

APPENDIX 4-2 RESOURCE EVALUATION FOR AGGREGATES

4-1.1 INTRODUCTION

The competent evaluation and reporting of mineral resources is essential as background to investment decisions relating to the exploitation of those resources. Bankers, private investors and stock exchanges typically require reports to be produced by competent persons suitably qualified to prepare such reports, more and more often to internationally recognised reporting codes¹. In many countries, applications for planning permissions and licences must be accompanied by reports classifying reserves and resources according to national standards and rules relating to criteria to be investigated, the qualifications of the persons undertaking the investigation, and the format and scope of the report itself.

Whilst essential, it is not sufficient simply to know that a resource of aggregate that is suitable for its intended purpose exists in the ground and to have an estimate of how much will be recoverable and how much will be waste. Investors also need to be confident that a viable stone extraction business can be developed from the mineral resources identified. In addition, before any working can proceed, permits and licences required by the relevant national and local authorities must be obtained, and these authorities will require supporting information as to the way in which the extraction will proceed and its impacts. Until these matters have been addressed and an appropriate level of confidence has been established in relation to the site, the minerals identified are classified as resources – the next steps are to improve the level of confidence so as to elevate these resources to the category of reserves. This is illustrated below in a sketch taken from the CRIRSCO draft international reporting template, also included in many other reporting codes including the PERC code.

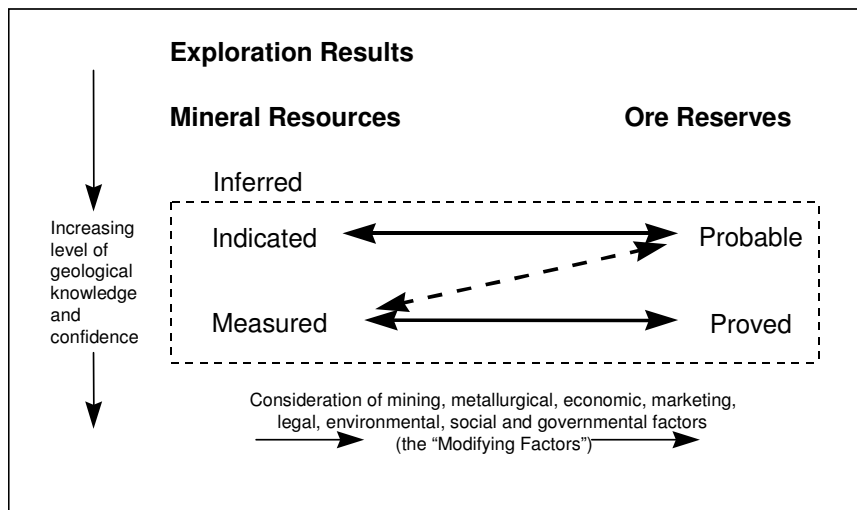


Figure 1: General relationship between exploration results, mineral resources and mineral reserves.

Whether the mineral in question is a metalliferous ore, an industrial mineral such as kaolin or cement feedstock, aggregate, dimension stone or building stone the fundamental questions to be addressed in an assessment for the purposes of defining proved reserves as background to informing investment decisions or regulatory processes amount to:

¹ For example, Institute of Materials Minerals and Mining (IOM³), European Federation of Geologists (EFG), Geological Society of London (GSL) and Institute of Geologists of Ireland (IGI), 1991: *Code for reporting of mineral exploration results, mineral resources and mineral reserves*. The same organisations are members of the Pan European Reserves Committee (PERC), which is represented on the worldwide body, the Committee for Mineral Reserves International Reporting Standards (CRIRSCO). This code is widely recognised on international stock exchanges including the London Stock Exchange. It is currently being updated by the PERC Code (see www.percreserves.com). Bilateral agreements between professional bodies in many countries ensure that there is mutual recognition of the professional qualifications held by persons competent to sign off resource and reserve reports.

- How much mineral can be recovered from the property and what are its properties (and variability in those properties) relevant to its market or use and in relation to standards and norms?
- Can the deposit be worked safely, and in accordance with local codes and laws?
- Is it possible to work the deposit in such a way as to satisfy all of the commercial objectives of the operating company and its investors (e.g. so as to release a certain production rate for a certain period within given quality or performance constraints and make a given return on investment)?
- What level of investment will be necessary, what payback period can be expected and what return on capital is likely? What is the sensitivity of the economic model to changes in key variables and how much uncertainty (risk) is associated with each of those key variables?

Taken together, these amount to 'Would you invest your money in this mineral operation?'

The particular issues and skills relevant to addressing the key questions listed above in relation to aggregates are described in the following sections. Section 2 is concerned with increasing the level of geological knowledge and confidence and Section 3 describes how the 'modifying factors' described along the horizontal axis of the diagram above are taken into account.

4-1.2 QUANTITY AND QUALITY OF MINERAL RESOURCES

4-1.2.1 Estimation of the recoverable tonnage of mineral

In simple terms, the tonnage of mineral that can be recovered from a particular deposit may be estimated by applying the following simple formula:

$$T = (V - W) * D$$

Where: T = recoverable tonnage of mineral

V = recoverable volume of mineral

D = in situ density (the number of tonnes per cubic metre of mineral in the ground)

W = the volume of waste that will be excavated or result from primary processing

Volume

Recoverable volumes may be measured in a number of ways. The simplest (and least accurate) involves the multiplication of surface area by depth of working (or depth of deposit). The most reliable method based on the definition, in three dimensions, of the following three important surfaces:

- The ground surface;
- The top of rock/base of soil or unconsolidated deposits at the surface;
- The intended working geometry; and
- The top and base of mineral where these are not coincident with the top of rock/base of soil and intended working geometry surfaces.

The volume between these surfaces can then be calculated using methods of sections or by triangulation and a method of prisms. The latter method is most commonly used when surface modelling packages are available and is described in Figure 2 below:

Volumes are measured using proprietary software, LSS (from McCarthy Taylor Systems Ltd). This is a surface modelling package in which each relevant surface (in this case the existing ground surface and a proposed excavation geometry) is represented as a continuous surface using strings of points and individual points, each of which has 3 dimensional co-ordinates. The measurement of volumes is by a method of prismatic triangulation. Each surface is triangulated, and prisms are formed between the two triangulated surfaces. The volume between the surfaces is the summation of the volumes of all the individual prisms.

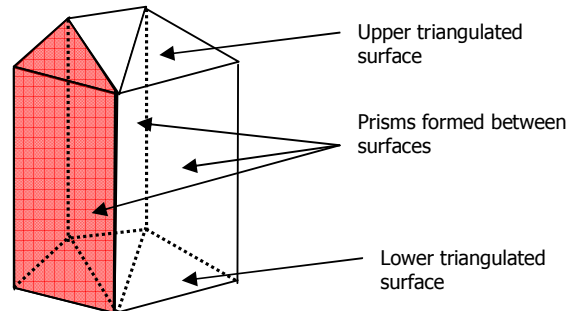


Figure 2: Volumetric measurement using the method of prisms

The ground surface model should be based on a topographic survey at a scale/point density suitable to describe the surface in detail.

The top of rock/base of soil, top of mineral and base of mineral surface models are likely to be refined as an evaluation project proceeds. Initially, an average thickness may be applied, but later, when more investigation and design have been carried out, these surfaces may be refined by contouring information from boreholes, pits and trenches or from geophysical surveys. It is essential to know the volume of overburden materials with reasonable certainty for the following reasons:

- These materials are 'not rock' and must not be included in the resources
- The stripping and storage of this material represents an important cost, which must be taken into account in business planning;
- They will need to be accommodated in tips during the operation, and space must be allowed for these tips to be constructed safely if the operation is not to become 'muck bound'; and
- They form restoration materials, the volume of which must be known as the basis for designing the restoration and rehabilitation of the site.

The total volume of rock can be calculated as the volume between the 'top of rock' or rockhead surface and the intended working geometry, or between the top and base of mineral lying within the intended working geometry. At the initial stages of an appraisal of resources and reserves, only a conceptual design of the final void geometry is likely to be available. As the project proceeds, this will be refined as described in Section 3 below.

Conversion of volume to tonnage

The in situ density of intact rock is likely to vary between around 2.5 and 3.0 tonnes/m³; in situ densities for gravel and sand deposits would typically be lower than this, in the range 2.0-2.75 tonnes/m³. The actual density is dependent on the intact density of the material as well as the density and openness of fractures within the rock mass. For crushed rock aggregate resources, geologists generally take an intact density (which can be measured in the laboratory) and apply a factor to it relating to the rock brokenness and variability. Most accurate figures for in situ density can be calculated by excavating material, weighing it and measuring the volume that it occupied in the ground by surveying the face before and after.

Waste

The volume of waste rock depends on the quality parameters relevant to the operation. This is discussed in more detail in the following section. Initially, it is common to estimate the volumes of waste and different

qualities of material to be worked from a deposit by applying a percentage for waste. Later in the evaluation process, as the assessment becomes more and more refined, it may be possible to show areas of different qualities in three dimensions (e.g. in a block model) and to apply different waste factors to each.

As with overburden materials, the volume of material that cannot be sold and remains on site (i.e. waste) is a critical item that must be taken into account in planning the operation and considering its viability. Where there is a high proportion of material that is waste or not suitable for the available aggregate markets, quarries can get into difficulties because this has been inadequately assessed and there has been a failure to design the operation to allow its accommodation without becoming 'muck bound' or the costs of handling and sometimes rehandling this material become crippling. The assessment of waste is intimately related to the assessment of quality variations as described below.

4-1.2.2 Modelling of quality variation

For any bulk mineral, the recoverable tonnage must fit quality criteria related to the end use of, or market for, the products.

Where quality variation is an issue (not always the case with aggregate deposits) a variety of software is available, allowing both 3D interpretation and block modelling/geostatistical analysis. There is a range of commercially available modelling software available, most of which combine the geological modelling with mine design capabilities. Some large organisations have developed in-house capabilities in this area.

An example of the results of geological modelling is given in Figure 3 below: