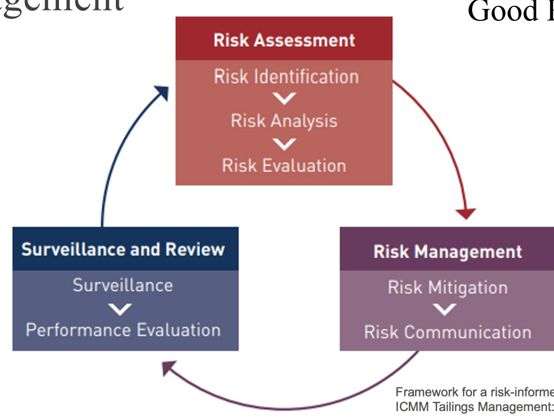
Risk Assessment & Management Tasks

Risk Assessment and Management main tasks:

- Risk *Identification*
- Risk *Analysis*
- Risk *Evaluation*
- Risk *Mitigation*
- Risk *Communication*

Updated based on performance

ICMM Tailings Management Good Practice Guide



Framework for a risk-informed approach for tailings management. ICMM Tailings Management: Good Practice Guide p. 77

Risk Identification

The first step of risk identification is to identify site-specific potential failure modes

Natural hazard

Examples:
- Earthquake
- Landslide
- Extreme weather event

Engineering structure event

Examples:
- Slope instability
- Overtopping
- Piping through embankment

Operational events

Example:
- Failure of tailings pipeline

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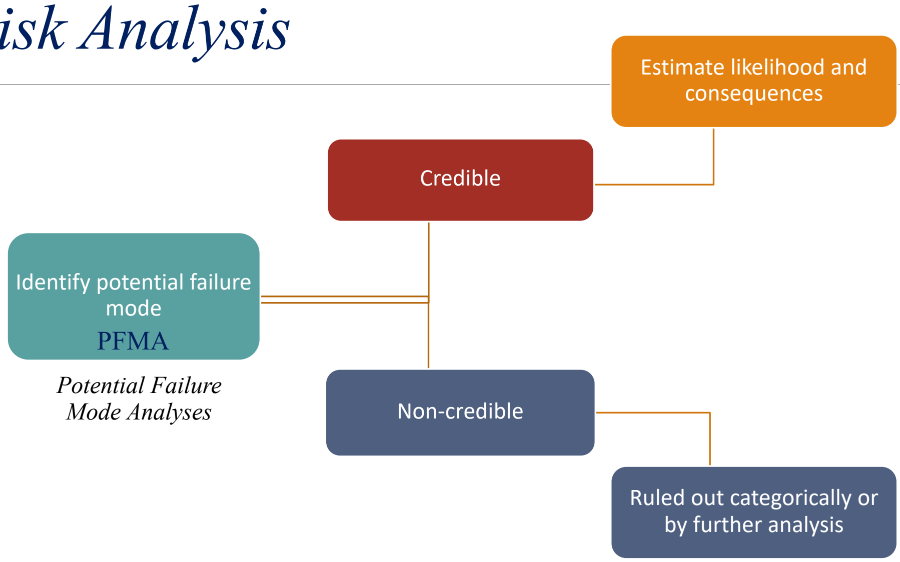
Risk Analysis



Potential Failure Mode Analyses

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Risk Analyses

Qualitative methods

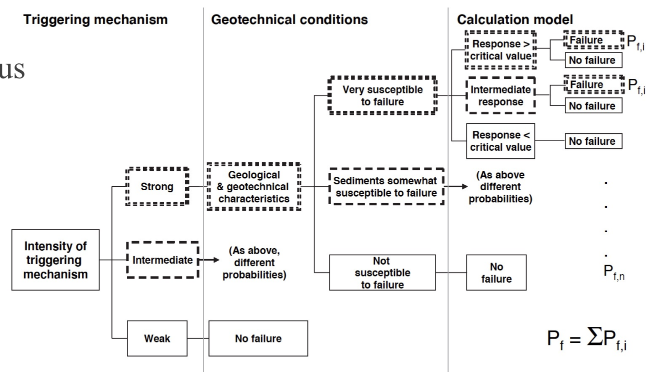
- Subjective estimates through consensus of experts

Semi-quantitative methods

- Semi-quantitative estimates through calculations and consensus of experts
  - e.g., Event-tree analyses

Quantitative methods

- Probabilistic analysis
  - e.g., Monte-Carlo simulations



Lacasse and Nadim, 2007

Yankee Doodle Tailings Impoundment (YDTI)

Guiding Objectives

Montana Resources (MR) Risk Statement:

MR's risk management objective for the YDTI is consistent with our core safety values, which includes a philosophy that no incident is acceptable, and every incident is preventable. MR is committed to continuously expanding our understanding of the facility and continuously improving our management of the facility to ensure that the YDTI is fully protective of our workforce, community and environment in which we operate and that there is never an unplanned discharge from the facility.

Overview of Process

Key Roles and Participants

Montana Resources (MR) – Mark Thompson, Mike Harvie
Atlantic Richfield Company (AR) – Chris Greco, Loren Burmeister
Engineer of Record (EOR) – Dan Fontaine
Knight Piésold Ltd. (KP) – Ken Brouwer, Tom Kerr, Kevin Davenport, Jason Gillespie, Ethan Alban, Roanna Dalton
AECOM – Brian Hippley; Richard Davidson and Dr. Norbert Morgenstern
Facilitator: Dr. Peter K. Robertson
Additional technical specialists providing input, as appropriate
Independent Review Panel (IRP), informed of planned process and results

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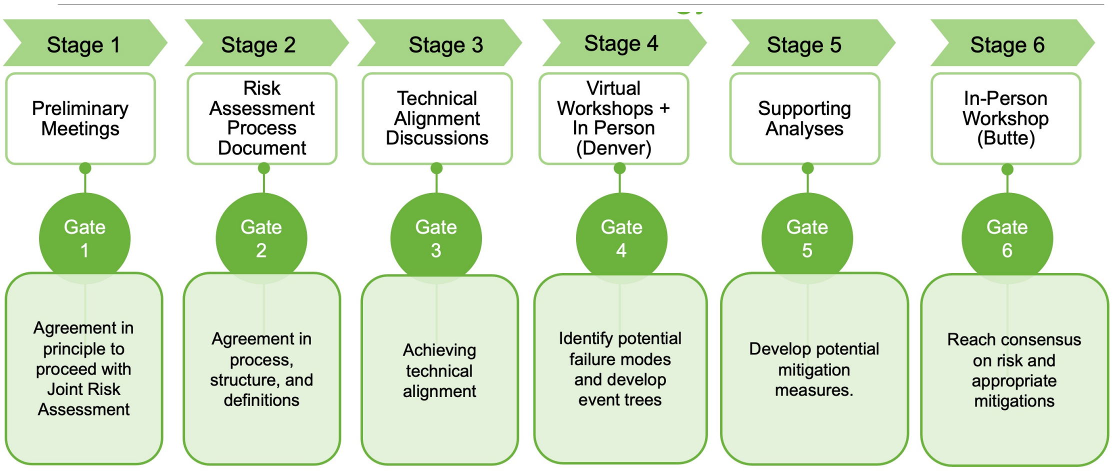
Process Structure and Execution Strategy



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Defining Likelihood

Two general approaches to assessing likelihood:

1. Defined probability of events (e.g., earthquakes and floods)
2. Subjective probability using expert judgement (verbal mapping scheme)

Subjective Probability Guidelines			
Description of Condition or Event		**%**	**Order of Magnitude**
Occurrence is virtually impossible		0.001	10^{-5}
The condition or event has not been observed, and no plausible scenario could be identified, even after considerable effort.		0.01	10^{-4}
The occurrence of the condition or event is not observed in the available database. It is difficult to think about any plausible failure scenario; however, a single scenario could be identified after considerable effort.		0.1	10^{-3}
The occurrence of the condition or event is not observed, or is observed in one isolated instance, in the available database; several potential failure scenarios can be identified.		1	10^{-2}
Occurrence of the condition or event are observed in the available database.	Unlikely	10	10^{-1}
	More unlikely than likely	25	
	Possible	50	
	More likely than not	75	
	Likely	90	
Occurrence is virtually certain		99.999	1

Defining Consequences

Subjective Consequence Criteria		
Category	**Impact to Mine Operations**	**Life Safety Risks**
Catastrophic/Extreme	Potential to render key site facilities inoperable and cause off-site damages	On-site worker and off-site public safety risks
Major	Potential impact on precipitate plant, maintenance workshop, and Booster Pump Houses	Potential impacts to permanent on-site workers
Moderate	Potential impact on operability of pipelines, mine haul ramps, and #3 Booster Pump House	Potential impacts to transient on-site workers
Minor/Low	No facilities impacted; resulting failure investigations may impact operations or have no impact to daily operations	Minimal to no on-site worker safety risk

YDTI Infrastructure

View looking South-west at NS Embankment

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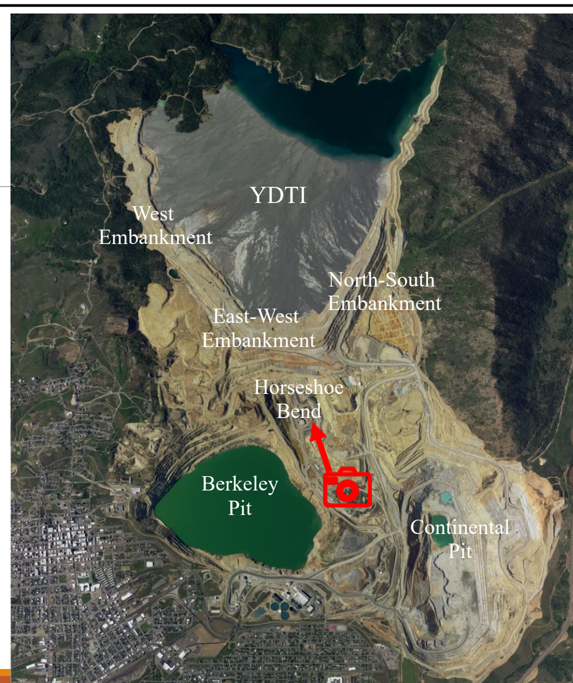
YDTI Infrastructure

View looking North at Horseshoe Bend (HsB)



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YDTI Infrastructure

Aerial view looking East along East-West Embankment towards Horseshoe Bend (HsB)

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YDTI Infrastructure

Aerial view looking Southeast at YDTI and West Embankment

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Identifying Major Hazards

- Earthquakes
- Floods
- Material degradation
- On-going construction
- Geologic and environmental

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Identifying Major Hazards

- **Earthquakes**
- **Floods**
- Material degradation
- On-going construction
- Geologic and environmental

Main Hazards of Concern

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Identifying Major Hazards

- **Earthquakes**
- **Floods**
- Material degradation
- On-going construction
- Geologic and environmental

Main Hazards of Concern (Earthquakes, Floods)

Current Normal Operating Conditions have Low Risk

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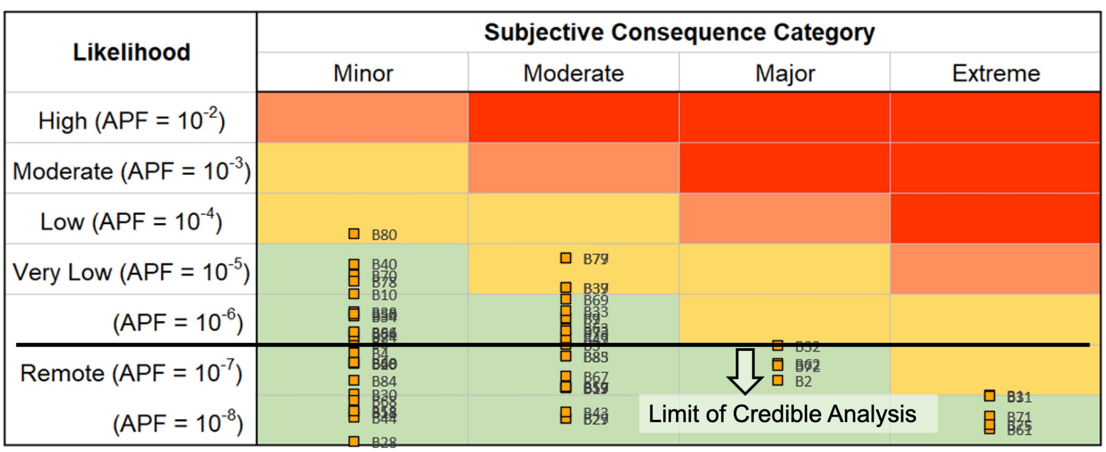
Main Outcomes – Risk Matrix (Earthquakes)



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Main Outcomes – Risk Matrix (Flood)

Likelihood	Subjective Consequence Category			
	Minor	Moderate	Major	Extreme
High (APF = 10^{-2})				
Moderate (APF = 10^{-3})				
Low (APF = 10^{-4})				
Very Low (APF = 10^{-5})				
(APF = 10^{-6})				
Remote (APF = 10^{-7})				
(APF = 10^{-8})				

Limit of Credible Analysis

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Risk Mitigation

Structural Controls:	*Priority:*
• On-site Containment Project	*High Priority*
• HsB RDS buttress	*High Priority*
• Truck shop relocation	*High Priority*
• North-South Embankment slope flattening and North RDS	*Secondary Priority to HsB RDS*
• Continued pond inventory management	*Important and On-going*

Non-Structural Controls:

• Review and update TOMS/EPRP (e.g. unusual occurrences indicators and corresponding communications protocols) *short-term*	*Continuous Improvement*
• On-going annual site investigation programs within 5-Year plan framework	*Important and On-going*
• Accelerated investigation of historical leach areas	*Medium to High Priority*

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On-Site Containment

Aerial view looking East along East-West Embankment towards Horseshoe Bend (HsB)

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Mitigation Evaluation

Mitigation Measure	Timeframe to Implement	Benefits (e.g. decreased APF, reduced PLL/N-value)	Drawbacks	Effectiveness / Appropriateness / Practicability	Comments / Priority
On-site Containment Project	Short-term Completed	• Clear reduction in potential consequences of failure for multiple failure modes • Readily understood by multiple stakeholders • Passive control (no further action required) • Facilitates continued mining operations and application of additional mitigation measures	• Short-term operations inconvenience • Introduces incremental increase to risks in Continental Pit area	• Will not increase coordination/communications with agencies (e.g. EPA) • Effective consequence mitigation • Highly practicable and can be achieved in months • Very minor incremental increase in on-site flooding	• High priority • In progress (estimated completion within the year)

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Mitigation Evaluation

Mitigation Measure	Timeframe to Implement	Benefits (e.g. decreased APF, reduced PLL/N-value)	Drawbacks	Effectiveness / Appropriateness / Practicability	Comments / Priority
Stage 1 HsB RDS (Buttress)	Short to Medium-term Underway	• Improved stability with resulting reduction in risk • Improved instrumentation • Reduces consequence by relocating Precipitation Plant staff • Improved water management capabilities • Improved access	• Active dumping adjacent to HsB workers poses potential safety hazard	• Well-established remedial measure • Achievable within a few years • High likelihood of rapid permitting • Efficient haul route • Cost-effective • Rockfill available within implementation timeframe • Improving surface reclamation potential	• Foundation layer construction in progress • Highest priority for surplus rockfill Estimated completion within next few years

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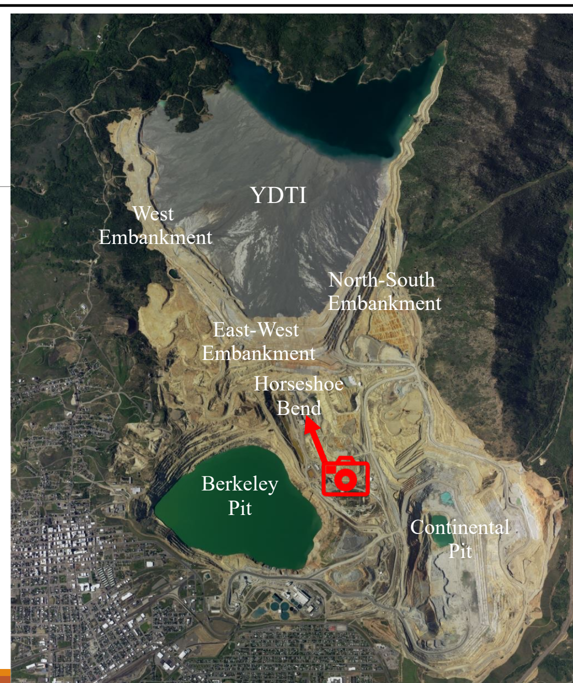
HsB (Rock Disposal Site)

View looking North at Horseshoe Bend (HsB)



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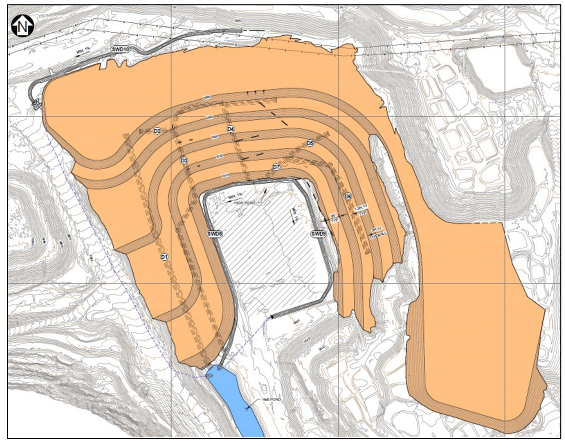
HsB - Rock Disposal Site

Rock Drains and Buttressing – Stage 1 HsB Rock Disposal Site (RDS)

- Enhance embankment stability with rockfill placed in the HsB area (Horseshoe Bend Rock Disposal Site – HsB RDS);
- Stage 1 HsB RDS (depicted) comprises ~20 Mt of rockfill placed around the existing truck maintenance workshop
- Rock Disposal Site includes a foundation drainage system designed to convey water discharge within the RDS foundation to the HsB Pond. Drainage System consists of:
  - Seven foundation drains
  - Three surface water ditches
  - Two pipelines



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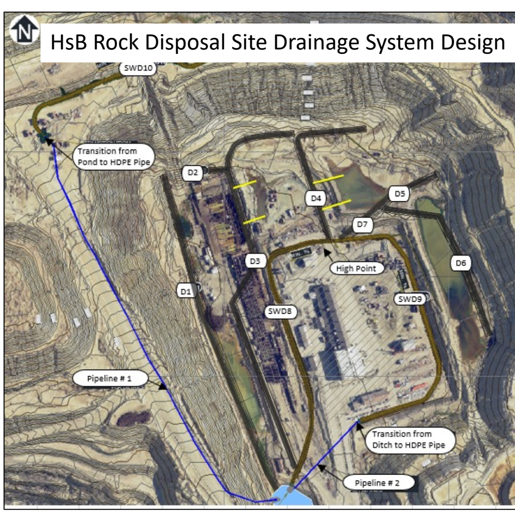
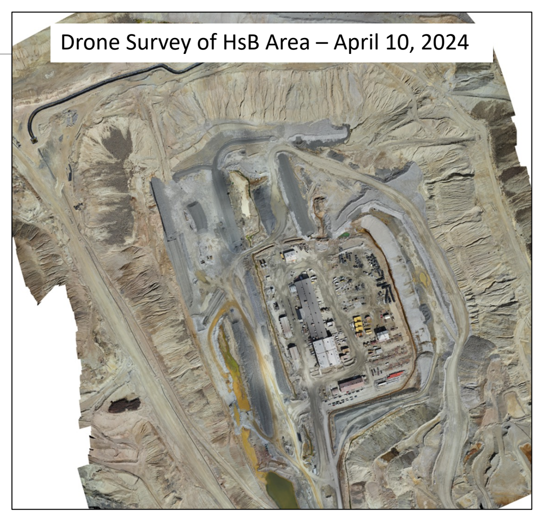
HsB – Rock Disposal Site



HsB Rock Disposal Site Drainage System Design


Drone Survey of HsB Area – April 10, 2024

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HsB – Rock Disposal Site (Under Drains)

Drone view looking Northwest within Horseshoe Bend (HsB) on March 14, 2024

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Mitigation Evaluation

Mitigation Measure	Timeframe to Implement	Benefits (e.g. decreased APF, reduced PLL/N-value)	Drawbacks	Effectiveness / Appropriateness / Practicability	Comments / Priority
North-South Embankment slope flattening and North RDS buttressing	Medium to Long-term Underway	• Improved stability with resulting risk reduction • Decreases regrading and material placement needs for early closure and/or reclamation		• Initial placement of 100 ft within 3H:1V slope is highest priority • On-going placement of additional buttress as surplus rockfill available	• Secondary priority to Stage 1 HsB RDS • Relative priority of North RDS and Stage 2 HsB RDS remains to be determined • Increased understanding of historical leached area materials may influence relative priority

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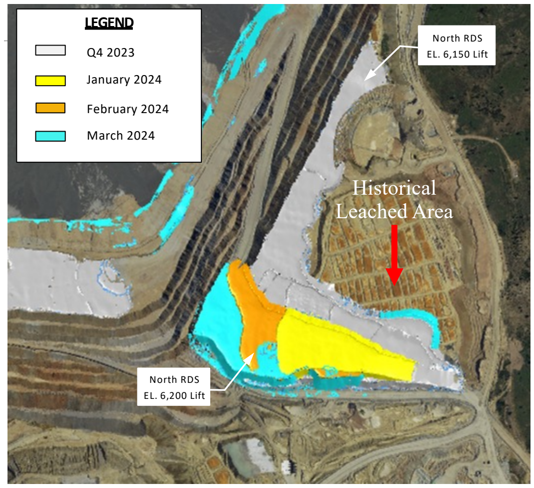
North-South Embankment Slope Flattening

Buttressing – North Rock Disposal Site (RDS) and Slope Flattening

- Enhance embankment stability along North-South Embankment and increase confining pressure over historical leached area
- Initial placement of 100 ft thickness within 3H:1V footprint of embankment is highest priority; progressive ongoing placement thereafter as surplus rockfill available from mining but secondary in priority to Stage 1 HsB RDS
- Future haul ramp to East-West Embankment also being developed in this area



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Historic Leached Area

Aerial view looking East along East-West Embankment towards Historical Leached Area

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Mitigation Evaluation

Mitigation Measure	Timeframe to Implement	Benefits (e.g. decreased APF, reduced PLL/N-value)	Drawbacks	Effectiveness / Appropriateness / Practicability	Comments / Priority
Investigation of Historical Leached Area	Short to Medium Term Part of Planned Work	• Improved understanding of historical leached material • Better site characterization • Improved confidence in designs and facility performance expectations	• Increased costs in near term to execute additional parallel program during 5-year plan	• Objectives of current investigation plans are important objectives • New investigation should be executed in parallel	• Should be executed during the next 5 years • Commence with surface seismic investigations and cone penetration testing in 2022, if possible. • Do not remove resources from current investigation plans

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Mitigation Evaluation

Mitigation Measure	Timeframe to Implement	Benefits (e.g. decreased APF, reduced PLL/N-value)	Drawbacks	Effectiveness / Appropriateness / Practicability	Comments / Priority
Truck Shop Relocation	Short- to Medium-term Process Started	• Significant consequence reductions • Allows for Stage 2 HsB RDS • Reduced safety hazard for personnel access • More convenient for mine operations • Reduced risk during Stage 1 HsB RDS construction	• Large costs to relocate (approximately $50M) • Likely downgrade to existing facilities • Zoning and construction permits	• Requires relocation of Alluvium Stockpile • Very effective potential consequence mitigation	• Estimated completion time is ~ 2 years following approval to proceed • High priority • No single measure will have greater positive impacts on potential consequences

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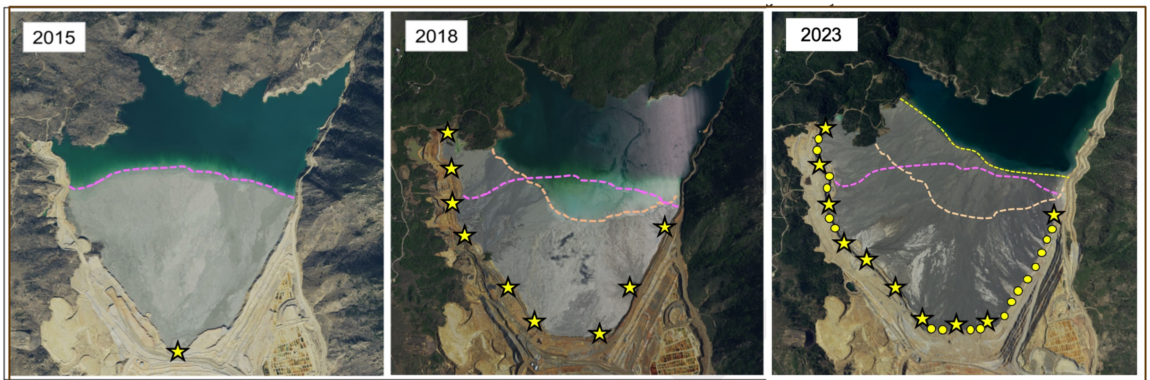
Pond and Beach Management

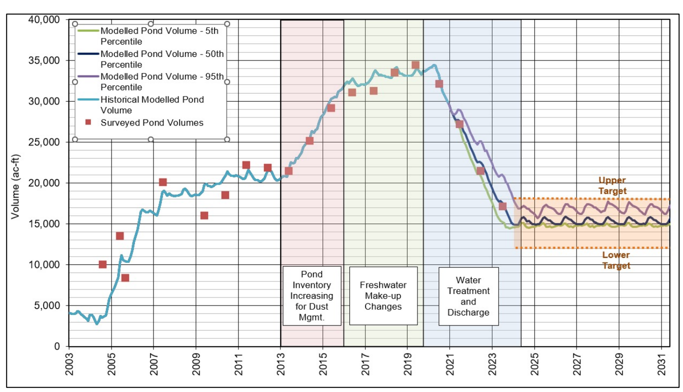
- Single point discharge changed to multiple points of discharge to enhance beach development and dust control
- Water inventory reductions since 2019 combined with tailings beach management significantly reduced risk



Mitigation Evaluation

Pond Management

- Reduction of pond volume towards target of 15,000 acre-ft
- Increased beach length



Summary

- Transparent collaborative process
- Identified and quantified risk
- Current operating conditions are very low risk
- Highest risks are related to extreme earthquake and flood events
- Consensus on recommended mitigation measures to reduce risk and order of priority
- Continued mining allows additional mitigation measures to further reduce risk and improve reclamation potential

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