Managing Mineral Resource Risk

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What are Mineral Resources?

CIM Definition Standards (2014):

- A **Mineral Resource** is a concentration or occurrence of solid material of economic interest in or on the Earth’s crust in such form, grade or quality and quantity that there are *reasonable prospects for eventual economic extraction*.

- The location, quantity, grade or quality, continuity and other geological characteristics of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge, *including sampling*.

- Sub-divided into: MEASURED, INDICATED, and INFERRED based on the level of confidence.
Mineral Resource Confidence

**Inferred**
An Inferred Mineral Resource is that part of a Mineral Resource for which quantity and grade or quality are estimated on the basis of limited geological evidence and sampling. Geological evidence is sufficient to imply but not verify geological and grade or quality continuity.

**Indicated**
An Indicated Mineral Resource is that part of a Mineral Resource for which quantity, grade or quality, densities, shape and physical characteristics are estimated with sufficient confidence to allow the application of Modifying Factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit.

**Measured**
A Measured Mineral Resource is that part of a Mineral Resource for which quantity, grade or quality, densities, shape, and physical characteristics are estimated with confidence sufficient to allow the application of Modifying Factors to support detailed mine planning and final evaluation of the economic viability of the deposit.
What is Mineral Resource Risk?

- Resource risk is that associated with geological characterization, data quality, and resource estimation including:
  - Risk of quality and quantity at various cut-off grades;
  - Risk on other inputs of geological characterization including: geotechnical, hydrogeological, geometallurgical, and deleterious materials.
- Resource risk is not just all downside. Risks are often asymmetric with potential for both positive and negative outcomes.
- Does the uncertainty range overlap with key decision points?
Example: Risk associated with CoG

- **CoG1**: Mineral Resource risk assoc. with grade is low to inconsequential.
- **CoG2**: Resource risk high to project success.
- Opposite in deleterious element assessment of thresholds.

Source: J. Vann (2007)
Risk & Opportunity is Relative

- Complexity typically increases uncertainty but it’s a spectrum based on deposit specifics.
  - Placer compared to Coal seams or bulks.
  - Au: Narrow vein versus Carlin-type Au
  - Cu: Porphyry versus sed-hosted.
  - Fe: Lake Superior versus Magnetite skarn.
Why Manage Mineral Resource Risk?

- Mining is a risky game. Despite inherent risk, Mineral Resources are the foundation of Reserves, Mine Plan, & Business plan;
- 40% of projects have problems with grade estimates and 24% with tonnage estimates (CMMI, 1998);
- Shareholders and external stakeholders require assurances on reported technical information supporting Mineral Resources (and Reserves);
- Producing companies commonly focus on short-term value – long-term value treated as expense;
- Resource uncertainty and errors remain a major source of economic failure in the mining industry!
Flow Through Risk to Reserves

- Only two inputs to Reserves: Resources & modifying factors

Mineral Resources

Geological inputs:
- Land status
- Sampling & testing
- Interpretations
- Modeling and domains
- Estimation
- Classification
- Economic viability
- Other (recovery, etc)

Modifying Factors

Study components:
- Mine Planning
- Geotechnical
- Hydrogeological
- Metallurgical / Process
- Environmental
- Social / Community
- Market
- Economic

Reserves $$$$
How well does your company understand and manage Mineral Resource risks?
“We Manage Just Fine”

What is your company’s Mineral Resource Risk Management Plan?

• Many mid-tier to smaller companies are light on technical expertise, resources (hours), and internal QA/QC;

• Internal company standards for reviews/audits rarely question dogma or established methods;

• Industry guidance (CIM) is good but relies on the expertise of the QP. Not all of whom see eye to eye;

• Across the industry, a general ignorance of technical details and risk by management teams (local and corporate);
Ex: Consequences

• Project value can be destroyed by shifts in Mineral Resources.
• Differences in Resources reported year over year erode shareholder confidence when they are negative.
• Variations in expected Resources and the rationale behind them are now often worked out in the court of public opinion or blogs, by hyperbolic “angry” people who cannot demonstrate qualification to reasonably assess them.
• Consultants are easy to toss under the bus as taking the paycheck without feeling the pain when things go wrong.
Documentation

Geology/Domains
Understanding of geological complexity, structure, rock types, alteration, mineralization, domains, spatial relationships, etc.

Tonnage
Density domains, variations in density across deposit, waste characterization, voids, friability, material properties.

Estimation
Exploratory data analysis, domains, spatial continuity, neighborhood analysis, estimation methodology, outliers, composite size, block size, anisotropy, etc.

Classification
Confidence in data and interpretations, interpolations distances, quality of estimates, production history, ore body variability, continuity of above cut-off grade, etc.

Data
(chemical, observational, physical, etc.)
Fundamental Data Risks

• “Garbage in = Garbage out”
• There is data error in all input information:
  – Geochemical, geological, physical, etc.
• Sample collection and preparation errors are typically much greater than analytical errors;
• Sample spacing in relation to the ore body geometry and intrinsic variability is an important concept;
• Data location, collection, and management often falls on the least experienced personnel or a contractor;
• Biases and interpretations in sampling increase the errors even more!
Fundamental Data Risk Management

- Process management and training programs;
- Correct location of samples (accurate collar and DH survey);
- Audits and reviews of sampling practices;
- Don’t let samplers make decisions on what is or what is not sampled;
- Robust QA/QC with feedback and improvements;
- Increasing multidiscipline data will reduce sampling risks such as:
  - Geophysical (surficial and downhole);
  - Geological, chemical, and geometallurgical to understand correlations;
- Statistical analyses to assess risks of data;
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Interpretation Risk

• Geological and Domain interpretation of volumes can be largest risk to Mineral Resources;
• How well-understood is mineralization?
• Complex ore bodies?
• Grade shell use to constrain estimation of high-grade?
  o “blobs” created by inexperienced users?
  o Overly optimistic volumes by exploration personnel?
  o Overly pessimistic volumes by mining personnel?
Interpretation Risk Management

- Alternative versions created?
- Quantified risk assessment through probability?
- Semi-Quantitative through implicit modeling?
- Peer Reviewed
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Tonnage Risks

Total metal (value) = Volume \times Density \times Grade

• Density often the forgotten critical factor;
• Errors rarely considered or quantified;
• Complex lithology, alteration, and mineralization;
• Appropriate testing methodology:
  o Friable material, competent rock, clays, voids…
• Sample size and scale: bulk samples, core, chips, etc.
• Minor differences in density across large volumes can drastically change Mineral Resources!
Tonnage Risk Management

• Geometallurgical / Physical characterization of deposit;
• Multiple methods of testing;
• Use of operational data;
• Ensure data population is appropriate for variability;
• Don’t “set it and forget it”
• Be wary of calculated densities based on theoretical assumptions (i.e. use of Fe or sulphide % to determine SG)
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Estimation Risk

- Either overly simplified or unnecessarily complex;
- Inexperienced staff;
- Incorrect anisotropy due to software confusion;
- Estimation busts, distribution unsupported by drilling/sampling;
- Inappropriate capping – lost or creating metal;
- Over smoothing – mean grade.

Nowak & Leuangthong, 2017
Estimation Risk Management

- Experienced personnel overseeing estimate;
- Does estimation parameter and geology align?
- Accuracy and precision of Resource estimates are limited by sampling and data uncertainty;
- Model validations;
- Alternative estimation methods trialed;
- Reconciliation!
- Quantitative risk assessment through probability?
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Classification Risk

- Two QPs = Two different classifications
- Often over-simplified and an after-thought;
- Spotted dog! What does this actually mean?
- Does classification truly correlate to Mineral Resource risk?
- How is short-term risk communicated?
- Ulterior motives to Classification?
Classification Risk Management

• Holistic and long-term view;
• Reconciliation by category;
• Probability of quarterly grade & tonnes?
  o i.e. 90% probability of quarterly GT within 10% prediction
• Use of estimation quality, subjective rankings, and priority data;
• QP decision, not management!

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Documentation

• “If it’s not documented, it didn’t happen”
• Updated, clear, and thorough to provide proof and process descriptions;
• Allows improved auditing and identify issues;
• Must be regularly updated and reflect what “really happens”;
• Not just a cook book! Context is key.
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Corporate Risk Management

- Who’s responsibility and accountable?
  - CEO or site geologist?
- Management of risk central to the business…is it a focus of ExCO / BoD?
- Risk tolerances in business terms are very different than geological/mining terms.
- Alignment of risk to business plan?
- What is your corporate assurance program for Mineral Resources?
System Process Risk Management

- Established system that documents process of calculation of Mineral Resources is key:
  - Paper trail on what was done, why, and by who;
  - Responsible individuals or roles clearly identified;
  - Auditable and repeatable;
  - Doesn’t rely on single person or external expertise;
- Can be easily reviewed by peers or external reviewer for comment and validity.
Audits and Reviews (Check the System)

• The unknown unknowns.
• Internal audits can be tricky!
  – Authority and knowledge required
  – Challenge company dogma
• External and independent
  – Sufficient time, experience, and knowledge
  – Paranoid and accusatory culture
  – Fresh eyes and Good Practices
• Who’s accountable for results and findings?
Conclusions

• Mining and Mineral Resources can be a risky business!
• Understanding Mineral Resource risk is critical for project success;
• Risk should be assessed across multiple areas;
  – Data, Geology, Tonnage, Classification, etc.
• Relatively small expenditures will unlock significant value or reveal potential for large value destruction;
• A process of internal assurances and external audits can provide value to ID risks before they become lost $$$;
• Must have champion at ExCo / BOD level for success.
Key Take Aways

• Mineral Resources is fraught with errors and risks that need to be understood, assessed, and addressed;
• The deposit is the only part of mining operations that cannot have an engineering solution!
• Risk reduction is cheap compared to the alternative;
• Managing Mineral Resource risks requires management systems, support, and resources (people + time + money) for success;
• Regular internal and external audits will test the system, provide value, and identify risks (then do something about it!);
• Understanding of the holistic system by geologists and engineers will improve risk management.
American Exploration & Mining Association (AEMA) Conference 2020

30-Nov through 4-December 2020
Sparks, Nevada

SRK is presenting a one-day short course on Mineral Resource Risk.

Registration through miningamerica.org