Earthlab

QAQC Report

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Volspruit South Body Resource Recreation

Pan Palladium South Africa (Pty) Ltd

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1 INTRODUCTION

This document contains a comprehensive report detailing the quality assurance and quality control implemented for the South Body on Volspruit 326KR.

The farm Volspruit 326KR has been the subject of numerous exploration campaigns, including African Metals Corporation (Amcor), Anglo American Corporation (AA), Shell, Rio Tinto Zinc (RTZ), Genmin, and Pan Palladium South Africa. These campaigns took place over 60 years, starting in the 1950s and ending in 2010.

1.1 Assay Quality Verification Procedure

The South Body drill hole assay results used in this document were supplied by Pan Palladium (Pty) Ltd (PPD) and have undergone a series of verifications and validations as part of quality control and assurance. The historic measures undertaken during the sampling process had not been well defined in the historical reports and can only be approximated from the data received from PPD, however, all measures were taken by Earthlab Technical Division (Pty) Ltd ('Earthlab') to ensure reliable and quality data can be used for any future resource modelling.

For quality control purposes, a relevant percentage of the sample consignment per drill hole must comprise certified reference materials. These are equally divided into standards and blanks. Standards are selected for a particular exploration project based on the relevant match of the matrix. Standards contain certified PGE content and are inserted at set intervals into a consignment to test the accuracy of assay results received from the primary laboratory. Blanks contain negligible PGE content and are used to detect contamination of samples during laboratory preparation and analysis.

Secondly, a precision analysis is undertaken on all exploration samples submitted. This is done using a process called twinstream, where a sample is milled into powder and split into two where they are then assayed separately. In cases where exploration samples have been duplicated in the field, either half diamond drill core is split into two equal weighted quarter core samples, or RC drill chips for a sample interval are run through a riffle split apparatus to acquire two representative equally weighted samples.

Finally, quality control analyses are performed on assay results, the results of which are documented in this report covering data migrated from the Access Database (Grasvally Project Borehole Database) to a secure and validated SABLE® 7.0 SQL Database. Unfortunately, due to the structure and design of the historic database, especially regarding sampling quality assurance i.e., submitted control samples, large portions of standardised and required data for these tables could not be stored onto the SABLE® 7.0 SQL Database either due to missing data or incorrect data type per field. Therefore, some of these data have been manually cleaned and formatted to be used in this assessment directly from the Access Database.

Python programming, with the aid of several data analytical and statistical modules (NumPy, Pandas, SciPy, Matplotlib) has been used, with custom scripts written by Earthlab's Database Manager, for the purpose of this evaluation.

2 DRILL HOLES ANALYSED

The Grasvalley Projects consists of drill hole data from two separately identified ore bodies, the North Body and the South Body. This document contains drill hole information on the South Body which is further separated into three projects: Grasvalley 'GVS', South Definition and South Infill.

A total of 76 drill holes were analysed for the South Body sample assay verification and all relevant data was extracted from the historic Microsoft Access Database, which was subsequently migrated to SABLE® 7.0 SQL Database for resource estimation purposes. All the samples were analysed by ALS Chemex as well as Set Point Laboratories.

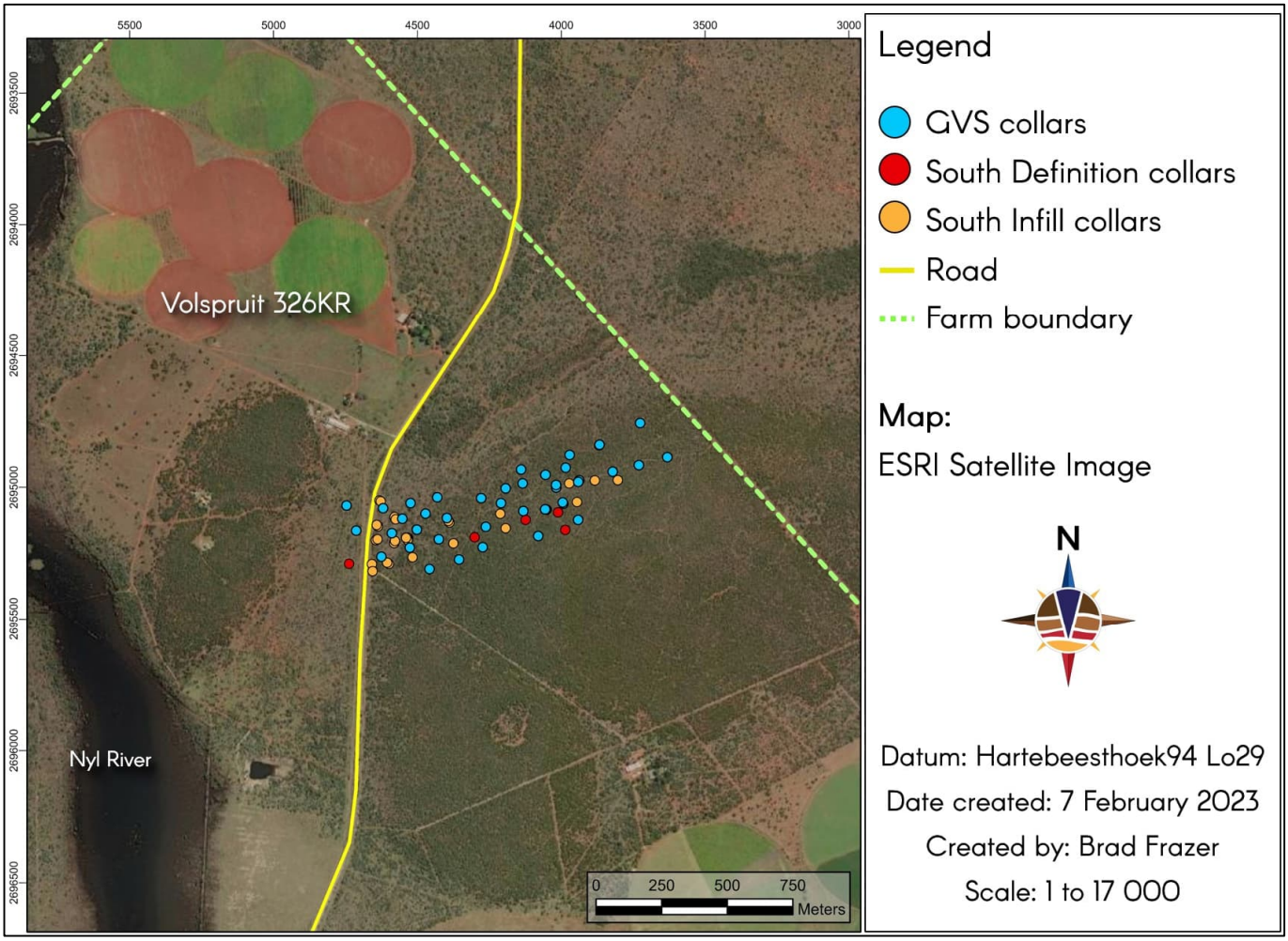

Figure 1 Geospatial map showing the positions of all the Grasvalley South pit projects.

3 QUALITY CONTROL ANALYSIS

This report contains all the parameters and graphical results used to assess the quality of the historic assay results.

3.1 Accuracy Analysis

Each project defined within the South Body has been subjected to quality verification standards by assessing the accuracy of the control samples submitted to the laboratories. This includes blanks and certified reference materials and, in some instances, non-certified reference materials. Blank samples that fall above 10x the detection limit and certified reference samples that fall outside the third standard deviation upper and lower limits of statistical control will be flagged and labelled as a failed sample. Each control sample is separated by element and will undergo this procedure to produce a list of failed samples. The failed samples are then used to produce a final list of primary samples that can be used for the resource estimation process.

Two control samples SARM7 and QC93 have been identified within the historic exploration programs, where the above criteria have been adjusted to pragmatically and reasonably represent the accuracy of the assay results reported by Set Point Laboratories. SARM7 is a CRM produced in 1975 and reported without the sophistication of today's modern analytical techniques. The 95% confidence limits set by SARM7s certificate elemental values are incredibly narrow, representing only 1.20%-4.84% of the accepted value for the PGEs. This tolerance may be considered too restrictive when looking at the modern-day AMIS-certified reference material tolerance limits. Therefore, fourteen different AMIS standards were used to measure the percentage that two and three standard deviations are of the accepted value. Approximately 10% of the accepted value can be considered a representative of the second standard deviation, where 15% of the accepted value can be considered a representative of the third standard deviation. SARM7 will be analysed according to this approach.

3.1.1 CRM Material Used

It is important to note that multiple in-house CRMs were used during the South Body drilling campaign, most of which did not have certificates of analysis available when conducting this report. These CRMs have not been included in this analysis due to the lack of information regarding their acceptance values. Table 1 below lists the CRMs used in the accuracy analysis which have available certificates detailing all necessary acceptance values.

Table 1 List of CRMs used for the South Body Drilling campaign.

Certified Reference Material	Description
AMIS0067	Platinum (PGM) Merensky Reef Ore Bushveld Complex, South Africa
AMIS0099	Platinum (PGM) Merensky Reef Ore Bushveld Complex, South Africa
AMIS0170	Platinum (PGM) Platreef Ore Bushveld Complex, South Africa
QC93	Material sourced from bulk sample of mineralised body of interest, Bushveld Complex, South Africa
SARM7	Platinum (PGM) Merensky Reef Bushveld Complex, South Africa
AMIS0577	Blank silica powder

3.1.2 Summary of Accuracy Analysis

The results for the accuracy analysis are summarised in the tables below. The samples were analysed and have been separated into their respective projects and analytes. Platinum and palladium control results show good accuracy throughout the 3 projects undertaken over the South Body, where 93.16% and 90.04% of the control samples fall within tolerance limits respectively. The accuracy of gold, copper, and nickel, however, were less convincing where 80.82%, 68.47% and 66.16% of the control results fall within the accepted tolerance limits respectively. There are a few considerations that need to be taken into account regarding the poorer performance of the control results of Au, Cu and Ni. Firstly, the certified materials used do not appropriately represent the material of the ore being analysed. Secondly, not all of the CRMs are certified for Au, Cu and Ni analysis methods. Additionally, the exploration sampling method and/or the laboratory analysis method for these elements were not subject to the proper protocols. This would introduce the risk of contamination of the samples which can be seen in Table 2 where there are a large number of failed blank control samples. Lastly, the small number of samples used in the South Definition and South Infill projects make it difficult to represent the true nature of the accuracy analysis as, in some cases, 2 or 3 sample failures in an entire batch may already exceed the accepted tolerance limits.

It should be noted that the Grasvally GVS Project contained only two control materials, SARM7 and QC93, where QC93 was being used for exploration due to budget considerations as SARM7 was deemed too costly. QC93 was produced during the exploration campaign as an internal laboratory reference material and is made up of earlier Volspruit drill hole samples. This reference materials composition and accepted values are unknown and uncertified.

Both the QC93 and SARM7 CRMs show a high percentage of failures for Au (Table 2). SARM7 also shows high failure rates in Cu and Ni which could be attributed to the laboratory not having their analysis machines calibrated correctly as there was clearly recalibration throughout the analysis timeline. This can be seen in Figures 2 and 3 where the precision and accuracy of Cu and Ni improve as the sample analysis progresses. In Figures 4 and 5 there is a positive bias on the reported results for Cu and Pd respectively, leading to additional failures. Since gold, copper, and nickel are expected to only make up a much lower value percentage than platinum and palladium for the South Body, the effect of a higher failure rate for these elements should be minimal.

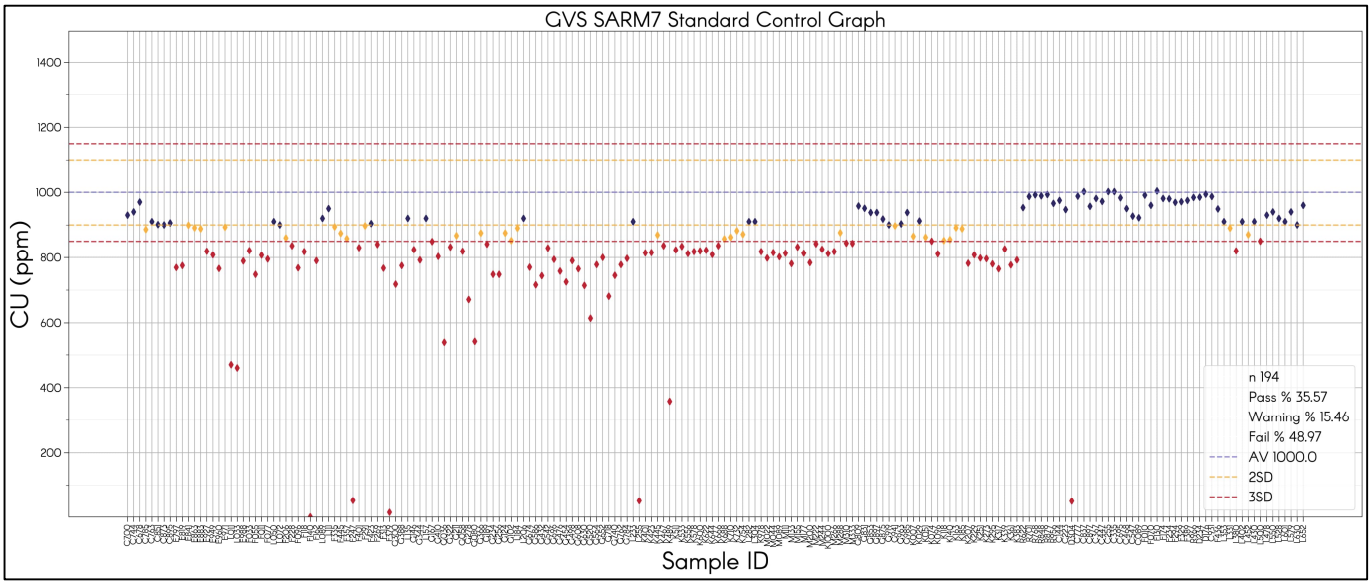

Figure 2 GVS SARM7 control graph for Cu

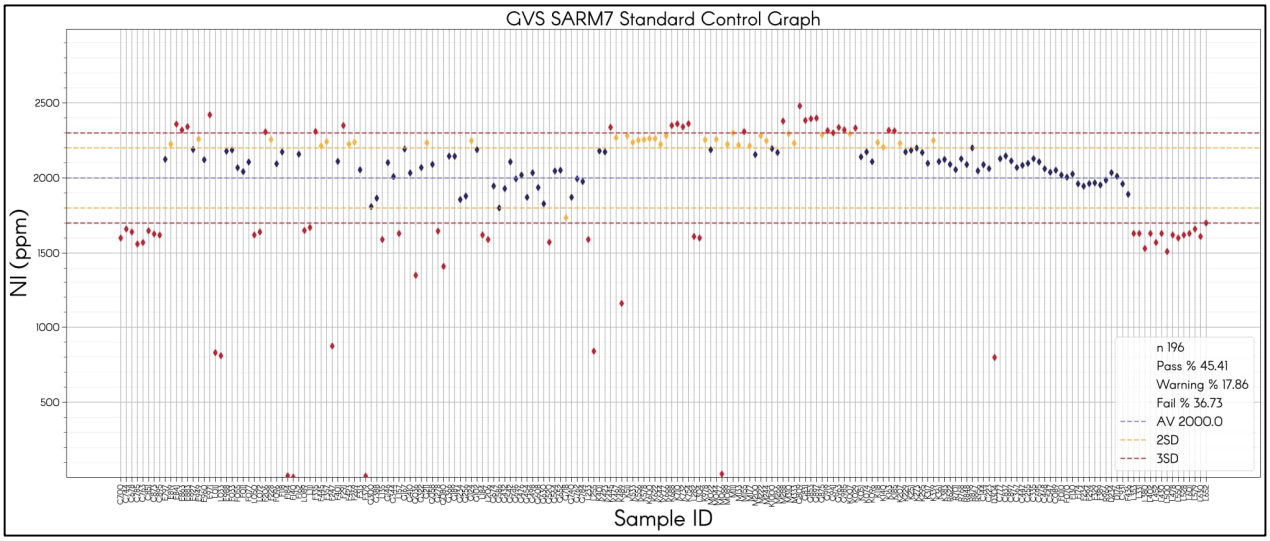

Figure 3 GVS SARM7 control graph for Ni

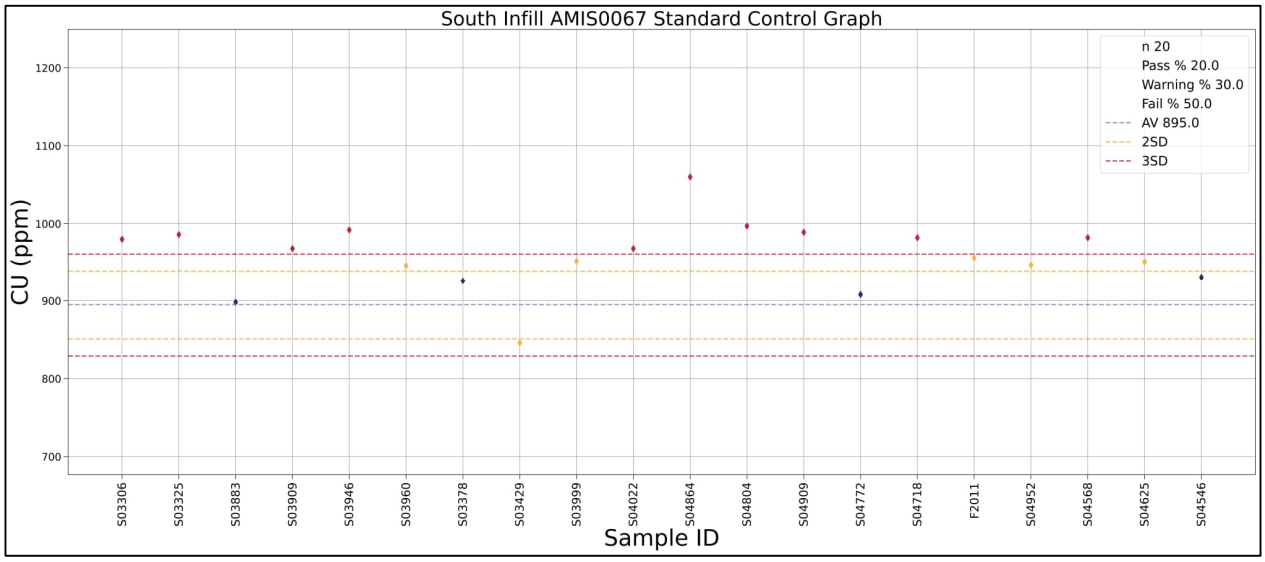

Figure 4 South Infill AMIS0067 control graph for Cu

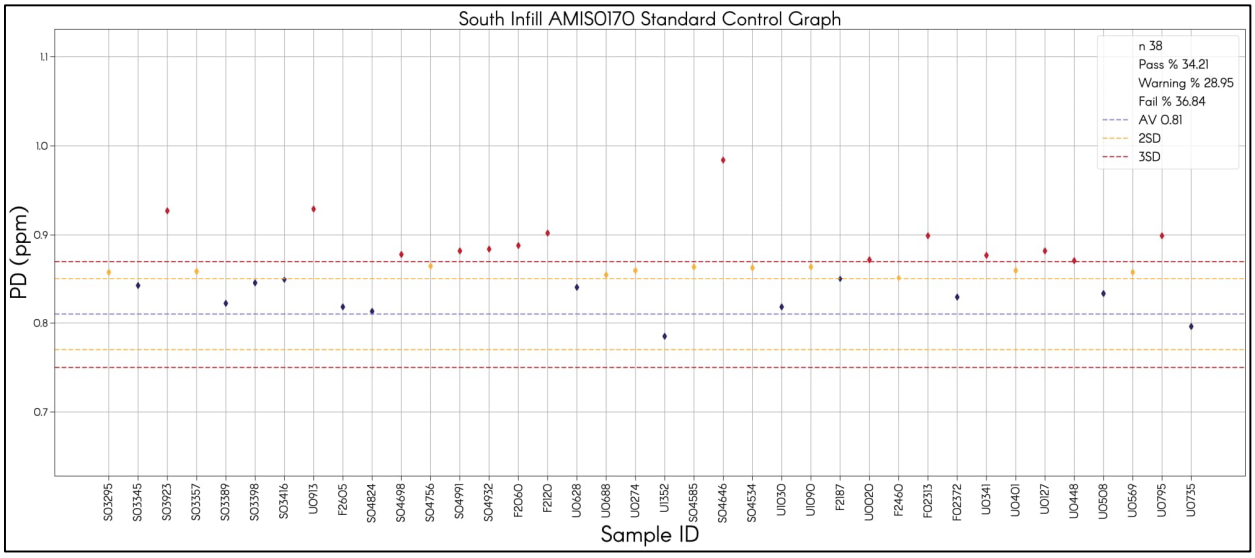

Figure 5 South Infill AMIS0170 control graph for PD

Table 2 Summary of GVS project's control samples analyses for accuracy analysis indicating the total percentage of failed samples per element.

CRM		Pt			Pd			Au			Cu			Ni		
		n	Outliers		n	Outliers		n	Outliers		n	Outliers		n	Outliers	
			n	%		n	%		n	%		n	%		n	%
Standards	QC93	75.00	12.00	16.00	75.00	3.00	4.00	74.00	16.00	21.62	103.00	3.00	2.91	103.00	3.00	2.91
	SARM7	180.00	17.00	9.44	180.00	28.00	15.55	180.00	70.00	38.89	194.00	95.00	48.97	196.00	72.00	36.73
BLANK		130.00	2.00	1.54	121.00	3.00	2.48	101.00	0.00	0.00	247.00	103.00	41.70	268.00	161.00	60.07
TOTAL		385.00	31.00	8.05	376.00	34.00	9.04	355.00	86.00	24.23	544.00	201.00	36.95	567.00	135.00	24.16

Table 3 Summary of South Definition project's control samples analyses for accuracy analysis indicating the total percentage of failed samples per element.

CRM		Pt			Pd			Au			Cu			Ni		
		n	Outliers		n	Outliers		n	Outliers		n	Outliers		n	Outliers	
			n	%		n	%		n	%		n	%		n	%
Standards	AMIS0067	6.00	0.00	0.00	6.00	0.00	0.00	6.00	0.00	0.00	5.00	1.00	20.00	5.00	0.00	0.00
	AMIS0099	10.00	0.00	0.00	10.00	0.00	0.00	10.00	2.00	20.00	10.00	0.00	0.00	10.00	0.00	0.00
	AMIS0170	25.00	0.00	0.00	25.00	2.00	8.00	25.00	4.00	16.00	26.00	0.00	0.00	26.00	0.00	0.00
BLANK		25.00	1.00	4.00	25.00	1.00	4.00	25.00	0.00	0.00	25.00	1.00	4.00	25.00	3.00	12.00
TOTAL		66.00	1.00	1.51	66.00	3.00	4.54	66.00	6.00	9.09	66.00	2.00	3.03	66.00	3.00	4.54

Table 4 Summary of South Infill project's control samples analyses for accuracy analysis indicating the total percentage of failed samples per element.

CRM		Pt			Pd			Au			Cu			Ni		
		n	Outliers		n	Outliers		n	Outliers		n	Outliers		n	Outliers	
			n	%		n	%		n	%		n	%		n	%
Standards	AMIS0067	18.00	1.00	5.55	18.00	1.00	5.55	18.00	1.00	5.55	20.00	10.00	50.00	20.00	0.00	0.00
	AMIS0099	22.00	0.00	0.00	22.00	0.00	0.00	22.00	0.00	0.00	21.00	0.00	0.00	21.00	0.00	0.00
	AMIS0170	38.00	3.00	7.89	38.00	14.00	36.84	38.00	5.00	13.18	40.00	7.00	17.50	40.00	3.00	7.50
BLANK		12.00	1.00	8.33	12.00	1.00	8.33	12.00	0.00	0.00	13.00	2.00	15.38	13.00	4.00	30.77
TOTAL		90.00	5.00	5.55	90.00	16.00	17.78	90.00	6.00	6.67	94.00	19.00	20.21	94.00	7.00	7.45

3.1.3 Data Comparison

Around the same time this campaign was undertaken on the South Body, there was also a drilling campaign taking place on the northern side of the Volspruit farm (North Body). This campaign used the same CRMs in their sampling procedures and the results of the accuracy analysis done on that campaign produced similar results seen above for this South Body campaign. Like this campaign, the North Body results also showed Platinum and Palladium performing the best with both falling within 90% absolute difference. Similarly, gold, copper and nickel showed poorer results despite not being as low as shown above.

3.2 Precision Analysis

The historical database used for this analysis contains two sets of duplicate sample data. One set consists of field duplicates that were physically taken during the sampling phase of the South Infill project. The other set includes pulp duplicates which were generated internally by the laboratory's twinstream process as part of their QAQC protocols. It is important to note that the twinstream pulp duplicates were not recorded in the standard sampling tables of the database and were assigned identical sample IDs to the originally reported results.

The twinstream results have been analysed graphically as XY plots to show regressions with 95% confidence intervals. These graphs will be made available on demand. Twinstream results have also been analysed using the Half Absolute Relative Difference method. Analyses have been separated into their respective elements including Gold (Au), Copper (Cu), Nickel (Ni), Platinum (Pt), and Palladium (Pd). Duplicate result analysis has only been concluded for the South Definition and South Infill Projects, as no results have been recorded for the GVS project. The South Definition project has only pulp duplicate data and South Infill has both pulp and field duplicate data.

3.2.1 Summary of Precision Analysis

Overall, the results analysed show that the repeatability and precision of the pulp duplicate assay results are relatively good for Cu, Ni, Pd and Pt in both projects as 85 – 100% of duplicate samples fall within 15% absolute difference (Table 5). Across all the sampling campaigns done between the two projects, Au shows poor repeatability with 75 – 83% of the pulp duplicate samples falling within 15% absolute difference. This could once again be due to the highly variable presence of Au within this kind of ore body.

The analysed assay results of the field duplicates inevitably show poorer repeatability and precision with only 77% of Au, 85% of Pt and 88% of Pd falling within 25% absolute difference (Table 6). Cu and Ni show relatively better results with both falling within 92% absolute difference. A higher tolerance percentage is used for field duplicates due to potential nugget effects and sampling biases when sampling in field conditions, which can contribute to the poorer results of Au, Pt and Pd.

Some errors in the historic assay quality control data may have arisen when capturing the data into the historic database at the time of importing the assay results or as a result of not capturing these data into the correct format as is stated in the section above. Unfortunately, due to the inherent nature of the received historic database used to perform this analysis, no further investigation can be launched to remove truly unprecise duplicate data, as the method of capture cannot be validated.

Table 5 Summary of South Body twinstream results using Half Absolute Relative Difference outlier method.

Project		Element	No. of Samples	Mean Original	Mean Duplicate	|Mean Difference|	Within 15%	No. of Outliers	Outliers (%)
South Definition Pulp Dups		Au	34	0.02	0.02	0.00	77.78	4	22.22
		Cu	23	315.78	320.83	5.04	100.00	0	0.00
		Ni	23	1717.52	1725.96	8.43	100.00	0	0.00
		Pd	34	0.35	0.35	0.00	100.00	0	0.00
		Pt	34	0.33	0.33	0.00	100.00	0	0.00
South Infill	Diamond Hole Pulp Dups	Au	88	0.02	0.02	0.00	75.96	12	23.08
		Cu	79	332.51	330.8	1.70	96.20	3	3.80
		Ni	79	1713.76	1705.32	8.44	97.47	2	2.53
		Pd	88	0.30	0.29	0.00	95.83	3	3.57
		Pt	88	0.27	0.27	0.01	85.12	11	13.10
	RC Hole Pulp Dups	Au	34	0.06	0.06	0.00	82.35	5	14.71
		Cu	35	896.69	823.14	73.54	100.00	0	0.00
		Ni	35	2425.14	2258.14	167.00	97.14	1	2.86
		Pd	34	1.30	1.43	0.13	97.06	1	2.94
		Pt	34	1.24	1.35	0.11	100.00	0	0.00

	>90%
	>85%
	<85%

Table 6 Summary of South Body twinstream results using Half Absolute Relative Difference outlier method for Field Duplicates.

Project		Element	No. of Samples	Mean Original	Mean Duplicate	|Mean Difference|	Within 25%	No. of Outliers	Outliers (%)
South Infill	RC Hole Field Dups	Au	26	0.06	0.06	0.00	76.92	6.00	23.08
		Cu	26	864.65	752.19	112.46	92.31	2.00	7.69
		Ni	26	2540.58	2377.65	162.92	92.31	2.00	7.69
		Pd	26	1.42	1.35	0.06	88.46	3.00	11.54
		Pt	26	1.37	1.21	0.16	84.62	4.00	15.38

	>90%
	>85%
	<85%

4 APPENDIX

4.1 Evaluation Methodology

Customised geostatistical scripts were developed by Earthlab's Database Manager using Python 3.9.0. to evaluate the quality assurance and quality control for the South Body deposit. The following methods were undertaken to perform the analysis.

4.1.1 Accuracy Analysis

The accuracy results contain all data on inserted control samples throughout the geological exploration campaigns for the South Body and include certified reference materials (CRMs), un-certified reference materials, and blanks. The following steps were taken to do their analysis:

- Extract the relevant datasets from the historic Database and convert them to comma-separated value format.
- Reading and manipulation of data is done using NumPy & Pandas libraries.
- Merge control sample data with assay result data using unique sample IDs.
- Data cleaning and sorting.
- Specify parameters and tolerance limits for the analysis using certificates of the reference materials used.
- Determine samples that are out of statistical control.
- Plotting of control charts using Matplotlib and Seaborn libraries.
- Create a list of all failed samples based on each element.
- Tabulate accuracy data summary.

4.1.2 Twinstream Analysis

Twinstream data analysis of duplicates vs original samples assessing the precision of the data measurements. The following steps were taken to perform this analysis:

- Extract the relevant datasets from the historic Database and convert them to comma-separated value format.
- Reading and manipulation of the data using NumPy & Pandas library.
- Custom data sorting to identify duplicate samples and their corresponding primary samples.
- Further data cleaning.
- Specify the parameters for the analysis.
- Calculate the percentage difference using the Half Absolute Relative Difference (HARD) method.
- Ordering of data by percentile rankings.
- Determination of outlier percentage.
- Plotting of both duplicate vs original data with regressions, and HARD vs percentile rankings.
- Tabulation of the precision data summary.

4.2 Definitions

Term	Description
Accepted Value	The concentration (usually ppm) of the certified element based on the specific certified reference material used
Accuracy	A measure of how close a datum result is to the true value.
Blanks	Reference material (often certified) containing negligible concentrations of the suite of elements being analysed in a specific exploration campaign. They are used to assess laboratory contamination. Tolerance limits are set at 10x the detection limits of the laboratory's equipment.
Certified Reference Material (CRMs)	Samples with known grades were made according to relevant ISO standards. They are inserted without labels randomly in a batch of samples to test the accuracy of the results reported by the laboratories.
Confidence Interval	A range of values is so defined that there is a specified probability that the value of a parameter lies within it.
Detection Limit	The lowest possible limit at which the grade of a sample can be detected. The detection limit is dependent on the laboratory and the analytical method used to report the assay results.
HARD	HARD stands for Half the Absolute Relative Difference between twinstream data. It is used to quantify and measure the percentage of the difference between two given values.
Matplotlib: Python plotting	Matplotlib is a plotting library for the Python programming language and its numerical mathematics extension NumPy.
NumPy	NumPy is a library for the Python programming language, adding support for large, multi-dimensional arrays and matrices, along with a large collection of high-level mathematical functions and operations to these arrays.
Outliers	Records or observations that fall outside the specified parameters for a specific element. Various methods can be used in determining the outliers of a given dataset
Pandas	Pandas is a software library for the Python programming language for large data manipulation and analysis. In particular, it offers data structures and operations for manipulating numerical tables and time series. It is heavily based on NumPy operations.
Precision	Precision, or repeatability, is an assessment of how close several data are to each other after repeated analysis.
Python	Python is an interpreted high-level general-purpose programming language. Its design philosophy emphasises code readability with its use of significant indentation. Its language constructs as well as its object-oriented approach aim to help programmers write clear, logical code for small – large scale projects.
SABLE	SABLE stands for Standardised Approach to Borehole Logging in Exploration. It is the geological database that contains all the geological and analytical data taken from the boreholes during exploration.
Standard Deviation	The quantity expressing by how much the members of a group differ from the mean value of the group
Standards	Certified reference materials with known compositions of specific elements were sent to the laboratories to detect anomalous analyses produced during assaying.
Twinstream	Records or observations of samples that have been prepared, split and analysed separately for precision analysis.

4.3 Tolerance Limits

Table 7 Accuracy Analysis Acceptance Criteria for CRMs.

Certified Reference Materials (CRMs)		
Acceptance/Passed	Warning	Failure/Suspect
Within ±3 Std. Dev. of the Accepted Value	Outside ±2 Std. Dev & Within ±3 Std. Dev. From the Accepted Value	Outside ±3 Std. Dev. From the Accepted Value
SARM7 and QC93 Exceptions. (QC93 has no accepted values, where the mean has been used instead)		
Acceptance/Passed	Warning	Failure/Suspect
SARM7: Within 15% of the accepted value above and below	SARM7: Outside 10% of the accepted value & within 15% of the accepted value	SARM7: Outside 15% of the accepted value above and below
QC93: Within 15% of the accepted value above and below	QC93: Outside 15% of the accepted value & within 22.5% of the accepted value	QC93: Outside 22.5% of the accepted value above and below

Table 8 Accuracy Analysis Acceptance Criteria for Blank Samples

Blank Sample Insertions	
Acceptance/Passed	Failure/Suspect
Within 10x Detection Limit of the Laboratory Equipment	Above 10x Detection Limit of the Laboratory Equipment

4.4 Additional Information

All additional information regarding the raw data, clean data, high resolution images as well as CRM certificates will be made available upon request.