SAMPLING PRACTICES AND PITFALLS

SOME ILLUSTRATED GUIDELINES FOR COLLECTING CORRECT SAMPLES FOR EXPLORATION, MINING AND PROCESSING

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AGENDA

- Why do we need to have correct sampling?
- How can we collect correct samples?
- An example of some problems

WHY?
RELIABLE INFORMATION FOR CAPITAL INVESTMENT

- Each development stage requires distinct data to guide investment
  - Exploration targeting
  - Global resource prediction
  - Ore/Waste delineation
  - Processing efficiency

- All are inputs to reconciliation which determines the most likely resource inventory

WHY?
SOMETIMES, IT IS NOT YOUR CAPITAL

- All regulatory bodies require an explanation of sampling methods and representivity
- They also require a <u>demonstration</u> of sample representativeness

JORC TABLE 1
Section 1 Sampling Techniques and Data
(Criteria in this section apply to all succeeding sections.)

Criteria	Explanation
Sampling techniques	• *Nature and quality of sampling (eg cut channels, random chips, or specific specialised industry standard measurement tools appropriate to the minerals under investigation, such as down hole gamma sondes, or handheld XRF instruments, etc). These examples should not be taken as limiting the broad meaning of sampling.* • *Include reference to measures taken to ensure sample representivity and the appropriate calibration of any measurement tools or systems used.* • *Aspects of the determination of mineralisation that are Material to the Public Report. In cases where 'industry standard' work has been done this would be relatively simple (eg 'reverse circulation drilling was used to obtain 1 m samples from which 3 kg was pulverised to produce a 30 g charge for fire assay'). In other cases more explanation may be required, such as where there is coarse gold that has inherent sampling problems. Unusual commodities or mineralisation types (eg submarine nodules) may warrant disclosure of detailed information.*

Criteria	Explanation
Drilling techniques	• *Drill type (eg core, reverse circulation, open-hole hammer, rotary air blast, auger, Bangka, sonic, etc) and details (eg core diameter, triple or standard tube, depth of diamond tails, face-sampling bit or other type, whether core is oriented and if so, by what method, etc).*
Drill sample recovery	• *Method of recording and assessing core and chip sample recoveries and results assessed.* • *Measures taken to maximise sample recovery and ensure representative nature of the samples.* • *Whether a relationship exists between sample recovery and grade and whether sample bias may have occurred due to preferential loss/gain of fine/coarse material.*
Logging	• *Whether core and chip samples have been geologically and geotechnically logged to a level of detail to support appropriate Mineral Resource estimation, mining studies and metallurgical studies.* • *Whether logging is qualitative or quantitative in nature. Core (or costean, channel, etc) photography.* • *The total length and percentage of the relevant intersections logged.*
Sub-sampling techniques and sample preparation	• *If core, whether cut or sawn and whether quarter, half or all core taken.* • *If non-core, whether riffled, tube sampled, rotary split, etc and whether sampled wet or dry.* • *For all sample types, the nature, quality and appropriateness of the sample preparation technique.* • *Quality control procedures adopted for all sub-sampling stages to maximise representivity of samples.* • *Measures taken to ensure that the sampling is representative of the in situ material collected, including for instance results for field duplicate/second-half sampling.* • *Whether sample sizes are appropriate to the grain size of the material being sampled.*

Form 43-101F1
Technical Report

Item 9: Exploration – Briefly describe the nature and extent of all relevant exploration work other than drilling, conducted by or on behalf of, the issuer, including

(a) the procedures and parameters relating to the surveys and investigations;

(b) the sampling methods and sample quality, including whether the samples are representative, and any factors that may have resulted in sample biases;

(c) relevant information of location, number, type, nature, and spacing or density of samples collected, and the size of the area covered; and

(d) the significant results and interpretation of the exploration information.

Item 11: Sample Preparation, Analyses, and Security – Describe

(a) sample preparation methods and quality control measures employed before dispatch of samples to an analytical or testing laboratory, the method or process of sample splitting and reduction, and the security measures taken to ensure the validity and integrity of samples taken;

(b) relevant information regarding sample preparation, assaying and analytical procedures used, the name and location of the analytical or testing laboratories, the relationship of the laboratory to the issuer, and whether the laboratories are certified by any standards association and the particulars of any certification;

(c) a summary of the nature, extent, and results of quality control procedures employed and quality assurance actions taken or recommended to provide adequate confidence in the data collection and processing; and

(d) the author's opinion on the adequacy of sample preparation, security, and analytical procedures.

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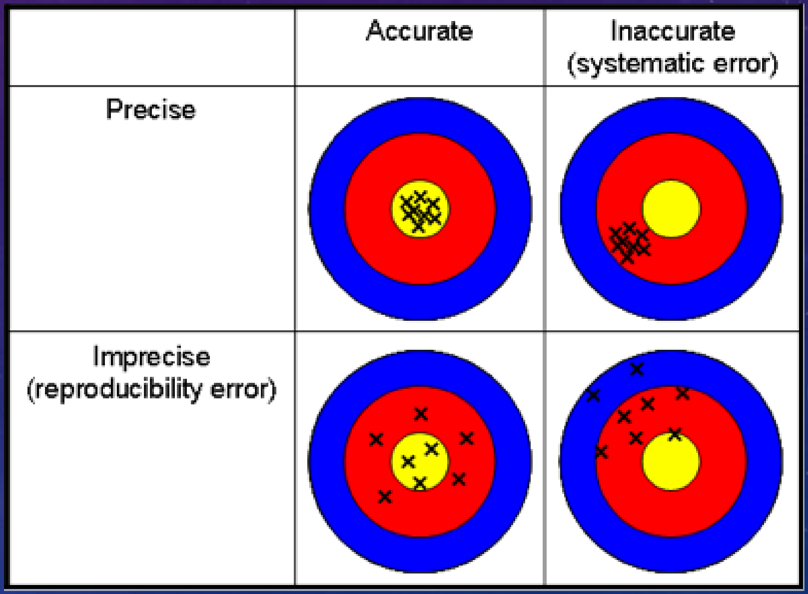
ASSESSMENT CRITERIA	EXPLORATION RESULTS	MINERAL RESOURCES	MINERAL RESERVES
Sampling Techniques and Data **Applicable to all reporting groups**			
Type(s) of sampling	*The type of sampling and its location, which will give rise to the results being reported, should be stated. Types of sampling include stream sediment, soil and heavy mineral concentrate samples, trenching and pitting, rock chip and channel sampling, drilling, auger etc. Examples of locations include old workings, mine dumps etc. Wherever possible the spacing of such samples should be stated, and locations shown on coordinated maps, plans and sections at suitable scales.*		
Drilling techniques	*Drilling techniques may include core, reverse circulation, percussion, rotary auger, down-the-hole hammer, etc. These should be stated and details (e.g. core diameter) provided. Measures taken to maximise sample recovery and ensure representative nature of the samples should be stated.*		
Drill sample recovery	*Whether sample recoveries have been properly recorded and results assessed should be disclosed. In particular the report should state whether a relationship exists between sample recovery and grade or quality and sample bias (e.g. preferential loss/gain of fine/coarse material).*		
Logging	*Whether samples have been logged to a level of detail to support appropriate Mineral Resource estimation, mining studies and metallurgical studies should be confirmed, and whether logging is qualitative or quantitative in nature should be stated. Core (or trench, channel etc.) photography should be included.*		
Other sampling techniques	*Nature and quality of sampling (e.g. cut channels, random chips etc.) and measures taken to ensure sample representativity should be stated. The precise location and unique numbering of each sample should be provided by reference to a coordinate system (which should be stated).*		
Sub-sampling techniques and sample preparation	*For sampling from core, whether cut or sawn or whether quarter, half or all core has been taken in the course of sampling should be stated. If non-core, whether riffled, tube sampled, rotary split etc. and whether split wet or dry. For all sample types, the nature, quality and appropriateness of the sample preparation technique should be described, together with quality control procedures adopted for all sub-sampling stages to maximise representativity of samples.*		

crirsco IOM³

HOW?
WHAT MAKES A CORRECT SAMPLE

- A correct sample is where all particles in a population have the same probability of ending up in the sample
- There is no “industry standard” method, there is no prescription in JORC, NI43-101 or PERC; there is only “general practice”
- In the absence of a correct sampling prescription, the problem becomes how to demonstrate your sampling is correct



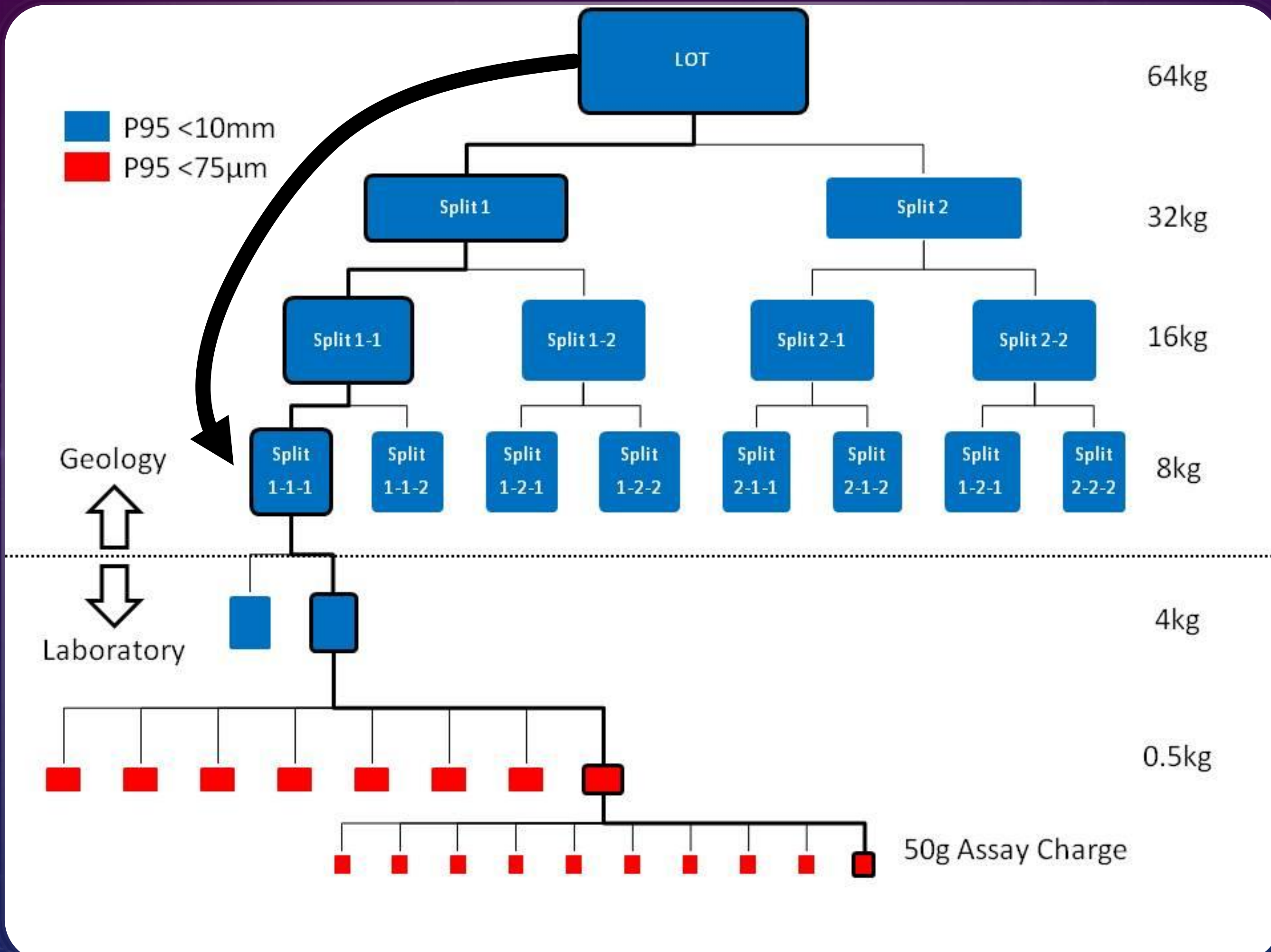
HOW?
RECOVERY

- Loss of critical components
- Did all of the intended target material get recovered
  - Easy with intact extraction methods (e.g. diamond core)
  - Difficult with particulate sampling methods (e.g. percussion, crushing)
- Relationships between recovery and concentration suggest bias

HOW?
PRECISION

- Sampling is a mass reduction problem (50kg → 50g, 40kg → 4g!!) performed by progressive sub-sampling
  - Riffle splitters, rotary splitters, cone splitters, cone and quartering
  - Again, no prescription on how to best reduce the mass

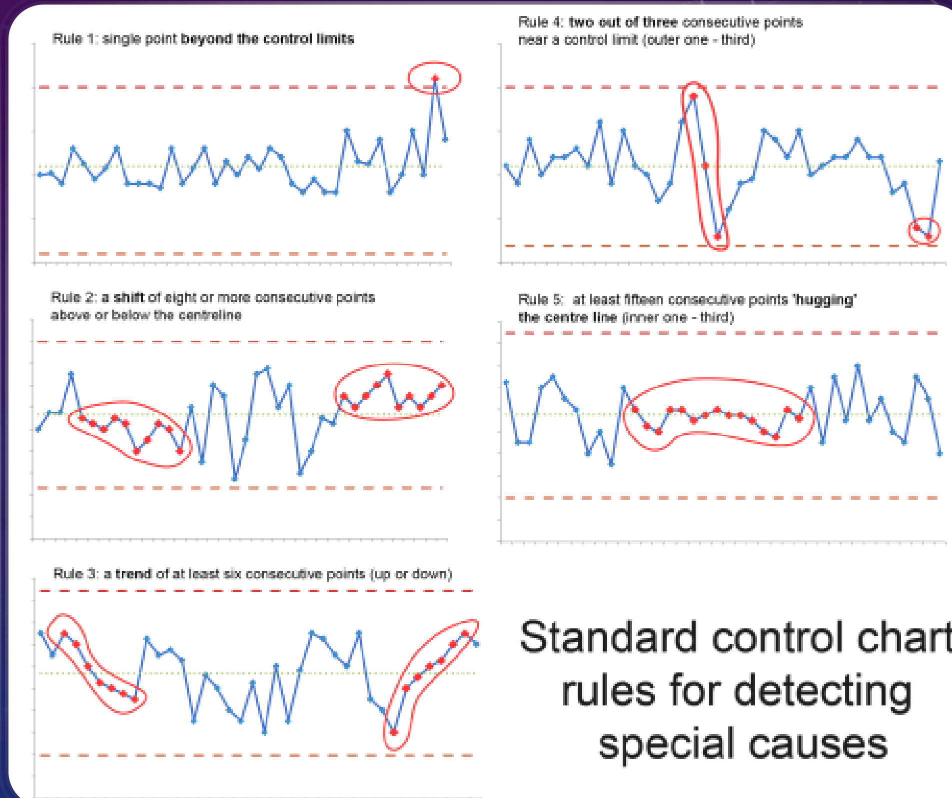
- The possible variation between sub-samples can be broadly determined by duplicate sampling
  - Reduction in mass decreases probability that all particles get represented in final estimate
  - It should be done at each point where mass is reduced and a sub-sample is taken



P95 <10mm
P95 <75µm
LOT
64kg
Split 1
Split 2
32kg
Split 1-1
Split 1-2
Split 2-1
Split 2-2
16kg
Split 1-1-1
Split 1-1-2
Split 1-2-1
Split 1-2-2
Split 2-1-1
Split 2-1-2
Split 1-2-1
Split 2-2-2
8kg
Geology
Laboratory
4kg
0.5kg
50g Assay Charge

HOW? ACCURACY

- The final estimate of critical content is generally an analytical method
- The accuracy of the method and the preparation is required
  - Standards
  - Blanks
- Regular submission in batches



Standard control chart rules for detecting special causes

EXAMPLE EXPLORATION DRILLING

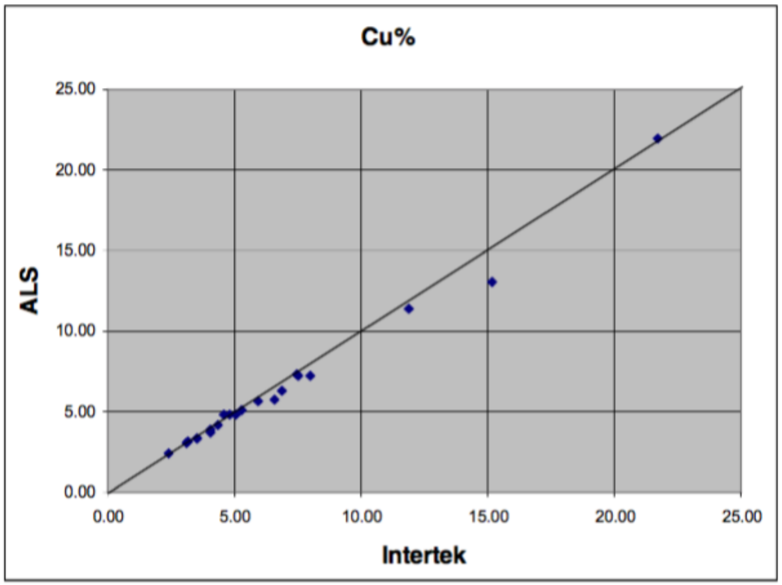


Figure 18. Check assays by ALS vs Intertek

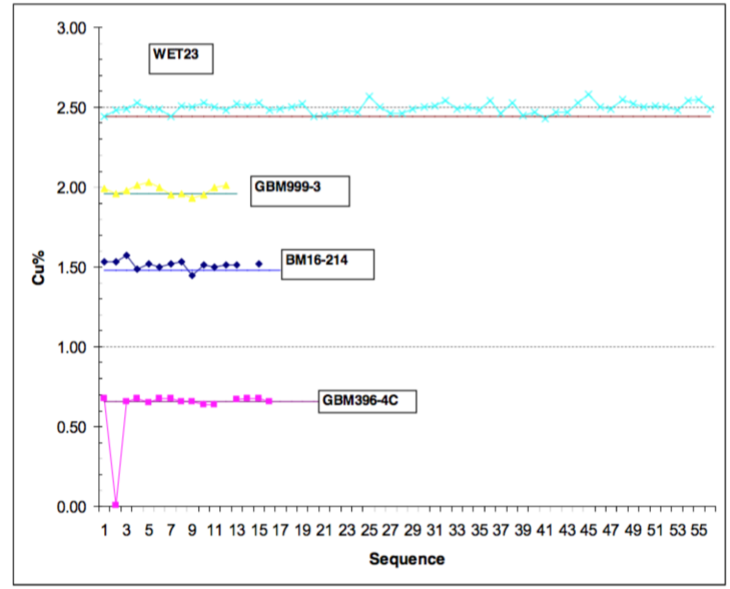
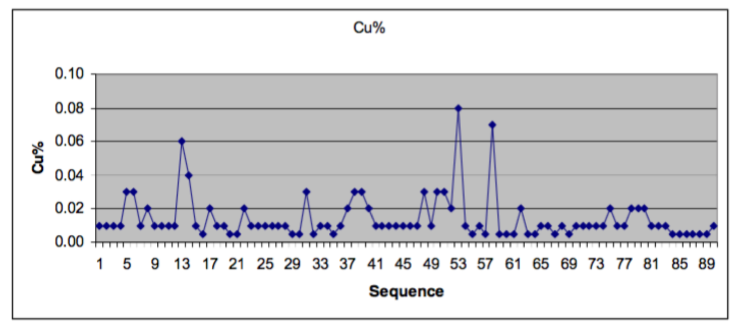


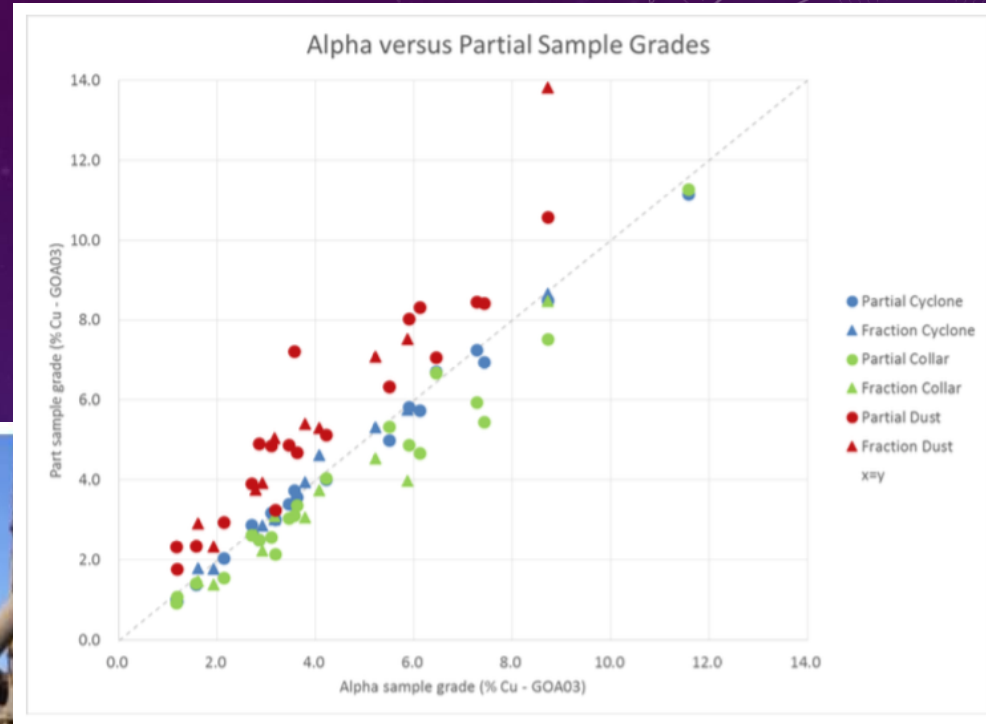
Figure 20. Control chart for standards
(lines mark Recommended Values)

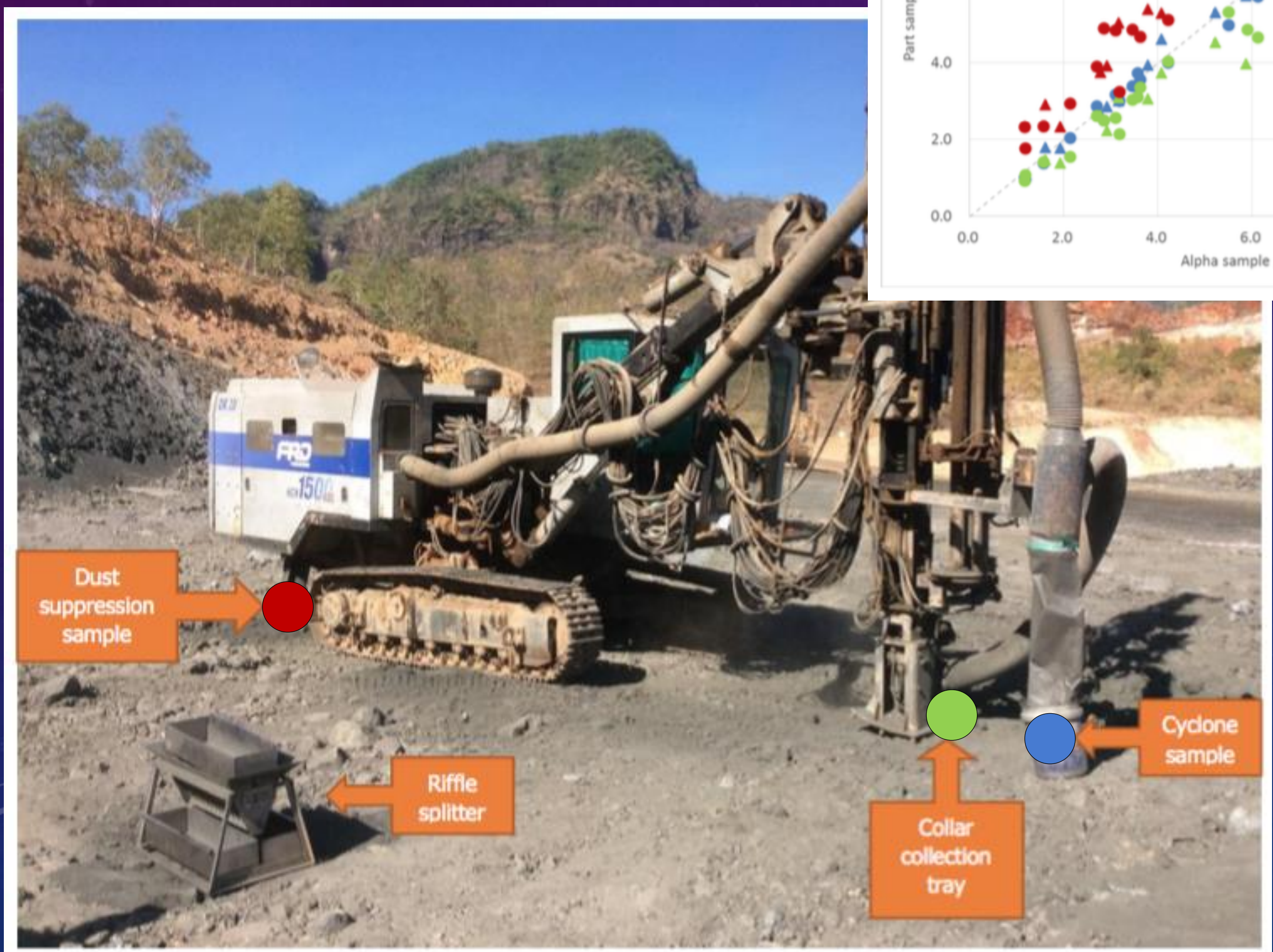


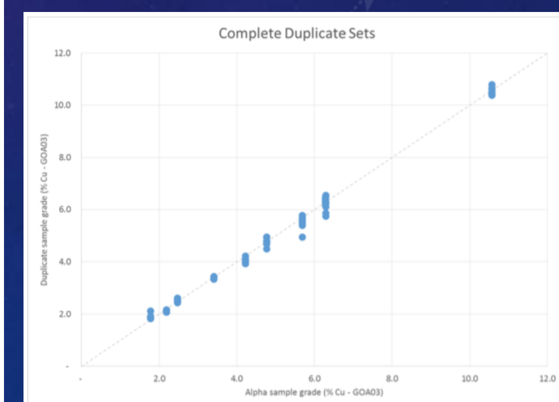
Criteria	Sludge Cu%	Core Cu%	Core Rec%	N
Recovery < 80%	0.97	0.52	59	38
Recovery > 80%	1.02	1.33	95	42

Table 7. Sludge samples

EXAMPLE
MINE DRILLING

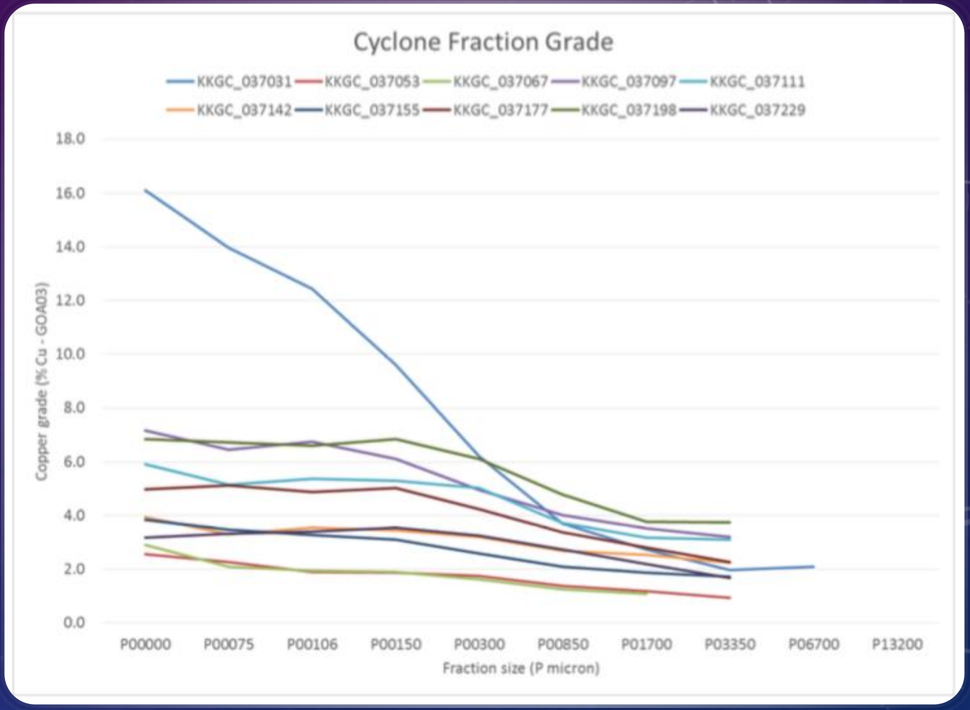




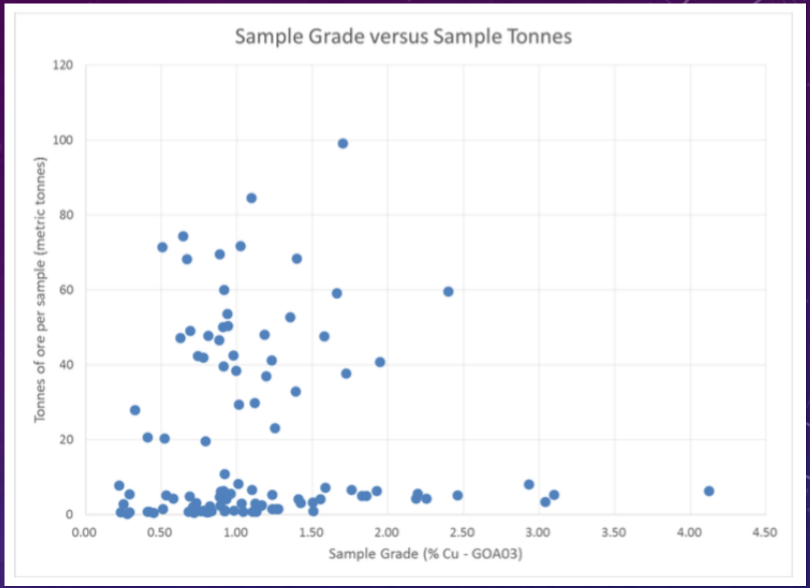


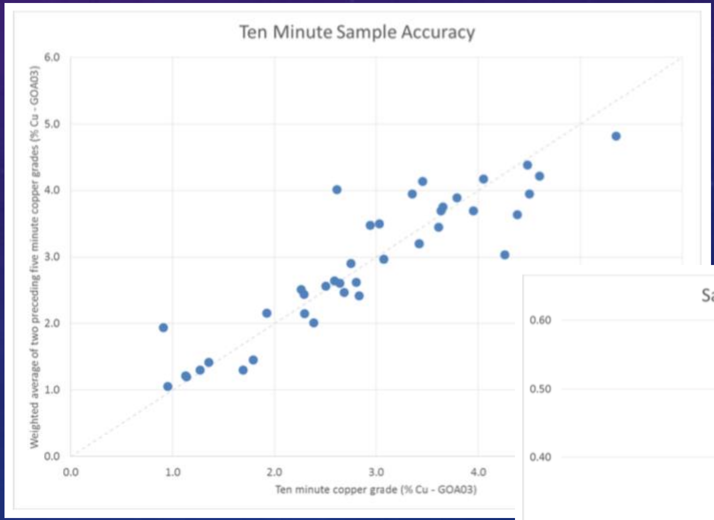
EXAMPLE
FRACTION ANALYSIS

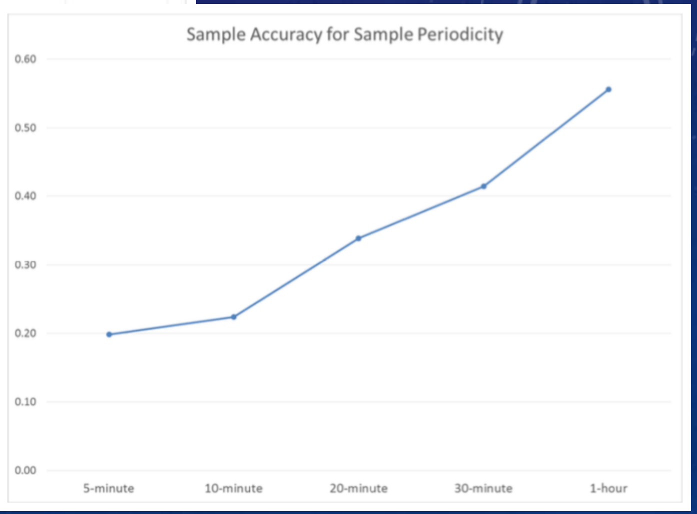
- Deportment of critical content confirms the issue
- The grade of finest material is at least double that of coarsest
- Fragmentation of the ore is going to cause grade segregation



EXAMPLE SEGREGATION







EXAMPLE
THE RESULT

- The crusher grades were 20-30% lower than that predicted from the grade control model
- An audit found that the grade control sampling appeared acceptable to needs and the grade control model agreed within 5% of the reserve model
- The crushing sampling was inadequate to accurately estimate grade of ore stacked on heap leach pads

IN CLOSING

- Some consequences of incorrect sampling
  - Unable to publicly report results
  - Misdirected exploration funds
  - Poor ore/waste delineation
  - Overestimate/Underestimate of critical data model
- The additional costs for demonstrating representative sampling should never be considered as “nice to have” but as a necessity

THANK YOU

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