# Communicating confidence in Mineral Resources and Mineral Reserves

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## Synopsis

Mining is an inherently risky business; from the technical, environmental, social, and economic uncertainties associated with advancing an exploration prospect to a viable project to the operating, market, and safety risks and uncertainties attached to a developed mine. Since we cannot totally escape the risk and uncertainty related to resource projects, as an industry we should improve our presentation of the upside and downside risks in the context of the project's development path and maturity. More transparent, consistent, and balanced views of technical confidence will better inform both internal and external stakeholders about the expected risk in the project.

International reporting codes set out the minimum standards, recommendations, and guidelines for public reporting of Exploration Results, Mineral Resources, and Mineral Reserves. However, the reporting code principles of transparency and materiality are largely subject to the interpretation of the competent person(s), which may introduce a degree of subjectivity in reporting, particularly the level of disclosure regarding supporting information. It is fundamental that Mineral Resources, Mineral Reserves, and study outcomes are reported so as to unambiguously present the level of inherent technical uncertainty (or confidence) in a project, while conveying a balanced view of the opportunities a project presents. Reporting needs to consider various stakeholders who may rely on this information, and present the data in the context of the changing risk profile associated with project development paths and project maturity.

This paper discusses the interdependence of resource-to-reserve conversion, the consideration of various technical-economic study types, and the level of confidence conveyed to stakeholders relying on these technical reports and other company public announcements.

**Keywords**
mineral resources, mineral reserves, ore reserves confidence, accuracy, reporting, classification, JORC Code, SAMREC Code, risk, uncertainty, reporting codes, scoping study, pre-feasibility, feasibility study.

## Introduction

Despite the definitions and guidance on the reporting of Mineral Resource and Mineral Reserve categories provided by the current and previous versions of the SAMREC Code and the JORC Code, the categories and technical-economic study outcomes are not necessarily reported with a consistent or common expectation of confidence in the estimates. Inconsistencies in clearly relaying the expected accuracy, precision and confidence in the estimates as they advance from Mineral Resources to Mineral Reserves and the reporting of associated project economics may result in misleading or incorrect interpretations of the project risk by those relying on this information.

The Competent Person (CP) should strive to improve the presentation of the technical risk and uncertainty associated with resource projects to provide a more consistent, and balanced, view of confidence, risk, and opportunities for both internal and external stakeholders relying on this information. Greater consistency is required across the resources industry to better convey the accuracy, precision, and confidence when assigning and reporting Mineral Resource and Mineral Reserve categories and the outcomes of technical studies in the context of the project's development path and maturity.

Reporting codes such as the SAMREC Code and the JORC Code ('the Codes') set out minimum standards, recommendations, and guidelines for Public Reporting of Exploration Results, Mineral Resources and Mineral Reserves (SAMREC, 2009; JORC, 2004; JORC, 2012). The Codes have been adopted by and included in the listing rules of the relevant securities exchanges (ASX, NZX, and JSE), and impose specific requirements on exploration and mining companies reporting to these exchanges. Furthermore, the Codes have been adopted by the relevant professional bodies, associations, and councils and are binding on members of those organizations.

While there is an expectation that all stakeholders involved in interpreting or relying on information reported under the Codes are familiar with their contents, this is not always the case. Despite the Codes being relatively brief documents, stakeholders relying on the

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reported results tend to skim the contents of the Codes and focus on parts deemed most applicable in the circumstance. This paper quotes extensively from the 2012 edition of the JORC Code (JORC, 2012) and the 2007 edition of the SAMREC Code as amended in July 2009 (SAMREC, 2009) to draw attention to parts of the Codes providing support and guidance for classifying and reporting Mineral Resources and Mineral Reserves, and particularly their accuracy, precision, and confidence.

Consider, for example, the requirement that a Mineral Resource must have 'reasonable and realistic prospects for eventual economic extraction' (SAMREC, 2009). While some resource practitioners debate what this actually means, the JORC and SAMREC Codes state this '*implies an assessment (albeit preliminary) by the Competent Person in respect of all matters likely to influence the prospect of economic extraction including the approximate mining parameters*.'

Some argue that the consideration of 'approximate mining parameters' is too restricting or conservative for defining a Mineral Resource and is akin to the consideration and application of modifying factors required for defining a Mineral Reserve. Others have compromised the intent of the Codes and selectively applied this economic assessment when defining Indicated and Measured Resources but not when defining Inferred Resources. There are then cases where the interpretation of 'eventual economic extraction' has been stretched to speculate on mining methods, metallurgical extraction, or land access that may in the future be possible, but are as yet not demonstrated, available, or viable. These extremes, or even more subtle variations, in interpreting the Mineral Resource definition and confidence criteria can result in materially different reported Mineral Resource categories, and even different quantities (tonnages and grades of total Mineral Resources) for the same deposit by different CPs. While the Codes do not prescribe how CPs should carry out their assessments, the Codes provide definitions and guidance to facilitate consistency and transparency, particularly through their checklists of the factors to be considered and reported, in order to avoid, or at least explain, such obvious differences in interpretation.

Consider another general example, namely the definition in the Codes that Mineral Reserves are derived from the Indicated and Measured portions of a Mineral Resource through the consideration and application of modifying factors assessed at the level of at least a pre-feasibility study, including a mine plan and production schedule. This does not necessarily mean that all the Measured Resources will automatically convert to Proved Reserves (or the Indicated Resources to Probable Reserves). The study must demonstrate a technically achievable and economically viable mine plan and schedule for the reported Mineral Reserves, and furthermore, the level of confidence in the relevant modifying factors must be sufficient to support the category of Mineral Reserve. It is therefore possible that only a portion of the Mineral Resource will convert to a Mineral Reserve, thus reflecting the uncertainty in the process. It is also possible that a lower level of confidence in even one key modifying factor may mean the relevant portion of the Measured Resource may be better classified as a Probable Reserve rather than a Proved Reserve, and indeed, the Indicated Resource may not convert to a Mineral Reserve at all. This downgrade in reported confidence recognizes and reflects the material impact of that one factor on the technical or economic viability of the project at the time of reporting, and has been allowed for in the 2012 JORC Code and the 2009 SAMREC Code, as illustrated in Figure 1.

Without transparent reporting and support for the key Mineral Resource and Mineral Reserve assumptions, those relying on the publicly reported Mineral Resource and Mineral Reserve category and study outcomes at face value may not be fully aware of the risks or opportunities inherent in this data, and thus may not be in a position to make an informed decision on the reported values.

The JORC and SAMREC Codes provide extensive guidance on the relative hierarchy of accuracy, precision, or confidence in reporting Mineral Resource and Mineral Reserve categories and technical studies. While the Codes do not insist that the relative accuracy, precision, and confidence level of estimates are described, they strongly encourage CPs to discuss this and, where possible, provide a statement of the relative accuracy and confidence level, or at least a qualitative discussion of the relevant uncertainties. Indeed, the Codes highlight the importance of the CP's assessment of confidence in reporting through the use of various terms, including 'accuracy', 'uncertainty', 'reliability', 'confidence', 'confidence level', 'quality of data', 'quality of information', and 'quality of reported results'.

The Codes rely on the CPs to provide their own interpretation of what is meant by confidence and accuracy levels in the context of their project. In the author's opinion, this requires better disclosure of the expected accuracy, precision, and confidence in reported Inferred, Indicated and Measured Resources, Probable and Proved reserves, and indeed the outcomes of scoping, pre-feasibility, and feasibility studies.

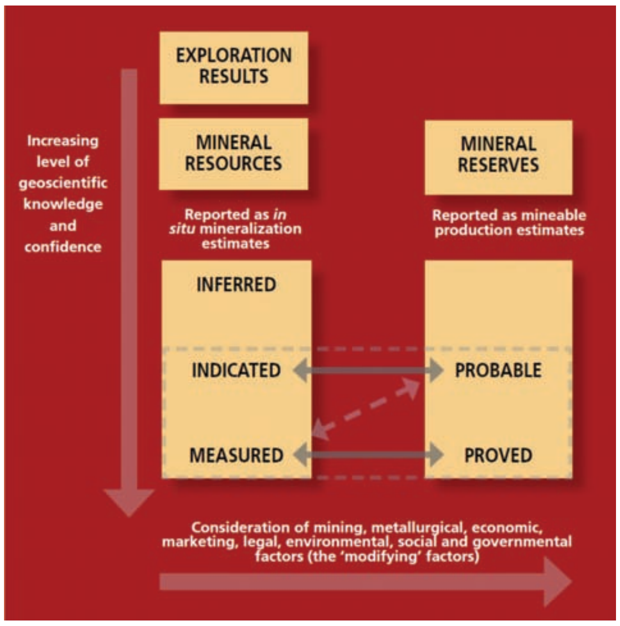


**Figure 1—General relationship between Exploration Results, Mineral Resources, and Mineral Reserves (SAMREC, 2009)**

### Project development stages

It is important to remember that the purpose of advancing prospects and projects and developing mines is to achieve a profitable business outcome. It is therefore equally important to understand and present a project's maturity when interpreting reported Mineral Resource and Mineral Reserve statements. The Australasian VALMIN Code (VALMIN, 2005) and South African SAMVAL Code (SAMVAL, 2009) classify mineral assets according to their maturity in the following project development stages: exploration, advanced exploration, pre-development/resource, development, and operating/producing. These development stages are outlined in Table I.

Logically, as a prospect or project advances along the development stages outlined in Table I, the understanding of the risks and opportunities improves with more and better-quality technical data collected and assessed through increasing levels of rigour and detail in technical and economic studies. The increasing level of project maturity reflects the increasing level of certainty in the estimated project outcomes, and it is reasonable to expect the value of the project to increase with this increasing confidence. The interrelationship of increasing certainty and project value with advancing development stages, including the definition of Mineral Resource and Mineral Reserve and the level of technical study, is presented schematically in Figure 2.

### Technical study types

The resources industry, like other industries, seeks to convey confidence (accuracy, precision, and risk) in study outcomes through the level of detail of the particular technical and economic study. The levels of study reported in both private and public announcements, and subsequently the expectation of certainty in the study outcomes, is generally conveyed simply by the study names, without providing the study definitions or expected levels of accuracy, precision, and confidence. Sometimes there is an inconsistent or even incorrect use of study terminology in our industry, for example referring to a feasibility study, when the study is actually at the level of a pre-feasibility study or perhaps even a scoping study. One way to consider the intended level of study is to consider the stage at which a project advances from an 'aspirational' project to one that is considered to be strictly 'data-driven'. In the latter case, the project is supported by extensive and good-quality data, technical studies, and engineering design at particular levels of detail.

For example, a scoping study may be considered largely 'aspirational' since, although it is generally partly data-driven (it may be based on Inferred Resources or better), it may be effectively conceptual as regards its technical and economic assumptions. A pre-feasibility or feasibility study, on the other hand, may be considered 'data-driven' as these are generally based mostly on Indicated and/or Measured resources and sufficiently detailed assessments of the modifying factors to enable a Mineral Reserve to be determined. This is why, even though under the JORC Code definitions a scoping study can be carried out on Indicated or Measured resources, the level of confidence in the modifying factors is not considered sufficient to determine a mine plan and production schedule that is technically achievable and economically viable, and from which the Mineral Reserves can be derived and reported.

Note that the term 'scoping study' is not defined or used in the SAMREC Code, which is to be expected since a scoping level study does not necessarily result in the delineation and reporting of Mineral Resources or Mineral Reserves.

It is not unusual to find quite different interpretations of Mineral Resource categories between different CPs, ranging from conservative to the highly optimistic. Indeed, it is not

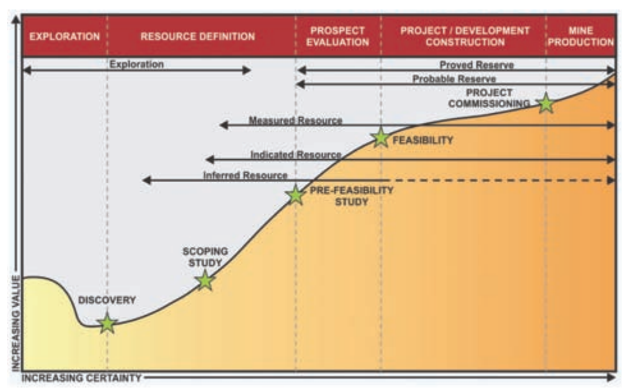


**Figure 2—The interrelationship of increasing certainty and project value with advancing development stages and the level of technical study (after Lilford, 2011)**

*Table I*

**Mineral asset development stages (VALMIN, 2005; SAMVAL, 2009)**

| Project development stage | Criterion |
|---|---|
| Exploration areas | Mineralization may or may not be defined, but where a Mineral Resource has not been identified. |
| Advanced exploration areas | Considerable exploration has been undertaken and specific targets identified. Sufficient work has been completed on at least one prospect to provide a good geological understanding and encouragement that further work is likely to result in the determination of a Mineral Resource. |
| Pre-development / resource | Mineral Resources and/or Mineral Reserves were identified and estimated. A positive development decision has not been made.This includes properties where a development decision has been negative and properties are either on care and maintenance or held on retention titles. |
| Development | Committed to production but not yet commissioned or not initially operating at design levels. |
| Operating | Mineral properties, in particular mines and processing plants, which were fully commissioned and are in production. |

unusual to see quite different implications applied to the meaning of a 'feasibility study', again ranging from a scoping study level to that of a final feasibility study. Unless the statement or report accompanying these results provides sufficient clarity or transparency of the material assumptions supporting the public announcement, the recipients of such data could indeed be misled by the information. For example, one CP's feasibility study, may be another's scoping study, one CP's Measured Resource may be another's Indicated Resource. Indeed, if the requirement for 'reasonable prospects for eventual economic extraction' for reporting any category of Mineral Resource are not considered by the CP and the assumptions made transparent, then one CP may report very different Mineral Resource quantities to another, even using the same basic data and a similar geological model. Clearly, stakeholders using this public information, for example investors or valuers, should be able to rely on this information or be able to drill down into the detail behind the announcements to establish the correct context of this information.

The definitions of study types are repeated here.

➤ *A Scoping Study* (JORC, 2012) is an order-of-magnitude technical and economic study of the potential viability of Mineral Resources. It includes appropriate assessments of realistically assumed modifying factors together with any other relevant operational factors that are necessary to demonstrate at the time of reporting that progress to a pre-feasibility study can be reasonably justified.

➤ *A Pre-feasibility Study* (SAMREC, 2009) is a comprehensive study of the viability of a range of options for a mineral project that has advanced to a stage at which the preferred mining method in the case of underground mining or the pit configuration in the case of an open pit has been established and an effective method of mineral processing has been determined. It includes a financial analysis based on realistic assumptions of technical, engineering, operating, and economic factors and the evaluation of other relevant factors that are sufficient for a CP, acting reasonably, to determine if all or part of the Mineral Resource may be classified as a Mineral Reserve. The overall confidence of the study should be stated. A pre-feasibility study is at a lower confidence level than a feasibility study.

➤ *A Feasibility Study* (SAMREC, 2009) is a comprehensive design and costing study of the selected option for the development of a mineral project in which appropriate assessments have been made of realistically assumed geological, mining, metallurgical, economic, marketing, legal, environmental, social, governmental, engineering, operational, and all other modifying factors, which are considered in sufficient detail to demonstrate at the time of reporting that extraction is reasonably justified (economically mineable) and the factors reasonably serve as the basis for a final decision by a proponent or financial institution to proceed with, or finance, the development of the project. The overall confidence of the study should be stated.

When conducting technical studies, from scoping studies through to final feasibility studies, it is considered crucial that such studies are suitably matched not only to the accuracy and precision of the cost estimates, but also to the level of confidence in the underlying asset, namely the Mineral Resource and Mineral Reserve base. The level of technical study needs to convey the appropriate risk and opportunity profile of the project to the stakeholders. For example, it is completely misleading to report a resource project at a final feasibility study level if there are insufficient Measured and Indicated Mineral Resources and Proved and Probable Mineral Reserves defined to support the minimum economic mine life, regardless of what level of detail is reportedly available on other inputs, such as equipment costs or processing plant.

Over recent years the need to maintain rigour in conducting robust technical and economic assessments has been under pressure by the 'need' of many developers to fast-track studies to keep timelines and costs down and to take advantage of commodity demand and price cycles. The short timelines applied to technical studies often result in various investigations running in parallel rather than in series, as would traditionally have been the case. This invariably results in some redundancies in the process, and can also lead to misleading interim results from incomplete study phases. So in effect, some 'final' feasibility studies resulting from a fast-track process may effectively be at the level of confidence that many major engineering and mining companies would consider to be only at a pre-feasibility study level. Stakeholders should be made aware if higher levels of uncertainty are associated with the outcomes of some of these fast-tracked studies to allow them to properly assess the associated project risks. In some instances, the fast-tracking approach may mean alternative scenarios, normally identified during scoping phases and pursued during pre-feasibility assessments, are not fully considered before advancing to the so-called final feasibility study, and stakeholders deserve to be made aware if this has been the case.

Does the completion of a final feasibility study mean there is no more technical work to be done? Is no further definition and resolution of the Mineral Resources and Mineral Reserves required once a final feasibility study has been completed? This is certainly not the case, since for most deposits, a Measured Resource and Proved Reserve do not provide sufficient detail for short-term mining control. Furthermore, after completion of a final feasibility study, a project still requires additional detail in terms of final engineering design during its development stage to improve the accuracy and precision of the results for planning, contracting, and construction purposes. In the case of the Mineral Resource and Mineral Reserve, final definition drilling and sampling and the development of a prototype short-term grade control model is typically required for the start-up mining areas, followed by ongoing grade-control activities. Clearly, a Measured Resource and Proved Reserve are not necessarily at the ultimate level of accuracy, precision, and confidence required for reliable short-term mine planning and scheduling.

The international Mineral Resource and Mineral Reserve reporting codes, including the JORC and SAMREC Codes, do not quantify the level of accuracy, precision, or associated uncertainty/risk expected to be conveyed by the various Mineral Resource and Mineral Reserve categories and technical study types. However, some rules of thumb for the levels of accuracy, expressed as confidence intervals, expected from the three main levels of study are presented in Table II. The levels of accuracy expressed as confidence intervals in Table II do not include the expected confidence levels, where for example a ±15 per cent accuracy interval at 90 per cent confidence limits would mean there is a 1 in 20 chance for the result to be less than 85 per cent of the estimate, and a 1 in 20 chance it may be 15 per cent higher than the estimate.

### Approximate mining parameters versus modifying factors

- *The 2012 JORC Code notes that with respect to a Mineral Resource*—'… in discussing 'reasonable prospects for eventual economic extraction' in Clause 20, the Code requires an assessment (albeit preliminary) in respect of all matters likely to influence the prospect of economic extraction including the approximate mining parameters by the Competent Person. While a Scoping Study may provide the basis for that assessment, the Code does not require a Scoping Study to have been completed to report a Mineral Resource'.
- *The JORC Code goes on the clarify that*—'In other words, a Mineral Resource is not an inventory of all mineralisation drilled or sampled, regardless of cut-off grade, likely mining dimensions location or continuity. It is a realistic inventory of mineralisation which, under assumed and justifiable technical, economic and development conditions, might, in whole or in part, become economically extractable'.
- *The SAMREC Code clarifies similarly that*—"The term 'reasonable and realistic prospects for eventual economic extraction'" implies a judgement (albeit preliminary) by the Competent Person in respect of technical and economic factors likely to influence the prospect of economic extraction, including the approximate mining parameters. In other words, a Mineral Resource is not an inventory of all mineralization drilled or sampled, regardless of cut-off grades, likely mining dimensions, location or continuity. It is a realistic inventory of mineralization that, at the time of reporting and under assumed and justifiable technical and economic conditions, might become economically extractable. Portions of a mineral deposit that do not have reasonable and realistic prospects for eventual economic extraction must not be included in a Mineral Resource.'

Some CPs argue that if these 'approximate mining parameters' are applied when estimating and reporting a Mineral Resource, then this is effectively the same as reporting a Mineral Reserve. However, as the following extracts from the 2009 SAMREC Code and the 2012 JORC Code show, the modifying factors for the reporting of Mineral Reserves are more stringently determined than the approximated mining parameters.

- *The SAMREC Code states*—"The term 'economically mineable' implies that extraction of the Mineral Reserve has been demonstrated as viable and justifiable under a defined set of realistically assumed modifying factors. What constitutes the term "realistically assumed" will vary with the type of deposit, level of study that has been carried out, and financial criteria of the reporting entity. Deriving a Mineral Reserve without a mine design or mine plan through a process of factoring of the Mineral Resource is unacceptable."
- The JORC Code states—'Confidence in the Measured Resource estimate is sufficient to allow application of Modifying Factors within a technical and economic study as defined in Clauses 37 to 40. Depending upon the level of confidence in the various Modifying Factors it may be converted to a Proved Mineral Reserve (high confidence in Modifying Factors), Probable Mineral Reserve (some uncertainty in Modifying Factors) or may not be converted at all (low or no confidence in

*Table II*

**Rule-of-thumb confidence intervals for technical studies (at assumed 90 per cent confidence)**

| Measure/item | Scoping study | Pre-feasibilitystudy | Final feasibility study |
|---|---|---|---|
| Cost accuracy | ±25%-50% | ±15-25% | ±10-15% |
| Cost contingency | 30-50% | 15-30% | <15% |
| Proportion of engineering complete | <5% | <20% | <50% |
| Resource categories | Mostly Inferred | Mostly Indicated | Measured and Indicated |
| Reserve categories | None | Mostly Probable | Proved and Probable |
| Mining method | Assumed | General | Optimized |
| Mine design | None or high-level conceptual | Preliminary mine plan and schedule | Detailed mine plan and schedule |
| Scheduling | Annual approximation | 3-monthly to annual | Monthly for much of payback period |
| Risk tolerance | High | Medium | Low |

Sources: (Parsons, 1999; McCarthy, 2003; Pincock, 2004; Barton, pers. comm., 2005; Macfarlane, 2007; Hatch, 2010; Bullock, 2011; AACE International, 2012) some of the Modifying Factors; or no plan to mine, e.g. pillars in an underground mine or outside economic pit limits)'.

Both the SAMREC Code and JORC Code provide extensive guidelines on the meaning and consideration of modifying factors in determining Mineral Reserves. The relevant portions of the JORC Code that discuss the application of modifying factors for the reporting of Mineral (Ore) Reserves are therefore reproduced here with little need for commentary:

*'The words "ore" and "reserves" must not be used in describing Mineral Resource estimates as the terms imply technical feasibility and economic viability and are only appropriate when all relevant Modifying Factors have been considered. Reports and statements should continue to refer to the appropriate category or categories of Mineral Resources until technical feasibility and economic viability have been established. If re-evaluation indicates that the Ore Reserves are no longer viable, the Ore Reserves must be reclassified as Mineral Resources or removed from Mineral Resource/Ore Reserve statements.*

*'An 'Ore Reserve' is the economically mineable part of a Measured and/or Indicated Mineral Resource. It includes diluting materials and allowances for losses, which may occur when the material is mined or extracted and is defined by studies at Pre-Feasibility or Feasibility level as appropriate that include application of Modifying Factors. Such studies demonstrate that, at the time of reporting, extraction could reasonably be justified.*

*'In order to achieve the required level of confidence in the Modifying Factors, appropriate Feasibility or Pre-Feasibility level studies will have been carried out prior to determination of the Ore Reserves. The studies will have determined a mine plan and production schedule that is technically achievable and economically viable and from which the Ore Reserves can be derived. The term 'Ore Reserves' need not necessarily signify that extraction facilities are in place or operative, or that all necessary approvals or sales contracts have been received. It does signify that there are reasonable grounds to expect that such approvals or contracts will eventuate within the anticipated time frame required by the mine plans. There must be reasonable grounds to expect that all necessary Government approvals will be received. The Competent Person should highlight and discuss any material unresolved matter that is dependent on a third party on which extraction is contingent'.*

Transparency in reporting requires the assumptions on which the reasonable grounds are based for expecting approvals, sales contracts, transport infrastructure etc., to be summarized and the risks regarding any 'material unresolved matter' provided by the CP. The other important point made above is that a Mineral Reserve must be re-classified if a sustained change in technical or economic parameters indicates that the Mineral Reserve is no longer viable. Indeed, the Mineral Resource may even need to be removed from future statements if the criteria for eventual economic extraction are no longer valid. This is not meant to include short-term commodity price movements or immediate demand constraints, but rather longer term price trends, market conditions, political, environmental, social or infrastructure issues, legislation or approvals, or funding issues that may prevent the intended project being developed in the time frame considered in the relevant technical study. If the driving factors are no longer appropriate and the revised factors are such that the project is no longer economically viable, then the outcomes of the original study, including the estimated Mineral Reserves, may not be current or meaningful.

### Accuracy, confidence, and quality

The terms and definitions for Mineral Resources and Mineral Reserves provided in the SAMREC Code, and summarized in Figure 1, are intended to provide a consistent meaning for the stakeholders assessing company and technical statements, reports, and announcements. However, do all CPs really mean the same thing when they use the defined terms?

The intent of SAMREC and JORC code-compliant reporting of Mineral Resources and Mineral Reserves is to ensure that the CP has considered the requirements of the Codes, followed the guidelines, and provided supporting information in terms of at least the Codes' Table 1 checklists. But what is the intended and expected outcome of such reporting? Ultimately, the reported values must be placed into the correct context with respect to the reliability and intended, but not necessarily quantified, accuracy or certainty of the reported results.

The Codes place as much reliance on the quality of the supporting data or information, including the quality and level of detail of the technical-economic study, as on the quantity of such data, when defining a Mineral Resource and/or a Mineral Reserve. The vertical axis in Figure 1 clearly highlights the consideration of the 'quality' of data when considering both Mineral Resource and Mineral Reserve classification. The importance of the quality or confidence in the data for classifying the Mineral Resources is generally well-accepted by CPs and the Codes re-emphasize the quality versus quantity relationship by commenting that the choice of the appropriate category of Mineral Resource (or Mineral Reserve) depends upon the nature, quantity, distribution, and quality of data available and the level of confidence that attaches to that data.

It is important to reiterate the application of the principle of confidence in the quality of data, information, and/or study type when considering the appropriate Mineral Resource or Mineral Reserve category. The Codes provide the following guidance (JORC, 2012):

*'Measured Mineral Resources may be converted to either Proved Ore Reserves or Probable Ore Reserves. The Competent Person may convert Measured Mineral Resources to Probable Ore Reserves because of uncertainties associated with some or all of the Modifying Factors which are taken into account in the conversion from Mineral Resources to Ore Reserves' and that 'Depending upon the level of confidence in the various Modifying Factors it may be converted to a Proved Ore Reserve (high confidence in Modifying Factors), Probable Ore Reserve (some uncertainty in Modifying Factors) or may not be converted at all (low or no confidence in some of the Modifying Factors; or no plan to mine, e.g. pillars in an underground mine or outside economic pit limits).'*

Clearly, the same consideration applies to the possible conversion of Indicated Mineral Resources to Probable Mineral Reserves: namely, depending on the confidence in the modifying factors, the Mineral Resource may not be converted to Probable Mineral Reserves at all.

It is worth noting that while a Probable Reserve has a lower level of confidence than a Proved Reserve, it is still of sufficient quality to serve as the basis for a decision on the development of the deposit. This is why some project financiers rely on the total Mineral Reserve rather than necessarily the proportion of Proved or Probable reserves in their assessments of project risk.

Further guidance within the 2012 JORC Code regarding reliability or confidence in reporting includes the following:

*'Where there are as yet unresolved issues potentially impacting the reliability of, or confidence in, a statement of Ore Reserves (for example, limited geotechnical information, complex orebody metallurgy, uncertainty in the permitting process, etc.) those unresolved issues should also be reported",* and that *"If there is doubt about what should be reported, it is better to err on the side of providing too much information rather than too little'.*

In the preamble to Table 1 in the 2009 SAMREC Code, the principle of materiality of the information with respect to reliability, uncertainty or confidence in reporting is reiterated:

*'… as always, relevance and materiality are overriding-principles that determine what information should be publicly reported".The 2012 JORC Code goes on to say "the Competent Person must provide sufficient comment on all matters that might materially affect a reader's understanding or interpretation of the results or estimates being reported. This is particularly important where inadequate or uncertain data affect the reliability of, or confidence in, a statement of Exploration Results or an estimate of Mineral Resources or Ore Reserves'.*

The topic of reliability, accuracy, or confidence in the final reporting and level of study supporting the Mineral Resources and Mineral Reserves is further addressed in the Codes, and in particular the JORC Code more so than the SAMREC Code.

The preamble to Table 1 in the SAMREC Code (SAMREC, 2009) calls on the CPs to 'Discuss whether account has been taken of all relevant factors, i.e. relative confidence in tonnage / grade computations, density, quality, value and distribution of primary data and information, confidence in continuity of the geological and mineralization models'.

The 2012 JORC Code expands on the requirement to discuss accuracy, precision and confidence as follows:

*'Where appropriate a statement of the relative accuracy and confidence level in the Ore Reserve estimate using an approach or procedure deemed appropriate by the Competent Person. For example, the application of statistical or geostatistical procedures to quantify the relative accuracy of the reserve within stated confidence limits, or, if such an approach is not deemed appropriate, a qualitative discussion of the factors which could affect the relative accuracy and confidence of the estimate,*

and

*'Accuracy and confidence discussions should extend to specific discussions of any applied Modifying Factors that may have a material impact on Ore Reserve viability, or for which there are remaining areas of uncertainty at the current study stage'.*

*'Competent Persons are encouraged, where appropriate, to discuss the relative accuracy and confidence level of the Mineral Resource [or Ore Reserve] estimates with consideration of at least sampling, analytical and estimation errors. The statement should specify whether it relates to global or local estimates, and, if local, state the relevant tonnage. Where a statement of the relative accuracy and confidence level is not possible, a qualitative discussion of the uncertainties should be provided in its place'.*

*'The application of the category of Proved Ore Reserve implies the highest degree of geological, technical and economic confidence in the estimate at the level of production increments used to support mine planning and production scheduling, with consequent expectations in the minds of the readers of the report. These expectations should be considered when categorising a Mineral Resource as Measured'.*

Various resource and reserve practitioners have attempted to provide semi-quantitative and quantitative guidelines for the classification of Mineral Resources and Mineral Reserves based upon the perceived confidence or precision of the estimates. While some of these approaches are more qualitative in nature, based on consideration of all the factors that might impact on confidence, there have also been a number of proposals that are more quantitative, for example derived from the results of geostatistical conditional simulation studies (Mwasinga, 2001; Khosrowshahi and Shaw, 2001; Snowden, *et al.*, 2002). Clearly there are contributing factors to Mineral Resource and Mineral Reserve risk that are sometimes ignored or are difficult to quantify, including the geological interpretation, bulk density, contact dilution, etc. Many of these factors are detailed in the JORC Code and SAMREC Code. Methods for considering how they may be assessed for confidence and reporting are explored by Dominy *et al.* (2002), who present a review of the possible sources of error that might occur during the various phases of an exploration and estimation programme and which are carried through into the Mineral Reserve estimates and hence mine design.

The ultimate outcome of any Mineral Resource and Mineral Reserve process and feasibility study path is to secure funding to develop a technically and economically viable mine. The final feasibility study is referred to by some as a 'bankable' study because it can be used to support project financing by commercial bank loan facilities, or other forms of financing. So what accuracy, precision, and level of confidence do the financiers require? Parker (pers. comm., 1997) has noted that 'the first rule is, there are no rigid standards, only guidelines … some lenders are very liberal, and others conservative'. Parker has also commented on the accuracy of feasibility study outcomes to say that 'although the relative width of the confidence interval is defined, the confidence level is not often mentioned or accurately quantifiable, because no two projects are exactly alike'. Parker noted that banks in general require sufficient confidence in the planned production to cover the loan service period plus a contingency period of 50 to 100 per cent of the payback period, depending on the perceived risks in the project. Typically this translates to a required amount of total Mineral Reserves over the payback plus contingency period, and some banks may require a certain proportion of Proved to Probable reserves in evaluating feasibility study outcomes.

Valuations of mineral assets using market-based or comparable transaction methods tend to rely ultimately on the quantities of reported Mineral Resources and Mineral Reserves: Proved and/or Probable reserves obviously command a premium value per unit, but where these are not defined, the valuations will tend to rely on the quantities of Measured and Indicated resources, generally as a total Measured plus Indicated Resource, to guide the valuation (McKibben, pers. comm., 2013; VALMIN, 2005). Inferred Resources may provide further support depending on the potential to convert these to Indicated or Measured resources within a 'reasonable' timeframe (Lawrence, 2012).

The above examples of how Mineral Resource and Mineral Reserve confidence is recognized by project financiers and mineral asset valuers illustrate why it is so important to provide transparent and consistent reporting of Mineral Resources, Mineral Reserves, and study outcomes, and to provide a discussion on the expected accuracy, precision, and confidence levels of the estimates. It is considered highly desirable, when discussing and reporting accuracy and confidence levels, that the measures and terminology consider the practical use and interpretation of these results for the various stakeholders. In general, stakeholders wish to appreciate the expected accuracy, precision, and confidence levels over a particular period of time. For example, the period of time may relate to a mine production scale, such as the confidence for a one week, one month, one quarter, one year, or life-of-mine period; or whether the confidence relates to a resource block, selective mining unit, mining panel or strip, or the entire resource domain.

The following descriptions of expected accuracy, precision, and confidence limits provide examples that would be meaningful to various stakeholders, from mine operators and management to investors and financiers:

- Measured Resource (or Proved Reserve): ±10 to 15 per cent (at 90 per cent confidence limits) for three-monthly production parcels
- Indicated Resource (or Probable Reserve): ±10 to 15 per cent (at 90 per cent confidence limits) for annual production parcels.

In other words, these metrics imply that 1 out of 20 periods are expected to be less than 90 to 85 per cent of the estimate, and 1 out of 20 periods may be 10 to 15 per cent higher than the estimate.

Alternatively, the measures could be reported over the same period or scale, but with different precision ranges:

- Measured Resource (or Proved Reserve): ±5 to 10 per cent (at 90 per cent confidence limits) for annual production parcels
- Indicated Resource (or Probable Reserve): ±10 to 15 per cent (at 90 per cent confidence limits) for annual production parcels,

or

- Measured Resource (or Proved Reserve): ±10 to 15 per cent (at 90 per cent confidence limits) for three-monthly production scale parcels
- Indicated Resource (or Probable Reserve): ±15-25 per cent (at 90 per cent confidence limits) for three-monthly production parcels.

Clearly, the accuracy, precision, and level of confidence that can be attained using this form of relative measurement depends very much on the nature of the deposit under consideration. For example, Mineral Resource estimates for a nuggetty gold deposit may never attain the same measure of relative confidence as a stratiform-style copper deposit. However, that is exactly the point: no two deposits are identical, and that is why further discussion and reporting of the CP's meaning when reporting a particular Mineral Resource or Mineral Reserve category is required. For example, it may be possible to express the same intended accuracy, say ±10 to 15 per cent confidence interval for Measured Resources, for various deposit styles but for different scales or periods of production; so it may be possible to achieve this accuracy and precision over three-month production areas for a stratiform base metal deposit, but this would need to be over six-month or one-year periods for a nickel sulphide deposit, or over the full life-of-mine for a nuggety gold deposit.

### Examples of poor project outcomes and reporting

The importance of completing a study to the required level of detail and placing the outcomes in the correct context of technical risk and confidence is highlighted by following anecdotes (cited in a presentation by Peter McCarthy to the Melbourne branch of the AusIMM in 2013, titled 'Why pre-feasibility studies fail'; McCarthy, 2003):

- In the 1980s, a study of 35 Australian gold mines found that 68 per cent failed to deliver the planned head grade (Burmeister, 1988)
- A review of nearly 50 North American projects showed that only 10 per cent achieved their commercial aims, with 38 per cent failing within about one year (Harquail, 1991)
- A study of the start-up performance of nine Australian underground base metal mines found that only 50 per cent achieved design throughput by year 3 and 25 per cent never achieved it at all (McCarthy and Ward, 1999)
- A US study comparing the final feasibility study production rate with the average sustained production rate from 60 steeply-dipping tabular deposits found that 35 per cent of the mines did not achieve their planned production rate (Tatman, 2001).

There have been a few recent company public announcements where the Mineral Resource, Mineral Reserve, and study level have presented the project in the incorrect context of the expected risk and level of maturity of the project.

In one example, a joint venture partner reported double the coal resource tonnage of the other JV partner, each using the same drill hole data. The simple reason for the difference was that the partner with double the resource had not applied the likely mining parameters for the expected underground mining scenario. The CP had therefore essentially reported all the *in situ* coal without adequately justifying how this coal would be economically and realistically extracted. Clearly, a stakeholder relying on the higher reported coal resource without being made aware of the implications of these assumptions for the accuracy and confidence in the reported tonnage and quality would be expected to derive a significantly higher valuation for the project.

In another example, where a company reported the technical and financial outcomes of a 'definitive feasibility study', the financial project outcomes were questioned by the Australian Securities and Investments Commission. The company subsequently downgraded the level of study to a 'feasibility study', but one for which no Mineral Reserves were reported and where it was acknowledged that the Mineral Resources were still to be updated before the study could be completed and Mineral Reserves actually defined. In other words, the company's original public statement reporting a definitive study supporting a project net present value of over A$2 billion was misleading and in effect, the original and revised company statement seem more correctly to represent the results of a scoping study carried out on preliminary Mineral Resource estimates. This context would have been abundantly clear if the announcement had used the JORC Code terminology and classifications correctly, and also contained a proximal cautionary statementto the effect: *'The Scoping Study referred to in this report is based on low-level technical and economic assessments, and is insufficient to support estimation of Ore Reserves or to provide assurance of an economic development case at this stage, or to provide certainty that the conclusions of the Scoping Study will be realised' (JORC, 2012)*. Further examples of the 'use and abuse' of feasibility studies can be found in Mackenzie and Cusworth (2007).

## Conclusions

Resource development and mining is an inherently risky business. Mineral Reserve estimation is not simply a measure of maximum net present value or return on investment, but involves a thorough appreciation of the underlying Mineral Resource assessments of the relevant modifying factors at least to a Pre-feasibility level, to satisfy a range of business objectives, both quantitative and qualitative. Uncertainty and errors in Mineral Resource and Mineral Reserve estimates remain a major reason for the economic failure of mining projects. The appreciation and consideration of this uncertainty is critical for realistic project reporting, planning, and risk aversion.

It must be recognized that two deposits can have the same reported Mineral Reserves and the same expected mining costs but have a very different financial attractiveness, solely as a result of different degrees of certainty inherent in their Mineral Resource and Mineral Reserve estimation. It should be standard practice to carry out a full risk analysis, including a detailed assessment of all sources of error, as an integral part of reporting any Mineral Resource or Mineral Reserve. For Mineral Resource reports, this will include all technical sources of error, while for Mineral Reserves this will also include economic, social, environmental, and infrastructure modifying factors as an integral part of the risk analysis. The aim is to provide a degree of quantification of the risk in the reported estimate to allow for better decision making by resource project stakeholders such as planners, operators, and investors.

Competent Persons should strive for better presentation of the technical risk and uncertainty associated with resource projects in the context of project maturity to provide more consistent and balanced views of confidence, risk, and opportunities for both internal and external stakeholders relying on this reported information. The international reporting codes, such as the SAMREC Code and the JORC Code, provide extensive guidance on the topics to be assessed. However, Competent Persons needs to step up and deliver the increased transparency that those relying on the reported data require.

In summary, together with due consideration of the assessment and reporting criteria outlined in the SAMREC and JORC Code checklists, the Competent Person and stakeholders relying on the Competent Person reports, need to challenge the reporting by asking themselves the following key questions:

➤ Would the vast majority of my Competent Person peers agree with my logic in defining, classifying, and reporting the Mineral Resources and Mineral Reserves?
➤ Does the stage of project development and level of confidence in the associated data and technical-economic studies support the reporting, and is this clearly and correctly presented?
➤ Would my peers and informed stakeholders be able to appreciate the assumptions, factors, and process followed in the reporting from the way in which the results are reported and supported?
➤ Are my assumptions for eventual economic extraction reasonable, realistic, and transparent, and have I adequately applied approximate mining parameters for reporting the Mineral Resources?
➤ Have I considered and used all representative data, and if I have excluded data have I adequately considered the advantages and risks in doing so?
➤ Have I applied realistic and justifiable mining factors in determining the mine plan and schedule for reporting Mineral Reserves, in particular geotechnical considerations, ore loss, dilution, mining extraction rates, ore sizing/fragmentation, blending requirements, and practical metallurgical recovery?
➤ Whether or not I have applied any quantitative assessment of accuracy and precision in my Mineral Resource and Mineral Reserve classification, have I considered the confidence I expect empirically over different length mining periods from the various categories, and are these consistent with what my peers and stakeholders would expect?

- Have I included a statement of the relative accuracy and confidence level in the estimates and provided a similar discussion regarding any of the input data and factors that may have a material impact on Mineral Resource or Mineral Reserve viability?
- Have I adequately presented any remaining areas of uncertainty at the current study stage, and how these will be addressed in future work and studies?

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