



Table of Contents

TABLE OF CONTENTS

1.	INTRODUCTION.....	1-1
1.1.	Project Proponent	1-1
1.2.	The Project.....	1-1
1.2.1.	Location.....	1-1
1.2.2.	Scope	1-3
1.2.3.	Project Phasing	1-6
1.2.4.	Rationale and Future Potential of the Mine	1-7
1.3.	Environmental Impact Statement.....	1-8
1.3.1.	Objective of the EIS	1-8
1.3.2.	Steps of the EIS Process	1-8
1.3.3.	Method of the EIS	1-9
1.3.4.	Key Issues Detailed in the EIS.....	1-9
1.3.5.	Structure of the EIS.....	1-10
1.4.	References	1-12
2.	VIABILITY AND PURPOSE OF THE PROJECT	2-1
2.1.	Proponent's Technical Expertise and Resources	2-1
2.2.	Project Viability.....	2-1
2.2.1.	Concept, Pre-Feasibility and Feasibility Studies.....	2-1
2.2.2.	Ore Reserve.....	2-3
2.2.3.	Wafi-Golpu Joint Venture Objectives.....	2-3
2.3.	Consistency with the State of PNG Development Policy and Strategies	2-4
2.3.1.	Constitutional Goals	2-4
2.3.2.	PNG Vision 2050.....	2-5
2.3.3.	Papua New Guinea Development Strategic Plan	2-5
2.3.4.	National Strategy for Responsible Sustainable Development	2-5
2.4.	Benefits of the Project	2-6
2.5.	References	2-7
3.	LEGAL, POLICY AND ADMINISTRATIVE FRAMEWORK	3-1
3.1.	Papua New Guinea Legislation and Regulations	3-1
3.1.1.	Mining Act 1992	3-1
3.1.2.	Environment Act 2000.....	3-3
3.1.3.	Other Relevant Legislation and Regulations	3-6
3.2.	Wafi-Golpu Joint Venture Policies and Standards	3-7
3.2.1.	Sustainable Business Management System	3-7
3.2.2.	Environmental and Social Management Framework	3-8
3.2.3.	Other Relevant Policies and Standards	3-8
3.3.	International Guidelines and Standards	3-8

3.4.	Assessment Criteria Used in the Environmental, Socioeconomic and Cultural Heritage Impact Assessment.....	3-9
3.4.1.	Air Quality.....	3-9
3.4.2.	Noise	3-10
3.4.3.	Terrestrial Ecology	3-10
3.4.4.	Surface Water and Freshwater Aquatic Ecology	3-10
3.4.5.	Marine Ecology	3-11
3.4.6.	Socioeconomic.....	3-11
3.4.7.	Cultural Heritage	3-11
3.5.	Other Assessment Guidelines.....	3-12
3.5.1.	Natural Hazards and Major Incidents	3-12
3.5.2.	Mine Closure	3-12
3.6.	References	3-13
4.	OVERVIEW OF IMPACT ASSESSMENT METHODS.....	4-1
4.1.	Introduction.....	4-1
4.2.	Specialist Studies Scopes of Work	4-1
4.3.	Baseline Characterisation	4-2
4.4.	Impact Assessment.....	4-2
4.4.1.	Environmental Impact Assessment.....	4-3
4.4.2.	Socioeconomic Impact Assessment	4-4
4.4.3.	Cultural Heritage Impact Assessment	4-5
4.5.	Health Risk Assessment	4-6
4.6.	Cumulative Impact Assessment.....	4-6
4.7.	Reconciliation with State of PNG Guidelines	4-7
4.8.	References	4-7
6.	PROJECT DESCRIPTION	6-1
6.1.	Project Setting.....	6-1
6.1.1.	Geographic Setting	6-1
6.1.2.	Climatic Setting	6-2
6.1.3.	Social Setting	6-4
6.1.4.	Cultural Heritage Setting.....	6-4
6.2.	Project Facilities Overview	6-5
6.3.	Project Development Schedule.....	6-6
6.4.	Mine Area Site Access	6-8
6.5.	Mine Area Preparation	6-10
6.5.1.	Vegetation Clearance	6-10
6.5.2.	Watut Declines Portal Terrace	6-10
6.5.3.	Nambonga Decline Portal Terrace.....	6-10
6.5.4.	Watut Process Plant Terrace	6-12

6.6.	Mining.....	6-12
6.6.1.	Mining Method.....	6-12
6.6.2.	Ore Production	6-17
6.6.3.	Subsidence	6-19
6.7.	Waste Rock Management.....	6-19
6.7.1.	Waste Rock Production and Geochemistry	6-22
6.7.2.	Waste Rock Dump Design	6-23
6.8.	Watut Process Plant.....	6-25
6.8.1.	Ore Treatment.....	6-25
6.8.2.	Ore Treatment Reagents	6-28
6.8.3.	Ore Stockpiles.....	6-28
6.9.	Mine Water Management.....	6-29
6.9.1.	Mine Water Management Overview.....	6-29
6.9.2.	Water Demand and Supply.....	6-31
6.9.3.	Underground Infrastructure.....	6-32
6.9.4.	Surface Infrastructure	6-34
6.9.5.	Wastewater Treatment.....	6-37
6.9.6.	Block Cave and Subsidence Zone Lake (Post-Closure)	6-41
6.10.	Tailings Management.....	6-42
6.10.1.	Overview	6-42
6.10.2.	Deep Sea Tailings Placement.....	6-43
6.11.	Infrastructure Corridor	6-49
6.11.1.	Pipelines.....	6-50
6.11.2.	Roads and Bridges	6-54
6.12.	Port Area	6-56
6.13.	Port Facilities Area	6-57
6.13.1.	Concentrate Filtration Plant	6-57
6.13.2.	Wastewater Treatment Plant and Filtrate Discharge	6-57
6.13.3.	Potable Water	6-57
6.13.4.	Containment Pond	6-59
6.13.5.	Concentrate Storage Shed	6-59
6.13.6.	Ship Loading	6-59
6.13.7.	Diesel Fuel Storage and Distribution	6-59
6.13.8.	Power Supply	6-59
6.13.9.	Ancillary Buildings.....	6-59
6.13.10.	Site Establishment	6-60
6.14.	Ancillary Project Infrastructure	6-60
6.14.1.	Laydown Areas	6-60
6.14.2.	Power Generation and Distribution	6-60

6.14.3.	Accommodation Facilities	6-62
6.14.4.	Borrow Pits, Quarry and River Gravel Extraction	6-63
6.14.5.	Explosives Magazine	6-63
6.14.6.	Concrete Batch Plants	6-64
6.15.	Fuel and Logistics	6-64
6.15.1.	Bulk Fuel	6-64
6.15.2.	Intermediate Fuel Oil Importation.....	6-65
6.15.3.	Bulk Intermediate Fuel Oil Storage Facility at Lae.....	6-65
6.15.4.	Mine Area Bulk Fuel Storage Facility.....	6-65
6.16.	Non-Mineral Waste Management	6-65
6.16.1.	Mine Area.....	6-67
6.16.2.	Port Facilities Area	6-68
6.16.3.	Outfall Area	6-68
6.16.4.	Infrastructure Corridor	6-68
6.16.5.	Non-mineral Waste Management Facilities	6-68
6.17.	Road Traffic and Transport	6-70
6.17.1.	Mine Area.....	6-70
6.17.2.	Infrastructure Corridor	6-70
6.17.3.	Port Facilities Area	6-70
6.17.4.	Outfall Area	6-70
6.18.	Resettlement	6-71
6.19.	Workforce	6-71
6.19.1.	Construction Workforce	6-71
6.19.2.	Operations Workforce	6-72
6.19.3.	Operating Hours.....	6-72
6.20.	Cleaner Production and Energy Balance.....	6-72
6.21.	Closure.....	6-72
6.22.	References	6-73
7.	ASSESSMENT OF ALTERNATIVES	7-1
7.1.	Stages in the Assessment of the Project	7-1
7.2.	Development Concept.....	7-1
7.3.	Alternatives Considered	7-2
7.3.1.	Assessment of Mineral Deposits.....	7-3
7.3.2.	Mining Method.....	7-3
7.3.3.	Production Rate	7-4
7.3.4.	Tailings Management.....	7-4
7.3.5.	Infrastructure Corridor	7-23
7.3.6.	Power Supply	7-29
7.4.	References	7-30

8.	PHYSICAL AND BIOLOGICAL ENVIRONMENT CHARACTERISATION	8-1
8.1.	Location and Climate	8-1
8.2.	Geology, Topography and Soils.....	8-1
8.2.1.	Geology.....	8-1
8.2.2.	Topography.....	8-5
8.2.3.	Soils	8-6
8.3.	Groundwater	8-12
8.3.1.	Hydrogeological Units.....	8-12
8.3.2.	Hydraulic Properties.....	8-14
8.3.3.	Groundwater Recharge.....	8-17
8.3.4.	Groundwater Levels and Flow Direction.....	8-18
8.3.5.	Groundwater Discharge and Use.....	8-23
8.3.6.	Groundwater – Surface Water Interaction	8-25
8.3.7.	Groundwater Quality	8-25
8.3.8.	Conceptual Hydrogeological Model	8-29
8.4.	Terrestrial Ecology	8-30
8.4.1.	Terrestrial Ecology Study Area	8-30
8.4.2.	Methods	8-33
8.4.3.	Bioregional Context.....	8-35
8.4.4.	Protected and Special Purpose Areas.....	8-36
8.4.5.	Vegetation and Flora.....	8-36
8.4.6.	Fauna	8-57
8.5.	Noise	8-63
8.6.	Air Quality.....	8-65
8.7.	References	8-67
9.	FRESHWATER ENVIRONMENT CHARACTERISATION.....	9-1
9.1.	Study Methods	9-1
9.1.1.	Hydrology, Water Quality and Sediment Quality	9-1
9.1.2.	Aquatic Ecology	9-9
9.2.	Drainage and Hydrology	9-18
9.2.1.	Lower Watut River Catchment.....	9-18
9.2.2.	Lower Markham River Floodplain	9-28
9.3.	Sediment Transport and Fluvial Geomorphology	9-28
9.3.1.	Sediment Load and Sources.....	9-28
9.3.2.	Fluvial Geomorphology	9-30
9.4.	Water Quality	9-34
9.4.1.	Lower Watut River catchment.....	9-34
9.4.2.	Lower Markham River Floodplain	9-50
9.4.3.	Summary of Background Water Quality	9-54

9.5.	Sediment Quality.....	9-57
9.5.1.	Organic Carbon in Sediment.....	9-65
9.5.2.	Summary of Background Sediment Quality.....	9-65
9.6.	Aquatic Ecology.....	9-65
9.6.1.	Aquatic Ecosystems and Habitats.....	9-65
9.6.2.	Aquatic Flora.....	9-75
9.6.3.	Aquatic Fauna.....	9-79
9.7.	References.....	9-86
10.	NEARSHORE MARINE ENVIRONMENT CHARACTERISATION.....	10-1
10.1.	Geology and Bathymetry.....	10-1
10.2.	Seismicity.....	10-5
10.3.	Tides, Currents and Waves.....	10-5
10.4.	Fluvial Influences.....	10-6
10.4.1.	Regional Sediment Regime.....	10-6
10.4.2.	Markham River Plume.....	10-9
10.4.3.	Markham River Morphodynamics.....	10-9
10.5.	Nearshore Marine Environment Sediment Geochemistry.....	10-12
10.5.1.	Method.....	10-12
10.5.2.	Particle Size Distribution.....	10-20
10.5.3.	Metals.....	10-21
10.5.4.	Nutrients and Carbon.....	10-22
10.6.	Nearshore Marine Environment Water Quality.....	10-22
10.6.1.	Method.....	10-22
10.6.2.	Physicochemical Parameters.....	10-24
10.6.3.	Nutrients, Faecal Coliforms and Oil and Grease.....	10-25
10.6.4.	Dissolved Metals.....	10-26
10.7.	Nearshore Marine Ecology.....	10-26
10.7.1.	Method.....	10-26
10.7.2.	Foreshore and Shallow Pelagic Environment.....	10-27
10.7.3.	Benthic Environment.....	10-32
10.7.4.	Coral Reefs and Seagrass.....	10-36
10.7.5.	Nearshore Marine Environment Fauna and Flora.....	10-38
10.7.6.	Summary of Species, Habitats and Ecosystems of Biodiversity and Conservation Significance in the Study Area.....	10-46
10.8.	References.....	10-47
11.	OFFSHORE MARINE ENVIRONMENT CHARACTERISATION.....	11-1
11.1.	Bathymetry.....	11-1
11.2.	Upper Ocean Profiling.....	11-5
11.3.	Potential for Coastal Upwelling.....	11-10

11.4.	Ocean Currents.....	11-12
11.4.1.	Ocean Current Data Collection.....	11-12
11.4.2.	Ocean Floor Mass Movement Events.....	11-13
11.4.3.	Outfall A Currents.....	11-15
11.4.4.	Canyon Mooring Currents.....	11-15
11.5.	Terrestrial Sediment Supply.....	11-18
11.6.	Sediment Transport Through the Markham Canyon.....	11-20
11.7.	Benthic Sediment Characteristics.....	11-24
11.7.1.	Particle Size Distribution.....	11-27
11.7.2.	Metals.....	11-27
11.8.	Offshore Marine Ecology.....	11-30
11.8.1.	Deep-Slope and Pelagic Fish.....	11-30
11.8.2.	Zooplankton and Micronekton.....	11-46
11.8.3.	Deep-Sea Benthic Ecology.....	11-54
11.9.	References.....	11-61
12.	SOCIOECONOMIC ENVIRONMENT CHARACTERISATION.....	12-1
12.1.	Study Areas.....	12-1
12.1.1.	Study Area 1: Mine Area, Surrounds and Access Corridors.....	12-1
12.1.2.	Study Area 2: Infrastructure Corridor from Zifasing to Lae.....	12-3
12.1.3.	Study Area 3: Lae.....	12-3
12.1.4.	Study Area 4: Wagang and Yanga villages.....	12-4
12.2.	Socioeconomic Baseline Studies.....	12-4
12.2.1.	Baseline Studies for Study Area 1.....	12-4
12.2.2.	Baseline Studies for Study Area 2.....	12-5
12.2.3.	Baseline Studies for Study Area 3.....	12-7
12.2.4.	Baseline Studies for Study Area 4.....	12-7
12.3.	National and Provincial Context.....	12-8
12.3.1.	National Context.....	12-8
12.3.2.	Morobe Province Context.....	12-10
12.4.	Socioeconomic Baseline: Study Area 1 (Mine Area, Surrounds and Access Corridors).....	12-14
12.4.1.	Biophysical Setting.....	12-14
12.4.2.	History.....	12-15
12.4.3.	Population.....	12-17
12.4.4.	Transport Infrastructure.....	12-19
12.4.5.	Income.....	12-19
12.4.6.	Housing.....	12-22
12.4.7.	Health and Wellbeing.....	12-22
12.4.8.	Education.....	12-24
12.4.9.	Subsistence Resources.....	12-25

12.4.10.	Traditions and Culture.....	12-26
12.4.11.	Law and order and social cohesion	12-26
12.5.	Socioeconomic Baseline: Study Area 2 (Infrastructure Corridor from Zifasing to Lae)	12-27
12.5.1.	Zifasing and Ganef.....	12-27
12.5.2.	Markham Farm.....	12-27
12.5.3.	Durung Farm	12-30
12.5.4.	Gabsongkeg and Surrounds	12-30
12.5.5.	Munum	12-34
12.5.6.	Yalu	12-34
12.5.7.	From Yalu to Outskirts of Lae	12-38
12.6.	Socioeconomic Baseline: Study Area 3 (Lae).....	12-38
12.6.1.	Population and Settlement.....	12-38
12.6.2.	Urban Land Use	12-40
12.6.3.	Water and Sanitation	12-50
12.6.4.	Utilisation of Marine Resources	12-50
12.6.5.	Economy	12-52
12.6.6.	Education	12-53
12.6.7.	Health.....	12-54
12.6.8.	Law and Order	12-54
12.6.9.	Vulnerable and Disadvantaged Groups.....	12-55
12.6.10.	Traffic and Transport.....	12-55
12.7.	Socioeconomic Baseline: Study Area 4 (Wagang and Yanga villages)	12-59
12.7.1.	Population and Settlement.....	12-59
12.7.2.	Cultural Overview.....	12-60
12.7.3.	Land and Water Resource Utilisation	12-60
12.7.4.	Housing	12-78
12.7.5.	Economy	12-78
12.7.6.	Education	12-80
12.7.7.	Health.....	12-80
12.7.8.	Law and Order	12-80
12.7.9.	Vulnerable and Disadvantaged Groups.....	12-82
12.7.10.	Traffic and Transport.....	12-82
12.8.	References	12-82
13.	CULTURAL HERITAGE CHARACTERISATION	13-1
13.1.	Study Methods	13-1
13.1.1.	Study Areas.....	13-3
13.1.2.	Cultural Heritage Studies and Other Document Reviews.....	13-4
13.1.3.	Cultural Heritage Significance Assessment.....	13-7
13.2.	Settlement History	13-9

13.2.1.	Hengambu and Yanta	13-9
13.2.2.	Babuaf	13-9
13.2.3.	Wampar.....	13-10
13.2.4.	Ahi	13-10
13.3.	World War II History	13-11
13.4.	Recorded Cultural Heritage.....	13-12
13.4.1.	Mine Study Area and Surrounds.....	13-12
13.4.2.	Infrastructure Corridor Study Area	13-16
13.4.3.	Coastal Study Area	13-20
13.5.	References	13-20
14.	PHYSICAL AND BIOLOGICAL ENVIRONMENT IMPACT ASSESSMENT	14-1
14.1.	Approach to Impact Assessment	14-1
14.1.1.	Significance Assessment Method	14-2
14.1.2.	Compliance Standard Assessment Method.....	14-2
14.1.3.	Benchmarking	14-3
14.2.	Landform and Soils	14-3
14.2.1.	Assessment Method Inputs.....	14-3
14.2.2.	Potential Impacts.....	14-5
14.2.3.	Proposed Management Measures	14-8
14.2.4.	Residual Impact Assessment.....	14-9
14.2.5.	Monitoring	14-14
14.3.	Groundwater	14-14
14.3.1.	Assessment Method Inputs.....	14-14
14.3.2.	Potential Impacts.....	14-17
14.3.3.	Proposed Management Measures	14-18
14.3.4.	Residual Impact Assessment – Groundwater Quantity	14-18
14.3.5.	Residual Impact Assessment – Groundwater Quality	14-28
14.3.6.	Monitoring	14-36
14.4.	Terrestrial Ecology	14-36
14.4.1.	Assessment Method Inputs.....	14-36
14.4.2.	Potential Impacts.....	14-41
14.4.3.	Proposed Management Measures	14-48
14.4.4.	Residual Impact Assessment.....	14-51
14.4.5.	Monitoring	14-76
14.5.	Air Quality	14-76
14.5.1.	Assessment Method Inputs.....	14-76
14.5.2.	Potential Impacts.....	14-79
14.5.3.	Proposed Management Measures	14-79
14.5.4.	Residual Impact Assessment.....	14-79

14.5.5.	Monitoring	14-81
14.6.	Greenhouse Gas Assessment	14-85
14.6.1.	Assessment Method Inputs.....	14-85
14.6.2.	Potential Impacts.....	14-85
14.6.3.	Proposed Management Measures	14-87
14.6.4.	Residual Impact Assessment.....	14-87
14.7.	Noise and Vibration	14-89
14.7.1.	Assessment Method Inputs.....	14-90
14.7.2.	Potential Impacts.....	14-92
14.7.3.	Proposed Management Measures	14-92
14.7.4.	Residual Impact Assessment.....	14-93
14.7.5.	Monitoring	14-101
14.8.	References	14-102
15.	FRESHWATER ENVIRONMENT IMPACT ASSESSMENT.....	15-1
15.1.	Approach to Impact Assessment	15-1
15.1.1.	Spatial and Temporal Scope.....	15-2
15.1.2.	Assessment Approach	15-5
15.1.3.	Summary of Freshwater Environment Values	15-10
15.1.4.	Model Inclusions and Exclusions	15-14
15.2.	Potential Impacts.....	15-15
15.2.1.	Potential Impacts from Physical Disturbance	15-16
15.2.2.	Potential Impacts from Altered Hydrology	15-21
15.2.3.	Potential Impacts from Erosion and Sedimentation.....	15-22
15.2.4.	Potential Impacts to Water Quality.....	15-23
15.2.5.	Potential Aquatic Weeds and Pest Species.....	15-24
15.2.6.	Existing Stressors and Adaptations	15-25
15.3.	Proposed Management Measures	15-25
15.3.1.	Hydrology and Sediment Transport	15-25
15.3.2.	Water Quality	15-25
15.3.3.	Freshwater Ecology	15-26
15.4.	Residual Impact Assessment Methods.....	15-26
15.4.1.	Hydrology and Flooding	15-27
15.4.2.	Sediment Transport	15-29
15.4.3.	Water Quality	15-30
15.5.	Residual Impacts to Surface Water	15-32
15.5.1.	Hydrology and Flooding	15-34
15.5.2.	Sediment Transport	15-40
15.5.3.	Water Quality	15-46
15.6.	Residual Impacts to Freshwater Ecology.....	15-58

15.6.1.	Boganchong Creek	15-59
15.6.2.	Womul Creek	15-62
15.6.3.	Lower Bavaga River.....	15-63
15.6.4.	Lower Watut River Eastern Floodplain	15-65
15.6.5.	Wafi River.....	15-67
15.6.6.	Lower Watut River.....	15-70
15.6.7.	Species of Conservation Significance	15-71
15.6.8.	Invasive Aquatic Flora and Fauna	15-72
15.6.9.	Post-closure Aquatic Ecology Impacts	15-73
15.6.10.	Residual Impact Summary.....	15-75
15.7.	Monitoring.....	15-75
15.8.	References	15-75
16.	NEARSHORE MARINE ENVIRONMENT IMPACT ASSESSMENT	16-1
16.1.	Approach to Impact Assessment	16-1
16.1.1.	Significance Assessment Method	16-1
16.1.2.	Compliance Standard Assessment Method.....	16-4
16.2.	Summary of Environmental Values.....	16-5
16.3.	Potential Impacts.....	16-7
16.3.1.	Habitat Deterioration and Loss	16-8
16.3.2.	Disturbance to Fauna.....	16-8
16.3.3.	Introduction of Invasive Marine Species	16-9
16.3.4.	Waste Discharge and Spills	16-9
16.4.	Management Measures	16-10
16.5.	Residual Impact Assessment.....	16-11
16.5.1.	Habitat Deterioration and Loss	16-11
16.5.2.	Disturbance to Fauna.....	16-13
16.5.3.	Introduction of Invasive Marine Species	16-13
16.5.4.	Waste Discharge and Spills	16-13
16.6.	Monitoring.....	16-16
16.7.	References	16-16
17.	OFFSHORE MARINE ENVIRONMENT IMPACT ASSESSMENT	17-1
17.1.	Introduction.....	17-1
17.2.	Approach to Impact Assessment	17-1
17.2.1.	Significance Assessment Method	17-2
17.2.2.	Compliance Standard Assessment Method.....	17-7
17.3.	Potential Impacts.....	17-10
17.4.	Management Measures	17-11
17.5.	Offshore Marine Environment Impacts	17-12
17.5.1.	Residual Impacts of DSTP to Pelagic Marine Ecology	17-12

17.5.2.	Residual Impacts of DSTP to Benthic Marine Ecology.....	17-44
17.5.3.	Residual Impact Summary.....	17-68
17.6.	Monitoring.....	17-71
17.7.	References.....	17-72
18.	SOCIOECONOMIC IMPACT ASSESSMENT.....	18-1
18.1.	Approach to Impact Assessment.....	18-1
18.1.1.	Objectives.....	18-1
18.1.2.	Impact Assessment Process.....	18-2
18.2.	Socioeconomic Impacts at Provincial and National Levels.....	18-6
18.2.1.	Employment.....	18-6
18.2.2.	Procurement.....	18-7
18.2.3.	Direct Financial Benefits.....	18-9
18.3.	Impact Assessment for Study Area 1 (Mine Area, surrounds and access corridors).....	18-9
18.3.1.	Socioeconomic Context.....	18-9
18.3.2.	Impact Identification and Initial Impact Assessment.....	18-10
18.3.3.	Proposed Management Measures.....	18-42
18.3.4.	Residual Impact Assessment.....	18-50
18.4.	Impact Assessment for Study Area 2 (Infrastructure Corridor from Zifasing to Lae).....	18-69
18.4.1.	Impact Identification and Initial Impact Assessment.....	18-69
18.4.2.	Proposed Management Measures.....	18-77
18.4.3.	Residual Impact Assessment.....	18-83
18.5.	Impact Assessment for Study Area 3 (Lae).....	18-92
18.5.1.	Impact Identification and Initial Impact Assessment.....	18-92
18.5.2.	Proposed Management Measures.....	18-99
18.5.3.	Residual Impact Assessment.....	18-105
18.6.	Impact Assessment for Study Area 4 (Wagang and Yanga villages).....	18-112
18.6.1.	Impact Identification and Initial Impact Assessment.....	18-112
18.6.2.	Proposed Management Measures.....	18-124
18.6.3.	Residual Impact Assessment.....	18-124
18.7.	Overview of Socioeconomic Impacts.....	18-131
18.8.	Framework for Managing Socioeconomic Impacts.....	18-131
18.8.1.	Monitoring.....	18-134
18.8.2.	Reporting.....	18-135
18.9.	References.....	18-135
19.	HEALTH RISK ASSESSMENT.....	19-1
19.1.	Approach to Risk Assessment.....	19-1
19.1.1.	Study Areas.....	19-1
19.1.2.	HHRA Study Method.....	19-3
19.1.3.	Data Sources.....	19-5

19.2.	Conceptual Site Model	19-5
19.2.1.	Source	19-6
19.2.2.	Transport Pathways	19-6
19.2.3.	Receptors	19-7
19.2.4.	Exposure Routes.....	19-7
19.2.5.	Exposure Pathways	19-7
19.2.6.	Selection of Contaminants of Potential Concern	19-9
19.2.7.	Assessment Criteria	19-10
19.2.8.	Project Conceptual Site Model.....	19-11
19.3.	Risk Assessment Results.....	19-11
19.3.1.	Baseline Conditions	19-13
19.3.2.	Predicted Project Conditions.....	19-22
19.4.	Design Controls and Management Measures.....	19-30
19.5.	References	19-30
20.	CULTURAL HERITAGE IMPACT ASSESSMENT.....	20-1
20.1.	Approach to Impact Assessment	20-1
20.2.	Potential Impacts.....	20-3
20.2.1.	Construction and Operation of Project Infrastructure	20-3
20.2.2.	Resettlement Program	20-7
20.2.3.	Chance Finds	20-7
20.3.	Management Measures	20-8
20.3.1.	Avoidance through Design	20-8
20.3.2.	Cultural Heritage Management Plan.....	20-8
20.4.	Residual Impacts.....	20-11
20.4.1.	Recorded Sites.....	20-11
20.4.2.	Chance Finds.....	20-13
20.5.	Monitoring and Reporting.....	20-13
20.6.	References	20-14
21.	UNPLANNED EVENTS (NATURAL HAZARDS AND ACCIDENTAL EVENTS)	21-1
21.1.	Regulatory and Corporate Framework.....	21-2
21.1.1.	Regulatory Framework.....	21-2
21.1.2.	Corporate Framework	21-2
21.2.	Specific Potential Unplanned Event Scenarios.....	21-3
21.2.1.	Natural Events.....	21-3
21.2.2.	Pipeline Rupture.....	21-4
21.2.3.	Underground Access Way Collapse	21-6
21.2.4.	Waste Rock Dump Failure	21-7
21.2.5.	Inundation of Port Facilities Area and Outfall Area	21-7
21.2.6.	Explosion.....	21-8

21.2.7.	Fire	21-9
21.2.8.	Major Loss of Containment	21-10
21.3.	References	21-10
22.	CUMULATIVE IMPACT ASSESSMENT	22-1
22.1.	Valued Environmental, Social and Cultural Heritage Components	22-1
22.2.	Criteria for Identifying Credible Projects	22-2
22.2.1.	Credible Projects	22-2
22.2.2.	Spatial Relationship	22-2
22.2.3.	Temporal Relationship	22-3
22.3.	Identification of Credible Projects	22-3
22.4.	Cumulative Impact Assessment.....	22-9
22.4.1.	Traffic and Transport.....	22-9
22.4.2.	Construction Workforce	22-9
22.4.3.	Air Emissions	22-10
22.4.4.	Physical Disturbance (Vegetation Clearing)	22-10
22.4.5.	Physical Disturbance (Sedimentation)	22-10
22.5.	Conclusion.....	22-11
22.6.	References	22-12
23.	INTEGRATED MANAGEMENT SYSTEM	23-1
23.1.	Sustainable Business Management System.....	23-1
23.2.	Environmental and Social Management Framework	23-1
23.2.1.	Project Environmental Management Plan	23-4
23.2.2.	Project Social Management Plan	23-6
23.2.3.	Project Cultural Heritage Management Plan	23-9
23.3.	Monitoring and Reporting.....	23-9
23.3.1.	Environmental Monitoring	23-9
23.3.2.	Environmental Reporting	23-10
23.3.3.	Socioeconomic Monitoring	23-10
23.3.4.	Socioeconomic Reporting	23-11
23.3.5.	Cultural Heritage Monitoring	23-11
23.3.6.	Cultural Heritage Reporting	23-11
23.4.	References	23-11
24.	STUDY TEAM	24-1
24.1.	Constitution of the Environmental Impact Statement Study Team	24-1
24.2.	Representatives of Wafi Golpu Joint Venture Participants	24-5

LIST OF FIGURES

Figure 1.1: General arrangement of proposed Project.....	1-2
Figure 1.2: General arrangement of proposed Mine Area.....	1-4
Figure 3.1: Environmental approvals process for the Project.....	3-5
Figure 5.1: Stakeholder engagement activities (May 2015 – November 2017)	5-5
Figure 6.1: Coastal Area.....	6-3
Figure 6.2: Indicative mine schedule	6-7
Figure 6.3: Preliminary community access road options.....	6-9
Figure 6.4: Watut Declines Portal Terrace general arrangement.....	6-11
Figure 6.5: Infrastructure associated with the Nambonga Decline.....	6-13
Figure 6.6: Process plant terrace and Watut Declines Portal Terrace infrastructure and general arrangement	6-14
Figure 6.7: Schematic of the declines and block caves and the block cave production profiles.....	6-15
Figure 6.8: Estimated mine production rates.....	6-18
Figure 6.9: Schematic showing subsidence features for block cave mines	6-20
Figure 6.10: Modelled subsidence zone and final lake approximately 39 years after closure	6-21
Figure 6.11: Diagram of waste rock dump cell construction.....	6-24
Figure 6.12: Miapilli Waste Rock Dump conceptual design	6-26
Figure 6.13: Mine water management schematic for construction and operations.....	6-30
Figure 6.14: Estimated median inflows to the underground workings during construction and operations	6-33
Figure 6.15: Surface water management infrastructure: process plant and Watut Declines Portal Terrace.....	6-35
Figure 6.16: Water treatment plant feed and treated water discharge to the Watut River during construction and operations	6-38
Figure 6.17: Water treatment plant module	6-39
Figure 6.18: Conceptual representation of tailings density current	6-44
Figure 6.19: 3D representation of the DSTP Outfall System and choke station	6-46
Figure 6.20: Example of typical trench sections for outfall and seawater intake pipelines	6-48
Figure 6.21: Typical onshore pipeline construction sequence	6-52
Figure 6.22: Typical pipeline right-of-way cross-section	6-53
Figure 6.23: Typical pipeline watercourse crossing (open trench, flume pipe method)	6-55
Figure 6.24: Port Facilities Area	6-58
Figure 6.25: Estimated average power demand profile.....	6-61
Figure 6.26: Waste management hierarchy	6-66
Figure 7.1: Tailings storage facility locations historically assessed	7-12
Figure 7.2: Worldwide mines with either shallow water marine placement or DSTP	7-18
Figure 7.3: DSTP site options.....	7-19
Figure 7.4: Comparison of tailings management options	7-22
Figure 7.5: Northern Access Road options.....	7-25
Figure 7.6: Infrastructure Corridor route options east of Yalu	7-28

Figure 8.1: Project Area geology	8-3
Figure 8.2: Project Area slope	8-7
Figure 8.3: Project Area landform.....	8-8
Figure 8.4: Project Area soil types.....	8-10
Figure 8.5: Geological cross-section through the mine showing faults and major geology units.....	8-15
Figure 8.6: Hydrogeological unit hydraulic conductivity variability	8-16
Figure 8.7: Pore pressure measurements for VWPs along the declines	8-20
Figure 8.8: Measured groundwater elevation and daily rainfall.....	8-21
Figure 8.9: Temporal groundwater levels	8-22
Figure 8.10: Springs on the eastern slopes of Mt Golpu	8-24
Figure 8.11: Conceptual hydrogeological model	8-31
Figure 8.12: Terrestrial ecology study area	8-32
Figure 8.13: Vegetation communities	8-39
Figure 8.14: Typical structure of Large to Medium Crowned Forest on plains.....	8-40
Figure 8.15: Typical structure of Large to Medium Crowned Forest on the banks of the Waime River	8-40
Figure 8.16: Typical Large to Medium Crowned Forest along the Busu River near Bomsu village	8-40
Figure 8.17: Small Crowned Forest on ridgelines	8-42
Figure 8.18: Typical structure of Medium Crowned Forest on foothills	8-42
Figure 8.19: Grassland areas in the Markham River valley	8-42
Figure 8.20: Mixed Swamp Forest.....	8-44
Figure 8.21: Swamp Grassland with dominant Phragmites vallatorius fringing an oxbow lake	8-44
Figure 8.22: Swamp Woodland emergent trees above sub-canopy of sago palm.....	8-44
Figure 8.23: Swamp Woodland visible as grey wash of emergent tree crowns above sub-canopy of sago palm	8-46
Figure 8.24: Lower Watut River showing continuum of several stages from point bars to developing grassland and shrubland on meandering river channel	8-46
Figure 8.25: Markham River braids partially stabilised by Saccharum robustum below the Watut confluence.. ..	8-46
Figure 8.26: Vegetation condition	8-50
Figure 8.27: Fruit and leaves of Diospyros lalinopsis (IUCN: Critically Endangered)	8-55
Figure 8.28: Fruiting specimen of Myristica buchneriana (IUCN: Vulnerable)	8-55
Figure 8.29: Winged seed of New Guinea rosewood (Pterocarpus indicus) (IUCN: Vulnerable)	8-55
Figure 8.30: New Guinea pademelon (Thylogale browni) (IUCN: Vulnerable)	8-61
Figure 8.31: Papuan eagle (Harpyopsis novaeguineae) (IUCN: Vulnerable)	8-61
Figure 8.32: Papuan hawk owl (Uroglaux dimorpha) (IUCN: Data Deficient)	8-61
Figure 8.33: Ambient noise and air quality monitoring sites	8-64
Figure 8.34: Dust deposition monitoring data (2011 – 2017)	8-66
Figure 9.1: Monitoring sites and stream gauging stations in the Lower Watut River catchment	9-2
Figure 9.2: Water quality sampling sites in the Lower Markham River floodplain.....	9-3
Figure 9.3: Upper Watut River	9-19

Figure 9.4: Middle Watut River	9-19
Figure 9.5: Lower Watut River	9-19
Figure 9.6: Sub-catchments in the Lower Watut River catchment	9-20
Figure 9.7: High energy tributary watercourses, Zamen River	9-23
Figure 9.8: High energy tributary watercourses, Bagava River Upstream	9-23
Figure 9.9: Low gradient floodplain watercourses, Chaunong Creek Upstream	9-23
Figure 9.10: Sunshine gauge: flow-duration relationship	9-24
Figure 9.11: Existing case 1:2 year AEP peak flood depth for the Watut River	9-26
Figure 9.12: Existing case 1:2 year AEP peak flood velocity for the Watut River	9-27
Figure 9.13: Buambub Creek, S/Site 3	9-29
Figure 9.14: Pumpkin Creek, S/Site 4	9-29
Figure 9.15: Markham River, S/Site 8	9-29
Figure 9.16: Landform ages in the Lower Watut River floodplain meander belt	9-32
Figure 9.17: Changes in river sinuosity with time on the Lower Watut River floodplain	9-33
Figure 9.18: Summary of WGJV turbidity data for Markham, Watut, Wampit, Bavaga and Womul catchments	9-36
Figure 9.19: Summary of WGJV TSS data for Markham, Watut, Wampit, Bavaga and Womul catchments	9-38
Figure 9.20: Summary of WGJV dissolved copper data for the Wafi River catchment	9-40
Figure 9.21: Summary of WGJV dissolved copper data for Markham, Watut, Wampit, Bavaga and Womul catchments	9-41
Figure 9.22: Summary of WGJV dissolved mercury data for the Wafi River catchment	9-43
Figure 9.23: Summary of WGJV dissolved mercury data for Markham, Watut, Wampit, Bavaga and Womul catchments	9-44
Figure 9.24: Summary of WGJV dissolved zinc data for the Wafi River catchment	9-45
Figure 9.25: Summary of WGJV dissolved zinc data for Markham, Watut, Wampit, Bavaga and Womul catchments	9-46
Figure 9.26: Summary of WGJV copper data for the Wafi River catchment: sediment	9-58
Figure 9.27: Summary of WGJV copper data for Markham, Watut, Wampit, Bavaga and Womul catchments: sediment	9-59
Figure 9.28: Summary of WGJV mercury data for the Wafi River catchment: sediment	9-60
Figure 9.29: Summary of WGJV mercury data for Markham, Watut, Wampit, Bavaga and Womul catchments: sediment	9-61
Figure 9.30: Summary of WGJV zinc data for the Wafi River catchment: sediment	9-63
Figure 9.31: Summary of WGJV zinc data for Markham, Watut, Wampit, Bavaga and Womul catchments: sediment	9-64
Figure 9.32: Aquatic ecosystem types in the Lower Watut River catchment area	9-67
Figure 9.33: Low gradient floodplain watercourses, Bobul Creek at Bobul Xing	9-69
Figure 9.34: Unconfined, turbid major river systems, Watut River at Maralina	9-69
Figure 9.35: Unconfined, turbid major river systems, Watut River at Uruf	9-69
Figure 9.36: Oxbow lakes at sites Bali Oxbow	9-71

Figure 9.37: Oxbow lakes at Uruf Oxbow	9-71
Figure 9.38: Major wetland systems in PNG	9-73
Figure 9.39: Schultze's snapping turtle captured at Uruf Oxbow	9-83
Figure 9.40: Underbelly of Schultze's snapping turtle captured at Uruf Oxbow	9-83
Figure 10.1: Huon Gulf bathymetry	10-3
Figure 10.2: Aerial photo of Labu Lakes facing south	10-4
Figure 10.3: Aerial photo of Labu Lakes, Markham River mouth and Lae	10-4
Figure 10.4: Busu River mouth, Site B1	10-8
Figure 10.5: Plume from Busu River as viewed from surface of ocean	10-8
Figure 10.6: Aerial photo of the Busu River mouth facing west towards Lae	10-8
Figure 10.7: Imagery showing the formation of a distributary of the lower Markham River	10-10
Figure 10.8: Aerial imagery of Markham River plume entering the mouth of the Labu Lakes	10-11
Figure 10.9: 2016 – 2017 nearshore marine survey sampling sites	10-13
Figure 10.10: Sediment collected from S2	10-14
Figure 10.11: Sediment collected from S2	10-14
Figure 10.12: Sands at site DV3.....	10-14
Figure 10.13: Sediment collected from R1	10-15
Figure 10.14: Sediment collected from L1	10-15
Figure 10.15: Sediment collected from L3.....	10-15
Figure 10.16: Sediment collected from L4.....	10-16
Figure 10.17: Sediment collected from M1	10-16
Figure 10.18: Sediment collected from LA5	10-16
Figure 10.19: Sediment collected from LA4	10-17
Figure 10.20: Sediment collected from LA3	10-17
Figure 10.21: Sediment collected from LA2	10-17
Figure 10.22: Sediment collected from LA1	10-18
Figure 10.23: Sediment collected from V1	10-18
Figure 10.24: Sediment collected from W1	10-18
Figure 10.25: Sediment collected from W2	10-19
Figure 10.26: Sediment collected from B1	10-19
Figure 10.27: Sediment collected from R2	10-19
Figure 10.28: Floating wood and other mobilised terrestrial vegetation accumulating near Voco Point ..	10-29
Figure 10.29: Shoreline at the Outfall Area. Note the woody debris and plastic litter along the shoreline	10-29
Figure 10.30: Tree limbs and other driftwood or debris deposited on the beach at Wagang and collected by villagers	10-29
Figure 10.31: Various debris and concrete either placed or accumulated on the beach near LA1	10-30
Figure 10.32: Plastic and other anthropogenic debris accumulated on the beach near Voco Point	10-30
Figure 10.33: Recreational swimming and shipwreck near Voco Point	10-31
Figure 10.34: Shipwreck along coast near LA1.....	10-31

Figure 10.35: Shipwreck on beach near Labu Tale.....	10-31
Figure 10.36: Aerial photo of Butudendeng and Nungawahac mangroves near Wagang village, with Lae visible in background.....	10-33
Figure 10.37: Butudendeng and Nungawahac mangroves to the north-east of Wagang village.....	10-33
Figure 10.38: Butudendeng and Nungawahac mangroves to the north-west of Wagang village.....	10-33
Figure 10.39: Mangroves of Labu Lakes, including unsubmerged portion of shipwreck.....	10-34
Figure 10.40: Fisherman in Labu Lakes. Extensive mangrove forest present in background.....	10-34
Figure 10.41: Shrimp (species unknown) collected during sediment sampling at V1.....	10-35
Figure 10.42: Green marine algae (Halimeda sp.) collected during sediment sampling at V1.....	10-35
Figure 10.43: Plating coralline algae (Padina sp.), branch algae and sponge growth retrieved from site LA1.....	10-35
Figure 10.44: Green macroalgae retrieved with sediment sampler at site LA1.....	10-35
Figure 10.45: Coral reef at S1.....	10-37
Figure 10.46: Coral reef at Busama.....	10-37
Figure 10.47: Seagrass at S2 (Thalassia sp.).....	10-37
Figure 10.48: Dolphins near site S1.....	10-40
Figure 10.49: Sea turtle nesting pit observed near Labu Tale.....	10-40
Figure 10.50: Gastropod molluscs (Family: Thiaridae) collected from the Labu Lakes by local villagers.....	10-40
Figure 11.1: New Britain Trench.....	11-2
Figure 11.2: Bathymetry of the western Huon Gulf.....	11-3
Figure 11.3: Huon Gulf deep water bathymetry to over 3,000m.....	11-4
Figure 11.4: Outfall Area high-resolution bathymetry.....	11-6
Figure 11.5: Upper ocean profiling locations.....	11-8
Figure 11.6: Surface mixed layer depth and euphotic zone thickness measured to date.....	11-9
Figure 11.7: Temperature profiles at transects A and B from February, July and August 2017.....	11-11
Figure 11.8: Huon Gulf ADCP oceanographic instrument mooring locations.....	11-14
Figure 11.9: Near-bed current speeds at Canyon B and Canyon C moorings from May to September 2017.....	11-17
Figure 11.10: Rivers draining to the northern shoreline of the Huon Gulf.....	11-19
Figure 11.11: Turbidity profiles from CTD location A3.....	11-21
Figure 11.12: Turbidity profiles from CTD location B5.....	11-22
Figure 11.13: Echo-sounder trace of acoustic backscatter indicating the presence of large bed waves along the floor of the Markham Canyon up canyon of the Trench Mooring.....	11-25
Figure 11.14: Benthic sediment and infauna box corer and multi corer sampling locations.....	11-26
Figure 11.15: Deep-slope and pelagic drop-line fishing locations.....	11-31
Figure 11.16: Pelagic trolling transects.....	11-32
Figure 11.17: Dwarf gulper shark (Centrophorus atomarginatus).....	11-34
Figure 11.18: Long-finned gulper shark (Centrophorus longipinnis).....	11-34
Figure 11.19: Gulper shark (Centrophorus granulosus).....	11-34
Figure 11.20: Fat spine spurdog (Squalus crassispinis).....	11-34

Figure 11.21: Vertical distribution of dwarf gulper sharks	11-35
Figure 11.22: Saddletail snapper (<i>Lutjanus malabaricus</i>)	11-36
Figure 11.23: Common pike eel (<i>Muraenesox baggio</i>)	11-36
Figure 11.24: Blackspotted croaker (<i>Protonibea diacanthus</i>)	11-36
Figure 11.25: Mean metals concentrations (As, Cu and Fe) in liver and muscle of fishes caught (Nov 2016; May 2017) and sourced from DCA Point fish market (Nov 2016).....	11-39
Figure 11.26: Mean metals concentrations (Hg, Se and Zn) in liver and muscle of fishes caught (Nov 2016; May 2017) and sourced from DCA Point fish market (Nov 2016).....	11-40
Figure 11.27: Metals concentrations (As, Cu and Fe) in liver and muscle of dwarf gulper shark by total weight and length	11-43
Figure 11.28: Metals concentrations (Hg, Se and Zn) in liver and muscle of dwarf gulper shark by total weight and length	11-44
Figure 11.29: Metals concentrations (Cd) in liver and muscle of dwarf gulper shark by total weight and length	11-45
Figure 11.30: Zooplankton and micronekton sampling locations	11-47
Figure 11.31: Copepod collected during zooplankton sampling	11-49
Figure 11.32: Ostracod collected during zooplankton sampling	11-49
Figure 11.33: Ghost shrimp 'Lucifer' collected during zooplankton sampling	11-49
Figure 11.34: Siphonophore (hydrozoan) collected during zooplankton sampling	11-49
Figure 11.35: Arrow worm (chaetognath) collected during zooplankton sampling	11-49
Figure 11.36: Early juvenile slimehead (possibly <i>Hoplostethus</i> sp. Family: <i>Trachichthyidae</i>) collected in night plankton sample	11-51
Figure 11.37: Slickhead (Family: <i>Alepocephalidae</i>) collected during micronekton sampling	11-51
Figure 11.38: Viperfish (<i>Chauliodus sloani</i>) collected during micronekton sampling	11-51
Figure 11.39: Leptocephalus stage larvae of anguilliform (eel) fishes collected during micronekton sampling	11-51
Figure 11.40: Average concentrations of As, Cd, Cu, Fe, Mn, Ni and Zn in zooplankton samples collected in March 2017 from the DSTP and reference study areas	11-52
Figure 11.41: Concentrations of As, Cd, Cu, Fe, Pb, Hg, Mn, Ni, Se and Zn in micronekton taxa collected in the DSTP study area in May 2017	11-53
Figure 11.42: Benthic video characterisation study sites	11-55
Figure 11.43: Sea whip (lower left of frame) at Site 13 (depth 757m). Note mounds and burrows in sediment	11-57
Figure 11.44: Cobble sized rocks of riverine origin at Site 1, 229m depth	11-57
Figure 11.45: Average meiofauna density for box and multi corer replicates	11-60
Figure 12.1: Socioeconomic baseline study areas	12-2
Figure 12.2: Surveys undertaken in the study areas to date	12-6
Figure 12.3: Demakwa Access Road	12-20
Figure 12.4: Transporting produce on the Lower Watut River by raft	12-20
Figure 12.5: House made of traditional material, Venembele	12-23
Figure 12.6: House made of range of materials, Hekeng.....	12-23
Figure 12.7: PPL transmission line corridor near Zifasing.....	12-28

Figure 12.8: 40 Mile Market, Zifasing	12-28
Figure 12.9: Cucumber garden at Ganef village	12-29
Figure 12.10: Offices of Markham Agro Pty Ltd	12-29
Figure 12.11: House and water well east of Niugini Tablebirds	12-31
Figure 12.12: Chicken hatchery of local individual in business with Niugini Tablebirds	12-31
Figure 12.13: Educational and health facilities accessed by Study Area 2 residents	12-32
Figure 12.14: Rice fields no longer in use within the study area near Gabsongkeg	12-33
Figure 12.15: House within Study Area 2, approximately 2km east of Gabsongkeg village	12-33
Figure 12.16: Water source for residents living in houses 2km east of Gabsongkeg	12-33
Figure 12.17: Garden at a Munum hamlet.....	12-35
Figure 12.18: Houses located near Munum village within 100m of the PPL transmission line corridor....	12-35
Figure 12.19: Yalu village hamlets/settlements and drinking water sources.....	12-37
Figure 12.20: Settler house near the Highlands Highway between Yalu village and Lae.....	12-39
Figure 12.21: Sago stand within Study Area 2 near Lae.....	12-39
Figure 12.22: Wanaru Farm (Niugini Tablebirds)	12-39
Figure 12.23: Field observation locations within Study Area 3	12-42
Figure 12.24: Housing commission in 3 Mile.....	12-43
Figure 12.25: Settler house in 3 Mile.....	12-43
Figure 12.26: Settler house and garden in Bugandi.....	12-43
Figure 12.27: Premises of Consort Express Lines Limited, situated along Bumbu Road.....	12-45
Figure 12.28: Brian Bell Plaza (a retail mall)	12-45
Figure 12.29: Balob Teachers College adjacent to Butibum Road (near Chinatown)	12-45
Figure 12.30: Sir Ignatius Kilage Sports Stadium in Lae on Airways Avenue.....	12-46
Figure 12.31: Supermarket in Chinatown	12-46
Figure 12.32: Bumbu Market (near Bumbu River) along Butibum Road.....	12-46
Figure 12.33: Nestle chocolate factory on Butibum Road	12-47
Figure 12.34: Majestic Seafood Company premises on Independence Drive	12-47
Figure 12.35: Business premises at Malahang Industrial Centre adjacent to Independence Drive.....	12-47
Figure 12.36: A business compound adjacent to Independence Drive, Malahang area.....	12-48
Figure 12.37: Settler residence and store in Malahang area	12-48
Figure 12.38: Settler garden in Malahang area	12-49
Figure 12.39: Assembly of God Primary School on Independence Drive	12-49
Figure 12.40: Bumbu River along Butibum Road.....	12-49
Figure 12.41: Public motor vehicle routes servicing Lae.....	12-57
Figure 12.42: Volume-to-capacity ratio of roads in Lae (2025 projection)	12-58
Figure 12.43: Communal tap stand at Wagang.....	12-62
Figure 12.44: Water tower feeding communal tap stands at Wagang	12-62
Figure 12.45: Rainwater tank installed at private home in Wagang	12-62
Figure 12.46: Wagang village drinking water sources.....	12-64

Figure 12.47: Yanga village drinking water sources.....	12-65
Figure 12.48: Composting toilet (exterior) at Wagang village	12-66
Figure 12.49: Wagang village fishing areas	12-68
Figure 12.50: Popular fishing locations for residents of Wagang village.....	12-69
Figure 12.51: Fishing frequency (fin fish) reported by residents of Wagang village	12-70
Figure 12.52: Fishing frequency (invertebrates) reported by residents of Wagang village	12-71
Figure 12.53: Types of fishing gear used by residents of Wagang village	12-72
Figure 12.54: Fishing net in Wagang village	12-73
Figure 12.55: Fishing rod and reel, and two handlines at Wagang village.....	12-73
Figure 12.56: 'Banana' boats on Wagang beach	12-75
Figure 12.57: Canoe (right) on Wagang beach	12-75
Figure 12.58: Shellfish caught by Wagang villagers: ('rainy shell' in bowl, kina shell white at front, 'long tail' front, far right)	12-76
Figure 12.59: Shellfish caught by Wagang villagers (called 'black shells' or 'gaha koc').....	12-76
Figure 12.60: PMV conveying visitors to Wagang beach on a Saturday	12-79
Figure 12.61: Beer store at Wagang beach	12-79
Figure 12.62: Market at Wagang beach on a Sunday.....	12-79
Figure 12.63: Educational and health facilities accessed by Wagang and Yanga residents	12-81
Figure 13.1: Cultural heritage study areas	13-2
Figure 13.2: Recorded cultural heritage sites relative to cultural heritage study areas	13-13
Figure 13.3: View south across gully containing Mia Yo Sacred Spring Site (WG060)	13-17
Figure 13.4: Fere cultural landscape in foreground, view southwest towards Watut River	13-17
Figure 13.5: Proposed Infrastructure Corridor (Eastern Study Area) located adjacent to high-voltage transmission line corridor.....	13-17
Figure 14.1: Simulated groundwater drawdown during construction (Year 4) and operation (Year 6)	14-20
Figure 14.2: Simulated groundwater drawdown at Year 12 and Year 27	14-23
Figure 14.3: Simulated post closure steady state groundwater drawdown and subsidence zone lake particle tracking	14-26
Figure 14.4: Annual average SO ₂ concentrations during construction (left) and operations (right).....	14-55
Figure 14.5: Resettlement sites and surrounding vegetation	14-64
Figure 14.6: Annual average PM _{2.5} and PM ₁₀ concentrations during operations.....	14-82
Figure 14.7: Annual average total suspended particulates concentrations and dust deposition rates during operations	14-83
Figure 14.8: One hour average NO ₂ and SO ₂ concentrations during operations	14-84
Figure 14.9: Scope 1, 2 and 3 greenhouse gas emissions	14-86
Figure 14.10: Summary of predicted greenhouse gas emissions	14-88
Figure 14.11: Mine Area construction noise emissions with neutral and enhanced meteorological conditions	14-94
Figure 14.12: Mine Area operation noise emissions with neutral and enhanced meteorological conditions	14-98
Figure 15.1: Assessment points	15-3

Figure 15.2: Watercourses in the Mine Area	15-4
Figure 15.3: Modelled flood depth and velocity for a 20-Year ARI for the Northern Access Road	15-39
Figure 15.4: Existing modelled TSS concentrations in the wet (left) and dry (right) seasons	15-50
Figure 15.5: Predicted mine-derived incremental TSS concentrations during construction in the wet (left) and dry (right) seasons (unmitigated)	15-51
Figure 15.6: Predicted mine-derived incremental TSS concentrations increment during operations in the wet (left) and dry (right) seasons (unmitigated)	15-52
Figure 16.1: Coastal Area location	16-6
Figure 17.1: CTD profile of turbidity at Site A3 in the Markham Canyon	17-14
Figure 17.2: Coherent tailings density current 10m below the Misima Gold Mine DSTP outfall in 1993..	17-16
Figure 17.3: Average incremental increase in TSS from tailings subsurface plumes at CTD sites	17-18
Figure 17.4: Average incremental increase in TSS from tailings subsurface plumes at ADCP mooring sites	17-19
Figure 17.5: Predicted distribution of tailings subsurface plumes in the water column.....	17-20
Figure 17.6: Modelled tailings subsurface plumes (suspended solids fraction)	17-23
Figure 17.7: Predicted extent of subsurface plumes – dilution of the tailings liquid fraction.....	17-27
Figure 17.8: Concentration of dissolved (<0.45µm) copper, cobalt, nickel and zinc in elutriate tests	17-31
Figure 17.9: Modelled natural riverine sediment deposition footprint after one year	17-46
Figure 17.10: Modelled tailings footprint from the density current after one year	17-47
Figure 17.11: Modelled tailings footprint from subsurface plumes after one year.....	17-48
Figure 17.12: Modelled total tailings footprint from subsurface plumes and density current after one year	17-49
Figure 17.13: Modelled total tailings footprint after 27 years of DSTP operation and inclusive of one mass movement event per year.....	17-51
Figure 17.14: Ratio of tailings solids to natural sediments (top panel) and predicted tailings depositional thickness (bottom panel) after 27 years	17-53
Figure 17.15: Predicted annual rate of natural sedimentation after cessation of DSTP	17-54
Figure 18.1: SEIA process.....	18-2
Figure 18.2: Proposed alluvial mining leases within and near SML 10	18-25
Figure 18.3: Socioeconomic impact significance – comparison across study	18-132
Figure 18.4: Environmental and Social Management Framework	18-133
Figure 19.1: HHRA study areas.....	19-2
Figure 19.2: Conceptual site model.....	19-12
Figure 19.3: Conceptual site model of DSTP and potential exposure pathways for biota	19-27
Figure 20.1: Cultural heritage sites included in the impact assessment	20-4
Figure 20.2: Water-based cultural heritage sites predicted to be impacted by groundwater drawdown ..	20-12
Figure 22.1: Credible and not credible projects - Watut River catchment.....	22-7
Figure 22.2: Credible and not credible projects - Lae	22-8
Figure 23.1: Sustainable Business Management System.....	23-2
Figure 23.2: Environmental and Social Management Framework	23-3

LIST OF TABLES

Table 1.1: Summary of Project infrastructure and facilities	1-5
Table 1.2: Proposed timing of key Project milestones	1-7
Table 1.3: Wafi-Golpu Project EIS documentation	1-10
Table 2.1: Wafi-Golpu Project studies	2-2
Table 3.1: Tenements required for the Project.....	3-2
Table 3.2: Environmental impact assessment process	3-4
Table 3.3: Relevant legislation and regulations.....	3-6
Table 5.1: Key Project Stakeholder Groups	5-2
Table 5.2: Stakeholder engagement activities conducted by the WGJV	5-6
Table 5.3: Issues raised by Project Stakeholders	5-10
Table 6.1: Project facilities and disturbance areas	6-5
Table 6.2: Approximate volume of waste rock to be extracted – declines	6-22
Table 6.3: Watut Process Plant stages and descriptions	6-27
Table 6.4: Watut Process Plant approximate reagent consumption at 16.84Mtpa production rate	6-28
Table 6.5: Estimated water demand (m ³ /h)	6-32
Table 6.6: Water management LOM treatment requirements.....	6-40
Table 6.7: Sewage plant predicted maximum discharge effluent limits	6-40
Table 6.8: Pipeline parameters.....	6-51
Table 6.9: Indicative pipeline trench rates	6-51
Table 6.10: Summary of Northern Access Road bridges	6-56
Table 6.11: Mine Area bulk fuel storage facility features.....	6-65
Table 6.12: Categories of non-mineral waste.....	6-67
Table 6.13: Estimated approximate annual mine waste generation during construction and operation.....	6-68
Table 7.1: High level overview of alternatives considered	7-2
Table 7.2: Significant constraints for the four key TSF locations assessed	7-13
Table 7.3 Comparison between the on-land tailings management and DSTP options.....	7-21
Table 8.1: Major terrain units within the Project Area.....	8-5
Table 8.2: Summary of measured and calibrated hydraulic conductivity and storativity for hydrogeological units	8-17
Table 8.3: PNG Water quality objectives and guideline values.....	8-25
Table 8.4 Selected groundwater quality values from 2014/2015 sampling campaigns	8-28
Table 8.5 Selected groundwater quality values in alluvial and bedrock aquifers	8-29
Table 8.6: Summary of terrestrial ecology surveys in the terrestrial ecology study area	8-34
Table 8.7: Vegetation communities within the terrestrial ecology study area	8-37
Table 8.8: Vegetation condition	8-48
Table 8.9: Conservation significant flora species from IUCN Red List.....	8-53
Table 8.10: Conservation significant fauna species from IUCN Red List.....	8-59
Table 8.11: Conservation significant fauna species listed in Fauna Act	8-62

Table 8.12: Noise monitoring results	8-63
Table 8.13: PM ₁₀ monitoring data	8-65
Table 9.1: Water quality guideline values	9-7
Table 9.2: Sediment quality guideline values	9-9
Table 9.3: Key historical freshwater aquatic ecology data sources	9-10
Table 9.4: Field sampling sites and freshwater ecology sampling parameters (Lower Watut River catchment)	9-11
Table 9.5: Aquatic ecology field sampling sites (Lower Markham River floodplain)	9-13
Table 9.6: Modified and natural habitat criteria	9-15
Table 9.7: Critical habitat assessment criteria	9-17
Table 9.8: Lower Watut River catchments overview	9-21
Table 9.9: Sunshine gauge: adopted design discharge	9-25
Table 9.10: Summary of labile metals, complexation capacity and DOC data	9-48
Table 9.11: Total metals concentrations for the Lower Watut River catchment	9-51
Table 9.12: Dissolved metal and metalloid concentrations in watercourses on the Lower Markham River floodplain (mg/L)	9-55
Table 9.13: Total metals and metalloids in watercourses on the Lower Markham River floodplain (mg/L)	9-56
Table 9.14: Aquatic ecosystem types based on different classification schemes	9-66
Table 9.15: Percentage of PNG land area by ecosystem type	9-72
Table 9.16: Aquatic macrophyte species recorded within the Lower Watut River catchment	9-76
Table 10.1: Sediment quality guidelines	10-20
Table 10.2: Sediment classification based on particle size (data in % of total) (November 2016)	10-20
Table 10.3: Sediment classification based on particle size (data in % of total) (February 2017)	10-21
Table 10.4: Water quality guideline values	10-23
Table 11.1: Estimated Speed of Turbidity Current Fronts	11-15
Table 11.2: Estimated suspended sediment load for the Markham and Busu rivers	11-20
Table 11.3: Particle size distribution in bed sediments from box core samples – February 2017	11-27
Table 11.4: Total sediment metals (mg/kg) concentrations from box core samples – February 2017	11-28
Table 11.5: EDTA sediment metals concentrations (mg/kg) from box core samples – February 2017	11-29
Table 11.6: Summary of food standards and guidelines	11-38
Table 11.7: Macrofauna abundance and density and meiofauna density in deep-sea sediment samples, February 2017	11-58
Table 11.8: Density (number/10cm ²) of meiobenthic fauna collected in the Markham Canyon survey, December 2017	11-58
Table 12.1: Data collection activities for Study Area 1 (2010–2017)	12-4
Table 12.2: Settlement of Tier 1 villages	12-16
Table 12.3: Population data and extrapolated 2017 population of Tier 1 villages	12-18
Table 12.4: Population data and extrapolated 2017 population of Tier 2 villages	12-18
Table 12.5: Land use types in Lae	12-41
Table 12.6: Shellfish types collected by residents of Wagang village	12-77

Table 12.7: Major law and order issues in Wagang	12-82
Table 13.1: Cultural heritage study areas.....	13-4
Table 13.2: Cultural heritage site types	13-7
Table 13.3: Cultural heritage criteria and ratings (based on Australia ICOMOS Burra Charter (2013)).....	13-8
Table 13.4: Ples tambu sites recorded in the Mine Study Area	13-15
Table 14.1: Matrix for assessing the level of significance of a residual impact.....	14-2
Table 14.2: Sensitivity of landform and soils environmental values definitions.....	14-3
Table 14.3: Sensitivity of landform and soils environmental values	14-4
Table 14.4: Definitions for the magnitude of impacts to landform and soils.....	14-4
Table 14.5: Disturbance to soil types	14-9
Table 14.6: Summary of landform and soils residual impact assessment	14-12
Table 14.7: Definitions for sensitivity of groundwater values	14-15
Table 14.8: Groundwater value sensitivity.....	14-16
Table 14.9: Definitions for the magnitude of impacts to groundwater	14-16
Table 14.10: Estimated stream length impacted by groundwater drawdown at end of mining.....	14-22
Table 14.11: Predicted baseflow reduction residual impact assessment.....	14-28
Table 14.12: Indicative block cave and subsidence zone water quality	14-29
Table 14.13: Predicted groundwater quality within the block caves at closure	14-31
Table 14.14: Simulated subsidence zone lake water quality during post-closure filling	14-32
Table 14.15: Summary of groundwater predicted residual impact assessment.....	14-35
Table 14.16: Habitat ecological values and their sensitivity	14-37
Table 14.17: Population level values and their sensitivity	14-38
Table 14.18: Definitions for sensitivity of terrestrial ecology values	14-40
Table 14.19: Definitions for the magnitude of potential impacts to terrestrial ecology	14-41
Table 14.20: Summary of potential issues and impacts during Project construction, operation and decommissioning	14-50
Table 14.21: Terrestrial ecology impact areas by vegetation type	14-53
Table 14.22: Terrestrial ecology impact areas by vegetation condition	14-53
Table 14.23 Summary of terrestrial ecology residual impact assessment	14-71
Table 14.24: Modelled emission sources	14-77
Table 14.25: Adopted Ambient Air Quality Criteria.....	14-78
Table 14.26: Emissions sources informing separation distance assessment.....	14-78
Table 14.27: Emissions sources.....	14-87
Table 14.28: Calculated annual greenhouse gas emissions.....	14-89
Table 14.29: Modelled noise emission sources	14-90
Table 14.30: Adopted Noise Level Criteria.....	14-91
Table 14.31: Project vibration and airblast criteria	14-92
Table 14.32: Mine construction noise predictions	14-95
Table 14.33: Infrastructure Corridor compliance assessment.....	14-96

Table 14.34: Mine Area operation noise predictions	14-97
Table 14.35: Borrow Pits, Quarry and Gravel Extraction Operation Compliance Assessment.....	14-99
Table 15.1: Sensitivity of an aquatic environmental value or receptor	15-8
Table 15.2: Magnitude of aquatic ecological impacts.....	15-9
Table 15.3: Matrix for assessing the level of significance of a residual impact.....	15-10
Table 15.4: Aquatic habitat ecological values and their sensitivity	15-11
Table 15.5: Project stage, activities, stressors and potential impacts on freshwater ecology	15-17
Table 15.6: Modelled Lower Watut River flows and predicted water abstraction during operations.....	15-37
Table 15.7: Modelled existing and predicted (unmitigated) sediment loads for construction in Boganchong and Womul creeks and the Wafi and Bavaga rivers	15-40
Table 15.8: Modelled existing and predicted (unmitigated) sediment loads for construction and operations in Lower Watut River catchment	15-45
Table 15.9: Modelled baseline and predicted dissolved metal and metalloid concentrations downstream of the discharge point in the Lower Watut River during construction (mg/L).....	15-47
Table 15.10: Semi-quantitative assessment of other parameters (mg/L)	15-48
Table 15.11: High-level summary of residual freshwater aquatic ecological impacts	15-59
Table 16.1: Sensitivity of nearshore marine environmental values	16-2
Table 16.2: Magnitude of nearshore marine environment impacts	16-3
Table 16.3: Matrix for assessing the level of significance of a residual impact.....	16-4
Table 16.4: Estimated treated filtrate water quality and dilutions required to meet PNG ambient water quality criteria.....	16-15
Table 17.1: Sensitivity of a marine environmental value or receptor	17-3
Table 17.2: Magnitude of offshore marine environmental impacts	17-4
Table 17.3: Matrix of significance	17-6
Table 17.4: Summary of Marine Environmental Values and Sensitivities	17-8
Table 17.5: Particle size distribution of solids in the Tailings 1 sample	17-15
Table 17.6: Tailings liquor composition – dissolved (<0.45µm) metal concentrations in tailings liquor	17-29
Table 17.7: Metals in the subsurface plumes requiring dilution to meet PNG water quality criteria	17-33
Table 17.8: Dilutions of tailings liquor required to meet species protection levels based on ecotoxicity testing	17-34
Table 17.9: Background concentrations of trace metals (wet weight basis) in bulk (mixed) zooplankton samples	17-40
Table 17.10: Literature Plankton and Micronekton Vertical Migration Velocities	17-40
Table 17.11: Particle sizes of natural sediments and tailings solids	17-55
Table 17.12: Comparison of natural sediments and tailings with sediment quality guidelines	17-60
Table 17.13: Summary of predicted residual impacts to the offshore marine environment	17-69
Table 18.1: Levels of likelihood adopted for the assessing significance	18-3
Table 18.2: Levels of consequence adopted for the assessing significance	18-4
Table 18.3: Assessment matrix for determining significance of potential socioeconomic impacts	18-5
Table 18.4 Potential opportunities for local businesses	18-8

Table 18.5: Potential impacts related to employment, procurement, Project payments and the local economy (Study Area 1).....	18-15
Table 18.6: Potential impacts related to in-migration (Study Area 1).....	18-18
Table 18.7: Potential impacts related to physical and economic displacement (Study Area 1).....	18-21
Table 18.8: Potential impacts related to water use and water-based livelihoods (Study Area 1).....	18-27
Table 18.9: Potential impacts related to community health and safety (Study Area 1).....	18-34
Table 18.10: Potential impacts related to education (Study Area 1).....	18-38
Table 18.11: Potential impacts related to community cohesion and law and order (Study Area 1).....	18-41
Table 18.12: Potential impacts related to tradition and culture (Study Area 1).....	18-43
Table 18.13: Potential impacts related to traffic (Study Area 1).....	18-43
Table 18.14: Proposed management measures for socioeconomic impacts.....	18-44
Table 18.15: Residual impact assessment for Study Area 1.....	18-53
Table 18.16: Initial impact assessment for Study Area 2.....	18-78
Table 18.17: Residual significance assessment for Study Area 2.....	18-84
Table 18.18: Initial impact assessment for Study Area 3.....	18-100
Table 18.19: Residual significance assessment for Study Area 3.....	18-106
Table 18.20: Initial impact assessment for Study Area 4.....	18-119
Table 18.21: Residual significance assessment for Study Area 4.....	18-125
Table 18.22: Plans under the WGJV Environmental and Social Management Framework.....	18-134
Table 19.1: Plausible exposure pathway evaluation – human receptors.....	19-7
Table 19.2: Ambient Air Quality Screening Assessment for Study Area 1 ($\mu\text{g}/\text{m}^3$).....	19-13
Table 19.3: Human health soil and sediment screening assessment (mg/kg).....	19-14
Table 19.4: Total metals drinking water screening assessment ⁽¹⁾	19-15
Table 19.5: Surface water screening assessment for recreational use.....	19-15
Table 19.6: Human biological specimen – Tier 1 (T1) screening assessment.....	19-17
Table 19.7: Exposure parameters – dermal, ingestion and incidental ingestion of water.....	19-19
Table 19.8: Total Hazard Index calculated for exposure to COPC by receptors in selected study areas (baseline conditions).....	19-21
Table 19.9: Predicted metal concentrations in DSTP subsurface plume and fish tissue in the Huon Gulf.....	19-28
Table 20.1: Impact significance assessment matrix.....	20-1
Table 20.2: Impact significance rating characteristics.....	20-2
Table 20.3: Cultural heritage significance ratings of potentially impacted sites.....	20-5
Table 20.4: Impact assessment ratings (pre-management measures).....	20-5
Table 20.5: Summary of residual impacts.....	20-13
Table 22.1: Evaluation of potential credible projects.....	22-4
Table 24.1: The WGJV Project team.....	24-1
Table 24.2: Coffey and Advisian teams.....	24-2
Table 24.3: Technical specialists.....	24-3
Table 24.4: WGJV Participants' Representatives.....	24-5