

TABLE OF CONTENTS

	EXECUTIVE SUMMARY	iii
	ACKNOWLEDGEMENTS	vi
	TABLE OF CONTENTS	vii
	LIST OF FIGURES	xi
	LIST OF TABLES	xiii
	ABBREVIATIONS	xiv
1	INTRODUCTION AND BACKGROUND	1-1
1.1	MOTIVATION FOR THE PROJECT	1-1
1.2	PROJECT OBJECTIVES AND AIMS	1-1
1.3	PROJECT TASKS AND METHODOLOGY	1-2
1.4	RESEARCH PRODUCTS	1-4
1.5	CAPACITY AND COMPETENCY DEVELOPMENT	1-4
2	SITE SELECTION	2-1
2.1	OBJECTIVES	2-1
2.2	SITE SELECTION CRITERIA AND PROCEDURES	2-1
2.2.1	Criteria	2-1
2.2.2	Procedures for selection of study sites	2-1
2.3	INFORMATION GAINED FROM INITIAL SITE VISITS	2-2
2.3.1	Location of sites and contacts	2-2
2.3.2	Gold tailings dams constructed by the cycloning method	2-3
2.3.2.1	<i>ERGO Brakpan tailings dam (Anglogold)</i>	<i>2-4</i>
2.3.2.2	<i>West Extension tailings dam, Vaal River Operations (Anglogold)</i>	<i>2-5</i>
2.3.3	Gold tailings dams constructed by the traditional paddock method	2-7
2.3.3.1	<i>Beatrix No 1 tailings dam, Welkom (Goldfields)</i>	<i>2-7</i>
2.3.3.2	<i>West Complex tailings dam, Vaal River Operations (Anglogold)</i>	<i>2-8</i>
2.3.3.3	<i>East tailings dam, Vaal River Operations (Anglogold)</i>	<i>2-10</i>
2.3.3.4	<i>Kloof No 1 tailings dam (Goldfields)</i>	<i>2-10</i>
2.3.3.5	<i>Venterspost No 1 tailings dam (Goldfields)</i>	<i>2-11</i>
2.3.3.6	<i>Venterspost No 2 tailings dam (Goldfields)</i>	<i>2-11</i>
2.3.3.7	<i>West Wits Old North Complex (Anglogold)</i>	<i>2-12</i>
2.3.3.8	<i>Driefontein No 3A tailings dam (Goldfields)</i>	<i>2-13</i>
2.3.4	Gold waste rock dumps	2-14
2.3.4.1	<i>Tao Lekoa waste rock dump, Vaal River Operations (Anglogold)</i>	<i>2-14</i>
2.3.4.2	<i>Kopanang waste rock dump, Vaal River Operations (Anglogold)</i>	<i>2-14</i>
2.4	SELECTED SITES	2-15
2.4.1	West Wits Old North Complex tailings dam	2-16
2.4.2	Driefontein No 3A tailings dam	2-16
2.4.3	Kopanang waste rock dump	2-16
3	MONITORING AND EXPERIMENTAL PROGRAMMES	3-1
3.1	INTRODUCTION	3-1
3.2	METHODOLOGY	3-1
3.3	DATA REQUIREMENTS AND INSTRUMENTATION	3-2
3.3.1	Weather data	3-2
3.3.1.1	<i>Rainfall</i>	<i>3-2</i>
3.3.1.2	<i>Evaporation</i>	<i>3-2</i>

3.3.1.3	<i>Other weather data</i>	3-2
3.3.2	Runoff	3-2
3.4	STORAGE DYNAMICS AND DRAINAGE	3-3
3.4.1	Tailings dams	3-3
3.4.1.1	<i>Tensiometers</i>	3-3
3.4.1.2	<i>Tensiometer data</i>	3-4
3.4.1.3	<i>WaterMark sensors</i>	3-4
3.4.1.4	<i>Lysimeters</i>	3-4
3.4.1.5	<i>Tailings dam runoff plots</i>	3-4
3.4.1.6	<i>In-situ hydraulic conductivity measurement</i>	3-5
3.4.2	Waste rock dump	3-5
3.4.2.1	<i>Waste rock lysimeter</i>	3-5
3.5	SAMPLING AND MATERIAL CHARACTERISATION	3-7
3.5.1	Sampling	3-7
3.5.1.1	<i>Tailings dams</i>	3-7
3.5.1.2	<i>Kopanang waste rock dump</i>	3-7
3.5.2	Laboratory measurements for physical characteristics	3-7
3.6	SUMMARY	3-8
4	DATA ASSESSMENT	4-1
4.1	METEOROLOGICAL DATA	4-1
4.1.1	Rainfall	4-1
4.1.2	Temperature	4-3
4.1.3	Humidity	4-4
4.1.4	Wind	4-4
4.1.5	Potential evapotranspiration	4-5
4.2	MATERIAL CHARACTERISTICS DATA	4-6
4.2.1	Physical characteristics	4-6
4.2.1.1	<i>Bulk density</i>	4-6
4.2.1.2	<i>Particle size distribution (PSD)</i>	4-6
4.2.2	Water retention characteristics	4-9
4.2.3	Hydraulic conductivity characteristics	4-13
4.3	HYDRAULIC RESPONSE MONITORING	4-16
4.3.1	Infiltration and redistribution monitoring	4-16
4.3.1.1	<i>Tensiometry</i>	4-16
4.3.1.2	<i>Watermark sensors</i>	4-18
4.3.1.3	<i>Time domain reflectometry</i>	4-19
4.3.1.4	<i>Lysimeter monitoring</i>	4-21
4.3.2	Runoff monitoring	4-24
4.3.3	Evapotranspiration	4-25
5	DATA EVALUATION AND MODELLING	5-1
5.1	WATER BALANCE FOR TAILINGS STORAGE FACILITIES	5-1
5.1.1	Conceptual model	5-1
5.1.2	Water balance for pre-closure tailings storage facilities	5-1
5.1.3	Physical water balance calculation	5-4
5.1.3.1	<i>Rainfall and potential evapotranspiration</i>	5-4
5.1.3.2	<i>Surface and side slope runoff and infiltration</i>	5-4
5.1.3.3	<i>Evapotranspiration</i>	5-6
5.1.3.4	<i>Percolation</i>	5-6

5.1.3.5	<i>Penstock decant and seepage</i>	5-7
5.1.4	Modelling the long term water balance for Driefontein	5-7
5.1.5	Modelling the long term water balance for ONC Dam No 3	5-11
5.2	WASTE ROCK WATER BALANCE FROM OBSERVED RESPONSES	5-14
6	DEVELOPMENT OF WATER BALANCE MONITORING AND MODELLING METHODOLOGIES	6-1
6.1	APPROACH	6-1
6.2	DATA REQUIREMENTS	6-1
6.2.1	Meteorological data	6-1
6.2.1.1	<i>Basic meteorological data</i>	6-1
6.2.1.2	<i>Potential evapotranspiration</i>	6-2
6.2.2	Material characteristic data	6-3
6.2.2.1	<i>Particle size distribution (PSD)</i>	6-3
6.2.2.2	<i>Bulk density and porosity</i>	6-4
6.2.2.3	<i>Water retention characteristics</i>	6-4
6.2.3	Hydrological response monitoring	6-4
6.2.3.1	<i>Hydraulic conductivity</i>	6-5
6.2.3.2	<i>Moisture status monitoring</i>	6-5
6.2.3.3	<i>Runoff dynamics and infiltration</i>	6-7
6.2.3.4	<i>Evaporation and deep drainage (recharge)</i>	6-7
6.3	TSF WATER BALANCE DETERMINATION	6-8
6.3.1	Conceptual model	6-8
6.3.2	Physical water balance calculation	6-9
6.3.3	Long term water balance prediction	6-10
6.3.3.1	<i>Conceptual model</i>	6-10
6.3.3.2	<i>Model simulation</i>	6-10
6.3.4	Screening or detailed model analyses	6-11
6.3.4.1	<i>Water balance for an operational TSF</i>	6-12
6.3.4.2	<i>Water balance for a decommissioned TSF</i>	6-12
6.4	WASTE ROCK DUMP WATER BALANCE DETERMINATION	6-14
6.4.1	Conceptual model	6-15
6.4.2	Screening or detailed model analysis	6-15
6.5	LONG TERM MONITORING	6-16
7	CONCLUSIONS AND RECOMMENDATIONS	7-1
8	REFERENCES AND BIBLIOGRAPHY	8-1

