HOME

Bit to Bag – The Importance of a Total Coordinated System in Reverse Circulation Drilling

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ABSTRACT

The use of reverse circulation (RC) drilling for grade control sample collection was selected by the Pueblo Viejo Mine Geology department at the recommencement of the operation in 2010. This method was selected because it allows:

- for multi-bench drilling (60 m hole depth, four benches of mining) to aid mine planning and provide a detailed close spaced drill data comparison with the reserve model
- angled drill holes to optimise the drill hole interception of the vertically controlled mineralisation
- dry sample collection in areas of excessive surface and groundwater
- mining operations to commence with the long assay return period (due to the need for the samples to be shipped overseas for analysis) until the on-site laboratory is operational.

To date, 118 302 m of drilling has been completed throughout the operations of two open pits: Monte Negro and Moore. Two drill rigs (contractor and site-owned and operated) with three generations of sampling systems have been used to date. Throughout the drilling a 20 per cent quality assurance, quality control (QAQC) sample check (blanks, field duplicates and standards) have been used to check the drilling and laboratories performance. In addition, a total of 1104 fines samples were collected to compare the drill chip samples collected and the fines lost with two of the sample systems used.

The drilling to date has highlighted the need for a complete and coordinated system to be used before sufficient confidence in the quality of the samples collected is achieved.

The complete system must be set-up and coordinated to obtain the best quality sample possible. This complete package includes:

- drill bit size and shape for the rock being drilled and mineralisation targeted
- face sampling hammers with the correctly sized hammer shrouds
- sample hose routing to reduce sample flow turbulence and choking
- blow-down valves to eliminate drill hole water that has entered the drill string during rod changes
- correct drilling techniques targeting sample quality
- a sample system that captures the fines for inclusion into the sample.

These improvements can be obtained without reducing the drilling rates.

The measurements required to demonstrate the improvement in the sample quality will be the focus of future work within the department.

INTRODUCTION

Two RC drilling campaigns totalling 118 302 m were undertaken at the Pueblo Viejo Gold operation from early 2010 until April 2012. A regular review of the QAQC data was undertaken to check the performance of the laboratories and sample quality. The field duplicate sample is taken to test the assay reproducibility to assist in determining the representativeness of the samples produced. These field duplicate samples were taken at a frequency of one in ten or one in 15 samples through the drilling programs. In total, 4299 field duplicate pairs have been used.

The initial drilling program was undertaken by a contractor drilling company and consisted of 61 476 m of drilling. The drilling contractor performed at a high standard with their drilling and sample presentation. They utilised a conventional cyclone and three tiered splitter sampling system until the Rotaport cone splitting system could be repaired and

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fitted to the drill rig. The Rotaport cone splitter utilised a dust filter system to reduce dust created by the drilling activities. The dust that normally escapes from the top of the conventional cyclone system was ducted into the dust filter and was periodically discharged onto the ground. This system functioned well and significantly reduced the dust at the drilling rig during operations. A sampling campaign was undertaken to sample this drilling dust for comparison with the drill hole assays. The comparison for 1104 drill holes indicated that the fines being collected in this dust system contained different grades to the drill hole samples.

During 2011, an RC drilling rig was purchased by the Pueblo Viejo Mine geology department for grade control drilling. In addition to this drill rig purchase, the Progradex PGX1350R sampling system was chosen due to its advertised ability to capture the drilling fines for inclusion into the sample. This system was the first unit to be used in any operation. The second drilling program continues and approximately 56 826 m of drilling is used in this study.

During the second drilling campaign the total system has been monitored, adjusted and modified with the aim of improving the sample quality. Since April 2012, the total system has been operating as required and producing a sample we believe is of high quality.

The difficulty in measuring the improvement in quality is the focus for future studies being undertaken. The traditional review of the field duplicate assay data does not provide the total picture on the sample quality.

This presentation of the results of the drilling is aimed to assist the department in determining better methods for the monitoring of the sample quality.

LOCATION, HISTORY AND GEOLOGICAL SUMMARY

The Pueblo Viejo Gold Operation (Joint Venture Barrick Gold 60 per cent and Goldcorp 40 per cent) is located within the central portion of the Dominican Republic on the Caribbean Island of Hispanola, in the province of Sanchez Ramirez (Figure 1). The project is 15 km west of the provincial capital of Cotui and approximately 100 km north-west of the capital Santo Domingo.

FIG 1 - Location map of the Pueblo Viejo project in the Dominican Republic.

The earliest records of Spanish mine workings at Pueblo Viejo date from 1505, where they mined the deposit until 1525. The mine was abandoned in favour of newly discovered deposits on the American mainland.

In 1969, Rosario Resources Corporation of New York optioned the property and commenced exploration activities. These activities included targeting the outcropping sulfide veins in the stream valleys. As the exploration activities progressed out of the valleys, the oxide portion (up to 80 m thick) of the deposit was discovered. In 1972, Rosario Dominicana S A was incorporated (40 per cent Rosario, 40 per cent Simplot Industries and 20 per cent Dominican Republic Central Bank) and commenced construction of the mine in 1973. Mining commenced in 1975 on the Moore Deposit. Mining, processing and exploration continued until July 1999, when with the oxide portions of the orebodies exhausted, poor sulfide recoveries of the metals resulted in the operation being shut down.

During 24 years of production the operation produced in total 5.5 Moz of gold and 25.2 Moz of silver.

In 2001, the Dominican Government conducted an auction for the site and Placer Dome Inc won the bid to evaluate the property.

Placer Dome Inc completed a feasibility study in 2005 and the project was approved. Barrick Gold Corporation acquired Placer in 2006 and commenced a project review in March 2006. In February 2008, the project commenced construction of the current Pueblo Viejo Project (Barrick Gold 60 per cent and Goldcorp 40 per cent).

The Pueblo Viejo precious and base metal deposit is classified as a Cretaceous high sulfidation epithermal gold, silver, copper and zinc deposit. It was formed in subvertical funnel-shaped alteration envelopes where the hydrothermal fluids migrated upwards and laterally along permeable horizons, depositing the precious metals.

The deposit is hosted in andesitic volcanic, andesitic volcaniclastics and carbonaceous sediments.

The hydrothermal alteration associated with the mineralisation consists of a core of silica, pyrophyllite, pyrite, koalinite and alunite. The silica enriched alteration zones are surrounded by a halo of quartz-pyrophyllite and pyrophyllite alteration.

Mineralisation is predominantly hosted in pyrite with lesser amounts of sphalerite and energite. The pyrite mineralisation occurs as disseminations, layers, replacements and veins. The sphalerite and enargite mineralisation is primarily found in veins.

The gold occurs as native gold, sylvanite ($AuAgTe_4$) and aurostibite ($AuSb_2$). The principal carrier of gold is pyrite where the submicroscopic gold occurs in colloidal size micro-inclusions (less than 0.5 μm) (Pueblo Viejo Dominicana Corporation, 2007).

At the end of 2011, Reserves for the Pueblo Viejo deposit, within the final pit design containing a total tonnage of approximately 619.8 Mt, consisted of approximately 25.29 Moz of gold, 160.2 Moz of silver and 590.5 Mp of copper. The final pit contains approximately 285.3 Mt of ore and is constrained by the current tailings dam capacity.

OPERATION SUMMARY AND GRADE CONTROL PLAN

The operation's current estimated mining life is approximately 20 years (with a further 12 years of processing life postmining operations) for the gold and precious metal pits. The mining operation commenced in September 2010, and to date approximately 15 Mt of ore containing approximately 1.7 Moz of gold has been stockpiled (May 2012) for processing.

The RC drilling is undertaken on a variably spaced grid (15 m north-south × 10 m east-west to 30 m north-south by 12.5 m east west) with angled (60°) drill holes down to 60 m in depth. The drilling is sampled on 2 m intervals. These are geologically logged before transport to the on-site sample preparation laboratory. The samples are prepared before being dispatched to an offsite laboratory (ALS Peru) for analysis (Table 1). The current assay turnaround time is approximately 25 to 30 days. A complete on-site laboratory is scheduled for the operation during 2012.

TABLE 1

Grade control sample elements analysed.

Principal assays used for the grade control system	Additional assays received from the analysis
Au (g/t), Ag (ppm), Cu (ppm), Zn (ppm) and S (%)	Al, As, B, Ba, Bi, C, Ca, Cd, Co, Cr, Fe, Hg, K, La, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Sr, Th, Ti, U, V and Zr

The geological logging is combined with the assay analysis and loaded into conditional simulation software for ore block definition. The principal elements used in the revenue calculation within the grade control system are Au, Ag, Cu, Zn and S. In addition we are modelling Hg and K.

FIG 2 - (Top left) conventional Schramm cyclone with three-tiered splitter; (bottom left) S200 emission filter; (centre) drill rig with Rotaport sampling system.

GRADE CONTROL DRILLING

2010 program reverse circulation drilling program

RC Grade Control drilling commenced on 13 January 2010 and concluded on 30 November 2010.

During 2010, a total of 61 476 m was drilled within the Monte Negro and Moore open pits. The sampling equipment utilised during this campaign was (Figure 2):

- a conventional cyclone with a three-tier riffle splitter
- a Rotaport sampling system with S200 emission filter.

QAQC traditional field duplicate results

Throughout the drilling a periodic review of the QAQC assay data for the field duplicate samples was undertaken. Comparisons across the different set-ups was based around the analysis of the paired data; this is shown in the half absolute relative difference (HARD) plots. A sample repeatability index (SRI) where the HARD plot crosses the 20th percentile was considered as a good indicator of repeatability for a gold deposit (Sheldon, 2004).

The field duplicate data in Figures 3 and 4 shows a reasonable correlation for both systems. It does appear that the conventional cyclone system gives a better correlation between the primary and duplicate samples. At this time it was believed that the sample quality was high, and good confidence could be placed in the assay results from both systems.

During the operation of this sampling system the sampling of the fines loss was undertaken.

The Rotaport sample system was used throughout the majority of the drilling because it has the following advantages over the conventional cyclone with three-tiered splitter:

- significantly reduced the manual handling requirements for the sampler personnel
- significantly reduced the dust levels at the drill rig (dust normally escaping at the top of the cyclone was piped to the dust collector)
- produced relatively uniform sample weights that could be adjusted to the desired weights for the laboratory.

The system still had problems when:

- moist samples were encountered (clogging of the cone splitter)
- dust was generated below the sampler (material not being captured in the sample bags is discharged onto the ground)
- there was a loss of fines material from the sample.

During the drilling program, samples were collected from the S200 emission filter discharge. This filter captured the

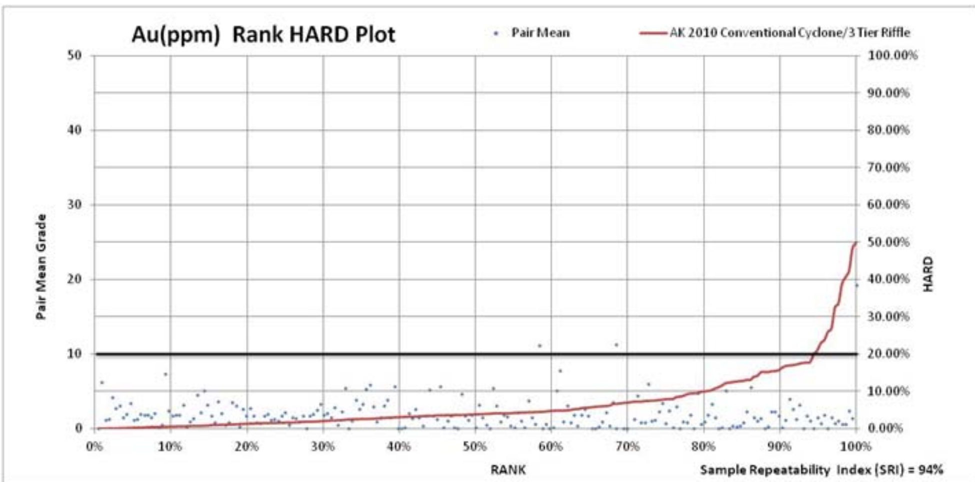

FIG 3 - The 2010 drilling program field duplicate Au half absolute relative difference plot for the conventional cyclone and three-tier splitter system. The data set consists of 216 field duplicate pairs.

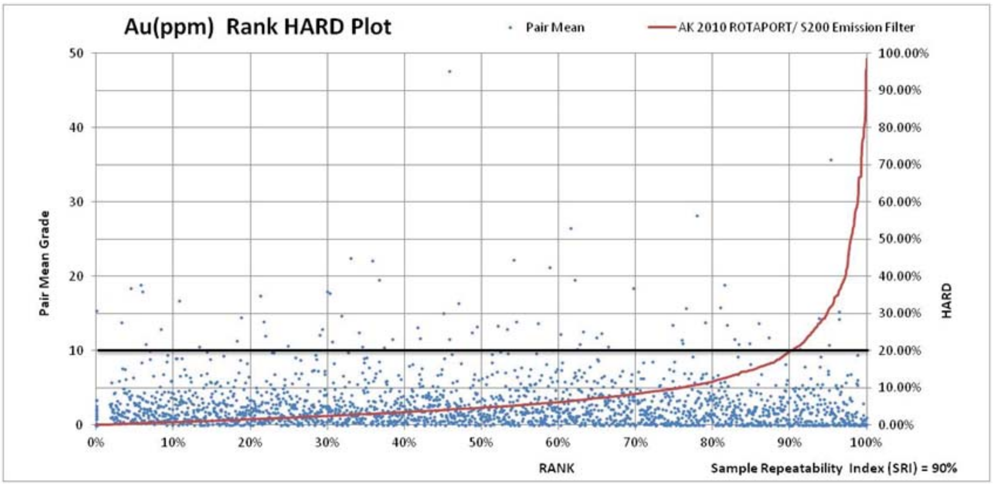

FIG 4 - The 2010 drilling program field duplicate Au half absolute relative difference plot for the Rotaport system. The data set consists of 2307 field duplicate pairs.

fines from the drilling that would normally be discharged to the atmosphere via the top of the conventional cyclone pipe. The filter discharged the fines periodically (when the sensors detected the filters were becoming full) and these were collected for each drill hole. The samples were analysed to compare with the average drill hole assays and the fines data from each hole.

No fines sample weights were recorded for the samples, but it is estimated the collectable samples were in the 10 - 15 kg range (for the 36 m deep holes). Comparing the average fines assays per hole with the average drill hole assays the results, as can be seen in Table 2.

TABLE 2

Comparison of 1104 drill hole fines assays against the corresponding drill hole cuttings assays. In total, 75 per cent of the fines assays are greater in value than the drill hole cuttings value (823 from 1104 total samples).

	Fines	Drill hole	% Fines/drill hole
Au g/t	3.95	2.92	135%
Ag ppm	30.5	25.7	119%
Cu ppm	726	498	146%
Zn ppm	8750	7743	113%
%S	6.05	6.77	89%

This comparison indicates that the fines component of the drill cuttings for the precious metals have a higher-grade than the drill cuttings. This extra grade component in the fines cannot easily be back adjusted to the grade due to the significant weight differences between the samples. The precious metals grade of the drill cuttings is conservative due to the loss of the fines from the sample.

2011 and 2012 reverse circulation drilling programs

In mid-2010, the Pueblo Viejo Mine geology department purchased a Schramm T450 RC drill rig to undertake the grade control and water well drilling for the site. As part of the drilling system, and with the knowledge that the fines generated during drilling contained higher grades, a sampling system that could capture these for incorporation into the sample was required. An extensive review of the known sample systems was undertaken. The only system we could find suitable, as it could incorporate the fines, was the newly released Progradex PGX1350R system.

This drilling commenced in early May 2011, and can be divided into three periods for QAQC data review. These periods are:

1. conventional cyclone with three-tiered splitter
2. PGX1350R system with testing and modifications (required on the drill rig, drill string and the sampling system to improve results)
3. PGX1350R system post-modifications.

Throughout the drilling a periodic review of the QAQC assay data for the field duplicate samples was undertaken. This data is presented in Figures 5 to 7.

The field modifications undertaken on the PGX1350R system included:

- The addition of a blowdown valve on the drill to expel water that enters the drill hole during rod changes. This water, if not expelled, is blown through the sample system and when drilling recommenced caused sample flow problems. The system would require regular cleaning, resulting in a loss of drill time.
- The distribution nozzle drive motor was relocated from inside the sample zone to below the cone and outside of the area. This relocation eliminated the loss of power to the motor due to clogging of the drive chain by sample particals.
- The realignment of sample hoses reducing sharp bends that cause airflow turbulence. This reduces the air back pressures and reduces air loss via the outside return.
- Matching of the drill bit size with the hammer shroud to reduce outside air return losses.

The field duplicate data in Figures 5 to 7 shows a reasonable correlation for all three systems. The conventional cyclone system gives the best correlation between the primary and duplicate samples of the three data sets reviewed from this drilling campaign.

The use of the field duplicate statistics alone would suggest that the conventional cyclone produces the best correlation. This conclusion is incorrect, knowing the field conditions during the drilling and sampling.

Actual drilling, using the conventional cyclone and three-tiered riffle splitter, is shown in Figure 8. The operations create significant dust from the drill collar and cyclone fines discharge pipe. Excessive manual handling is required by the sampling personnel in their sampling duties. Observation of the cyclone and regular splitting process reveals significant contamination occurs between samples. The system has no

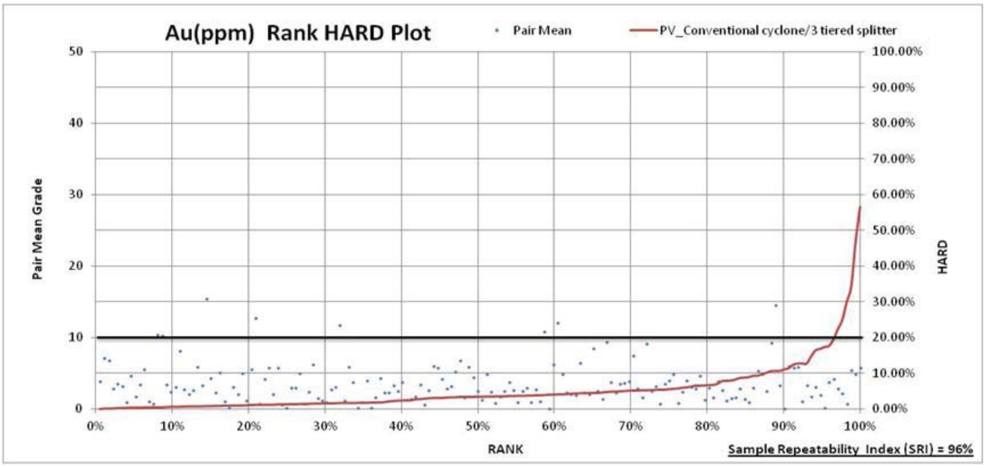

FIG 5 - The 2011 and 2012 drilling program field duplicate Au half absolute relative difference plot for the conventional cyclone with three-tiered splitter system. The data set consists of 172 field duplicate pairs.

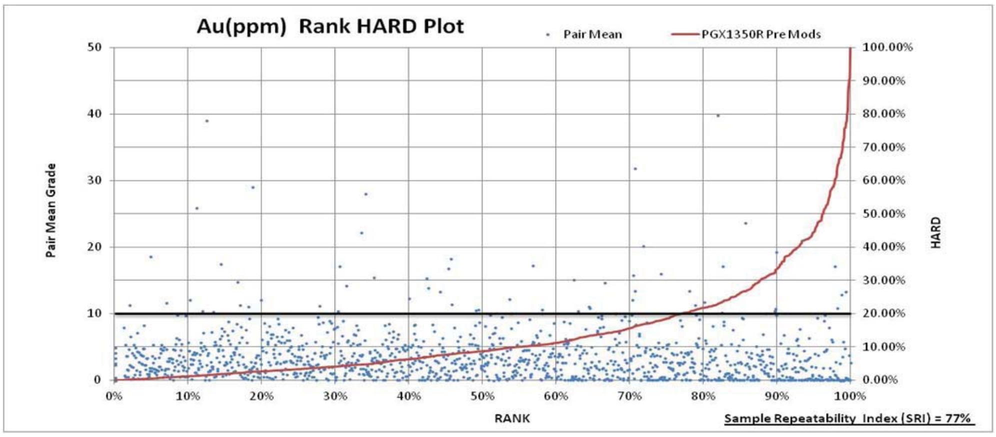

FIG 6 - The 2011 and 2012 drilling program field duplicate Au half absolute relative difference plot for the PGX1350R system (during modifications). The data set consists of 1385 field duplicate pairs.

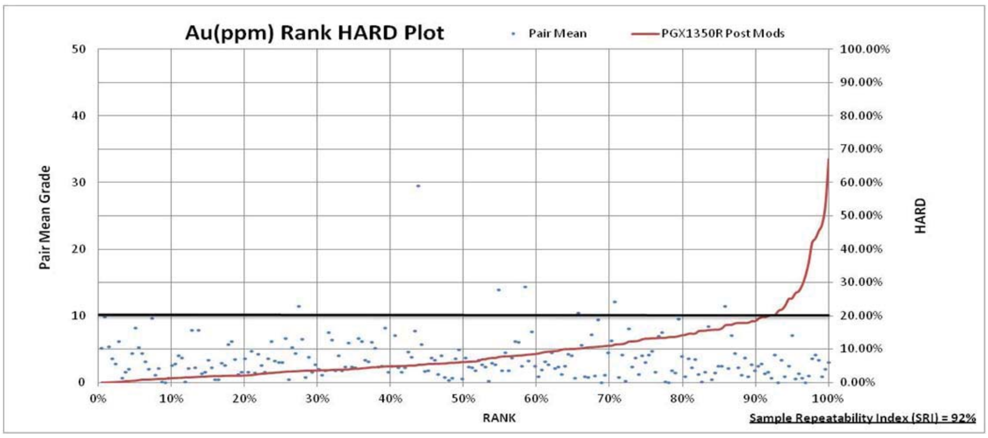

FIG 7 - The 2011 and 2012 drilling program field duplicate Au half absolute relative difference plot of the PGX1350R system (post modifications). This data set consists of 219 data field duplicate points.

sample gates, so the sample stream is continuous. The actual samples taken are dependant upon the time the sampler personnel change the bags.

Actual drilling using the PGX1350R sampling system is shown in Figure 9. This photograph was taken in Monte Negro pit after a normal storm event. Normal drilling encounters ground and surface water. The use of a blow-down valve is required to eject the water from the hole during rod changes, so it does not pass through the sample system. Note the surface water in the pit and the dry sample cone below the sample system. The face sampling bit matches the bit shroud, reducing the fines and air loss in the outside return. The sample hose connections are planar to the joints where possible (no 90° bends that create turbulence and back pressure).

This system, as it is designed and currently working, is an improvement on the Rotaport system for:

FIG 8 - Drilling operations utilising the conventional cyclone and three-tiered splitter system.

FIG 9 - Drilling operations using the PGX1350R sampling system.

- field duplicate results
- reducing the manual handling requirements for the sampler personnel
- reducing the number of personnel around the drilling during drilling operations (bags changed at rod change instead of during drilling)
- significantly reducing dust from the drilling operations
- producing a consistent sample weight for primary and field duplicate samples
- incorporating the drill fines in the drill sample.

The system requires:

- blow-down valve to eliminate the water that ingresses into the hole during rod changes
- maintenance and care from drilling personnel
- a system to reduce the dust created from the material as it passes through the sample capture area and onto the ground.

Additional areas that require improvement include:

- removal of dust from below the sample chutes, as the remainder of the drilled interval material is discharged
- reducing the outside return fines.

This comparison does not compare field duplicate sample weights to assist in the determination of the various sampling systems effectiveness, due to:

- incomplete data sets for the different drilling campaigns with the different sampling systems
- a portion of the field duplicate sample were used for logging purposes (reducing the weight of the field duplicate).

CONCLUSION

A total of 118 302 m of RC drilling was undertaken by a contractor and Pueblo Viejo personnel, two different RC drilling rigs (Schramm 685 and 450 machines), three different generations of sampling systems (conventional cyclone with three-tiered splitters, Rotaport cones splitter and the PGX1350R) and numerous combinations of drilling setups has allowed the determination of the optimum drilling and sampling setup for sample quality at Pueblo Viejo.

The RC grade control drilling was undertaken to produce the sample for analysis. The work to date has been targeted to improve the sample quality resulting from the drilling.

The optimum set-up on the site drill rig involves a coordinated system from the drill bit through the sample system and finally into the sample bag . This set-up is designed to produce the required sample quality and does not reduce the drilling performance.

Our optimum system includes:

- Schramm T450 RC drill rig with the Sullair 1050/350 compressor
- face sampling hammers with matching bit size and shroud diameter
- blow-down valve
- sample hoses aligned so as to reduce flow turbulence
- Progradex sampling system.

This system is currently producing a consistent sample that includes the drill fines allowing a high confidence level in the sample being submitted into the laboratory.

To date, the Pueblo Viejo operations processing plant has not commenced, allowing the mine to mill reconciliations a critical judgement of the ore control total system (of which the assay data is a significant part).

In field drilling observations, the inclusion of the drill generated fines into the sample and a review of the field duplicate data indicates the current drill, drill string, sample routing and sampling system is providing a quality sample for dispatch to the laboratory.

The use of the field duplicate assay data alone cannot be used to determine the sample quality. The sample material lost during drilling operations (fines and outside return) reduces the material being collected as the sample. This loss of material may be significant and thus, render the conventional methodology of field duplicate data comparisons for sample quality determinations misleading.

With sample analysis costs of US$ 25 - 30 per sample and annual total drilling assay costs of US$1 - 1.5 M confidence that sample quality is high is critical. The efforts and costs to produce these high quality samples are justified with the knowledge that the downstream effects of poor samples and the decisions made from them can result in the loss of profits and increase in production costs.

Additional studies of the sample weights, granulometrics and size fraction weights will be undertaken to assist in establishing the criteria required for sample quality.

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