Quantifying Water related Financial Risk for the Mining Industry

Tia Maria, Peru
Water Pollution → Social Conflict

Samarco, Brasil, Tailings Dam Failure

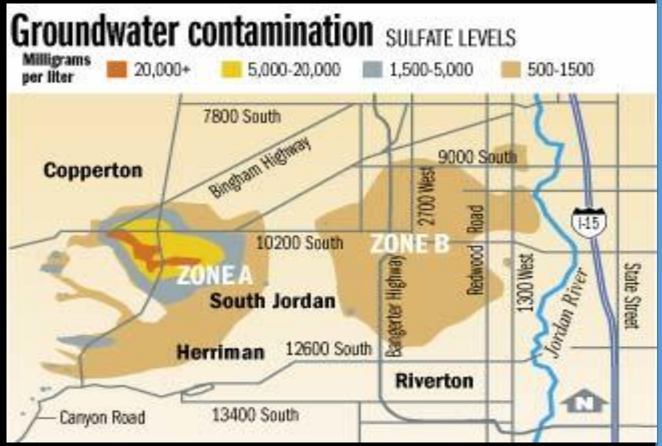
Atacama Floods, Chile

PNG drought halts mining at Porgera

Minera Escondida Copper, Chile
Water Scarcity - Desalination

Tuslequah Chief Copper-Lead Mine, BC
Cumulative Effects - Acid Mine Drainage

Kennecott Copper, Utah



Operator/Investor

CAPEX, OPEX, Production Losses, Profit Margins
Asset Stranding, Operating License, Reputation, Regulatory Pressure

Society

Environmental Degradation, Loss of Access to Water, Poverty Trap, Property and Life Casualty Losses

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Research Objective

How to quantify financial risks from environmental factors for long term investors?

Specific Case: Copper/Gold Mining & Water Risks

Water Management Risks in Mining:

- Scarcity - Aridity, Drought
- Water Quality/Pollution, Waste Spills
- Increasing Water Sourcing & Treatment Costs
- Flooding
- Social Conflict & Asset Stranding
- Regulations & their Effectiveness
- Failure of Risk Mitigation Actions

Research Questions

1. How do increasing water management costs for mining impact project risk and long run industry cost curve?
2. What are the financial risk exposure pathways for mining related to water & climate? How can data and estimates on these be developed?
3. What are the mine's risk mitigation strategies, their costs and residual risks?
4. Given limited data, high uncertainty, and the potential for catastrophic events, how best can financial risk at the asset and portfolio level be assessed?
5. How well do regulatory and financial disclosure processes address these risks?

Problem framing

- Mines are heavily engineered and regulated with life > 10 years
- Environmental/water factors have led to significant social conflict, non-performing assets and production cost risks
- Mining companies disclose their efforts to address these challenges and provide environmental and financial reports
- Analysts and regulators use these reports to assess performance and value the mines
- Is there data to assess whether the risks are properly assessed and disclosed?
- How does one assess the **residual financial risk (beyond the market valuation)** recognizing the complexity in the physical, social/legal, environmental inter-dependence over the long life of a mine? Or for a portfolio of mines?

What are the material financial risks related to water, how do they emerge, and how can one value them? Are they priced right?

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Short vs Long Term Investor Perspectives

Short Term Investors:

- Will the company (and its assets) beat market expectations when it announces its results?
  - Is the spot commodity price going up (or down) this quarter?
  - Will the company have positive exploration results in the near-term?
  - Will the company produce more (less) payable metal than the market expects?
  - Are costs going to be lower (or higher) than anticipated?
  - Will the company's assets get permitted in the near-term?

Long Term Investors:

- Are the company's assets fundamentally more/less valuable than market perception?
  - What should the fundamental commodity price be (supply and demand)?
  - Is it likely that company's assets will have reserves higher than estimated?
  - Will the company be able to economically extract all of its defined resources?
  - What level of costs are sustainable in the long-run?
  - Will the company's assets get permitted?
  - Are there potential increases in costs due to unforeseen factors that could lead to a stranded or non-productive asset?

Long Term Investment & Sustainability Goals

What kind of risks are captured by Market Research & Valuation?

- **Typically Discounted Cash Flow is Used**
  - Emphasizes Short or Near term Cash Flows
  - Valuations are updated as companies disclose costs, yields and reserves, and analysts update metal prices
  - Production Costs change relatively slowly
    - Water Management cost changes are included
  - Risk discounts are applied to address uncertainties
    - Cost and production uncertainties are high in early stages of mine development
    - Remediation costs occur late in mine development and are highly discounted in Present Value, but = liabilities.
    - Not clear how “shocks” are priced accounting for potential mitigation efforts by the company?
    - Correlated risks across mines limited to metal prices

Residual Financial Risk due to systematic bias in estimation and disclosure of either the value at risk or the uncertainty associated with the risk

Financial Implications of Environmental Factors

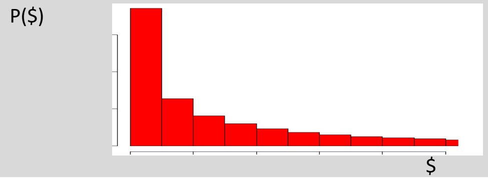
VALUE

UNCERTAINTY

REVENUE

Examples: Production stoppage, permanent mine closure, modified expansion plans

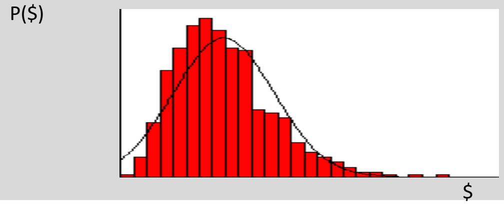
PROBABILITY OF FOREGONE REVENUE



COSTS

Examples: Legal costs, monitoring, community relations, ongoing remediation, permitting

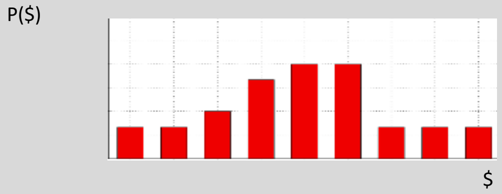
PROBABILITY OF INCREASED COSTS



CAPEX

Examples: Clean-up costs, settlements, reconstruction

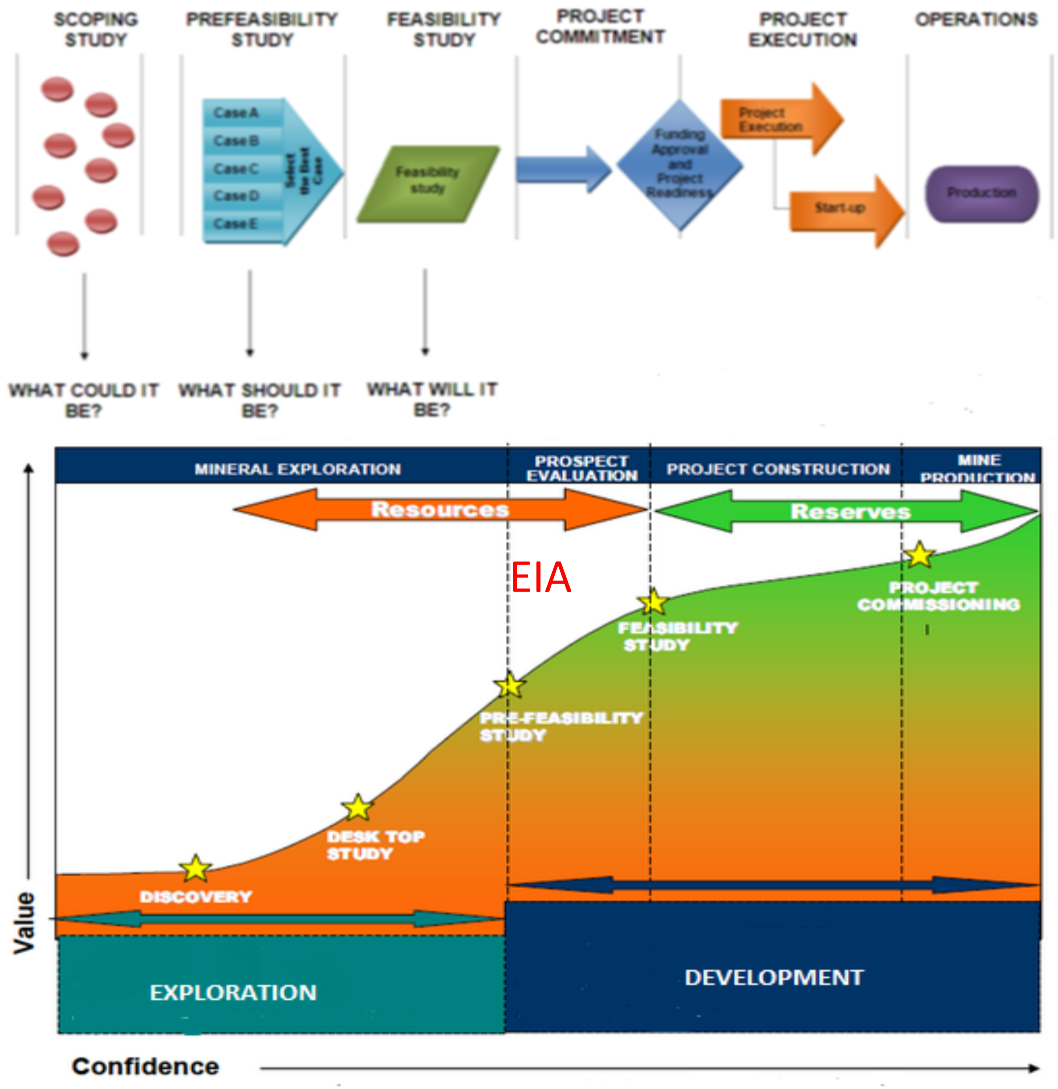
PROBABILITY OF INCREASED CAPEX



Decisions are made in response to “risk events” → may change assumed mine trajectory

Value Creation / De-risking Over Time

- Mine Plans include environmental impact assessments and mitigation over decades. They are updated over time.
- **<u>Value is created as the mine is "de-risked"</u>** as analyses and data improve (therefore theoretically **<u>more accurate</u>**)
- Mines become less risky as future outcomes are better understood
- Biggest water risks → non-performing or stranded assets
  - Loss of license to operate
  - Social conflict
  - Irreversible Pollution
  - Catastrophic Infrastructure failure
  - Competition over water



Are there critical triggers and exposure pathways for water risks ?

Understanding Profitability Impact of Environmental Factors

EXAMPLE: TAILINGS SPILL

REVENUE

WILL THE ASSET EVER MAKE MONEY AGAIN?

FULL WRITE-OFF: Asset does not have sufficient economic reserves to justify restart → ASSET HAS RESIDUAL VALUE OF ZERO

PARTIAL WRITE-OFF: Asset has sufficient reserves to justify restart → ASSET HAS RESIDUAL VALUE GREATER THAN ZERO

COST

WHAT ARE THE CARE & MAINTENANCE AND ONGOING MONITORING COSTS?

IF FULL WRITE-OFF → ZERO
IF PARTIAL WRITE-OFF → EQUAL TO FIXED COSTS OF MINE DURING PERIOD OF RESTART + INCREASED MONITORING COSTS AS A RESULT OF THE INCIDENT

CAPEX

WHAT WILL BE THE RESULTING CLEAN-UP COSTS / LIABILITY / LITIGATION?

FUNDAMENTAL ESTIMATE BASED ON:

- Proximity to major population centers / water resources
- Capacity and quantity of tailings
- Impurities / toxicity
- Mine / Company insurance protection

Issues with Reliance on Company Provided Information

- **<u>Investors rely heavily on mining company analyses</u>** as a basis for their investment decisions
- **<u>Regulators have tried to standardize these analyses</u>** under JORC and 43-101 to protect investors and preserve the credibility of these studies / public data and their respective classifications
- Research has shown that **<u>analyses are historically inaccurate</u>**. However, in the absence of other publicly available information investors have no alternative as a basis for their analyses
- Thus, investors have to come up with subjective determinations of risk associated with company estimates (**<u>discounts to NAV</u>**)

M&A Discounts to NAV by Project

Date	Target (Acquiror)	Corporate / Asset	Adj. Acq. Price (US$ mm)	P/NAV[1] (x)	1-Day Premium (%)	Spot Cu[3] (US$/lb)	LT Cu[3] (US$/lb)
13-Mar-17	Rosh Pinah & Perkoa (Trevali)	Asset	$400	na	-	$2.63	$2.91
15-Nov-16	Tenke (BHR)	Asset	$1,136	0.89x	-	$2.47	$2.86
29-Sep-16	Mina Justa (Minsur)	Asset	$85	na	-	$2.18	$2.81
5-Jul-16	Thompson Creek (Centerra)	Corporate	$934	0.79x	32%	$2.20	$2.80
30-Jun-16	Batu Hijau (PT AMI)	Asset	$1,300	1.09x	-	$2.19	$2.80
9-May-16	Tenke (China Moly)	Asset	$2,650	0.88x	-	$2.15	$2.84
25-Apr-16	Reservoir (Nevsun)	Corporate	$615	0.56x	35%	$2.27	$2.84
10-Mar-16	Kevitsa (Boliden)	Asset	$712	0.97x	-	$2.23	$2.86
15-Feb-16	Morenci (Sumitomo)	Asset	$1,000	1.26x	-	$2.07	$2.86
15-Jan-16	Grasberg (Indonesian Gov.)	Asset	$1,700	1.95x	-	$1.96	$2.90
24-Aug-15	Norte (Audley Capital)	Asset	$300	0.57x	-	$2.22	$2.99
30-Jul-15	Zaldivar (Antofagasta)	Asset	$1,005	1.38x	-	$2.38	$3.02
26-May-15	Kamoa (Zijin)	Asset	$412	0.50x	-	$2.78	$2.97
25-May-15	Sirius (Independence)	Corporate	$1,133	1.03x	35%	$2.81	$2.97
28-Mar-15	PanAust (GRAM)	Corporate	$1,039	0.94x	50%	$2.79	$3.01
3-Nov-14	Duluth Metals (Antofagasta)	Corporate	$95	0.50x	120%	$3.08	$3.05
6-Oct-14	Candelaria (Lundin)	Asset	$1,800	1.02x	-	$3.04	$3.09
3-Oct-14	Niobec (Magris)	Asset	$530	1.10x	-	$3.02	$3.09
8-Sep-14	Curis (Taseko)	Corporate	$93	0.36x	17%	$3.19	$3.05
28-Aug-14	Kipoi (Tiger)	Asset	$111	0.34x	-	$3.19	$3.05
28-Aug-14	Blackthorn (Intrepid)	Corporate	$30	0.81x	4%	$3.19	$3.05
13-Jul-14	Jabal Sayid (Ma'aden/Barrick)	Asset	$210	0.62x	-	$3.24	$3.01
17-Jun-14	Lumina (First Quantum)	Corporate	$412	0.48x	28%	$3.04	$3.01
13-Apr-14	Las Bambas (MMG)	Asset	$5,850	1.01x	-	$3.03	$2.95
9-Feb-14	Augusta (Hudbay)	Corporate	$594	0.75x	11%	$3.27	$2.99
			Average[2]:	0.83x			
			Producer Average[2]:	0.99x			
			Developer Average:	0.66x			

Producing
Development

[1] Based on analyst consensus estimates of NAV.
[2] Average excludes Grasberg and Kipoi as outliers.
[3] Spot copper prices and consensus LT copper price estimates as of date of initial offer.
Source: Bloomberg Financial Markets and CIBC database.

Changing environment/climate and socio-economic conditions may invalidate mine company assumptions and disclosure

Issues with Reliance on Company Provided Information

- There are empirical examples of bonds being inadequate to cover reclamation costs
- Examples include:
  - Summitville Mine in Colorado, cyanide spill required $192 million Superfund cleanup while financial assurances posted by operating company were $4.5 million.
  - 2005 GAO Report: Financial assurances not adequate to cover cleanup costs of majority of investigated abandoned mines on Bureau of Land Management property.
- **<u>Later in this presentation</u>**, we discuss in detail how bias is prevalent in reclamation cost estimates which can have a profound impact on stakeholders (including local communities, regulators and investors)

Remediation Costs vs. Posted Reclamation Bonds

State	Number of notice-level hardrock operations	Percentage of notice-level hardrock operations without financial assurances	Number of plan-level hardrock operations	Percentage of plan-level hardrock operations without financial assurances
Alaska	134	1-4	106	0
Arizona	130	50-74	55	25-49
California	205	5-14	98	15-24
Colorado	102	0	30	0
Idaho	32	5-14	23	5-14
Montana	150	1-4	30	0
Nevada	450	0	324	1-4
New Mexico	24	15-24	11	15-24
Oregon	165	1-4	10	0
Utah	167	50-74	49	15-24
Washington	127	Do not know	12	0
Wyoming	18	0	38	0

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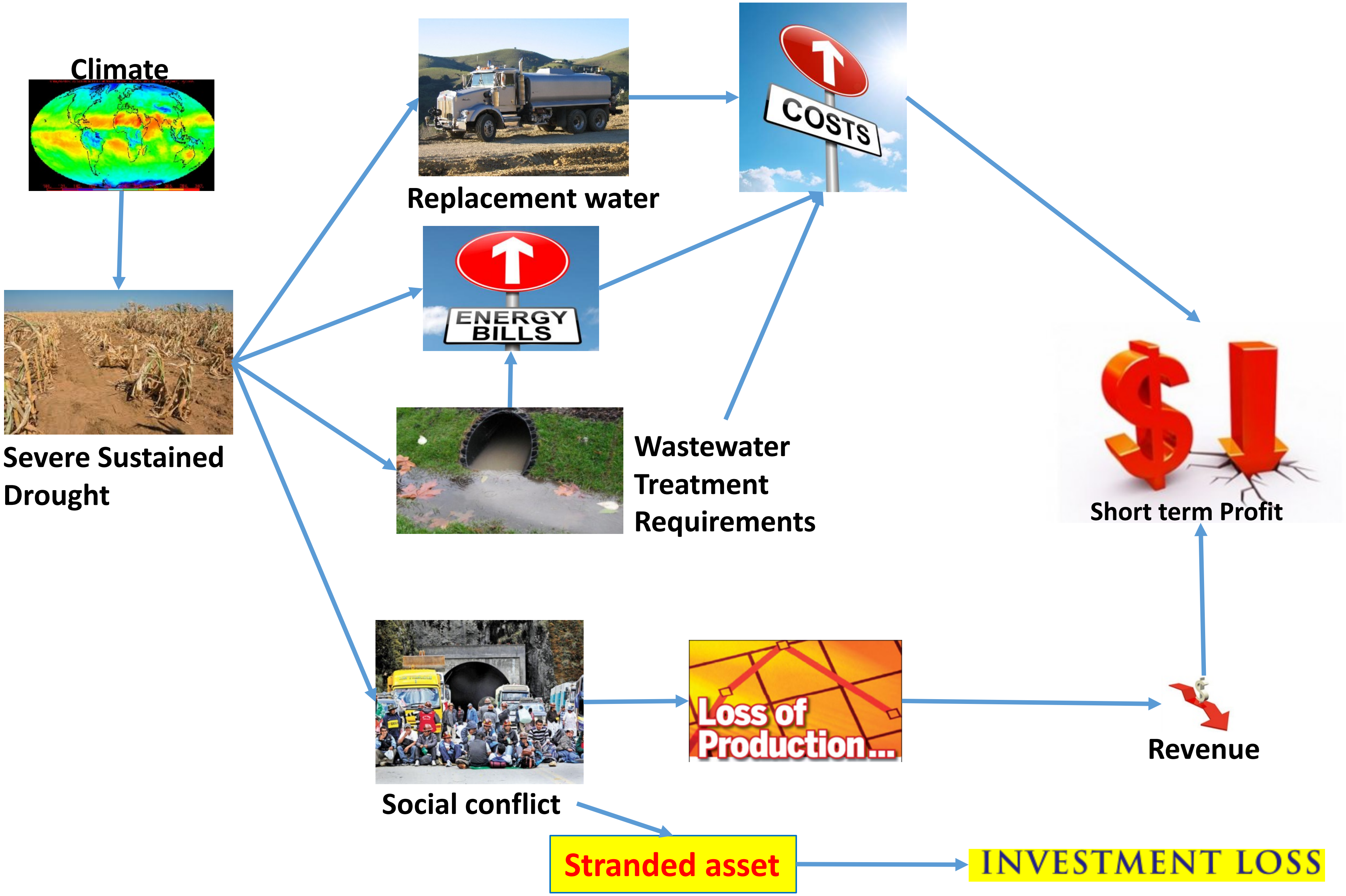
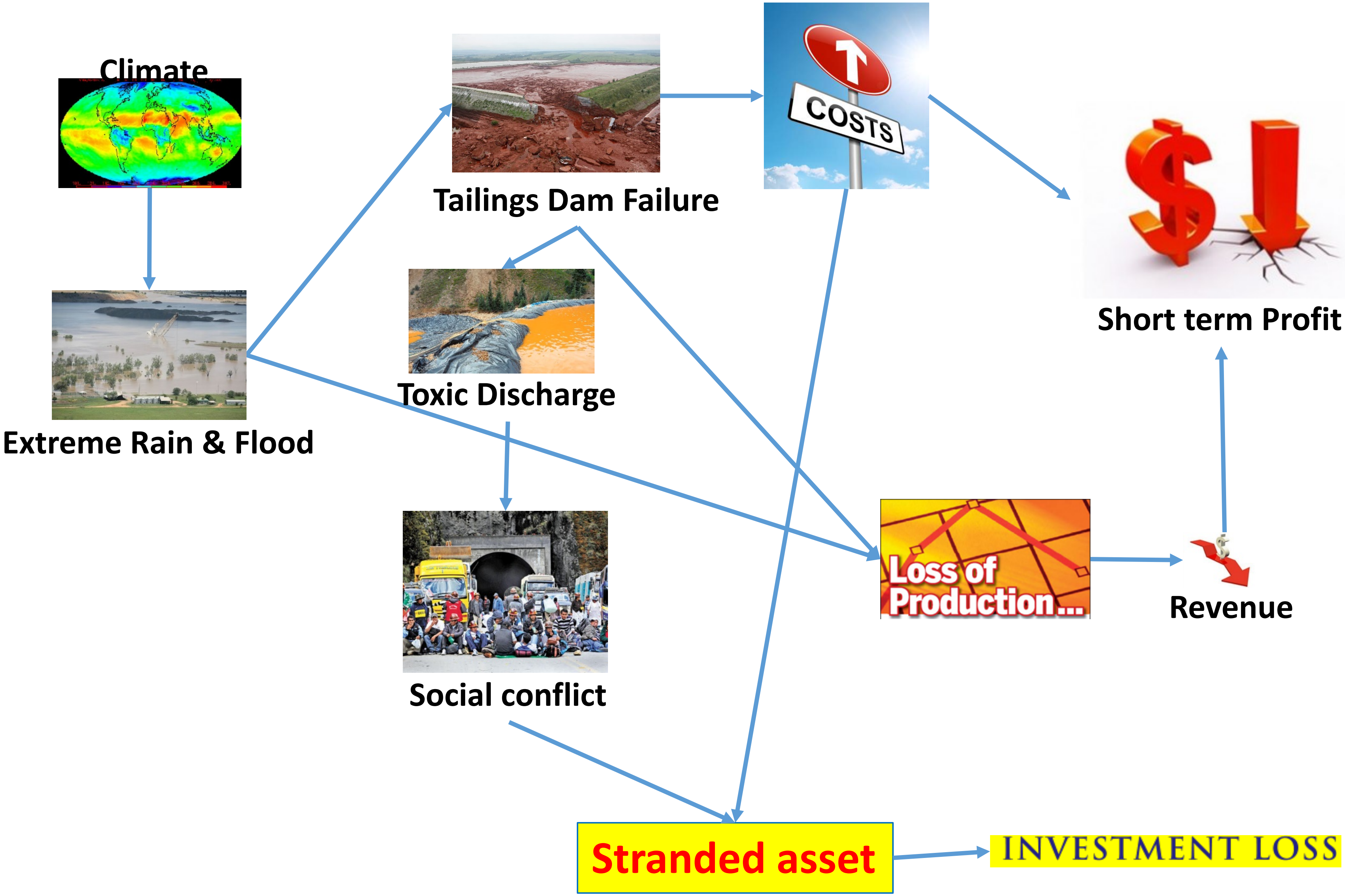
Key Issues Focused on

FINANCIAL RISK MODELING	Model long term risk evolution and mitigation, over quantifiable risk exposure pathways ← information biases & uncertainties	Robust real options model theory and application
CLIMATE EXTREMES	As a trigger for water scarcity & flooding → infrastructure impacts and social conflict	Mispricing of at site risk Correlated Portfolio risk
LOW PROBABILITY / HIGH IMPACT EVENTS	Infrastructure Failure with water system impacts	Tailings Dam State Identification & Failure Impact Analysis
CUMULATIVE WATER POLLUTION EFFECTS	Regulatory effectiveness and outcomes	Reputational Risk, Watershed Impacts
WATER USE & COSTS	Bounds on potential water use and wastewater treatment costs	Long run cost risk for at site water use
SOCIAL CONFLICT	Covariates of water related social conflict	Asset Stranding potential
BIAS IN REPORTING	Mispricing of Risk due to systematic errors in company reports	Reclamation Cost Disclosure Analysis
REGULATIONS	Comparative Analysis Across Countries	Potential Effectiveness, Delays

1. Financial exposure pathways for a mine ← water related risks?



2. Financial exposure pathways for a mine ← water related risks?



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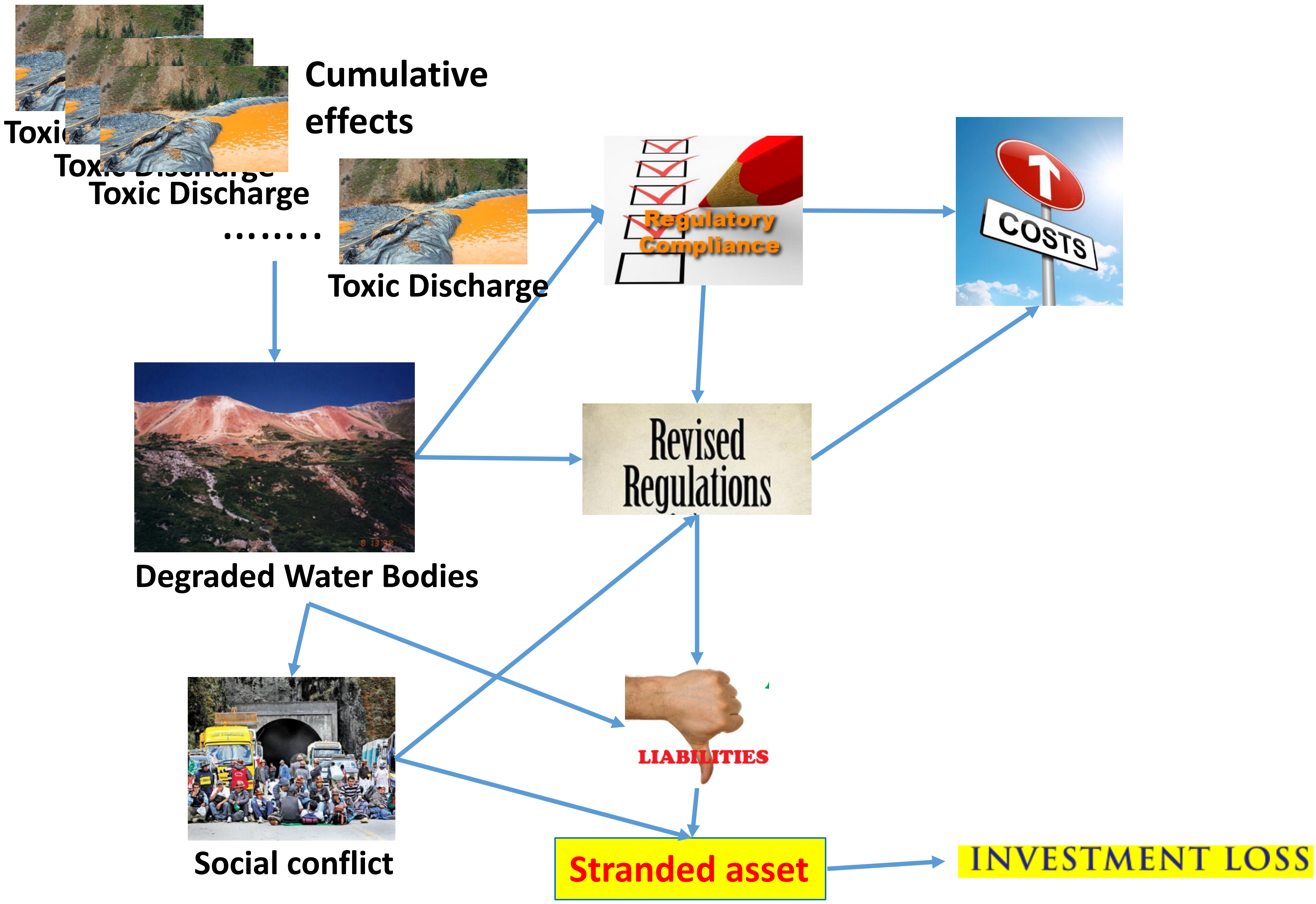

Social/Legal
EIS, Permits, Conflicts
Systems Design
Financing

Regional Drought

Water Available ↓
Discharge Allowed ↓
Waste Treatment ↑
Social Conflict ↑
Production ↓
Net Revenue ↓

WWT failure Spill

Social Conflict ↑
Regulatory fines ↑
Regulation ↑
Production ↓
Net Revenue ↓

Acquire   Permitted   Operational

Flood Event

Power & Transportation ↓
Infrastructure ↓
Waste Spill ↑
Production ↓
CAPEX ↑
Net Revenue ↓

Tailings Dam Failure

Power & Transportation ↓
Infrastructure ↓
Waste Spill ↑
Regulation ↑
Legal Actions & Fines ↑
Production ↓
CAPEX ↑
Net Revenue ↓

Consider climate extremes, Tailings failures, Social conflict emergence as stochastic shocks whose probability of occurrence changes over time based on covariates → risks that change over time

Mining companies design/insure some of the risks

Outcomes = function of planning + event effects

Discounted present value reflects the risk?
Simulate all possible occurrences, and best decision forward at each time

Site Remediation
New standards?
Adequate Bond?

Wet Period

Groundwater Contamination ↑
Regulation ↑
Acid Mine Drainage ↑
Liabilities ↑

Mine Closure

Robust Real Options Model Theory and Applications

Real Options Model:

Simulation-Optimization Modeling framework for risk and asset/portfolio valuation

Simulation = performance/outcomes in the face of stochastic shocks over time that lead to decisions on changes in system design or operation and hence costs and revenues

Optimization = at any given time where such a decision is needed, assuming the company is a rational economic actor, identify the economically optimal decision to the end of the operating horizon

Thus, the nonlinear dependence between shocks, decisions and outcomes is explicit

Shocks = financial or environmental

Robust:

Recognizes that data on shocks and the outcomes of the shocks may be quite limited and or biased.

How does one derive appropriate bounds for the probabilities of shock events in this setting?

How does one simulate shocks using these robust probability bounds?

Theory Developed. Database and App Developed and available.

Applied to Assess whether a Mine/Company is over/under Valued considering risks