

Secondary Metal Recovery From Pit Lake Remediation: A Screening Assessment of Revenue Potential and Policy Support for Sustainable Mining

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INTRODUCTION & RESEARCH PROBLEM

Abstract

Global demand for critical minerals is increasing rapidly, while the mining industry continues to manage large volumes of tailings, sludge, and mine water treatment residuals that create long-term environmental liabilities. Recent research suggests that these waste materials may also represent an unused source of recoverable critical minerals, creating opportunities to support both remediation and circular-economy objectives. This capstone evaluates whether pit lake sediments and treatment residuals can be repositioned from waste streams to secondary resources through integrated remediation and recovery. Using a mixed-method approach, the study combines a screening-level revenue assessment for copper and molybdenum recovery with an analysis of a Canadian mining case study with water quality data to review mine water treatment and circular-economy policies.

Problem

Research Question

Can revenue generated from biologically recovered copper and molybdenum, together with policy incentives and infrastructure support programs, create a compelling value proposition for implementing secondary recovery of critical metals in pit lake sediment compared with a Do-Nothing baseline ?

42

Mo

Molybdenum

95.96

Alloy production (engines, heating elements, strength enhancement)
Clean energy production
Corrosion-resistant metal

29

Cu

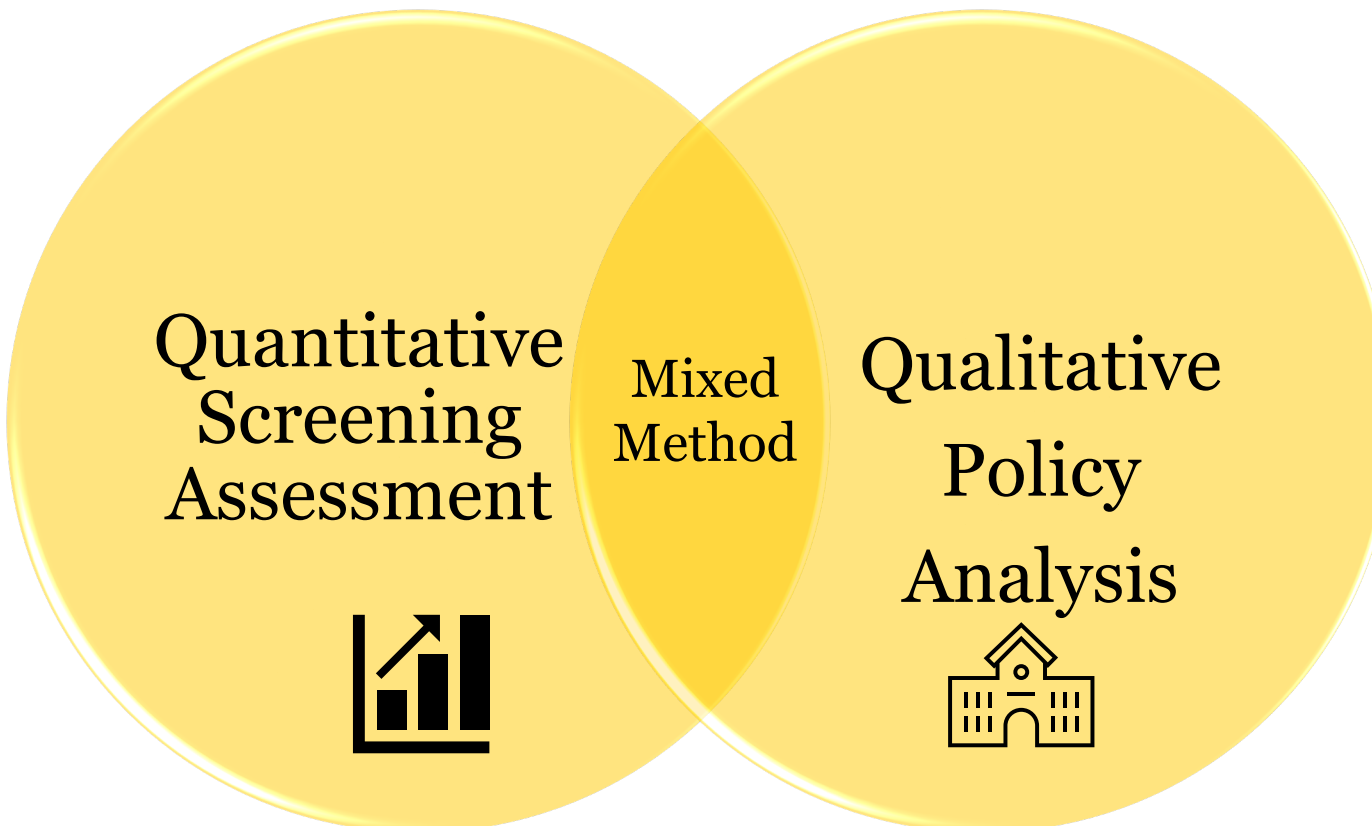
Copper

63.546

Grid electrification
Digital trading platforms
Nuclear
Navigation & Quantum Processor
Cochlear implants, Bionic eye
Solar Panels

METHODOLOGY & SCREENING DESIGN

Screening Assumptions



- Screening-level revenue assessment for Cu and Mo recovery vs. Do-Nothing baseline
- Narrative literature review focus on biological treatment, waste, circular mining
- Analysis of Canadian federal and provincial mining policies

SCREENING MODEL

Revenue = mass x grade x recovery x price

Parameter	Copper	Molybdenum	Units
Pit Lake Water volume	33,000,000	33,000,000	m³
Lake footprint	41.25	41.25	ha
Sediment thickness	2	2	m
Dissolved Concentration	0.002	0.67	Mg/L
Bulk Density (t/m³)	1.30	1.30	t/m³
Sludge dry mass	1,072,500	1,072,500	tonnes
Avg Price (US/lb.)	2-5.5	8-15.9	USD/lb.
Metallurgical Recovery	50-75	50-75	%
Grade in sludge	1-2	0.02	%
Material Available	10,725	215	tonnes
Exchange rate	1.33	1.33	CAD/USD

RESULTS AND REVENUE POTENTIAL

Sustainable Development



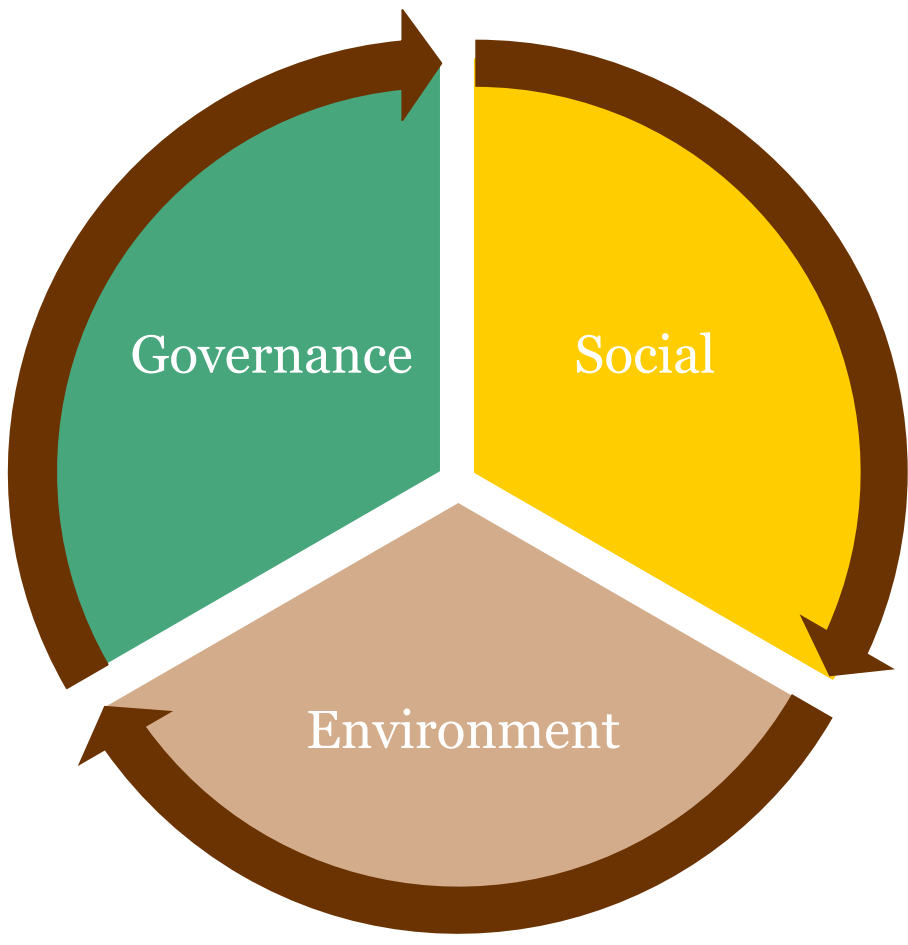
Figure 1: Sustainable Development Goals (United Nations, 2015)

#9 Industry Innovation and, Infrastructure – Sustainable industrialization and foster innovation

#12 Responsible Consumption - Ensure sustainable consumption and production patterns

Results

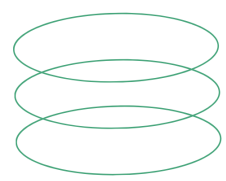
The screening assessment shows positive revenue estimate across all three grade scenarios examined. Applying the base case parameters of 1.0% Cu, 0.02% Mo, 65% recovery and average commodity prices.



Critical mineral development is critical for supply chain vulnerability, national security and alignment with low-carbon economic goals. The energy transition will increase demand for primary mineral production and the need to manage waste and water liabilities with production.

Secondary recovery can strengthen industry performance in three ways:

- Responsible residual waste management
- Social vaule of clear closure planning for local communities
- Transportation governance and waste characterization

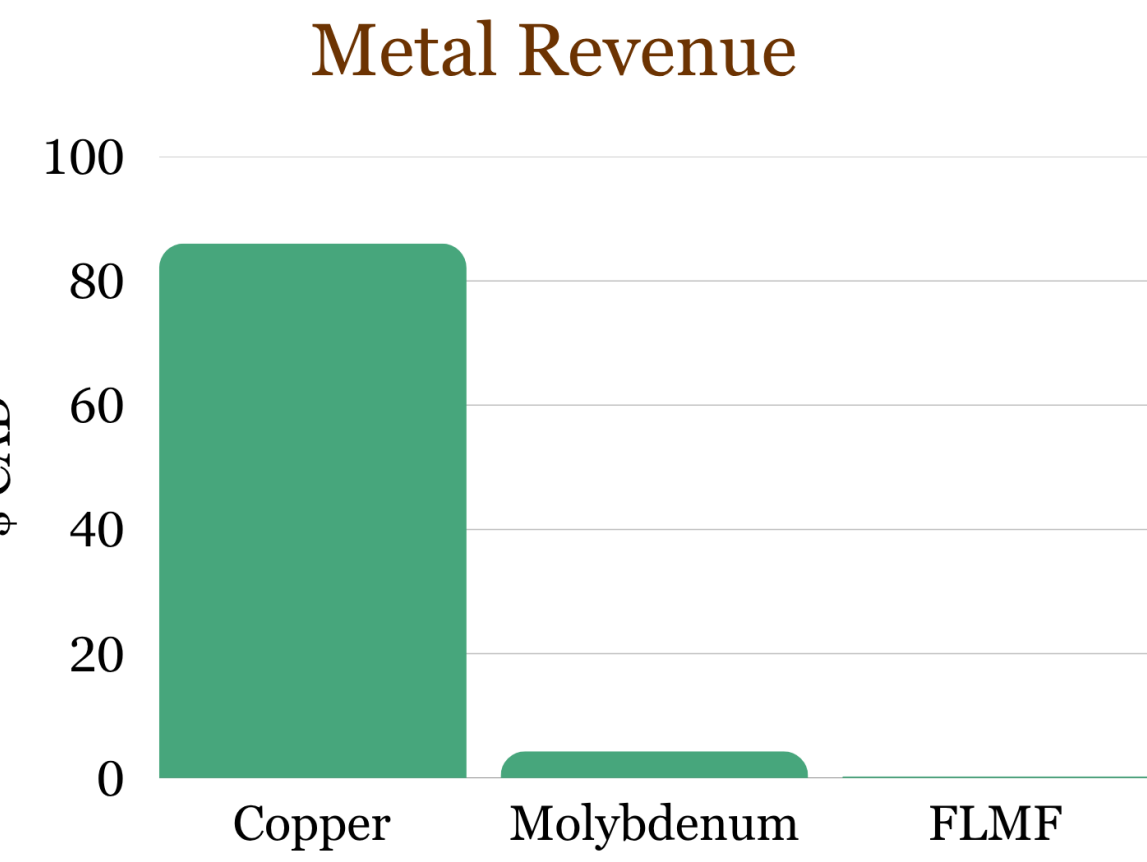


Precautionary Principle supports proactive remediation by advocating cost-effective measures to prevent environmental harm even when scientific certainty is incomplete.

Every year of “Do-Nothing” means we pay for treatment, monitoring, and water liability — while copper, molybdenum, and other critical minerals sit at the bottom, of pit lakes untouched!

REVENUE BREAKDOWN

Secondary Metal Revenue		
Copper	Molybdenum	FLMF
\$ 86.26 M	\$ 4.26 M	\$ 250 K
Total Revenue \$ 90.77 million		



POLICY & REGULATORY LANDSCAPE

Fragmented but Evolving

Canada’s framework is evolving – Ontario mineral recovery permit and a British Columbia’s Technology Readiness Assessment (TRA) guidance offer two different approaches for integrating remediation with secondary recovery minerals.

Federal	British Columbia	Ontario
Metals and Diamond Mine Environmental Regulation (MDMER) Fisheries Act	Mines Act Health, Safety & Reclamation Code	Building More Mines Act O. Reg. 463/24 permitting for recovery mine waste
Critical Mineral Strategy 2022: \$8B over 8 years	MEMLCI interim TRA maturity evidence based	CMIF 50% funding ≤ \$500K/project
CMETC 30% tax credit for flow-through share investors	GeoScience BC mapping tools for waste resource potential	MIRARCO bioleaching + battery-metal recovery programs
FLMF Indigenous grants \$250K/ initiative		

BIOLOGICAL WATER TREATMENT

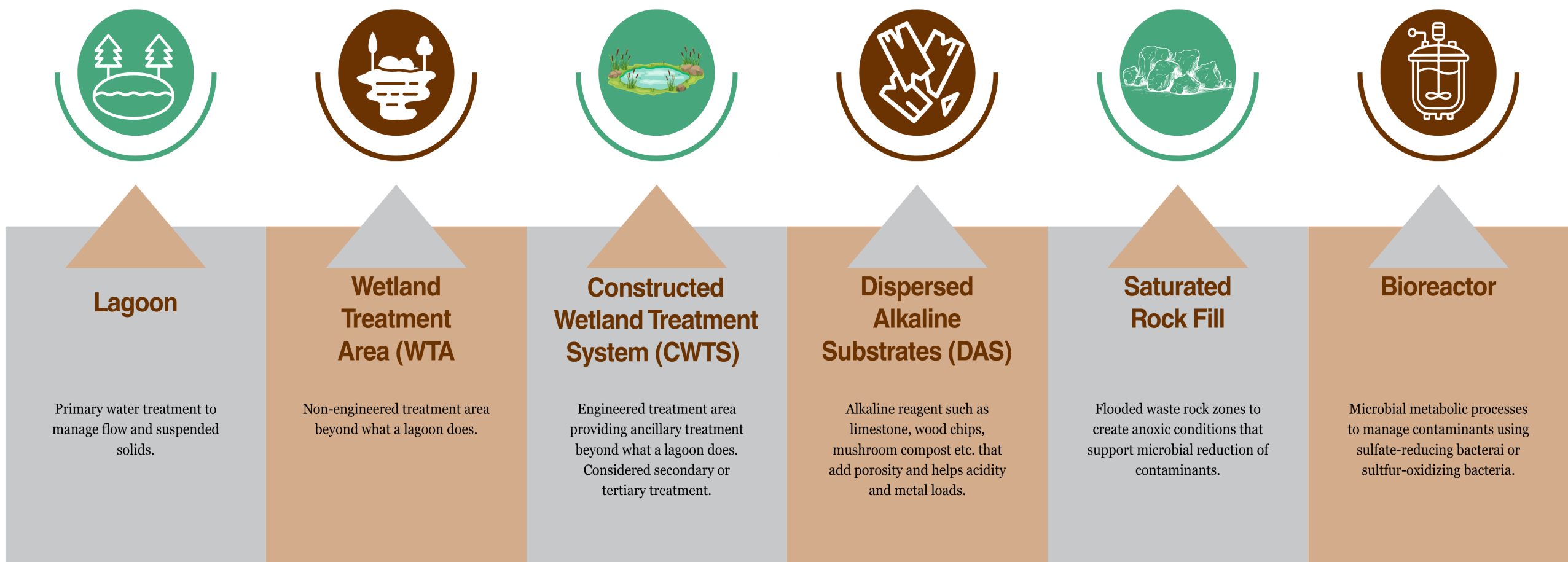


Figure 3: Biological Water Treatment Methods

Passive water treatment, uses natural biogeochemical processes such as metal precipitation, sorption, and microbial transformations to aid removal of contaminants. Enhanced Passive Water Treatment Systems (EPWTS) are passive treatment systems engineered to improve removal of target contaminants, and that offer lower long-term energy and operating requirements compared to active water treatment methods.

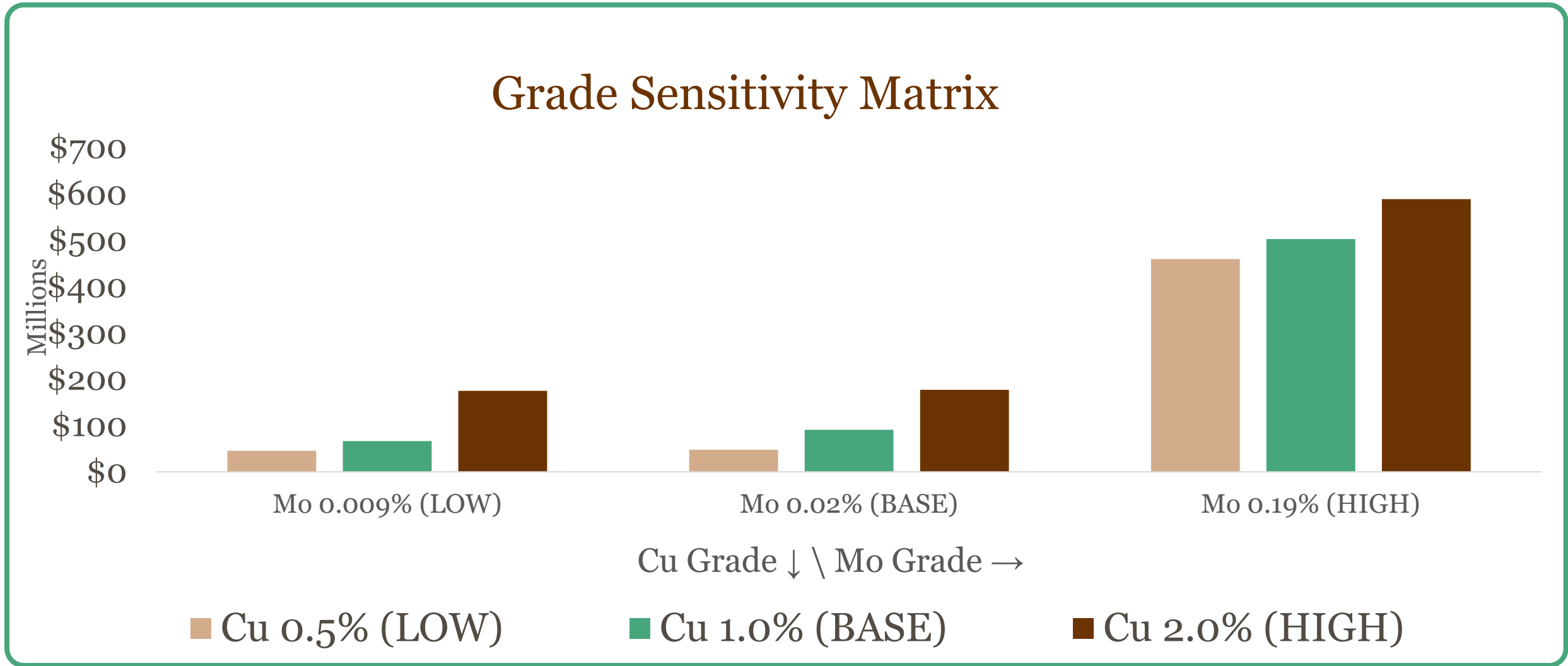


Figure 2: Grade Sensitivity matrix spread \$45M - \$588M

The sensitivity results in Figure 2 confirm that molybdenum and copper grade dominates the revenue, followed by copper price, while metallurgical recovery has a comparatively smaller influence

Limitations

Direct, representative sampling of pit bottom sediment and treatment sludge was not available; therefore, reasonable assumptions or literature-based benchmarks were made for sediment thickness, dry bulk density, copper and molybdenum grades, and metallurgical recovery rather than measured project values.

Future Research

- Evaluate harmonized standards + Gaps across all provinces
- Adaptive Policy Implementation to support technology innovation
- Techno-economic assessment to evaluate true ESG

Acknowledgement:



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FLMF: First and Last Mile Fund for Indigenous
GSTM: Global Industry Standard on Tailings Management
MEMLCI: Ministry of Energy, Mines and Low Carbon Innovation (BC)
MIRARCO: Mining Innovation, Rehabilitation and Applied Research Corporation
NOAMI: National Orphaned/Abandoned Mines Initiative