

<b>EXECUTIVE SUMMARY</b>	<b>iii</b>
<b>ACKNOWLEDGEMENTS</b>	<b>v</b>
<b>TABLE OF CONTENTS</b>	<b>vii</b>
<b>LIST OF FIGURES</b>	<b>xi</b>
<b>LIST OF TABLES</b>	<b>xii</b>
<b>ABBREVIATIONS AND ACRONYMS</b>	<b>xiii</b>

<b>1</b>	<b>INTRODUCTION</b>	<b>1-1</b>
1.1	MOTIVATION	1-1
1.2	PROJECT AIMS	1-2
1.2.1	Primary aim	1-2
1.2.2	Secondary aims	1-2
1.3	PROJECT METHODOLOGY	1-2
1.4	OVERVIEW OF THE CHAPTERS	1-3
1.5	GENERAL	1-3
<b>2.</b>	<b>LITERATURE REVIEW</b>	<b>2-1</b>
2.1	INTRODUCTION	2-1
2.2	OVERVIEW OF GEOCHEMICAL SAMPLING AND ANALYSIS	2-1
2.2.1	Stages in geochemical sampling and analytical processes	2-2
2.2.2	Sampling	2-2
2.2.3	Sample preparation	2-6
2.2.4	Analyses	2-6
2.2.5	Statistical inferences	2-9
2.2.6	Reporting of analytical results	2-9
2.2.7	Importance of geochemical sampling and analytical measurements	2-9
2.3	QUALITY ASSURANCE AND QUALITY CONTROL	2-9
2.3.1	Definitions	2-9
2.3.2	Objectives of a Quality Assurance/Quality Control (QA/QC) program	2-10
2.3.3	Crucial aspects for a QA/QC program	2-10
2.3.3.1	Sampling	2-11
2.3.3.2	Analyses	2-12
2.4	BASIC STATISTICAL THEORY	2-16
2.4.1	Sampling distribution	2-16
2.4.2	Central limit theorem	2-18
2.4.3	Confidence limits or levels	2-18
2.5	SAMPLE SIZE	2-18
2.5.1	Definition of sample size	2-19
2.5.2	Factors affecting sample size	2-19
2.5.3	Methods of determining sample size	2-20
2.5.4	Procedure for sample size determination	2-24
2.5.5	Summary	2-24
2.6	UNCERTAINTY	2-25
2.6.1	Definitions	2-26

2.6.2	Uncertainty vs. error	2-27
2.6.3	Need for evaluating uncertainty	2-28
2.6.4	Types of uncertainty	2-28
2.6.5	Sources of uncertainty	2-30
2.6.6	Methods for quantifying uncertainty	2-32
2.6.6.1	Top Down and Bottom Up approach	2-32
2.6.6.2	Particulate sampling theory, Pierre Gy	2-33
2.6.6.3	Quantifying uncertainty in analytical measurements (EURACHEM/CITAC Guide CG4)	2-39
2.6.6.4	Analysis of variance (ANOVA)	2-45
2.7	SUMMARY	2-50
<b>3.</b>	<b>CASE STUDY INFORMATION</b>	<b>3-1</b>
3.1	BACKGROUND	3-1
3.2	METHODOLOGY	3-1
3.3	SAMPLING TARGET	3-2
3.3.1	West Wits Mine (AshantiGold)	3-2
3.3.2	Vaal River Mine (AshantiGold)	3-3
3.4	SAMPLING PROTOCOL	3-3
3.4.1	Sampling tool	3-3
3.4.2	Sample collection	3-3
3.5	ANALYTICAL PROTOCOLS USED	3-5
3.5.1	Sample compositing	3-5
3.5.2	Acid Base Accounting (ABA)	3-6
3.6	RESULTS	3-7
<b>4.</b>	<b>DETERMINATION OF SAMPLE SIZE</b>	<b>4-1</b>
4.1	INTRODUCTION	4-1
4.2	OVERVIEW OF THE STATISTICAL METHOD	4-1
4.3	PARAMETERS THAT AFFECT SAMPLE SIZE	4-3
4.3.1	Confidence level	4-4
4.3.2	Standard deviation or population spread	4-4
4.3.3	Standard error	4-5
4.3.4	Cost of taking the samples	4-5
4.4	PROCEDURE FOR DETERMINING SAMPLE SIZE	4-5
4.4.1	Specify the sampling objective	4-5
4.4.2	Determine the population parameters	4-6
4.4.3	Choose the sampling strategy	4-7
4.4.4	Determination of the acceptable standard error	4-7
4.4.5	Determine standard deviation	4-7
4.4.6	Specify confidence level	4-8
4.4.7	Determine sample size	4-8
4.4.8	Limitations	4-8
4.5	SPREADSHEET FORMAT FOR SAMPLE SIZE DETERMINATION	4-9
4.6	APPLICATION: SAMPLE SIZE DETERMINATION	4-10
4.7	SUMMARY	4-11

<b>5.</b>	<b>METHODOLOGY FOR QUANTIFYING UNCERTAINTY IN GEOCHEMICAL SAMPLING AND ANALYSES AS A FUNCTION OF SAMPLE SIZE</b>	<b>5-1</b>
5.1	INTRODUCTION	5-1
5.2	THE IMPORTANCE OF QUANTIFYING AND REPORTING UNCERTAINTY ASSOCIATED WITH A MEASURAND RESULT	5-2
5.3	PROCEDURES FOR QUANTIFYING UNCERTAINTY	5-2
5.3.1	Step 1: Define the objectives of the study	5-2
5.3.2	Step 2: Definition of the sampling target	5-3
5.3.3	Step 3: Definition of the measurand	5-4
5.3.4	Step 4: Description of the sampling and analysis protocols followed	5-5
5.3.5	Step 5: Identifying sources of uncertainty	5-5
5.3.6	Step 6: Quantify the uncertainty components	5-10
5.3.7	Step 7: Calculation of combined uncertainty	5-16
5.3.8	Step 8: Calculating the expanded uncertainty	5-17
5.3.9	Step 9: Reporting the uncertainty	5-18
5.3.10	Advantages of the method	5-18
5.3.11	Limitations of the technique	5-19
5.4	SUMMARY	5-19
<b>6.</b>	<b>APPLICATION OF METHODOLOGY OF QUANTIFYING UNCERTAINTY</b>	<b>6-1</b>
6.1	INTRODUCTION	6-1
6.2	EXAMPLE 1: ACID POTENTIAL (AP)	6-3
6.3	EXAMPLE 2: NEUTRALISATION POTENTIAL (NP)	6-9
6.4	EXAMPLE 3: PASTE pH MEASUREMENTS	6-14
6.5	SUMMARY	6-19
<b>7.</b>	<b>DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS</b>	<b>7-1</b>
7.1	INTRODUCTION	7-1
7.2	DISCUSSION	7-1
7.2.1	Sample size determination	7-1
7.2.1.1	Interpretation of results	7-2
7.2.1.2	Methods of reducing the required sample size	7-3
7.2.2	Quantifying uncertainty	7-3
7.3	CONCLUSIONS	7-7
7.3.1	Sample size determination	7-8
7.3.2	Quantifying uncertainty	7-8
7.3.3	Challenges	7-10
7.4	RECOMMENDATIONS	7-10
<b>8.</b>	<b>REFERENCES</b>	<b>8-1</b>

## LIST OF APPENDICES

APPENDIX A	EPA SAMPLE SIZE DETERMINATION
APPENDIX B	SAMPLE SIZE DETERMINATION USING COMBINED COST AND STATISCAL METHODS
APPENDIX C	QUALITY CONTROL SAMPLES
APPENDIX D	SAMPLE RECORDS PRIOR TO ANALYSIS
APPENDIX E	INPUT DATA (ABA) USED IN VARIOUS EXAMPLES
APPENDIX F	CAPACITY BUILDING

