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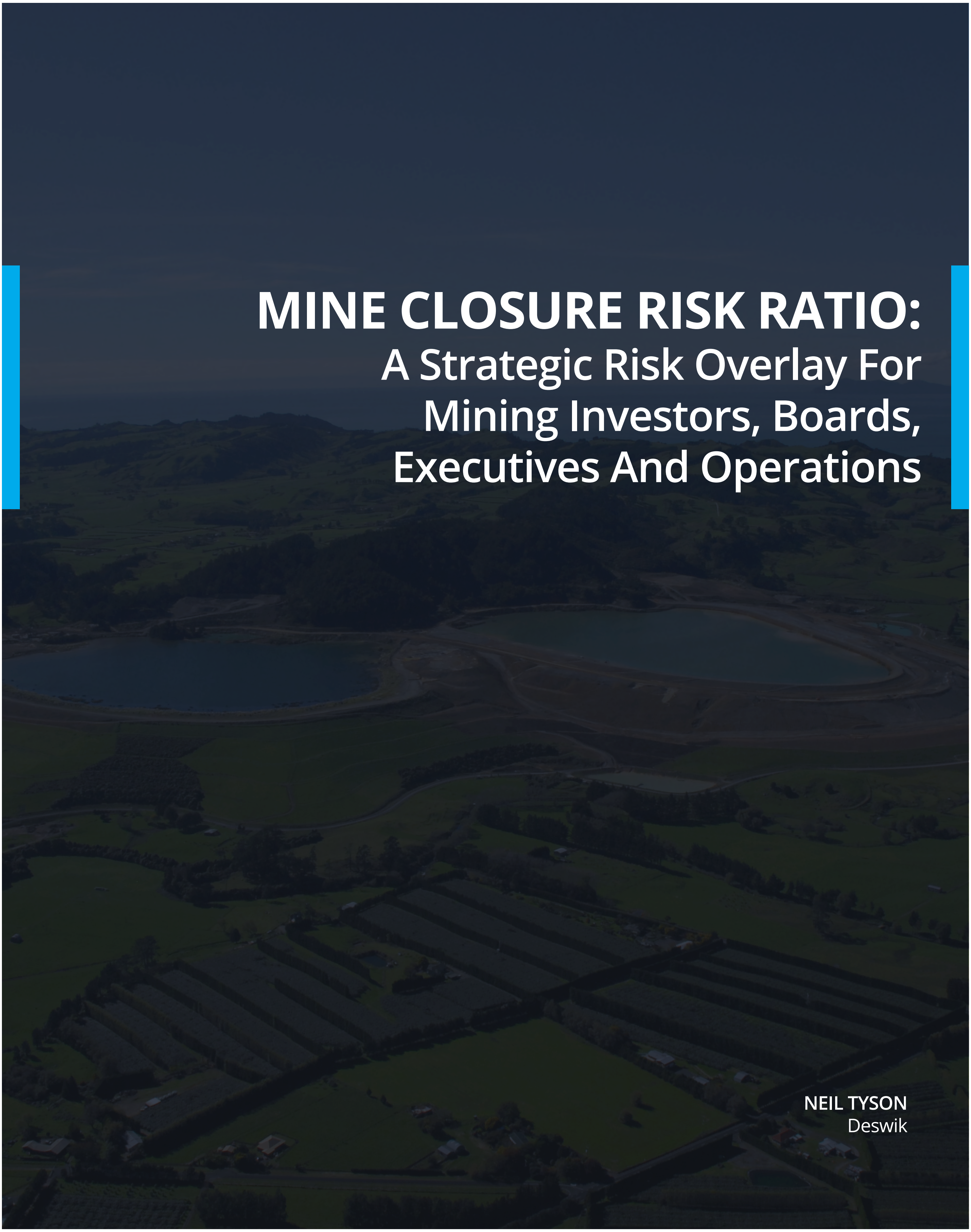

MINE CLOSURE RISK RATIO:
A Strategic Risk Overlay For Mining Investors, Boards, Executives And Operations

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CONTENTS

Introduction

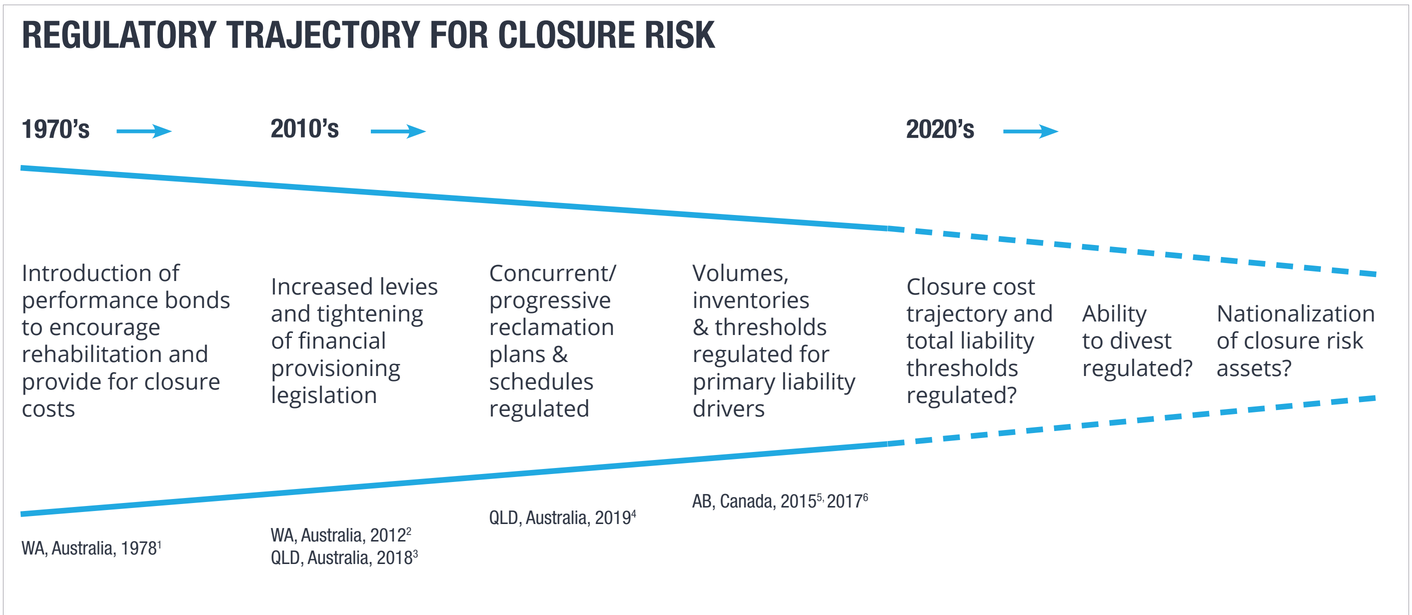
The Mine Closure Risk Ratio (MCRR) is proposed as a simple method of measuring Life of Mine risks related to mine closure. MCRR is a decision support metric used to integrate mine production and closure considerations when evaluating all business plan scenarios.

By applying a "Maturity Model" to key risk drivers, planners can use MCRR as a strategic risk overlay that can be used with other project decision metrics to produce risk-weighted trade-offs. MCRR clearly illustrates the strategic risk trajectory for selected business plans and highlights opportunities to minimize exposures. Investors, boards, executives and operations can use MCRR to:

- Make informed, risk-weighted asset strategy decisions (buy / hold / drill / develop / operate / divest / close).
- Provide assurance around strategic risk mitigation and ethical investment outcomes.
- Balance and trade off operating cashflow vs balance sheet liability.
- Devise a concurrent reclamation strategy that has greatest impact on closure liability.
- Monitor 'closure runway' i.e. time until expected cashflow from the deposit is exceeded by closure costs.
- Manage the risk of unplanned closure and / or unplanned erosion of asset value.
- Set risk trigger levels and key performance indicators to enforce consideration of closure impacts in operational decisions.

Background: Tightening Regulatory Trajectory

Progressive tightening is an emergent property of global mine closure regulation. This is a systematic response to poor closure outcomes (physical and financial) and a gap between expectations and performance of concurrent reclamation. Mining companies must assess and manage mine closure risk for both current and future regulatory environments by blending tactical responses with strategic positioning for greatest resilience.



[1] Government of Western Australia, Mining Act 1978.
[2] Government of Western Australia, Mining Rehabilitation Fund Act 2012.
[3] Queensland Government, Mineral and Energy Resources (Financial Provisioning) Act 2018
[4] Queensland Government, Environmental Protection Rehabilitation Reform Amendment Regulation 2019.
[5] Government of Alberta, Lower Athabasca Region Tailings Management Framework for Mineable Athabasca Oil Sands.
[6] Alberta Energy Regulator, Directive 085: Fluid Tailings Management for Oil Sands Mining Projects.

Figure 1 - Tightening Regulatory Trajectory for Closure Risk.

Scope

MCRR applies to resource assets with potential for economic exploitation and sale of mined products. It is not applicable for depleted or abandoned assets, or downstream / stand-alone processing facilities and infrastructure. It can be calculated for any mining asset either as a one-off (asset valuation / mergers & acquisitions) or as a regular output from business planning.

In best practice, MCRR is output from integrated Life of Asset mining production and closure planning systems – an example framework is provided in Appendix A. An integrated mining and closure planning system is more likely to generate MCRR inputs at higher Maturity Model levels thereby reducing risk, however strategy and considerations for implementing such systems is beyond the scope of this document.

Defining Mine Closure Risk Ratio (MCRR)

The MCRR approach is a strategic risk overlay for current and future mining assets to quantify the risk associated with closure cost and closure outcomes. It has two key components:

- A **ratio calculation** graphed for each year of the life of an asset.
- A **Mine Closure Maturity Model** providing a risk range overlay to the predicted Closure Costs and MCRR.

MCRR Calculation

MCRR is calculated as follows:

$$MCRR_{year\ n} = \frac{Net\ Recoverable\ Value\ (NRV) = \sum Net\ Asset\ Cashflow}{Closure\ Costs\ (CC)_{year\ n}}$$

Net Recoverable Value: Net asset cashflow in real terms, summed from the reporting year for the life of the asset. Cashflow calculation inclusive of Concurrent Rehabilitation[i] costs. Cashflow calculations may include anticipated return of financial surety provided to cover Closure Costs, depending on the jurisdiction.

Closure Costs: A 'blended' estimate of closure costs outstanding as at the reporting year. This uses the ICMM 'Life of Asset closure cost estimate' allowances for owner operator costs, however is also calculated in pre-closure years similar to the ICMM 'Sudden closure cost estimate'[ii]. This recognizes anticipated cost efficiencies realized through planned Concurrent Rehabilitation. This calculation includes an allowance for Residual Risk[iii] or jurisdictional equivalent.

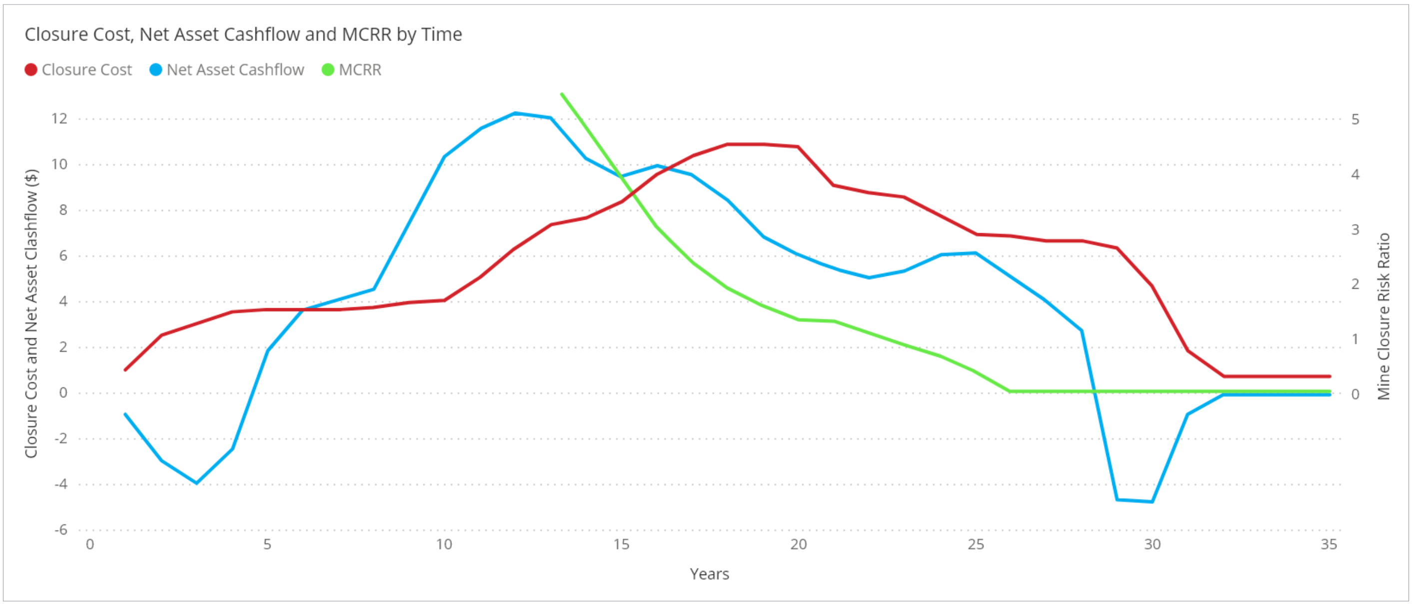


Figure 2 - Mine Closure Risk Ratio.

Figure 2 maps Net Asset Cashflow, Closure Costs and the resultant MCRR. In this simplified example, there are three zones of interest:

MCRR >> 1

When MCRR is much greater than 1, future cashflows of the operation greatly outweigh the estimated Closure Costs. At this stage of the mine life the MCRR illustrates the trajectory of liability generation relative to cashflows.

MCRR approaching or equal to 1

Taking a closer look at the end of mine life, Figure 3 illustrates a notional MCRR scaled to highlight impacts towards the end of asset life. As MCRR approaches 1, companies are nearing the tipping point where future expenditure on Closure Costs are matched by the remaining cashflows expected to be generated by the asset.

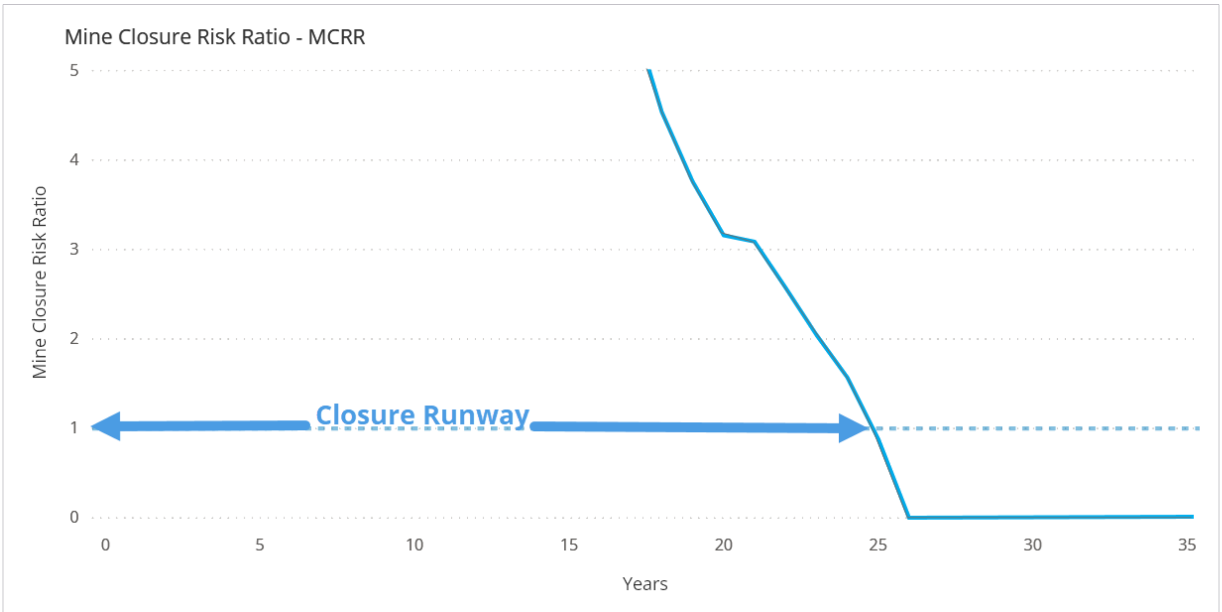


Figure 3 - Mine Closure Risk Ratio and Closure Runway.

The time remaining before the tipping point is referred to as the remaining 'closure runway'. There are limited options to proactively mitigate costs and improve outcomes once the tipping point is reached.

MCRR = 0

From this point onward, cashflow for funding closure activity needs to be from sources external to the Asset. This is a critical juncture due to the potential draw on cashflow from other areas of the business and the impact on asset valuation.

Mine Closure Maturity Model

A Mine Closure Maturity Model is used to generate a risk range for each Closure Cost type by assessing the **quality** of individual closure Assessment Items. The risk ranges should be based on industry examples and reconciliation of actual closure cost outcomes. Figure 4 illustrates the dependency of risk ranges based on the quality of input Assessment Items. It also illustrates that multiple aspects of a Closure Cost estimate may be impacted by the quality of a single input. Appendix B shows an abbreviated example of applying this methodology.

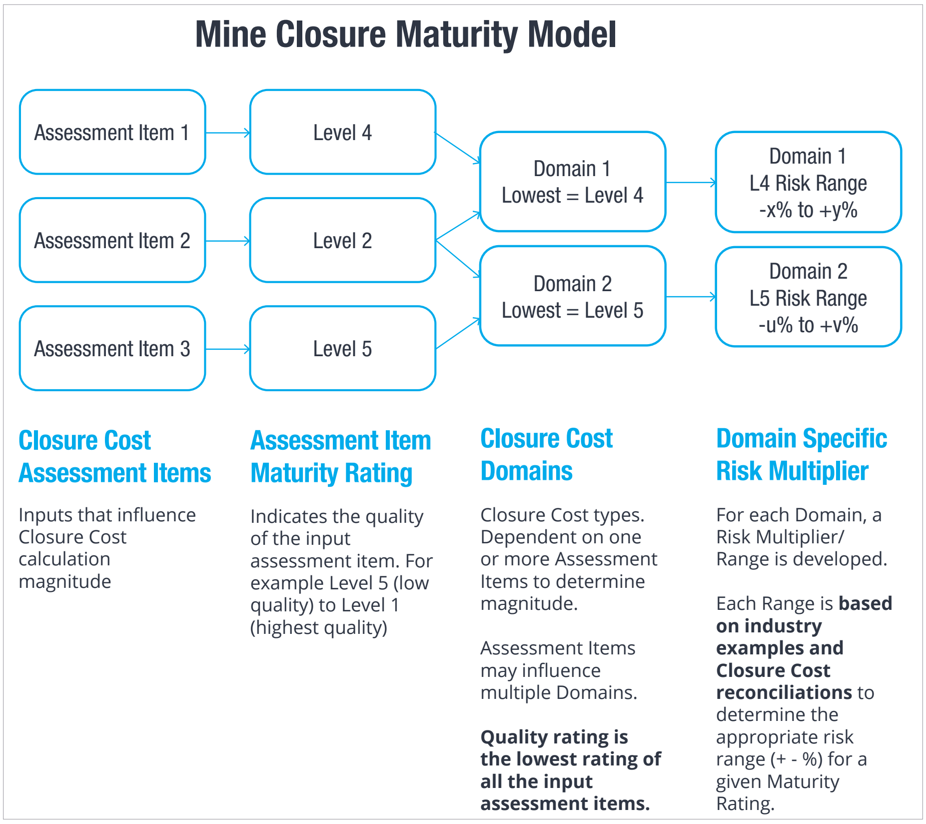


Figure 4 - Mine Closure Maturity Model Used to Determine Risk Ranges.

A risk-adjusted Closure Cost is calculated using the risk ranges for each Closure Cost Domain:

$$CC_{risk\ adjusted} = \sum^{n} (Domain\ Cost_n \text{ x } (1 + Risk\ Range\ \%_n))$$

Figure 5 illustrates the effect of using the Maturity Model with the MCRR to range Closure Cost risks, and the resultant impact on closure runway:

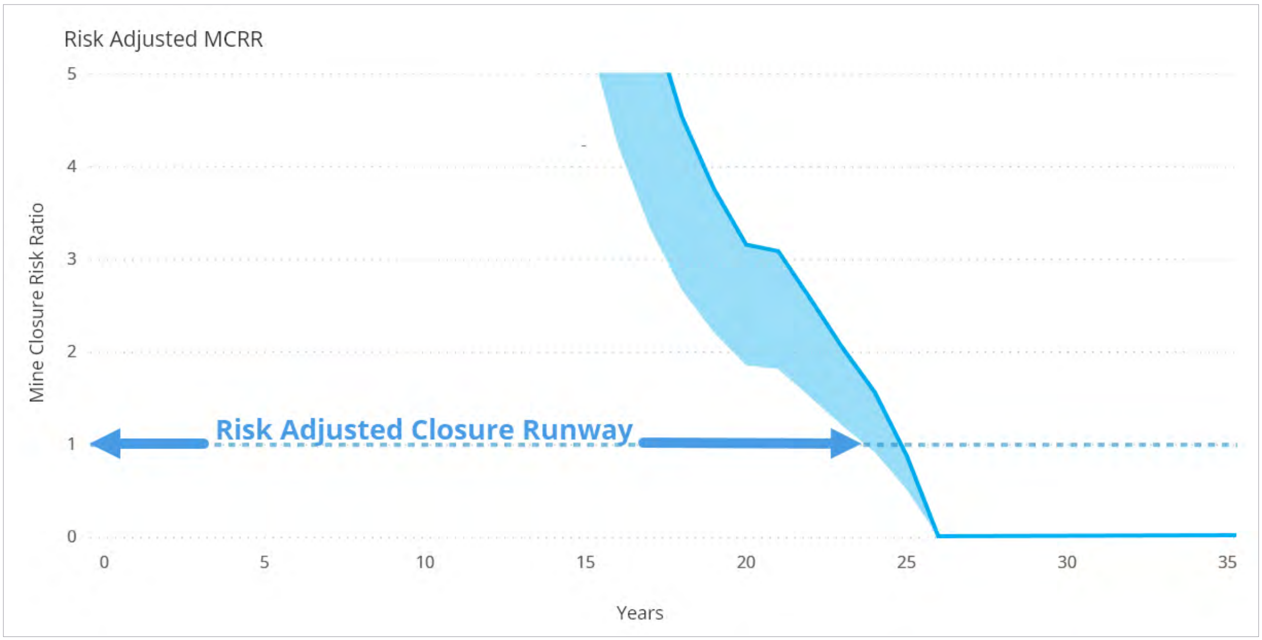


Figure 5 - Risk-adjusted Mine Closure Risk Ratio.

The risk range overlay is used to graphically illustrate the implication of having different "Maturity Levels" of Closure Costs, and resultant effect on the strategic risk trajectory. **This overlay complements other decision metrics such as NPV and allows companies to retain operational flexibility while remaining cognizant of value at risk across business plan scenarios**.

Maturity Model Contrast With Capital Estimation Frameworks

The Maturity Model component of MCRR exists to resolve a key issue arising from the common practice of applying a capital estimation framework[iv] to mine closure. Such frameworks specify a time before closure by which estimates should be completed to levels commensurate with industry standards for Class 1-5 estimates, using terminology such as Pre-feasibility, Feasibility and so on (Table 1).

TIME TO PLANNED CLOSURE	>20 YEARS	20-10 YEARS	10-5 YEARS	5-3 YEARS	3-1 YEARS	1-0 YEARS	DECOMMISSIONING, MONITORING & MAINTENANCE
Estimate Class	Class 5 estimate	Improved class 5 estimate	Class 4 estimate	Class 3 estimate	Class 2 estimate	Class 1 estimate	Class 1 estimate
Low range	-30% to -50%	-20% to -50%	-15% to -30%	-10% to -20%	-5% to -15%	-3% to -10%	-3% to -10%
High range	+50% to +100%	+30% to +100%	+20% to +50%	+10% to +30%	+5% to +20%	+3% to 15%	+3% to +15%

Table 1 - Common practice application of capital estimation framework class estimates to mine closure using 'time to closure'.

In some cases, closure studies that occur late in the mine life result in closure cost estimates being revised upwards[v], as shown in Figure 6.

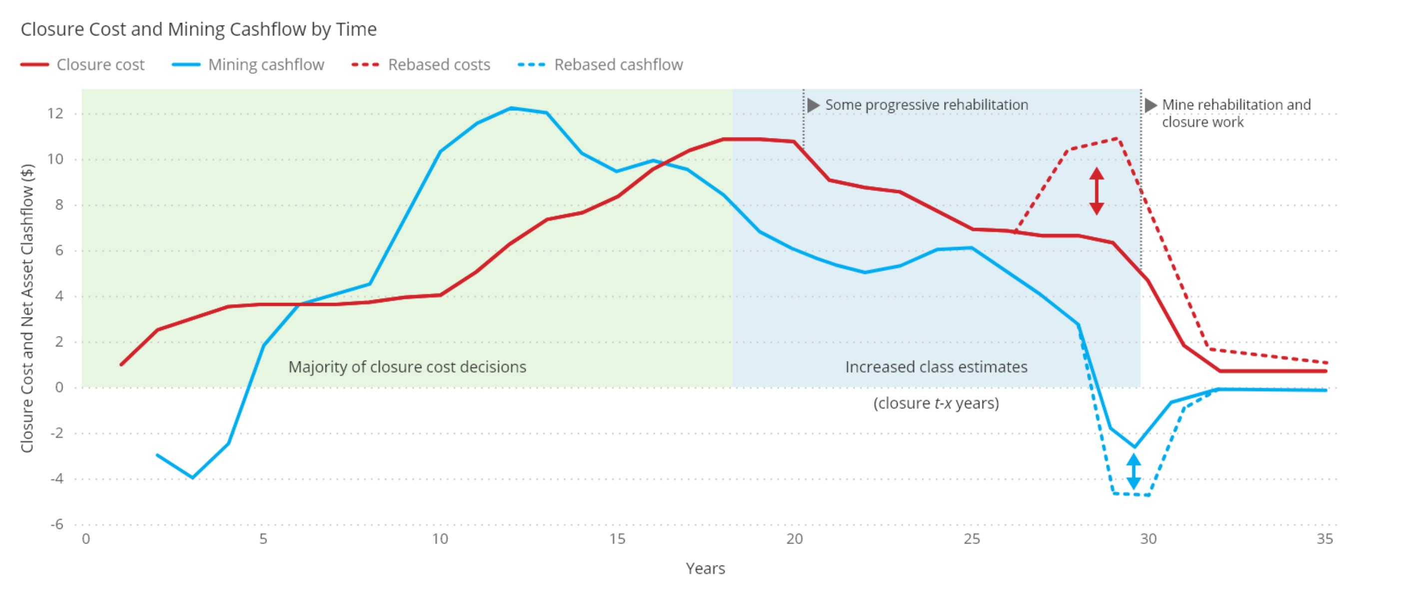


Figure 6 - Detailed Studies Towards End of Mine Life May Result in Cost Escalations.

This outcome is caused by the late timing of the improved closure cost estimate maturity, relative to the projected closure date. Large cost drivers such as the volume of bulk earthworks rehandle required at end of mine life, are influenced by decisions made much earlier in the mine life when inputs were understood to a low level of maturity.

Although cost driver Domains often change in magnitude of cost impact as knowledge increases, the overall impact can be strategically reduced for high risk areas by understanding and incorporating key concepts during operations, such as:

» Developing design strategies and factors for constructing a successful final landform.
  – It's often too early for a final landform design. Instead, incorporate design principles that are likely to generate good final landform outcomes when the time comes.
» Schedule using fit for purpose material characterization and maintain a temporal material balance.
  – Base case understanding is required for where, how much and when each material will be placed.
» Assess all impacts to the site water balance.
  – Consider water. If not, a problem may be incubating.

Timely understanding also enables transparent and ethical engagement with communities based on principles of free and informed prior consent.

There are three key differences in the Maturity Model approach when compared to traditional capital estimation frameworks:

» The driver maturity is estimated and assessed throughout mine life, rather than applying classification standards at a specific 'time to closure' cutoff.
» Risk multipliers are set using site, company and industry specific reconciled factors, specific to each cost domain, rather than attempting to fit closure cost estimate variabilities into standard bands developed for cost estimation in process industries.
» Interdependencies are mapped and incorporated to reflect that one key low maturity input can influence risk across multiple cost domains.

Insights gained from applying risk multipliers to key closure cost drivers and the resultant MCRR overlay are used to prioritize and improve the understanding and certainty of high-impact items earlier in the mine life, unlocking the ability to conduct trade-offs, work smarter, and minimize risk exposure.

MCRR In Use

MCCR as a Decision Support Metric

MCRR is used alongside other decision metrics (e.g. NPV) to evaluate the resilience of a given scenario for an asset. As the ratio decreases, the risk of the asset becoming a cashflow drain on the enterprise increases, especially in context of cyclical revenue or cost fluctuations.

Put simply, boards, executives and asset strategists need to understand as soon as possible if the deposit may not generate enough cash to cover its own closure costs plus residual risk considerations, net of financial surety. This is a dynamic position over time and hence requires forecasting with a risk overlay provided by the Maturity Model to estimate the ranges of ‘closure runway’ remaining.

Trigger Action Response Protocols (TARP’s) can be set if desired to ensure escalation to boards and executives of scenarios that may lead to high-risk outcomes.

Strategies for Improving MCRR Position

The key benefit of using MCRR as a risk overlay is it provides a clear metric to drive positive behaviours to minimize closure liabilities and risk, while retaining operational flexibility. Strategies for improving MCRR position include:

- Exploration success and upgrading of the resource to reserve quality.
- Improving saleable quality and therefore realized price for products.
- Finding ways to monetize previously unsaleable mined materials.
- Implementing precise mining techniques that minimize dilution (needless processing of waste materials).
- Relative reductions in capital intensity and mining costs for a given unit of revenue.
- Front-end loading sufficient engineering detail to design engineered waste landforms that can be concurrently constructed and rehabilitated to minimize closure effort and residual risk.
  - Systemizing compliance to plan for these structures.
- Achieving early understanding of design strategies that are most likely to result in an acceptable final landform so that liability can be minimized through ‘mining for closure’ strategies.
- Evaluating the original 'decision to mine' (reserve delineation) for all material types excavated by considering the closure cost impacts.
  - In some cases, high value outcomes can be achieved by reclassifying reserves and leaving some material types unmined[vi].
- Implement systematic collection and maintenance of key knowledge base items (e.g. ‘as-dumped’ material models of waste landforms).
  - These become valuable digital assets and can be used for detailed closure designs to provide assurance around planned outcomes.
- Identify beneficial post-closure uses that decrease closure and residual risk costs.
- Resourcing continuous improvement programs for supporting science and technology streams for both operational and planning activities.

Conclusions

MCRR delivers a fit for purpose metric that supports business decisions by mitigating risks characterized by tightening regulatory trajectories in response to poor closure outcomes and concurrent rehabilitation performance. Implementation is flexible, allowing companies to calibrate this measure for specific risk appetites and context. Maximum benefit accrues to companies that align this methodology with governance, reporting transparency, science and technology continuous improvement, organizational capability strategy and operational KPI’s to assure validity for asset strategy decision support.

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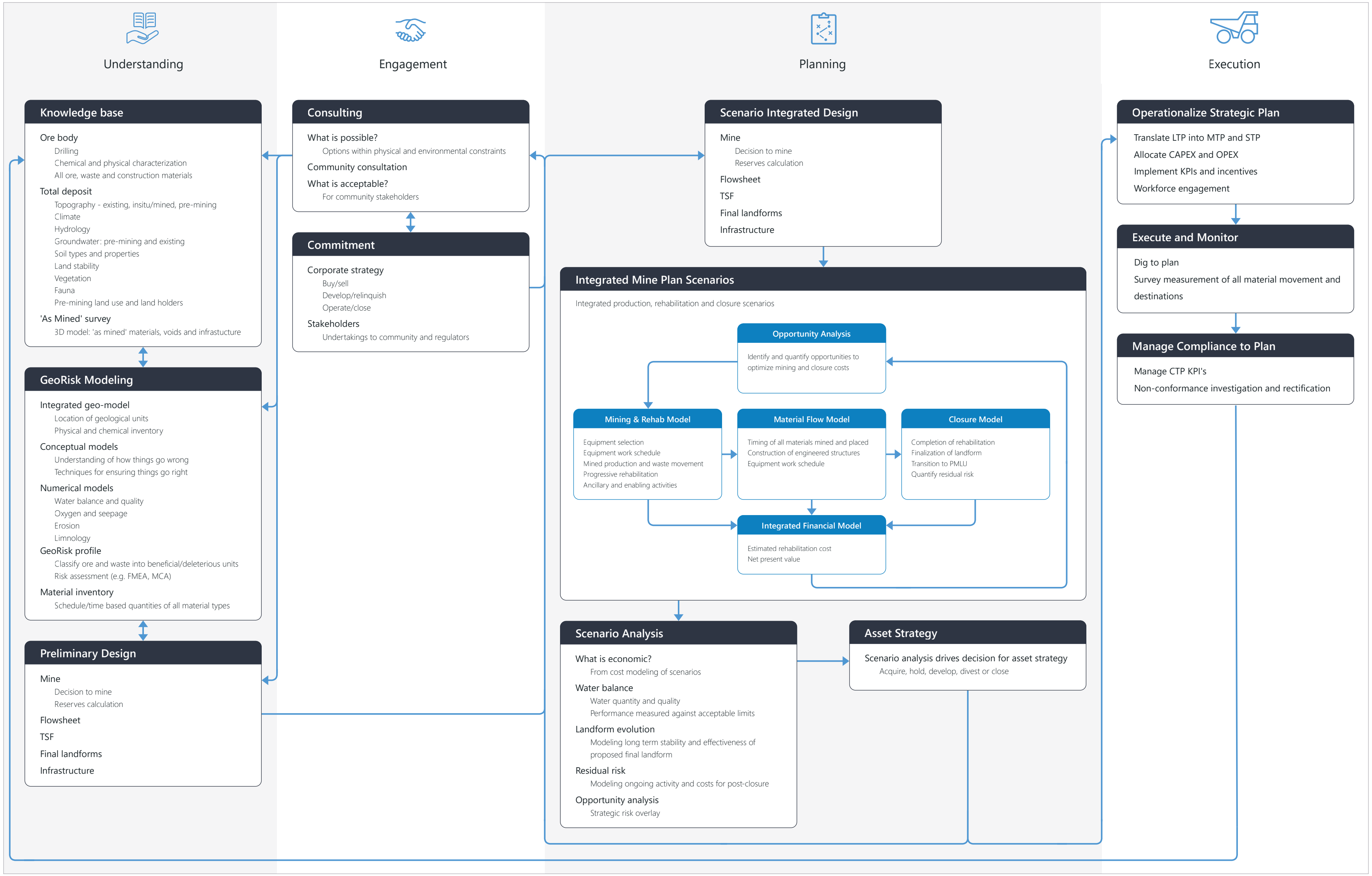
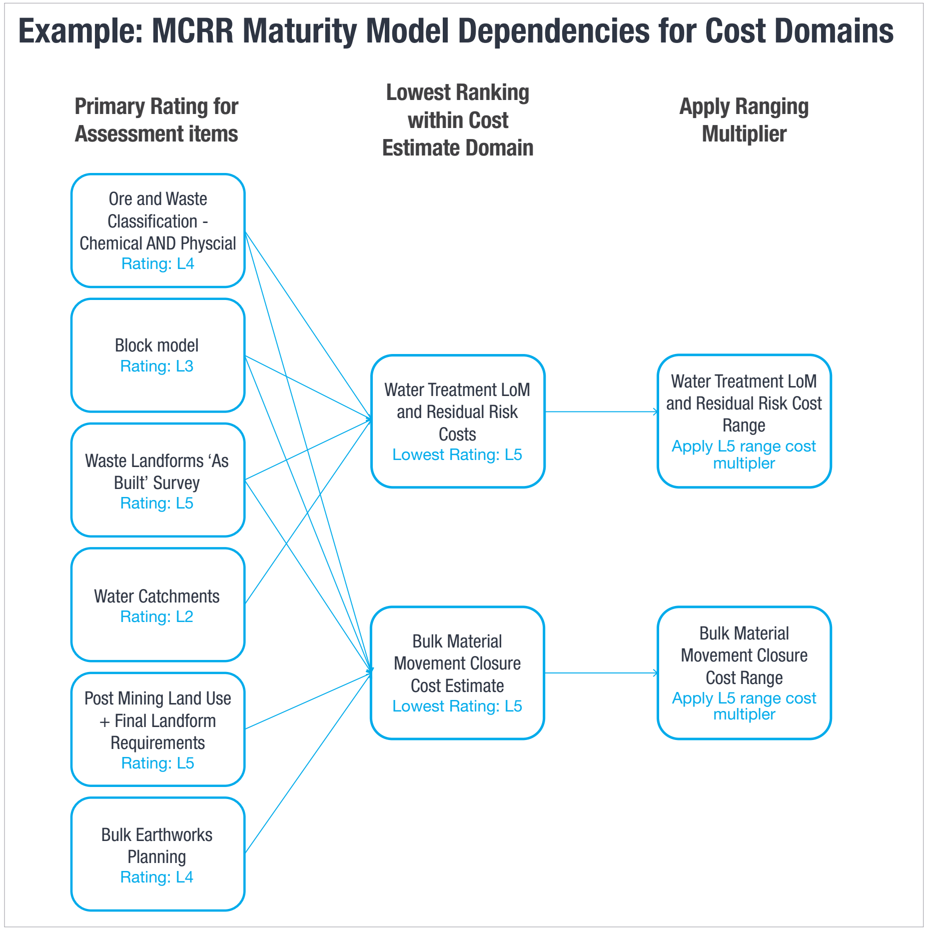
For further discussion of any issues raised including next steps for implementation, please contact the author or your local Deswik office.

Appendix A



Understanding
Engagement
Planning
Execution
Knowledge base
Ore body
Drilling
Chemical and physical characterization
All ore, waste and construction materials
Total deposit
Topography - existing, insitu/mined, pre-mining
Climate
Hydrology
Groundwater: pre-mining and existing
Soil types and properties
Land stability
Vegetation
Fauna
Pre-mining land use and land holders
'As Mined' survey
3D model: 'as mined' materials, voids and infrastucture
GeoRisk Modeling
Integrated geo-model
Location of geological units
Physical and chemical inventory
Conceptual models
Understanding of how things go wrong
Techniques for ensuring things go right
Numerical models
Water balance and quality
Oxygen and seepage
Erosion
Limnology
GeoRisk profile
Classify ore and waste into beneficial/deleterious units
Risk assessment (e.g. FMEA, MCA)
Material inventory
Schedule/time based quantities of all material types
Preliminary Design
Mine
Decision to mine
Reserves calculation
Flowsheet
TSF
Final landforms
Infrastructure
Consulting
What is possible?
Options within physical and environmental constraints
Community consultation
What is acceptable?
For community stakeholders
Commitment
Corporate strategy
Buy/sell
Develop/relinquish
Operate/close
Stakeholders
Undertakings to community and regulators
Scenario Integrated Design
Mine
Decision to mine
Reserves calculation
Flowsheet
TSF
Final landforms
Infrastructure
Integrated Mine Plan Scenarios
Integrated production, rehabilitation and closure scenarios
Opportunity Analysis
Identify and quantify opportunities to optimize mining and closure costs
Mining & Rehab Model
Equipment selection
Equipment work schedule
Mined production and waste movement
Progressive rehabilitation
Ancillary and enabling activities
Material Flow Model
Timing of all materials mined and placed
Construction of engineered structures
Equipment work schedule
Closure Model
Completion of rehabilitation
Finalization of landform
Transition to PMLU
Quantify residual risk
Integrated Financial Model
Estimated rehabilitation cost
Net present value
Scenario Analysis
What is economic?
From cost modeling of scenarios
Water balance
Water quantity and quality
Performance measured against acceptable limits
Landform evolution
Modeling long term stability and effectiveness of proposed final landform
Residual risk
Modeling ongoing activity and costs for post-closure
Opportunity analysis
Strategic risk overlay
Asset Strategy
Scenario analysis drives decision for asset strategy
Acquire, hold, develop, divest or close
Operationalize Strategic Plan
Translate LTP into MTP and STP
Allocate CAPEX and OPEX
Implement KPIs and incentives
Workforce engagement
Execute and Monitor
Dig to plan
Survey measurement of all material movement and destinations
Manage Compliance to Plan
Manage CTP KPI's
Non-conformance investigation and rectification

Appendix B


Example: MCRR Maturity Model Dependencies for Cost Domains
Primary Rating for Assessment items
Lowest Ranking within Cost Estimate Domain
Apply Ranging Multiplier
Ore and Waste Classification - Chemical AND Physcial
Rating: L4
Block model
Rating: L3
Waste Landforms 'As Built' Survey
Rating: L5
Water Catchments
Rating: L2
Post Mining Land Use + Final Landform Requirements
Rating: L5
Bulk Earthworks Planning
Rating: L4
Water Treatment LoM and Residual Risk Costs
Lowest Rating: L5
Bulk Material Movement Closure Cost Estimate
Lowest Rating: L5
Water Treatment LoM and Residual Risk Cost Range
Apply L5 range cost multiplier
Bulk Material Movement Closure Cost Range
Apply L5 range cost multiplier

EXAMPLE MINE CLOSURE MATURITY MODEL STREAM	ASSESSMENT ITEM	LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 2	LEVEL 1	EXAMPLE: LOA 2020 ASSESSMENT ITEM RATING
Orebody knowledge	Ore and waste classification chemical and physical	Ore characterization only	Waste characterized in a few samples - not representative	All ore, waste and construction materials characterized on representative sampling density to NAF / PAF level or similar	All ore, waste and construction materials characterized on representative sampling density inclusive of NAG potential	All ore, waste and construction materials characterized on representative sampling density inclusive of NAG potential. Material allocation control (ore and waste streams) supersede ore-only grade control processes. Waste is reconciled against modeling for each material type	Level 4
	Block model	No waste characterization model	Low confidence waste characterization model	Basic NAF / PAF characterization model to appropriate confidence level	Full characterization block model to appropriate confidence level	Reconciled full characterization resource model plus short-term material allocation control model updated routinely	Level 3
Total deposit knowledge	Waste landforms 'As Built' survey	No / few records of internal material type distribution. E.g. verbal/ typed reports with no volumetrics / survey	Global level records and understanding of types of materials in landform e.g. yearly surveys cross referenced with production actuals and estimates of NAF / PAF within waste for that period	Global level records plus some verification through external sensing e.g. drilling / sampling of points in waste landform	Weekly / daily records of loads of each type of material e.g. load sheets, FMS records. Can be cross referenced with monthly surveys of waste landform	Continuous update of digital model of material distribution within waste landform, at packet size commensurate with the minimum significant volume of harmful material types, verification and compliance to plan governance in place and actively managed	Level 5
	Water catchments	No catchments mapped and accessible to mine planners during planning activities	Current topo catchments understood for active surface. No survey of land surface prior to mining or construction including for areas of waste disposal e.g. waste rock dumps in pits, tailings footprint excavated surface, and no understanding of 'sub-surface' catchments along surface of deepest excavation	Catchments understood both on active topo surface as well as beneath constructed landforms and tailings dams. These are available to all mine planners in digital format	Catchments understood both on active topo surface as well as beneath constructed landforms and tailings dams. These are available to all mine planners in digital format	Change in catchments over mine life (both surface and sub-surface) are calculated for any mine plan scenario at any desirable timestep	Level 2
Consultation	Post mining land use + Final landform requirements	Assumed only. No PMLU / FL discussed or agreed	Single option discussion of PMLU / FL	Multiple option discussion of PMLU / FL	PMLU / FL agreed with high-confidence evidence the approved mine plan will be able to deliver	PMLU / FL agreed and execution plan in place and funded	Level 5
Concurrent reclamation / Mine closure cost estimates	Bulk earthworks planning	2D / $ / hectare simple calculations only	Global volumes calculated from 3D analysis. Unit rate costs applied	3D volumes and material types / allocations understood - more granular costing by material type e.g. trucks vs bulldozer	3D volumes by material type with available destinations allocated and variable placement costs by destination calculated (e.g. using required haul distances to derive variable trucking costs)	3D volumes by material type and destination scheduled and resource levelled (concurrent and/or during closure) with known fleet e.g. loading unit and truck combinations supporting productivities, variable and fixed costs buildups	Level 4

Glossary

LoM – Life of Mine. The time in which, through the employment of the available capital, the ore reserves--or such reasonable extension of the ore reserves as conservative geological analysis may justify--will be extracted.

Mine Closure – This is the period when the active extraction of resources from a mine has ceased, and final decommissioning and mine reclamation are being completed.

MM – Maturity Model. Maturity is a measurement of the ability of an organization for continuous improvement in a particular discipline. The higher the maturity, the higher will be the chances that incidents or errors will lead to improvements either in the quality or in the use of the resources of the discipline as implemented by the organization.

Endnotes

i. As defined in the Glossary of Anglo American, "Mine Closure Toolbox Version 3," (2019): pp 59. https://www.angloamerican.com/~/media/Files/A/Anglo-American-Group/PLC/sustainability/mine-closure-toolbox-version-3-2019.pdf.

ii. International Council on Mining and Metals, "Financial Concepts for Mine Closure," (2019): pp 23-24. https://www.icmm.com/website/publications/pdfs/closure/190205_icmm_financial-concepts-for-mine-closure.pdf.

iii. As defined in Appendix C of Queensland Government, "Franework for Queensland's Residual Risk in the Resource Sector," (2018): pp 44. https://s3.treasury.qld.gov.au/files/Framework-for-Queenslands-Environmental-Residual-Risks-in-the-Resources....pdf.

iv. AACE International, "Cost Estimate Classification System - As Applied in Engineering, Procurement, and Construction for the Process Industries," (2005). https://www.costengineering.eu/Downloads/articles/AACE_CLASSIFICATION_SYSTEM.pdf.

v. Australian Broadcasting Corporation, "Ranger Uranium Mine rehabilitation costs blow out by $296m amid fears over long-term monitoring," (2018). https://www.abc.net.au/news/2018-12-11/ranger-uranium-mine-rehabilitation-cost-blowout-jabiru/10601696.

vi. I.; Plant Neilsen, J., "Case Study in Evaluating Value of Active vs Reactive Rehabilitation Planning" (Planning for Closure 2018: 2nd International Congress on Planning for Closure of Mining Operations, Gecamin, 2018).

vii. Cover image credits to Kit Wilson / OceanaGold.