San Jorge Nickel Project

Environmental Impact Statement (EIS) | Draft

Prepared for Axiom Mining Limited | 18 January 2018

San Jorge Nickel Project

Environmental Impact Statement

Prepared for Axiom Mining Limited | 18 January 2018

Ground Floor, Suite 01, 20 Chandos Street
St Leonards, NSW, 2065

T +61 2 9493 9500
F +61 2 9493 9599
E info@emmconsulting.com.au

www.emmconsulting.com.au

San Jorge Nickel Project

Final Draft

Report J17022RP1 | Prepared for Axiom Mining Limited | 18 January 2018

Prepared by	**Rob Morris**	Approved by	**Luke Stewart**
Position	Associate Director	Position	CEO
Signature		Signature	
Date	18 January 2018	Date	18 January 2018

Document Control

Version	Date	Prepared by	Reviewed by
V2	03/11/2017	R. Morris / E. Thackray	L. Stewart
V3	18/01/2018	R. Morris / E. Thackray	L. Stewart

T +61 (0)2 9493 9500 | F +61 (0)2 9493 9599

Ground Floor | Suite 01 | 20 Chandos Street | St Leonards | New South Wales | 2065 | Australia

www.emmconsulting.com.au

Table of contents

Chapter 1	Introduction	1
1.1	Overview	1
1.2	The Proponent	2
1.3	Project area	2
1.4	Project summary	4
1.4.1	Components	4
1.4.2	Objectives	5
Chapter 2	Legislation and regulatory framework	9
2.1	Legislation	9
2.1.1	The Constitution 1978	9
2.1.2	Mines and Minerals Act 1990 [Cap 42], Mines and Minerals (Amendment) Act 1996, 2008 and 2014, and the Mines and Minerals Regulations (1996) as amended in 1999, 2008 and 2014.	9
2.1.3	Environment Act 1998 and Environment Regulations 2008	12
2.1.4	Land and Titles Act [Chapter 133]	14
2.1.5	Protected Areas Act 2010	14
2.1.6	Wildlife Protection and Management Act (1998), Wildlife Protection and Management Act (Amended) (2017)	14
2.1.7	National Park Act 1978	15
2.1.8	Fisheries Act 1998	15
2.1.9	River Waters Act 1964	15
2.1.10	Forest Resources and Timber Utilisation Act 1969 [Cap 40], Forest and Timber (Amendment) Act 1984, Forests Act 1999, Forests Bill 2004.	15
2.1.11	Town and Country Planning Act 1982 [Cap 154], Town and Country Planning (Amendment) Act 2017	16
2.1.12	Environmental Health Act 1980 [Cap 99]	16
2.1.13	Shipping Act 1988 [Cap 163]	16
2.1.14	Petroleum Act 1987	16
2.2	Ordinances	16
2.2.1	Isabel Province Draft Resource Management and Environment Protection Ordinance 2006	16
2.2.2	Isabel Province Conservation Area Ordinance 1993	17
2.3	Policy	17
2.3.1	National Minerals Policy 2017-2021	17
Chapter 3	Project justification and alternatives	19
3.1	Background	19
3.1.1	Nickel market	19
3.1.2	Economy of the Solomon Islands	19

Table of contents

3.2 Project justification 19
3.2.1 Direct economic benefits 19
3.2.2 Indirect economic benefits 20
3.3 Alternatives 20
3.3.1 Not proceeding with the project 20
3.3.2 Alternative location 21
3.3.3 Alternative mining method 21
3.3.4 Alternative infrastructure 21

Chapter 4 Project description 23
4.1 Construction 23
4.2 Operations 24
4.3 Nickel resource 26
4.3.1 San Jorge nickel resource geology 26
4.3.2 Nickel laterite deposits 26
4.3.3 Resource deposits 27
4.3.4 Background to development of the Isabel nickel deposits 27
4.3.5 Mining method 28
4.3.6 Mining fleet and equipment 31
4.4 Project infrastructure 32
4.4.1 Power and communications 32
4.4.2 Lay down areas 32
4.4.3 Ore handling facility and mine infrastructure area 33
4.4.4 Ship mooring and transfer 34
4.4.5 Water supply 34
4.5 Waste management 34
4.5.1 Solid waste 34
4.5.2 Waste water 35
4.6 Transport 35
4.7 Workforce 35
4.7.1 Accommodation camps and office facilities 36
4.8 Rehabilitation and closure plan 36
4.9 Expected project schedule 37

Chapter 5 Environmental impact assessment 39
5.1 Assessment approach 39
5.1.1 Background information and data collection 39
5.2 Environmental and social values 39
5.3 Impact assessment method 39

Table of contents

5.3.1 Significance assessment method 40
5.3.2 Compliance assessment method 40
5.4 Impact prioritisation and assessment 40

Chapter 6 Physical setting 45
6.1 Physical setting 45
6.1.1 Location and topography 45
6.1.2 Climate and weather 45

Chapter 7 Soil assessment 47
7.1 Assessment objectives 47
7.2 Assessment method 47
7.2.1 Field surveys 47
7.3 Existing environment 47
7.3.1 Soil 49
7.3.2 Limonitic zone 49
7.3.3 Saprolitic layer 50
7.4 Impact assessment 50
7.4.1 Loss of soil stability 52
7.4.2 Loss of soil function 52
7.5 Management plans and mitigation measures 52
7.5.1 Management plans 52
7.5.2 Rehabilitation 54
7.6 Residual impacts 54
7.7 Conclusion and summary 54

Chapter 8 Terrestrial ecology 55
8.1 Assessment objectives 55
8.2 Assessment method 55
8.2.1 Limitations of surveys 56
8.3 Existing environment 56
8.3.1 Flora 56
8.3.2 Fauna 65
8.4 Impact assessment 74
8.4.1 Land clearance 74
8.4.2 Habitat fragmentation and edge effects 75
8.4.3 Water quality impacts 76
8.4.4 Direct and indirect mortality 76
8.4.5 Noise and vibration 77
8.4.6 Artificial light 77

Table of contents

8.4.7 Traffic 77
8.4.8 Dust and air quality 77
8.4.9 Increased risk of fire 77
8.4.10 Erosion and sedimentation 77
8.4.11 Invasive weeds 78
8.4.12 Introduction of Invasive species 78
8.5 Management plans and mitigation measures 80
8.5.1 Habitat loss / land clearance 80
8.5.2 Habitat fragmentation and edge effects 80
8.5.3 Water quality 81
8.5.4 Artificial light 82
8.5.5 Traffic 82
8.5.6 Dust and air quality 82
8.5.7 Fire control 82
8.5.8 Erosion and sedimentation 82
8.5.9 Invasive weeds 83
8.5.10 Introduction of invasive species 83
8.6 Residual impacts 84
8.7 Conclusion and summary 85

Chapter 9 Fresh water environment 87
9.1 Assessment objectives 87
9.2 Assessment method 87
9.3 Existing environment 87
9.3.1 Climate 87
9.3.2 Vegetation and soils 88
9.3.3 Watercourses 89
9.3.4 Hydrogeology 92
9.3.5 Water quality 92
9.3.6 Sediment characteristics and quality 95
9.3.7 Freshwater resource use 95
9.4 Impact assessment 95
9.5 Management plans and mitigation measures 97
9.5.1 Water management strategy 97
9.5.2 Management plans 97
9.6 Residual impacts 99
9.7 Conclusion and summary 100

Chapter 10 Physical marine environment 101
10.1 Assessment objectives 101

Table of contents

10.2 Assessment method 101
10.3 Existing environment 102
10.3.1 Metocean 102
10.3.2 Marine water quality 102
10.3.3 Marine resource use 103
10.4 Impact assessment 103
10.4.1 Surface water runoff 103
10.4.2 Marine loading impacts 105
10.4.3 Summary of potential impacts 107
10.5 Management plans and mitigation measures 109
10.5.1 Management plans 109
10.6 Residual impacts 110
10.7 Conclusion and summary 111

Chapter 11 Marine ecology 113
11.1 Assessment objectives 113
11.2 Assessment method 113
11.2.1 Desktop assessments 113
11.2.2 Field surveys 114
11.2.3 Habitat mapping 114
11.3 Existing environment 114
11.3.1 Overview 114
11.3.2 Marine habitats 116
11.3.3 Marine flora 117
11.3.4 Marine fauna 118
11.3.5 Species of conservation significance 118
11.4 Impact assessment 118
11.4.1 Erosion and sedimentation 119
11.4.2 Increased turbidity 119
11.4.3 Eutrophication 120
11.4.4 Hazardous spills and leaks 120
11.4.5 Acid sulphate soils 120
11.4.6 Ballast water dumping 120
11.4.7 Litter and waste 121
11.4.8 Vessel collisions with fauna 121
11.5 Management plans and mitigation measures 123
11.6 Residual Impacts 125
11.7 Conclusion and summary 126

Table of contents

Chapter 12 Amenity 127

12.1 Visual amenity 127

12.1.1 Assessment method 127

12.1.2 Existing environment 128

12.1.3 Impact assessment 130

12.1.4 Mitigation measures 133

12.1.5 Residual impacts 133

12.2 Air 133

12.2.1 Assessment method 133

12.2.2 Existing environment 134

12.2.3 Impact assessment 135

12.2.4 Mitigation measures 136

12.2.5 Residual impacts 136

12.3 Noise 137

12.3.1 Assessment method 137

12.3.2 Existing environment 139

12.3.3 Impact assessment 139

12.3.4 Management measures 139

12.3.5 Residual impacts 139

Chapter 13 Socio-economics 141

13.1 Assessment objectives 141

13.2 Assessment method 141

13.3 Existing socio-economic context 141

13.3.1 Country setting 141

13.3.2 Governance and society 142

13.3.3 Demographics 143

13.3.4 Livelihoods and employment 147

13.3.5 Land tenure 148

13.3.6 Education 149

13.3.7 Community health 150

13.3.8 Houses and accommodation 153

13.4 Isabel Province and the San Jorge Study Area 154

13.4.1 Governance and society 154

13.4.2 Demographics 156

13.4.3 Livelihoods and employment 160

13.4.4 Land tenure 165

13.4.5 Education 167

13.4.6 Health care 167

Table of contents

13.4.7 Houses and accommodation 171
13.4.8 Stakeholder engagement 172
13.5 Impact assessment 177
13.5.1 Beneficial impacts 177
13.5.2 Adverse impacts 178
13.5.3 Socio-economic mitigation measures 183
13.6 Residual impacts 186
13.7 Conclusion and summary 188

Chapter 14 Cultural and historical heritage 189
14.1 Introduction 189
14.2 Solomon Island legislative framework 189
14.2.1 Solomon Islands Legislation 189
14.3 Assessment method 192
14.3.1 Overview 192
14.3.2 Community Consultation 192
14.4 Project area demography and cultural groups 192
14.5 Existing cultural and historical heritage values 193
14.6 Non indigenous cultural aspects 193
14.6.1 Santa Isabel Province 1500 – 1900 193
14.6.2 Santa Isabel Province 1900 – 2000 194
14.7 Impact assessment 195
14.8 Mitigation measures 198
14.8.1 Overview 198
14.8.2 Chance finds protocol 198
14.9 Residual Impacts 199
14.10 Conclusion and summary 201

Chapter 15 Management plans and mitigation measures 205

Chapter 16 Summary and conclusions 211

References 213

Study team 217

Appendices

A	Soil assessment
B	Rehabilitation plan
C	Freshwater assessment
D	Physical marine assessment
E	Terrestrial species list
F	Marine ecology species lists
G	Noise assessment
H	Stakeholder consultation

Tables

2.1	Requirements of an Environmental Impact Statement (EIS)	13
4.1	Disturbance areas	31
4.2	Equipment fleet numbers	32
5.1	Significance assessment matrix	40
5.2	Key issues	41
5.3	Impact prediction	42
7.1	Summary of unmitigated impacts and their significance	51
7.2	Summary of residual impacts	54
8.1	Mammal species recorded by SMM (2014) on adjacent parts of Santa Isabel Island	65
8.2	Mammal species recorded from the vicinity of the project area	66
8.3	Primary / valley (gulley) forest	67
8.4	Open areas of woodland / Fernland	69
8.5	Coastal and Marine areas	69
8.6	Bird species recorded from the vicinity of the project area	70
8.7	Amphibians and Reptiles recorded on the tenement	72
8.8	Land clearance by habitat type (ha) (base case scenario)	74
8.9	Summary of unmitigated impacts and their significance	79
8.10	Residual impacts following the implementation of proposed management measures	84
9.1	Summary of unmitigated impacts and their significance	96
9.2	Residual impacts following the implementation of proposed management measures	99
10.1	Summary of unmitigated impacts and their significance – physical marine environment	108
10.2	Residual impacts following the implementation of proposed management measures	111
11.1	Summary of unmitigated impacts and their significance – marine ecology	122
11.2	Residual impacts following the implementation of proposed management measures	125
12.1	Air quality criteria	134
12.2	Ambient air quality in tenements D and E	134

Tables

12.3	Operational plant and equipment sound power levels	138
12.4	Noise modelling results	139
13.1	Population Indicators Solomon Islands 2009	145
13.2	Projected population by province 2010 – 2025	145
13.3	Number of Schools by Type, 2007	149
13.4	Mortality and health indicators, selected years 1980-2012	151
13.5	Cause of death	151
13.6	Population in five-year age groups: 1 Jul 2017	157
13.7	Isabel Province Ward Populations (2009)	158
13.8	Percentage (%) distribution of income by sub-category in provinces	161
13.9	Percentage (%) distribution of home production by selected goods by province	162
13.10	Annual Expenditure Distribution by Category and Type, Isabel Province	162
13.11	Isabel Province schools by type, 2007	167
13.12	Health facility network by province	168
13.13	Health facility status Isabel Province, 2015	169
13.14	Distribution of health personnel and facilities by province, 2010	170
13.15	Stakeholder engagement summary	173
13.16	Summary of potential beneficial impacts	182
13.17	Summary of potential adverse impacts	183
13.18	Social-economic management measures	184
13.19	Residual impacts following the implementation of proposed management measures	187
14.1	Potential unmitigated impacts and their significance	197
14.2	Cultural heritage – residual impacts following the implementation of proposed management measures	200
15.1	Proposed management plans and mitigation measures	205
15.2	General mitigation measures	209

Figures

1.1	Project location	3
1.2	Project area	7
2.1	Application process for a prospecting and a mining lease	11
4.1	Proposed mine layout plan	25
4.2	San Jorge Tenement lateritic profile	27
7.1	Geological setting	48
8.1	Habitat mapping	58
9.1	Catchment areas and watercourse alignments	91
9.2	Surface water sampling locations	94
10.1	Digital imagery showing increased sediment concentrations in the receiving waters from freshwater sources (imagery date 7 July 2013)	102
10.2	Scenario SW1: Typical rain event (120 mm over five days), average wind conditions, no development	104
10.3	Scenario SW2: Extreme rain event (250 mm over five days), strong wind conditions, no development	104
10.4	Scenario SW3: Extreme rain event (250 mm over five days), strong wind conditions, project development with surface clearance	105
10.5	Scenario ML1: Wet season conditions, 1% direct spillage over one month	106
10.6	Scenario ML2: Wet season conditions, 2% direct spillage over one month	106
10.7	Scenario ML3: Dry season conditions, 2% direct spillage over one month	107
11.1	Habitat Map	115
12.1	Viewshed analysis	132
13.1	Solomon Islands provinces	144
13.2	Percentage of Children Aged 6-15 Attending School Across Provinces, 2009	150
13.3	DALYs for Solomon Islands 2012	152
13.4	The location of the Gao-Bugotu Constituency, Isabel Province	155
13.5	Population Map of Isabel Province by ward	158
13.6	Population Pyramid, Isabel Province (2009)	159
13.7	Land ownership plan	166
13.8	Health facilities in Isabel Province, 2015	168
14.1	Alvaro Mendaña	193
14.2	Site of Cultural importance	196

Photographs

7.1	Soil sampling on San Jorge	50
8.1	The higher area of San Jorge showing the extent of ultramafic forest on the two closer ridgelines. Santa Isabel Island can be seen in the far distance.	57
8.2	Coconut plantation	57
8.3	Fernland habitat	59
8.4	Coastal mangroves	60
8.5	Beach Forest	62
8.6	Ultramafic forest	63
8.7	The endemic Solomons Pied Monarch	67
8.8	A pair of the endemic Ultramarine Kingfishers	68
8.9	Solomon Islands Eyelash Frog (*Cornufer guentheri*)	71
8.10	Weber's Wrinkled Ground Frog (*Cornufer weberi*)	71
8.11	Fauro sticky-toed Frog (*Cornufer vertebralis*)	73
8.12	An Elegant Forest Skink (Sphenomorphous concinnatus) caught with a sticky-board trap	74
9.1	View from project area facing north-west	88
9.2	Typical higher reach watercourse (Sumia Creek)	89
9.3	Typical lower reach watercourse	90
9.4	Davu Creek with logging in the background after a rainfall event	92
9.5	Confluence of two watercourses showing the impacts of soil disturbance from logging operations	93
12.1	View of Thousand Ships Bay from San Jorge (L) to Santa Isabel (R)	129
12.2	View of San Jorge from Thousand Ships Bay	129
13.1	Traditional housing Talise	171
13.2	Village shop / house Talise	172
13.3	Public consultation meeting – Talise September 2017	175
13.4	Public consultation meeting – Vulavu September 2017	176
13.5	Public consultation meeting – Loghutu September 2017	176
13.6	The recent settlement at Kogarutu	177

1 Introduction

1.1 Overview

Axiom KB Limited (Axiom KB), a subsidiary of Axiom Mining Limited (Axiom), proposes to develop the San Jorge Nickel Project on San Jorge Island in Isabel Province of the Solomon Islands (the project)(Figure 1.1). Isabel Province is one of nine administrative provinces within the Solomon Islands, in addition to the capital territory of Honiara, and is located approximately 135 km north-west of the capital, Honiara.

The project will extract approximately 2 million tonnes per annum (Mtpa) of nickel laterite deposits over a period of approximately five to ten years. The ore will be partially dried, then transferred by barge and loaded onto ships moored in Thousand Ships Bay, and then transported to regional processing hubs. Axiom has secured a Prospecting Licence (PL 01/15) and a 50 year leasehold over the San Jorge Tenement (36 km^2). Mining is a "prescribed" development under the *Environment Act 1988* (Environment Act) and requires the production of an Environment Impact Statement (EIS) compliant with the Environment Regulations (2008) (Environment Regulations).

Axiom has engaged EMM Consulting Pty Ltd (EMM) to prepare this environmental impact statement (EIS), which describes the construction, mining and rehabilitation activities proposed by Axiom. This EIS has been prepared in accordance with the requirements for approval of the Solomon Island Government as set out in Section 23 of the Environment Act and clause 29 of the Environment Regulations for the development of a project.

This EIS describes:

- the proponent, the nickel resource and the project;
- the legislative framework relevant to the environmental assessment and management of mining projects in the Solomon Islands;
- project-related stakeholder consultation;
- EIS methodology and issues prioritisation;
- the existing environment, impact assessment method, potential impacts and environmental management and monitoring for each potentially impacted environmental aspect;
- the potential cumulative impacts associated with the concurrent operation of the project with adjoining proposed and operational projects; and
- the proposed environmental commitments, management framework and monitoring requirements.

The following technical assessments are appended to, and inform the EIS:

- soil assessment;
- mine rehabilitation plan;
- freshwater environment assessment;

- physical marine environment assessment; and
- noise assessment.

1.2 The Proponent

Axiom KB is a joint venture company which is 90% owned by Axiom and 10% owned by the Bungusule customary land owning tribes for the San Jorge deposit. This ownership structure accords with Axiom's core values of partnership with traditional land owners and development of mining that benefits the local community and wider region.

The parent company, Axiom, is engaged in exploration for nickel, copper, gold, uranium and shale oil in Queensland, Australia; and is 100% owner of the West Guadalcanal Project in the Solomon Islands. The West Guadalcanal Project comprises exploration for gold, silver and copper.

Axiom was listed on the Australian Stock Exchange in November 2006 and re-listed in November 2009. Axiom commenced relationship building with the local community, government and landholders near the Isabel nickel deposit in October 2010, and continues to actively engage all stakeholders in regard to the project.

Axiom KB's registered office in the Solomon Islands is at the following address:

Address: Upper Level, Solomon Post Haus, Mendana Ave, Honiara, Solomon Islands (PO Box 845)

Phone: +677 29877; Fax: +677 23539

Axiom's (parent company) registered office in Australia is at the following address:

Address: Level 6, 15 Astor Terrace, Spring Hill Queensland 4000 Australia

Phone: +61 7 3319 4100; Fax: 61 7 3252 7577

1.3 Project area

The tenement area (area covered by Prospecting Licence (PL 01/15)) is approximately 9 km by 4 km, and includes the area bound by the Ghobu Creek catchment in the north-west to the Unk and Hughu Creek catchments in the south. The eastern extent includes the marine waters adjacent to the coastline, including Albatross Bay to the north, Astrolabe Bay to the east and Tanatola Bay to the south; beyond these bays, is the deep water mooring in Thousand Ships Bay.

The tenement area is referred to as the 'project area' for the purposes of this EIS.

San Jorge Island is very sparsely populated, with only one major settlement on the island at Talise on the central part of its east coast (Figure 1.2).

\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps\EIA002_Regional_20171101_05.mxd 6/11/2017

Source: EMM (2017); Axiom Mining Limited (2017)

Project location

Axiom Mining Limited
San Jorge Nickel Project
Environmental impact statement
Figure 1.1

1.4 Project summary

1.4.1 Components

This section summarises the project, which is described in detail in Chapter 3. The San Jorge nickel deposits are located at a relatively shallow depth (5 to 15 m beneath the ground surface). The deposits are also located within 2 km of the coast, and mined ore will be partially dried and transported to a loading facility within the tenement, as the pathway to shipment. The bay is close to deep water in Thousand Ships Bay to allow easy seaborne access to regional processing hubs.

There are some existing facilities and infrastructure from logging activities and previous exploration including haul roads and lay down areas that Axiom will upgrade, replace and maintain for use by the project. The project will comprise three phases, as outlined below.

- Construction phase:
  - site preparation works, eg vegetation clearance for construction, surface water controls and water supply;
  - development of mine administration facilities, mine accommodation, laydown areas and site services infrastructure;
  - establishment of haul roads and stockpiles between mining areas and the ore loading facility;
  - development of the ore loading facility, including a concrete ramp and a personnel jetty; and
  - trans-shipment infrastructure in Thousand Ships Bay such as channel markers.
- Operations phase:
  - progressive clearing of vegetation and topsoil prior to mining, and stockpiling of these materials for use in rehabilitation;
  - progressive haul and service road development within the mining area;
  - ore extraction within the mine area;
  - ore drying using windrows;
  - ore transport to ore loading facility;
  - barge loading;
  - transfer from barges to ocean-going vessels at an off-shore mooring;
  - ancillary activities, including operation of the mine camp, worker transportation, waste disposal; and
  - progressive rehabilitation.
- Mine and facilities closure.

1.4.2 Objectives

The project aims to develop the deposits within the San Jorge Tenement, shown in Figure 1.2.

The project can be effectively and efficiently implemented due to the shallow nature of the deposit, direct access to deep water and limited infrastructure requirements. Further, no ore processing is proposed onsite reducing the potential for environmental impacts and there are no settlements within the project area.

Axiom is committed to an enduring partnership with traditional land owners and development of mining that benefits the local community and wider region. This is reflected in its ownership structure, with this project being 10% owned by the customary land owners of the San Jorge tenement.

The project will create a significant number of jobs – projected to be 300 during construction and 120 to 140 during operations. Axiom will aim to recruit locally where possible, particularly from villages with customary ownership of the land, thereby ensuring the mine benefits local communities. Not only will this significantly increase income, but the training will provide ongoing benefits such as attainment of new skills that can be taken back to home villages.

The project will generate significant revenue through taxes and royalties for the government. It is anticipated that taxes and royalty benefits will be used for social infrastructure and social development such as education, healthcare and other long term community projects.

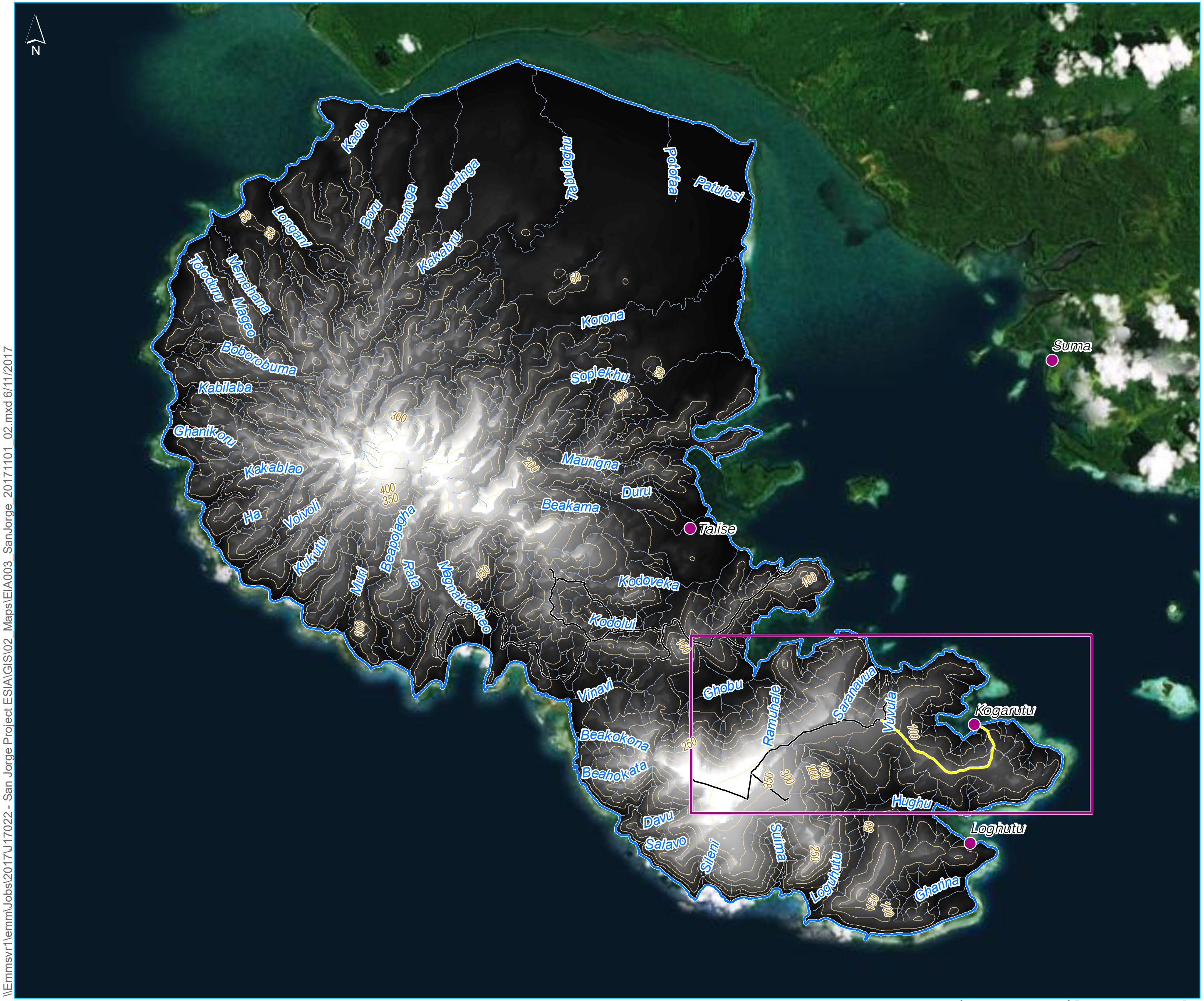
The project is aligned with government policy identifying the need to diversify the economy and aims to improve the standard of living, with just under a quarter of the Solomon Islands population estimated to be living under the poverty line in 2015 (https://data.worldbank.org/data-catalog/GDP-ranking-table Index).

Axiom's commitment to the project's socio-economic benefits is reflected in the following development principles.

- Build a skilled, local workforce:
    - Axiom currently employs approximately 50 local Isabellans, and as referenced above, will provide more employment opportunities for local people during the project's construction and operation phases; and
    - Axiom has commenced training Solomon Islanders to ensure the mine will be fully run by Solomon Islanders in the future.
- Share benefits from Axiom's operations:
    - Axiom's aim is to support and build capacity for landowner and community business opportunities such as market gardens and local fishermen to supply camps;
    - continuation of stakeholder engagement to enable the timely provision of relevant and clear project information and to provide a process that enables stakeholders to express their views, including opportunities for improvement, and allow timely feedback on any mattes raised; and
    - the project will enable the continuation of donations that help many people, including providing funds for renovations to Buala Hospital and buildings for local schools.

- Protect the wellbeing of people and local communities through safe and environmentally responsible operations:
    - Axiom will ensure that all mine development activities are carefully planned and executed in a manner that minimises impacts on the environment and people. This is reflected in the commitments made in this EIS; and
    - progressive mine rehabilitation planning will ensure that the mine voids, roads and drill pads and associated disturbed areas are stabilised as soon as practicable and allow rapid rehabilitation of the disturbed areas.

Mining is expected to expand to include development of the Kolosori Tenement. Approvals will be sought separately for the subsequent mine developments at Kolosori at the appropriate time and are not covered in this EIS.



KEY

- Village
- Prospecting licence boundary
- San Jorge Island coastline
- Main access road
- Local road
- Watercourse / drainage line
- Contour (50 m)

Elevation

High : 461

Low : -11

Project area

Axiom Mining Limited
San Jorge Nickel Project
Environmental impact statement
Figure 1.2

Source: EMM (2017); Axiom Mining Limited (2017)

0 2.5 5
km
WGS 1984 UTM Zone 57S

\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps\EIA003_SanJorge_20171101_02.mxd 6/11/2017

2 Legislation and regulatory framework

This chapter describes the relevant Solomon Islands legislation, regulations and ordinances under which the EIS has been prepared and will be assessed, and which will regulate the ongoing environmental management of the project, should it be constructed.

A range of other legislation will also apply to the project, for example in relation to quarantine, immigration, labour, customs, pharmacy and poisons, foreign investment and taxes. However, much of this legislation does not directly apply to the environmental management of the project and is, therefore, not considered further.

2.1 Legislation

2.1.1 The Constitution 1978

The Preamble of the 1978 Constitution of the Solomon Islands states that the natural resources of Solomon Islands are vested in the people and the government. It recognises customary land ownership and the right to compensation, with protections from the deprivation of property. However, it allows for the acquisition of property under certain conditions.

2.1.2 Mines and Minerals Act 1990 [Cap 42], Mines and Minerals (Amendment) Act 1996, 2008 and 2014, and the Mines and Minerals Regulations (1996) as amended in 1999, 2008 and 2014.

The *Mines and Minerals Act 1990 [Cap 42]* (Mines Act) vests the government with the exclusive right to develop mineral resources and deals with the legal, regulatory and contractual aspects of reconnaissance, prospecting, mining and closure.

Reconnaissance or exploration provisions are contained in Part III of the Mines Act (Price et al. 2015). Where the Minister is satisfied that the applicant possesses 'adequate' financial resources and technical competence and proposes an 'adequate' reconnaissance program, the Minister may grant a reconnaissance permit. Landowner consent is not required for the grant of the permit but the holder must obtain consent before they can access the land.

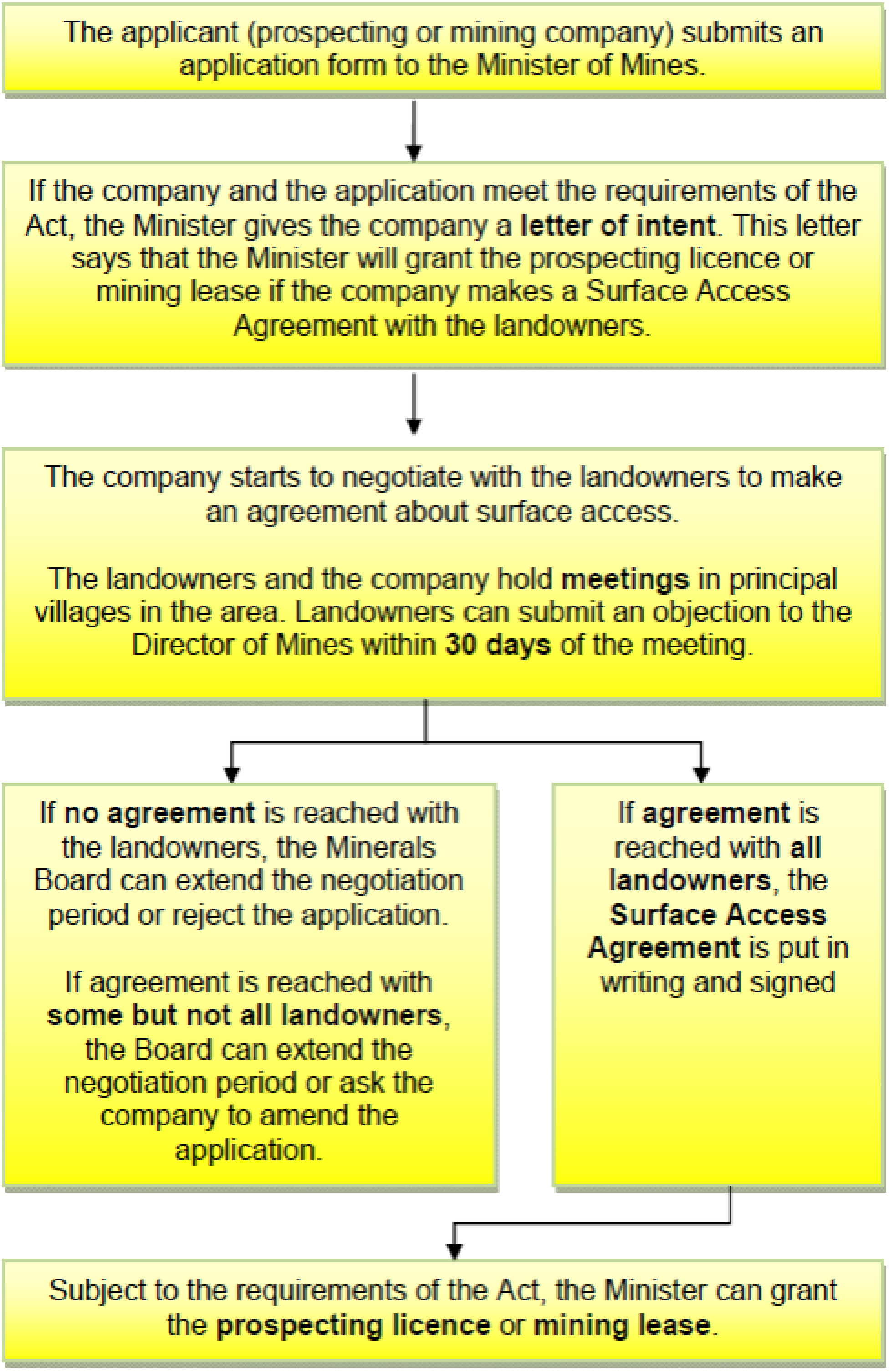
The provisions relating to prospecting are provided in Part IV of the Mines Act. A 'baseline' environmental study detailing the environmental impact of the prospecting must be submitted with the application. The Director must refuse the application if the area subject to the application overlaps with an existing prospecting license or mining lease area. Furthermore, the Director must refuse the application if the applicant is currently holding three or more prospecting licenses over other areas, and it has not applied for a mining lease or commenced mining in at least one area.

Where the Director deems the application for a prospecting license to be in order, the Minister of Mines must issue a 'letter of intent' indicating the Minister's intention to grant a prospecting license subject to the applicant acquiring surface access rights. 'Surface Access Rights' are negotiated under the supervision of the Director with the landowners and signed before prospecting activities begin.

Mining lease provisions are set out in Part V of the Mines Act. An applicant for a mining lease must hold a current prospecting license over the area it proposes to mine, and it must have made a commercial discovery and have in place a domestically incorporated company.

Before applying for a mining lease, the applicant must inform the Government of its proposed terms for the mining agreement and mining lease including the Government's share of production, revenue, profits or the equity capital of the mining company. Where the Director considers the application in order, he must determine whether the applicant has already obtained access rights for mining. If the applicant has surface access rights in place, the Minister may grant the lease. If the applicant has not already acquired surface access rights, then the Minister may issue a 'letter of intent' indicating the Minister's intention to grant the mining lease, subject to the applicant obtaining surface access rights.

The following diagram summarises the application process for a prospecting and a mining lease.



Source: Stephanie Price et al (2015) p 131

Figure 2.1 Application process for a prospecting and a mining lease

Although the principal purpose of the Mines Act and the Mines Regulations is to regulate the grant of reconnaissance, prospecting and mining rights, they also contain provisions for the protection of the environment. Section 6 of the Mines Act empowers the Minister for Mines to make regulations for conservation and to minimise damage to the environment.

For implementing Section 6 of the Mines Act, Section 18 of the Mines and Minerals Regulation 1996 (Mines Regulations) requires mining companies to:

- conserve and avoid the waste of the mineral deposits of Solomon Islands;
- result in minimum ecological damage or destruction;
- control the flow and prevent the escape of contaminants, tailings and other matters produced in the course of such operations;
- prevent avoidable damage to trees, crops, buildings and other structures;
- avoid any action which could endanger the health and safety of persons; and
- avoid harm to fresh and marine waters, and animal life.

As environmental conservation and protection are clearly criteria for a company to maintain its legal license to operate, it is in the developer's interest to ensure that its entire operation is compliant with the relevant environmental provisions in the Mines Act and the Mines Regulation.

2.1.3 Environment Act 1998 and Environment Regulations 2008

The *Environment Act 1998* (Environment Act) came into force in 2003 and is the first comprehensive environmental legislation in the Solomon Islands. The Environment Regulations was promulgated in 2008. This is the principal legislation the Solomon Islands Government uses to regulate the conduct of an EIS and monitor developer obligations.

It established the Environment and Conservation Division (ECD) within the Ministry of Environment, Climate Change, Disaster Management and Meteorology. It also established the position of the Director of the ECD and inspectors and the power of the Minister. The functions of the ECD include protecting the quality of the environment, developing national standards to promote sustainable development and promoting the participation of the community in environmental decision making (Price et al. 2015).

Section 4 (1) of the Environment Act states "[i]n the event of any conflict between the provisions of this Act and the provisions of any other Act, the provisions of this Act shall, to the extent of inconsistency prevail." This provision gives overriding power over other legislation with the exception of provisions within the National Constitution.

The Environment Act introduced a requirement for developers to obtain an approval called 'development consent' from the Director of the ECD before commencing certain 'prescribed developments' set out under the Second Schedule to the Act. Prescribed developments have to complete either a Public Environment Report or an Environment Impact Assessment to the satisfaction of the Director in accordance to the requirements set down in the Act. Mining is a prescribed development and requires compliance with the requirements of Section 23 of the Act. These requirements have been met, and the section where they are addressed is provided in Table 2.1.

Table 2.1 Requirements of an Environmental Impact Statement (EIS)

Requirement	Chapter / Section of the EIS where this element is addressed
Contain a full description of the objectives of the prescribed development;	Chapter 3, Chapter 4
Analyse the need for the prescribed development;	Chapter 3
Indicate the consequences of not implementing or carrying out the prescribed development;	Chapter 3
Include adequate information and technical data adequate to allow assessment of the impact of the prescribed development on the environment;	Chapter 4, Chapters 7 to 14.
Examine any reasonable alternatives to the prescribed development, including alternative sites for it;	Chapter 3
Describe the environment that is or is likely to be affected by the prescribed development and by any reasonable alternatives to it;	Chapters 6 to 14
Assess the actual or potential impact on the environment of the prescribed development and of any reasonable alternatives to it, including the primary, secondary, short-term, long-term, adverse and beneficial impacts on the environment;	Chapters 7 to 14
Outline the reasons for the choice of the prescribed development;	Chapter 3
Estimate the time period of any expected impacts;	Chapter 4, Chapters 7 to 14
Describe the geographic boundaries of the impacts;	Chapter 4, Chapters 7 to 14
State the methods of predicting and assessing each impact from the construction, operational and where relevant, the de-commissioning phase of an implemented development and for each alternative presented;	Chapter 5, Chapters 7 to 14
Justify the prescribed development in terms of environmental, economic, culture and social considerations;	Chapter 3, Chapters 7 to 14
Identify and analyse all likely impacts or consequences of implementing the prescribed development, including implications for the use and conservation of energy;	Chapter 4, Chapters 7 to 14
Describe measures to prevent or reduce significant adverse impacts and enhance beneficial effects and an account of their likely success with estimated costs as appropriate;	Chapters 7 to 15
Describe residual impacts which cannot be mitigated or can only be mitigated partially;	Chapters 7 to 14
Describe proposed monitoring and reporting schemes with estimated costs as appropriate;	Chapters 7 to 15
Describe and assess the estimated cost-effectiveness of any safeguards or standards for the protection of the environment to be adopted or applied including its implementation, monitoring or reporting;	Chapter 4, Chapters 7 to 15, Appendix B
Give an account of the impact on the environment of any of a series or programme of similar development (whether implemented or not) over a period of time;	Chapter 5
Give any sources and references of information relied on and outline any consultations with any persons made during the preparation of the report;	Chapter 17
Include a site survey report concerning National Heritage items or traditional artefacts as specified by the Director;	Chapter 14
Address any further matters as the Director specifies; and	Not applicable
Give a clear and concise summary printed on a separate page.	Non technical summary, Chapter 16

Once the EIS is in a form acceptable to the Director, notice is given for interested parties to lodge any submissions with regard to the granting of development consent. Upon examination of the objections, the Director either grants the Development Consent or refuses it (Price et al. 2015). Conditions for the development are set out in the Development Consent which the Director uses to regulate the development.

Any person who disagrees with the decision of the Director may within 30 days of the decision being published appeal to the Advisory Committee. A further 30 days is given for an appeal from the Advisory Committee to the Minister of Environment. Part IV of the Environment Act makes provision for the control of pollution from premises and standards to meet where waste is discharged from an operator's premises.

2.1.4 Land and Titles Act [Chapter 133]

Ownership, use and dispossession of rights to land in Solomon Islands are regulated under the Land and Titles Act first introduced in 1969 but now contained in Chapter 133 of the Solomon Islands Revised Edition 1996 (Price et al. 2015). Unregistered land, also commonly known as customary land, is regulated under the customs and practices of each region and differs from place to place. Where customary land is required for development, access rights are acquired through purchase or lease pursuant to Part V Division I of the Act or through compulsory acquisition pursuant to Part V Division II of the Act.

Mining rights as discussed in Section 2.1.2 above depend on having access to the surface of the land in what has been referred to as Surface Access Rights. Having access to the land is essential for reconnaissance, prospecting and mining. Where rights to surface access of the land have been obtained through Part V, Division I and II, the operator can proceed to deal with mining rights. Where only a surface access agreement has been used for operations during prospecting, the applicant would need to apply for a more permanent and longer term right, such as a mining lease to underpin the mining rights. The Land and Titles Act makes provisions for the various land rights and interests as well as the obligations that go with these.

2.1.5 Protected Areas Act 2010

The *Protected Areas Act 2010* gives the Minister for Environment power to declare an area of land or sea a protected area. An area can only be protected if it meets certain criteria such as containing habitat of species of national or international importance, and the consent of persons having rights or interests in the area has been obtained. It is a balancing act in the Solomon Islands with pressures both for conservation and for extraction of resources.

The Protected Areas Regulations 2012 prescribe the activities which are prohibited in a protected area, including mining. To date, no protected areas had been created under the Act and no protected areas have been proposed in the project area.

2.1.6 Wildlife Protection and Management Act (1998), Wildlife Protection and Management Act (Amended) (2017)

The Wildlife Protection and Management Act (1998) and the Wildlife Protection and Management Regulations (2008) were enacted in an attempt to regulate the export and import of certain animals and plants. The 2017 amendment to this act establishes a legislative regime for the protection of wildlife and threatened species in accordance with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

The Act is administered by the ECD and provides a prohibition on international trade of CITES specimens unless a permit for the export or import of CITES specimens can be granted by the Director of the ECD. The Act and Regulations list various matters that the Director of the ECD must take into account before granting a permit.

2.1.7 National Park Act 1978

The *National Parks Act 1978* enables the Minister for Environment to declare a national park, within which it is unlawful to carry out certain activities without a permit. The Minister also has the power to acquire any private land within a national park but must pay the landowners compensation. No national parks have been declared in the project area. The National Parks Act gives the Minister the sole power to decide whether an area should be a national park. The Act does not empower customary landowners to make decisions about the conservation or management of their natural resources. No national parks are located near the San Jorge tenement (Price et al. 2015).

2.1.8 Fisheries Act 1998

The *Fisheries Act 1998*, *Fisheries (Amendment) Act 2009* and regulations are the main law related to fisheries in Solomon Islands and aim to ensure the long term conservation and sustainable use of the fishery resource. The licensing and approvals mechanisms under the Act do not apply to the project as it is not a fisheries development.

The Act gives provinces the power to make fisheries ordinances which can, for example, declare it an offence to discharge pollution into a waterway. Makira-Ulawa, Western, Choiseul, Guadalcanal and Temotu Provinces have provincial fisheries ordinances. Isabel Province does not have a fisheries ordinance (Price et al. 2015).

2.1.9 River Waters Act 1964

It is an offence under the *River Waters Act 1964* to contravene the restrictions in the Act, for example to divert a river or fell a tree into a river. However, the Act only applies to certain declared rivers, with only seven rivers having been declared by 2015, none of which are in Isabel Province.

2.1.10 Forest Resources and Timber Utilisation Act 1969 [Cap 40], Forest and Timber (Amendment) Act 1984, Forests Act 1999, Forests Bill 2004.

The *Forest Resources and Timber Utilisation Act 1969* aims to control and regulate the forestry industry. A local harvesting license or commercial harvesting license is generally required under the Act before felling or removal of timber can commence for the purpose of sale. In order to clear trees at the site prior to development, approval will be required from the Minister under the Environment Act. This authorisation will outline suitable uses for any felled trees.

2.1.11 Town and Country Planning Act 1982 [Cap 154], Town and Country Planning (Amendment) Act 2017

The *Town and Country Planning Act 1982* and *Town and Country Planning (Amendment) Act 2017* are the main planning laws in Solomon Islands. They enable the Minister for Lands, Housing and Survey to declare an area for which a Local Planning Scheme may be prepared. A Local Planning Scheme may be prepared for any area of registered land (ie not customary land). Before a Local Planning Scheme is prepared, the Board must study the matters that may affect the area of development, including the physical, environmental, social and economic characteristics. A Board for a province may approve a Provincial Plan for the development of land in that province. The provincial Plan must include the location and extent of registered land and customary land in the province, as well as outline existing and proposed uses of land in the province. There is no provincial plan in Isabel Province (Price et al. 2015). The amendment act sets out details on the transparency and publication of development applications and Board decisions, and a formalised appeals tribunal, as well as changing some of the terminology.

2.1.12 Environmental Health Act 1980 [Cap 99]

The *Environmental Health Act 1980* provides for securing and maintaining environmental health in Solomon Islands and makes the Minister for Health responsible for environmental health services. The Minister can delegate responsibilities to enforcement authorities such as provincial assemblies and Honiara City Council, which can make their own by-laws.

The Environmental Health (Public Health Act) Regulations prohibit causes of nuisance, for example, the discharge of noxious matter into a waterway.

2.1.13 Shipping Act 1988 [Cap 163]

The *Shipping Act 1988* requires the person in command of a vessel to report the leak of any potential pollutants from a vessel into the ocean to the Principal Surveyor.

The Shipping (Marine Pollution) Regulations 2011 apply to all vessels in Solomon Islands waters and also apply to pollution of the marine environment from land based activities. It is an offence under the Regulations to discharge a pollutant from a vessel, platform or the land into any waters.

2.1.14 Petroleum Act 1987

The *Petroleum Act 1987* prescribes the storage requirements for fuel oils such as diesel and requires the implementation of measures to prevent the escape of petroleum into drains, creeks, or outlets to the sea.

2.2 Ordinances

2.2.1 Isabel Province Draft Resource Management and Environment Protection Ordinance 2006

The Isabel Province Draft Resource Management and Environment Protection Ordinance 2006 provides for the protection of flora and fauna, prevention of pollution, restriction of logging and harvesting, and prevention of anchorage within 500 yards of a reef. It allows the right for customary groups to make policies regarding the use of resources on their land and to seek Santa Isabel Provincial Government protection of wildlife, natural resources and areas with spiritual or cultural significance.

2.2.2 Isabel Province Conservation Area Ordinance 1993

The Isabel Province Conservation Area Ordinance 1993 reinforces the customary landowners' rights over their land by enabling the Provincial Executive to declare a conservation area, where mining earthworks, cultivation and logging are prohibited. There are no declared conservation areas in the project area.

2.3 Policy

2.3.1 National Minerals Policy 2017-2021

The National Minerals Policy 2017-2021 sets out a vision for the development of mining activities in the Solomon Islands for the next four years. It addresses a significant number of issues with current legislation that have led to negative outcomes in the mining sector. It highlights areas where legislation requires an update, promotes greater inclusion of landowners and communities in the negotiation of land access and requirements for community development benefits. It also streamlines and standardises processes for agreements, assessments and approvals. Much of the policy is in the form of guidance, but it does include formal requirements such as financial assurance for rehabilitation, and health and safety standards.

3 Project justification and alternatives

3.1 Background

3.1.1 Nickel market

The project area contains significant deposits of nickel rich laterites. Nickel on its own has few uses; however addition to other metals such as iron and copper can create strong and versatile alloys including stainless steel. Nickel is also resistant to corrosion, and is used by the electroplating industry to provide a corrosion resistant coating to other more reactive metals. Nickel is also used in the production of rechargeable batteries; previously a niche market, this is expanding significantly with the development of electric and hybrid vehicles (Nickel Institute 2017). In 2015, 68% of nickel was used in the production of stainless steel, 20% in other alloys, 9% in electroplating and the remaining 4% for a variety of uses, including batteries.

The continuous global demand for nickel for use in the manufacture of stainless steel and other alloys means that while the price of nickel may fluctuate, a constant supply of nickel is required to meet the demands of growing economies (International Nickel Study Group 2017).

3.1.2 Economy of the Solomon Islands

The economy of the Solomon Islands is predominantly based on forestry and agriculture, which makes it vulnerable to changing climate and market forces. In 2011, the government decided to establish alternative export industries to compensate for the expected decline of the forestry industry; these industries include mining, tourism and fishing (The Economist Intelligence Unit 2017).

The Solomon Islands is considered a lower middle income country, with a 1.202 billion USD GDP in 2016, when it grew 3% year on year. It is currently ranked joint 176th out of 196 countries by the World Bank (https://data.worldbank.org/data-catalog/GDP-ranking-table). Close to one quarter of the population was living under the poverty line in 2015.

The nickel mined from the San Jorge deposit will be exported in a raw (unrefined) state, and processed overseas. This reduces the potential for adverse environmental impacts from the project on the Solomon Islands, but also means that the mining output is not economically tied to a particular smelter or company for processing, and can be traded on the open market.

3.2 Project justification

3.2.1 Direct economic benefits

i Revenue contributions

It is estimated that the project will contribute significant revenues directly to the Solomon Islands Government, depending on the market price of nickel, over the life of the project. These contributions will grow with the continuation of mining.

It is anticipated that a proportion of taxes and royalty benefits will be used for local social infrastructure and social development such as education, healthcare and other long term community projects in southern Isabel Province.

ii Direct and indirect employment

The project will employ an estimated 300 people during construction and approximately 120 to 140 national Solomon Islands people directly, locally and from elsewhere in the Solomon Islands during operations. Further indirect employment will be generated through the provision of goods and services.

Implementation of Axiom's workforce strategy will result in a significant increase of employment and training for many locals, which will increase overall employment, skills and income in Isabel Province.

iii Profit sharing

The project is 10% owned by the customary landowners, resulting in a direct flow of funds to the local communities and tribes through a share of profits in the project. In addition to the social and economic benefits from the jobs created, this profit sharing structure allows the landowners and communities to share directly in the success of the project over the life of the mine.

3.2.2 Indirect economic benefits

The project will indirectly contribute to the Solomon Islands economy through the purchase of goods and services from local suppliers, both in Isabel Province and other parts of the country. It is projected that Axiom will spend significant amounts on goods and services within the Solomon Island. This will increase gross domestic product in the Solomon Islands over the life of the project.

Employing and training local people in construction, eg camp building and project infrastructure, increases the skill set of each person who then takes these skills back to their home village. These skills may be used to construct, develop and/or repair and maintain homes and village infrastructure.

The project will be the first nickel laterite mine in the Solomon Islands, and help showcase the potential of mineral resources in the country. The project will provide an economic benefit locally to the islands of San Jorge and Santa Isabel, as well as nationally to the Solomon Islands. The development of the project will reduce the Solomon Islands' reliance on forestry and agriculture exports, and help to diversify the economy.

Increased development and competition will bring advantages to the Solomon Islands, including diversity and competition with local markets that supply goods and services to the projects. Further development and new companies would bring new opportunities for others in the region and the benefits that extend from these arrangements.

Axiom holds further prospecting licenses in the Solomon Islands, at Guadalcanal (gold, silver and copper). Development of the San Jorge Deposits will allow Axiom to invest further in the Solomon Islands through the exploration and development of these tenements.

3.3 Alternatives

3.3.1 Not proceeding with the project

If the project does not go ahead, and the resource is in-situ, the economic benefits described above will not be realised. These include foregone tax revenue for the government and training, employment, community development funds and local spending for southern Isabel Province.

3.3.2 Alternative location

The main ore bodies are on the tops of ridges within the San Jorge Tenement. The location of the ore bodies is a fixed geological phenomenon and mining the nickel has to involve these areas.

The proposed location of the mine represents the best option for the project as it comprises ore bodies which are close to the ocean, have some existing infrastructure and have been previously explored.

Axiom holds the prospecting license for the San Jorge Tenement so development of other deposits in other tenements, is not an option for Axiom.

Construction of processing facilities on Santa Isabel Island is not economically feasible at this stage due to the proposed short initial period of mining. Therefore, ore processing will be in alternative locations such as Australia or other facilities where Axiom's clients will be located. Further, offshore processing reduces the potential for adverse environmental impacts at San Jorge from the project.

3.3.3 Alternative mining method

Open cut strip mining is the only mining option as the resource is shallow and there is relatively high in situ soil moisture content (30% to 40%).

Top down mining, that is, commencing mining at the top of a slope rather than at the base, is the preferred method as the geology is inherently unstable due to seismicity, moisture content, rock strength and steep terrain.

3.3.4 Alternative infrastructure

Axiom propose to use existing infrastructure where possible such as roads and the jetty as they are already optimally located and the unnecessary construction of new infrastructure would result in increased environmental impacts and reduced financial outcomes.

i Transfer to ship

The location of the proposed mooring facility for transferring ore to ship provides a deep harbour that is sheltered from the ocean currents.

Other than via a long, expensive and possibly environmentally disruptive loading jetty, it would not be possible to load the ore ships at the ore handling facility as the inshore areas will be too shallow to accommodate the type of ship likely to transport the ore. Therefore, this option was dismissed.

The boat ramp on San Jorge is at a relatively flat area near the deposits and the deeper water of Thousand Ships Bay. An alternative location further south may be nearer the deep water of Thousand Ships Bay and New Georgia Sound, but it would be further from the deposits so new roads would be required to be built through forested areas and trucks would have a greater distance to traverse. This would result in additional vegetation disturbance and cost.

ii Shipping

Axiom proposes to construct the deep water mooring in Thousand Ships Bay. This location provides water of a sufficient depth, and is nearer to Honiara where ships may have to transit if customs clearances are required.

4 Project description

4.1 Construction

Mine construction activities will include establishment of accommodation facilities and ore handling facility; construction of the mine infrastructure area (MIA); and upgrade and construction of roads to all sites including the camps and office facilities.

Construction will generally be in the following sequence, although some steps may be carried out concurrently where appropriate:

- installation of erosion and sediment control measures (ESC) as described in the water management strategy (see Appendix C);
- demarcation of limits to be cleared and protection of areas to be retained;
- construction of boat ramp;
- localised dredging (if required);
- clearance of vegetation and topsoil from the MIA and ore handling facility, and stockpiling of these materials for use in rehabilitation;
- establishment of temporary construction accommodation camps;
- construction of ore handling facility;
- upgrade of access roads; and
- construction of the MIA.

Construction cargo such as equipment and materials will be shipped from overseas to Honiara for customs clearance, where it will be loaded onto barges and transported to the ore handling facility.

ESCs will be installed across the project area in accordance with an erosion and sedimentation control plan (ESCP) that will be prepared prior to construction. Once the controls are installed, required vegetation will be cleared and 'grubbing' will remove roots.

Trees that can be used by the project or community will be marked and temporarily placed separately to other cleared vegetation. Other cleared vegetation may be wood chipped, composted and stockpiled for use in rehabilitation. Grubbing will not occur at temporary laydown areas so that soil continues to be stabilised by the existing vegetation's root system.

Areas disturbed for construction, but not required for operations, will be rehabilitated and revegetated as soon as possible.

Construction activities at the ore handling facility will occur on land and in the water, with in-water sediment controls comprising coffer dams. A jetty will be constructed to handle usage by customs boats, pilot boats and ferries.

A barge heavy loading ramp will be constructed to enable the delivery of heavy equipment and cargo during construction, and ore loading during operations. The barges will be shallow draught roll on roll off vessels which will have a front loading ramp.

The ore handling facility will comprise a ramp constructed into the water with a rock or concrete surface. The loading facility will be designed in accordance with the limit state approach in *Australian Standard 4997–2005 Guidelines for the Design of Maritime Structures* and will allow the barges to dock at the ramp, lower their ramp door and receive front end loaders or trucks delivering the ore.

Fender and mooring piles will be installed at the water side of the facility to stabilise barges during docking.

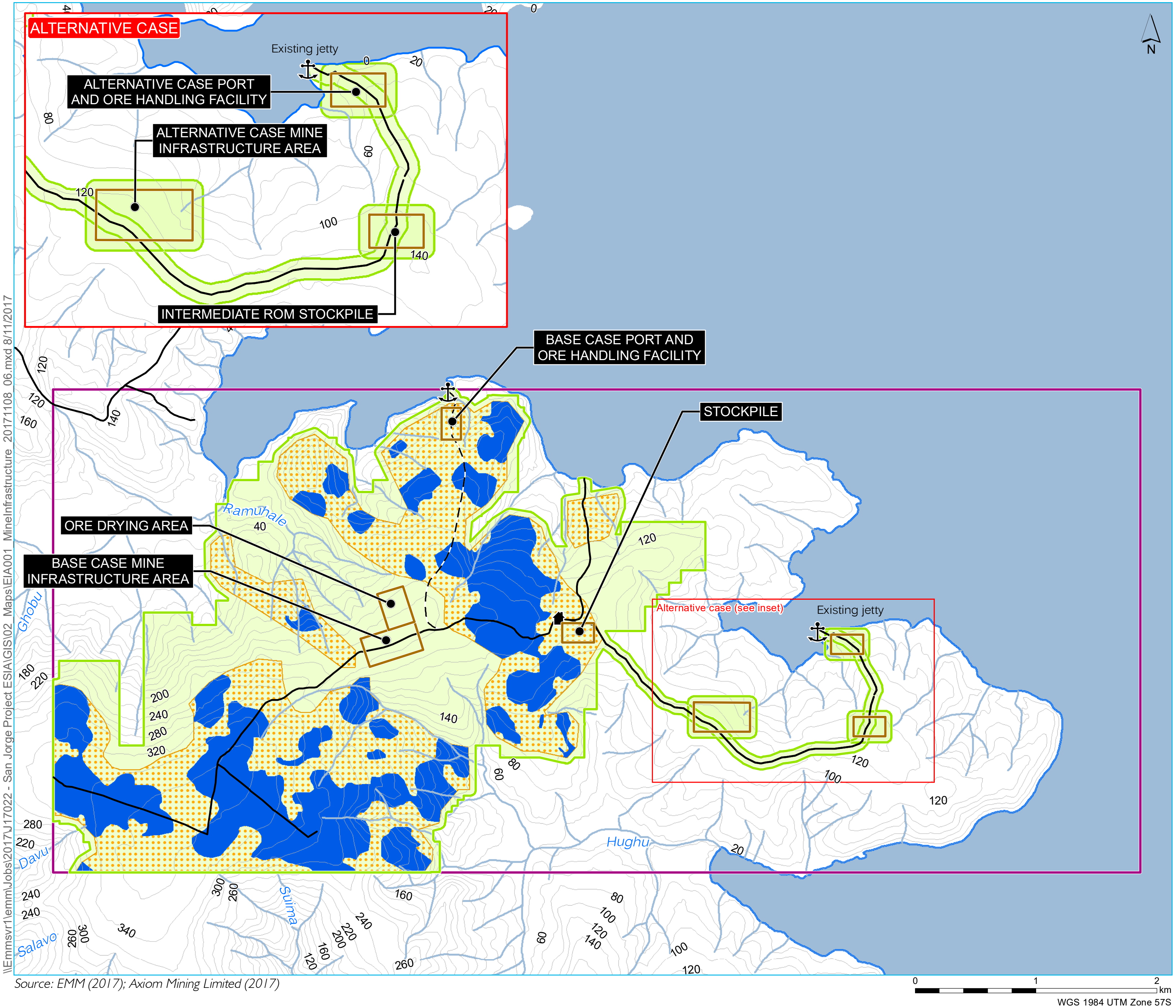
Aggregate material will be required for the foundations of built elements and some surfaces which will be traversed by vehicles. The aggregate will be sourced from borrow pits which will likely be sourced locally, or from elsewhere in the Solomon Islands, with final locations to be determined during detailed design.

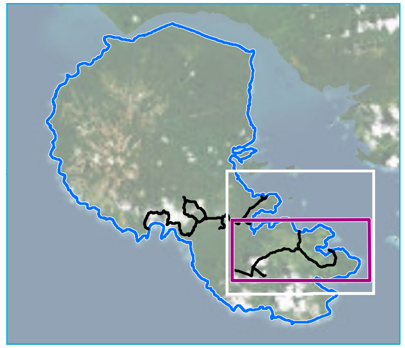
The indicative project layout is provided in Figure 4.1. The operational phase of the project is described in the following sections.

4.2 Operations

Operations will generally occur progressively in the following sequence:

- installation and maintenance of erosion and sediment control measures as described in the water management strategy (see Appendix C);
- construction and upgrade of access roads;
- vegetation clearing and grubbing where necessary, with stockpiling of topsoil and overburden for re-spreading during rehabilitation;
- progressive mining of limonite and saprolite from the mining blocks and transport of ore to temporary stockpiles, either directly to the ore handling facility or interim stockpiles;
- drying in windrows;
- loading of ore by loader onto barges for transfer to ocean going vessels moored in Thousand Ships Bay;
- progressive placement of overburden and waste rock into completed mining areas for rehabilitation; and
- progressive revegetation.





KEY

- Accommodation camp
- Port options
- Potential area of disturbance
- Prospecting licence boundary
- San Jorge Island coastline
- Access road
- Proposed access road
- Watercourse / drainage line
- Contour (20 m)
- Stockpile location
- Current known resource extent
- Identified deposits to be mined

Source: EMM (2017); Axiom Mining Limited (2017)

\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps\EIA001_MineInfrastructure_20171108_06.mxd 8/11/2017

Proposed mine layout plan

Axiom Mining Limited
San Jorge Nickel Project
Environmental impact statement
Figure 4.1

4.3 Nickel resource

4.3.1 San Jorge nickel resource geology

The Solomon Islands archipelago is at the boundary of the Australian and Pacific continental plates. The Santa Isabel and San Jorge islands form part of a linear north-west to south-east trending chain of islands in the New Georgia Group and are adjacent to an active volcanic region (Berly 2006, cited by Reseval 2016).

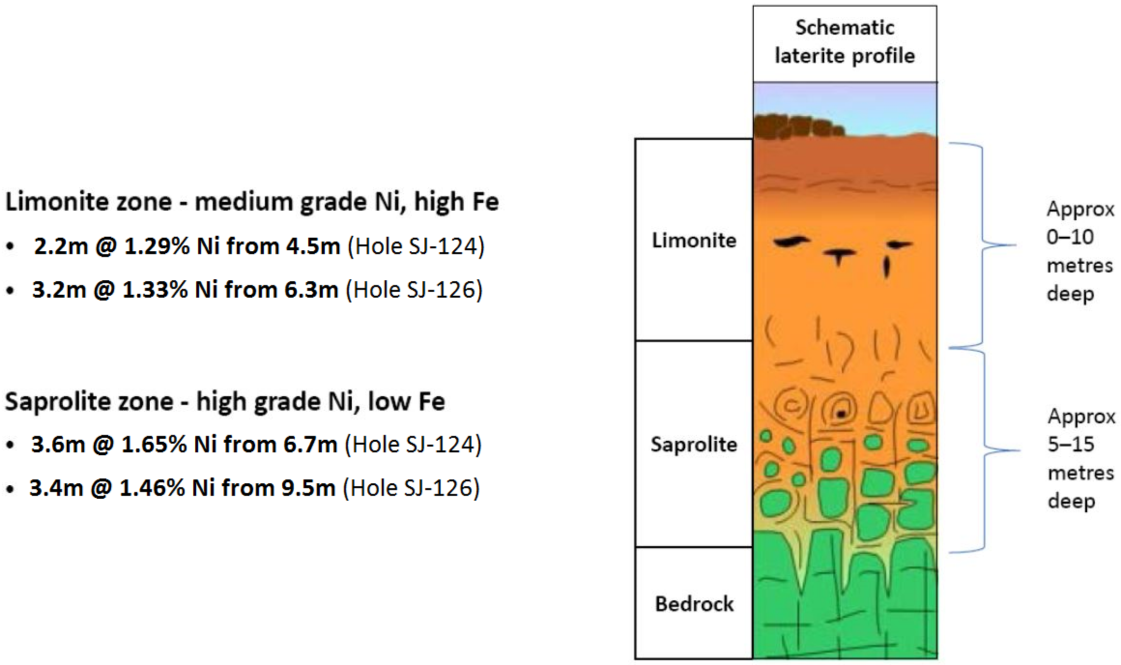
Collision of tectonic plates has resulted in the uplift of sea floor sediments including some limestone and mostly volcanic sediments. This has included overthrusting of ultramafic rocks that now form pods of minerals, including serpentinised harzburgite and dunite, cut by pyroxenite veins. These ultramafic rocks then weather to form the nickel laterite deposits (Berly 2006, cited by Reseval 2016).

4.3.2 Nickel laterite deposits

The nickel laterite deposits of the Solomon Islands have developed under tropical conditions over ultramafic rocks. They have largely formed by weathering and decomposition of the underlying ultramafic rocks which leads to enrichment of nickel within the soil profile (refer to Figure 4.2) (Sagapoa 2011, cited by Reseval 2016). The laterite formation comprises two separate zones:

- The saprolite zone, where weathered silicate minerals remain. This zone can include weathered to fresh remnant rocks and silicate clay minerals from the initial decomposition and weathering of the underlying ultramafic rocks.

- The limonite zone, where silicate minerals are largely destroyed and removed leaving dominantly the iron rich oxides such as limonite (goethite) that can grade into higher alumina oxide mineral towards the surface. Residual enrichment of iron, aluminium, manganese, cobalt and nickel occur from the intense leaching from tropical rainfall over time (Reseval 2016).



Source: *Axiom Mining*
Note: *Ni (Nickel); Fe (Iron)*

Figure 4.2 San Jorge Tenement lateritic profile

4.3.3 Resource deposits

The San Jorge Tenement has been extensively explored and studied by industry leaders including International Nickel Co. Of Canada, Ltd (INCO) in the 1950s–1970s and Kaiser in the 1990s, but has never proceeded to mine development due to failure to gain the support of customary landowners.

In 2010, Axiom signed a binding agreement for the development of the San Jorge and Kolosori Tenements with the Kolosori and Bungusule tribes, the customary landowners of the San Jorge Tenement and Kolosori Tenement (the latter located on neighbouring Santa Isabel Island).

Axiom has secured a Prospecting Licence (PL 01/15) for the San Jorge Tenement and 50 year leasehold over 36 km^2 of the San Jorge Tenement(refer to Figure 1.2).

4.3.4 Background to development of the Isabel nickel deposits

INCO started exploring for nickel at Takata (Isabel Island), San Jorge and Jejevo (north of Isabel Island) in 1957 and continued until 1975. INCO also undertook trial mining from bulldozed benches and investigated the feasibility of limonite ore processing. Development did not proceed due to unsuccessful resolution of traditional landowner access and title matters (Reseval 2016).

Bogotu Nickel Ltd (BNL) engaged Kaiser Engineers Pty Ltd (Kaiser) to validate the INCO exploration results by excavating 34 pits for comparison with information from 43 INCO pits. The work concentrated on verification, density measurement and metallurgical sampling. Similar to the situation with INCO, development did not proceed due to the traditional owners not granting approval.

Both INCO and Kaiser concentrated on the high iron ore processing options for the upper part of the laterite, which meant the full laterite profile was not tested or defined.

The San Jorge and Takata tenements were released for international tender in 1999. Pacrim Resources Ltd surveyed orientation using ground penetrating radar in three lines across the San Jorge deposit in 2004.

The survey modelled the upper and lower boundaries of the weakly mineralised lower saprolite but not the boundary between the limonite zone and the saprolite zone.

Axiom commenced landowner negotiations in 2011 which enabled granting of the prospecting licence by the provincial government in 2014. A second international tender was issued for the Takata, San Jorge and Jejevo tenements in 2011.

Axiom was granted a Prospecting Licence for San Jorge in 2015, and commenced exploration drilling in September 2016; the program included 2,500 m over 154 holes.

4.3.5 Mining method

i Overview

Mining of nickel laterites in sloping terrain is typically undertaken using a 'top-down approach' of contoured strips fanning out from an access road along the ridgeline. Mining will include sequential clearing of vegetation, pre-stripping of overburden and relocation of waste rock and topsoil to a previous mining block for progressive backfilling of the mined-out pits.

The top-down method commences at the highest point on a bench with mining progressing downhill in benches to provide for continued stability of the slope. More than one panel may be mined at a time, but, preparation (clearing of vegetation and topsoil, and overburden removal) of the next bench below will only start once all panels of the previous bench have been prepared.

The main benefits of this method are that disturbance is minimised as clearing and removal of overburden only occurs immediately prior to mining and the mined area is rehabilitated as soon as practicable after mining. This approach maximises progressive rehabilitation so that the potential for erosion and sedimentation is reduced during the operations phase and the rehabilitation burden at the conclusion of the project is minimised.

Once the panel is cleared, limonite will be mined through the formation of narrow benches that will allow grade control. The saprolite will then be mined in high grade areas. The ore will be trucked to a laydown area at the ore loading facility for drying prior to blending and shipping.

There are two potential options for the location of the ore handling facility and the port; both of these are presented in Figure 4.1. The base case scenario for the port and ore handling facility is located on the northern boundary of the project area, where no infrastructure currently exists. The alternate case scenario for the port and ore handling facility is close to the existing jetty at Kogarutu.

ii Establishment of erosion and sedimentation controls

The high rainfall and hilly terrain within and adjacent to the proposed mining areas pose a risk to surface stability and could lead to erosion and sedimentation of waterways and the marine environment if not well managed. Key erosion and sediment control measures will be installed to control water upslope and downslope of mine pits, haul roads, stockpiles, laydown areas and the ore load-loading facility. As described in Section 4.1, installation of ESC will initially occur as part of the project's construction phase. As the project evolves, further ESC will be required and will include:

- vegetation clearing and overburden removal immediately prior to mining of a block;
- retention of gully and stream vegetation;
- retention of strategic vegetation strips where no mining is planned;
- erosion and sediment control plans specific to each mining block that will be implemented prior to mining. Controls will include installation of diversion drains, silt fencing, sediment dams/traps and riprap near roads;
- construction of sediment dams where required to prevent discharge of sediment from the mine into downstream waterways;
- covering exposed limonite that will not be mined with crushed rock;
- sheeting of road surfaces using aggregate material; and
- diversion of upslope runoff around mine blocks.

ESCs will be regularly maintained during and immediately following heavy rainfall.

iii Access

Where access to mining blocks is not available on an existing road, additional roads will be constructed after ESCs are installed. New roads or extensions of existing roads will only be constructed as far as the next bench to be mined to reduce the level of disturbance open at any one time. Roads will be surveyed, mapped and staked to mark the limits of disturbance. The following main road types will be required:

a. Primary haul roads

There are existing haul roads (old logging roads and exploration roads) within the project area that are being used for Axiom's exploration and drilling program. These will be upgraded prior to mining. The primary haul roads will be of an appropriate width (including berms or drains either side) to enable two way passage of haul trucks. The roads will be sheeted to an appropriate depth with aggregate sourced locally, or from other areas of the Solomon Islands.

b. Mine access roads

The mine access roads will enable access for vehicles and equipment from the primary haul roads to the mining areas. The internal road within the mining area will run from the highest to lowest benches and the external road will run from the primary haul road to the top of the first bench. The roads will be constructed progressively as the benches progress downslope.

The mine access roads will be of appropriate width, and will be sheeted to an appropriate depth. These roads are intended for short-term use and will be rehabilitated once the final bench in a mining block is rehabilitated. Aggregate recovered from the rehabilitation of access roads may be reused for the sheeting of subsequent access roads.

c. Bench access roads

The bench access road will enable access to individual benches from the mine access road and will be of appropriate width, including drains, with a slight gradient for drainage. The roads will be at the base of each bench and will be sheeted to an appropriate depth. These roads are also intended for short-term use only and will be rehabilitated as part of progressive pit rehabilitation. Aggregate recovered from the rehabilitation of bench access roads may be reused for the sheeting of subsequent access roads.

iv Vegetation clearance

The deposits occur along ridgelines that are typically fern covered with small shrubs scattered throughout the proposed mining areas. However, some areas of the ore deposits extend into forested areas. A chainsaw will be used to remove trees, rather than a bulldozer, so that they are in good condition for use as a community resource. Clearing will only occur immediately prior to mining to reduce the time the surface is exposed to wind and rain. Grubbing requirements will be determined on a site by site basis as it may be preferable to retain roots in certain cleared areas to maintain soil stability.

v Soil and overburden removal, stockpiling and re-use

Topsoil depth within the deposit areas is generally limited to 0.5 to 1.0 m. Initially, soil and overburden will be placed in separate stockpiles adjacent to the mined areas in previously cleared areas as far as possible. Overburden will be used for filling pit voids and topsoil will be used for rehabilitation.

Once mining is more advanced, a bulldozer will push the cleared vegetation, topsoil and overburden to stockpiles where it will be loaded with excavators onto haul trucks. The material will be transported to finished panels where it will be used to fill the voids and for rehabilitation and revegetation of the surface. Soil and overburden may also be used for construction of ESCs.

vi Ore extraction

The limonite, which occurs below the overburden, will be extracted first. It is expected the limonite will be easily extracted using a bulldozer which will push the ore to an excavator for loading into a haul truck. Once the limonite layer is mined, some transitional material may require removal, which will be carried out as per the overburden.

The saprolite will be mined using hydraulic excavators on formed benches to enable separate stockpiling into high and low grade ore. Some ripping may be required to break up the material prior to extraction.

Extracted ore will be hauled to stockpiles/windrows in the ore handling facility for drying and await testing prior to shipment (depending on moisture content). Poor grade ore may be removed to the overburden stockpiles and used for filling voids or road maintenance and, where appropriate, rehabilitation and stabilisation.

Rehabilitation can commence once the saprolite is mined (see Section 4.8). ESCs will remain in place until vegetation is established and the landform is stable.

a. Resource deposit areas

The resource deposit areas, pit area outlines and preliminary haul road designs are shown in Figure 4.1.

b. Disturbance areas

The disturbance area for the mine as a whole is described in Table 4.1. External pit emplacement areas (waste rock dumps) will be located within the area of disturbance on low gradient areas for geotechnical purposes. External pit emplacement areas have been designed with extra capacity based on a preliminary schedule and will be positioned in appropriate locations within the general area of disturbance shown in Figure 4.1.

Table 4.1 Disturbance areas

Location	Area (m^2)	Area (Ha)
Base case	13,213,000	1321.3
Alternative port option	13,481,000	1348.1

4.3.6 Mining fleet and equipment

The vehicles used to develop a laterite nickel operation are considerable. The ancillary fleet is required to construct roads, sediment control structures and to provide support to the primary excavation equipment.

The type and indicative number of primary mining fleet and ancillary plant are presented in Table 4.2; these are averaged over the lifetime of the project (IMC 2016).

Table 4.2 Equipment fleet numbers

Item	Units
Excavators	
70 tonne excavator	1
90 tonne excavator	3
Trucks	
24 tonne Iveco truck	12
40 tonne articulated truck	10
Small water cart	1
Dozers	
Track dozer (CatD8R Equivalent)	3
Soil compactor	1
Front end loaders	
Front end loader (988H Equivalent)	5
Graders	
Motor grader	1
Ancillary plant	
Lighting plant	10
Pit dewatering pump	3
Fuel/lube truck	1
Light vehicle / 4WD	10
Mobile crusher	1

4.4 Project infrastructure

The exploration program has included development of infrastructure that will also be used for mining. Development completed to support the exploration program has included repairs to existing roads; establishment of new roads; construction of the initial camp; and the establishment of logistics and transport systems between Honiara and San Jorge Island.

4.4.1 Power and communications

Camp and site office facilities will be powered by a diesel generator, with cabling to the main office, mess, laundry and site manager's residence. Satellite communications are in place in the exploration camp. The camp, power and communications systems will be upgraded to support the mining operation.

4.4.2 Lay down areas

Lay down areas will facilitate ore drying and also provide storage for heavy machinery, fuel and equipment. The existing lay down area adjacent to the jetty, currently used for fuel and equipment storage, will be expanded to include areas for the MIA and ore drying if the alternative case is developed.

4.4.3 Ore handling facility and mine infrastructure area

The ore handling facility will be located adjacent to the port, and used for personnel and material movements, as well as ore handling. It will operate in accordance with the *Ports Act 1998* and all movements of goods, vessels, vehicles, and personnel will be in accordance with Solomon Islands Customs and Quarantine and Inspection Authority requirements.

The ore will be delivered to separate windrows for limonite and saprolite by the long haul fleet, for drying. These windrows will measure approximately 4 to 5 m high and 30 m long, and will be covered with large tarpaulins during rain. The windrows will be managed and turned continuously to reduce moisture to the correct level. Once the ore has dried sufficiently (<30% moisture by weight) it will be loaded onto barges by tip truck or loader for transfer to ocean going vessels moored in Thousand Ships Bay. Ore transport vessels may be required to clear customs and quarantine.

The following will be provided at the ore handling facility and MIA:

- maintenance workshop for marine and heavy/light land vehicles, supplies storage and electrical and carpentry services. Day to day service, maintenance and change out activities will take place in the workshop, however, major repairs will be carried out off site;

- bunded and fenced fuel storage and fuelling facility;

- heavy and light vehicle washdown facility using water from a local supply, including an oil/water separator and sediment pit with collected wastes disposed at the project landfill;

- administration and personnel service buildings, including first aid room, geotechnical and environmental laboratory, offices, training rooms, lunch room, wash rooms and prayer room. These facilities will also be used as a cyclone refuge if personnel cannot be evacuated in advance of the onset of cyclones; and

- utilities such as power, communications, water and sewerage. Water infrastructure is likely to comprise a raw water supply, water management system, waste water treatment plant, sewage treatment plant and fire fighting system.

All fuels, oils, lubricants and chemicals will be stored in bunded areas and waste water/sewage will be treated to a standard adequate for discharge in accordance with the *National Water Quality Management Strategy: Australian Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000). Sludge from the waste water/sewage plants will be disposed at the project landfill.

Diesel and petrol will be the main fuels used by land and water based vehicles and generators. Fuel storage will be used to store 30 days' supply of fuel. The tanks will be installed and maintained in accordance with Solomon Islands and international standards.

The land side of the ore handling facility will be graded inland so that stormwater and other surface water drains away from the marine environment. Water will be directed to a sediment pond via open channels. The sediment pond will not be lined. Water which does not seep into the ground will either be used for dust suppression throughout the project area or diverted into the water management system.

ESCs at the stockpiles and roads leading to the ore handling facility/MIA, for example trenches, will direct runoff to the sediment pond in accordance with the ESCP.

4.4.4 Ship mooring and transfer

Anchorages for ocean going vessels awaiting loading or being loaded will be provided near the entrance to Thousand Ships Bay in deeper water but close the ore handling facility. The ocean going vessels are expected to be of the Panamax dry bulk carrier class with a holding capacity of 35,000 to 50,000 deadweight tonnage. Ships will enter and depart Thousand Ships Bay from the south.

Barges will traverse Thousand Ships Bay to the moored ship. Loading will be by crane, operating either in or adjacent to the ship and barges. Loading and unloading will avoid exposure to rain and seawater where practicable using tarpaulins.

4.4.5 Water supply

A raw water supply will be provided at all times to ensure continued water availability during a break down or maintenance. Above ground water tanks will be provided at facilities requiring water. Raw water will be used for fire-fighting, dust suppression and vehicle washdown, amongst other uses, and may require filtration if it is too turbid or contains organic matter.

The water treatment plant will draw from the raw water supply to produce potable water and may include screening, flocculation, sedimentation, filtration, pH and alkalinity correction, chlorination and/or ultra-violet disinfection and clean water storage. Potable water will be used for drinking, food preparation, toilets and safety showers and will meet World Health Organisation (WHO) guidelines.

4.5 Waste management

A waste management plan (WMP) will be prepared that considers prevention, reduction, reuse, recovery, recycling, removal and finally disposal of wastes. The WMP will address solid waste and waste water as outlined below.

4.5.1 Solid waste

Solid waste from construction and operations will be contained, transported, handled and disposed of in such a manner as to reduce potential impacts on human health and the environment.

The following options will be considered for the disposal of all solid wastes:

- landfill;
- composting, incineration and recovery (landscaping); and
- capture and removal to approved facilities.

Hazardous waste will be stored in a secure and bunded location for collection and disposal at an accredited and registered waste disposal facility.

4.5.2 Waste water

Waste water will mostly be generated from domestic sources such as the accommodation camp; however, small quantities may be generated by trade activities at the ore loading facility/MIA. The plant may be required to treat water via screening, aerobic, anaerobic and disinfection processes so that effluent meets the *WHO Guidelines for safe water use of Wastewater, Excreta and Greywater* and can be disposed of via the following options:

- sub-surface release; and
- recycled for non-potable use, such as dust suppression.

4.6 Transport

Transport within the tenement will predominantly be by light vehicle (4WD) with small boats also available for transfer to surrounding areas by water. Vessels for transportation of equipment and supplies from Honiara and surrounding areas (including rock materials and crushing equipment for roads), will depend on the cargo type but will vary from open boats with outboard motors to large barges and tugs.

4.7 Workforce

The estimated construction workforce is 300 and the estimated operations workforce is 120 - 140. It is expected that the construction workforce will peak within four months of commencement and reduce as the project infrastructure is completed (9-12 months) and the operations phase commences.

Operations will be on a 24/7 basis. Axiom's priority is to employ personnel from local communities to the extent possible. Most personnel will be transported to and from the island via sea. Personnel from outside the Solomon Islands will be flown to Honiara and ferried to San Jorge Island by boat.

Axiom has developed a training and induction program for all employees involved with the exploration program. This will be expanded to address the mining program and include contractors and visitors to the work site. The exploration training program consists of:

- induction training;
- environmental awareness training; and
- toolbox talks.

The expanded program will address the protocols for the construction and mining program to ensure that all personnel on-site are aware of:

- the environmental and socio-economic context of the site and surrounds;
- the potential environmental and community impacts associated with the work they are undertaking and how to undertake appropriate mitigation measures;
- any legal requirements relevant to the work they are undertaking;
- roles and responsibilities of Axiom employees, contractors and visitors;
- environmental operating practices;

- incident management;
- health and safety requirements; and
- complaints management.

Axiom has commenced workforce development, though some lead time will be required to assemble and train all staff required for the mining operations.

4.7.1 Accommodation camps and office facilities

The project will use (and expand) the existing exploration camp and office facilities at Camp Bungusule. The camp will accommodate up to 120 people, and will include:

- laundry, administration office, kitchen/dining hall, and first aid facility;
- recreational building and gymnasium;
- maintenance workshop and stores;
- waste and recyclable material transfer station;
- communications yard and tower; and
- helicopter pad.

The camp will be designed to withstand seismic events and cyclones.

An additional accommodation building will be established at the camp during the construction period to house the additional workers. This will be dismantled once the workforce has reduced to operational levels. Accommodation is likely to be similar to that found locally on Santa Isabel to accommodate the range of roles expected at the project, ie trades, supervisory, management and executive personnel.

Potable water will be supplied from the water treatment plant at the MIA and sewage will be treated at either a built for purpose sewage treatment plant or wastewater recycling system, also at the MIA.

4.8 Rehabilitation and closure plan

A mine rehabilitation plan has been prepared as part of this EIS, and is included as Appendix B. The plan describes the environmental controls that will stabilise the landforms following mining, and reduce and prevent soil erosion after mining has finished. Ultimately, the objectives of these controls will be to:

- prevent the loss of soil from disturbed areas;
- ensure that the mine voids, roads and drill pads and associated disturbed areas are stable;
- allow rapid rehabilitation of the disturbed areas to a condition that is appropriate to the original condition of the land; and
- reduce long-term degradation of the downstream receiving environment and associated impacts on aquatic fauna due to sediment-laden runoff.

Rehabilitation of mined areas will be undertaken progressively, replacing the saprolite seam with overburden and lower grade material as soon as possible. It will include measures to prevent impacts to watercourses; and trial stabilisation of land disturbed during the development of initial mining activities to ensure environmental controls are effective.

Once mining is completed, related infrastructure will be decommissioned as soon as possible. Following decommissioning, the rehabilitation will include the following steps:

- hardstands, roads, building pads and other compacted areas will be ripped to remove compaction and seeded;
- contaminated soil will be excavated and appropriately managed;
- any eroded areas will be rehabilitated by re-contouring and seeding to stabilise the area against further erosion; and
- open-cut pits will be rehabilitated by replacing the ore with overburden or low-grade ore, as appropriate, and soil as soon as feasible followed by seeding to stabilise the final landform.

Some infrastructure ie roads, buildings or parts of the ore loading facility may remain after mining provided suitable future uses can be identified in consultation with the Government and landowners.

Once landforms are shaped and stabilised, the surface will be revegetated as quickly as practicable. Appropriate native species will be used to temporarily bind and stabilise the landform surface, which will make the soil conditions more suitable for the establishment of long-term native species.

In order to establish a stable final landform, maintenance of rehabilitated areas will be essential. Stability of the final landform and the presence of weed species will be monitored and assessed against performance criteria. Where performance criteria have not been met, maintenance works, and continued monitoring may be required until the performance criteria are met. Maintenance inputs will decrease as the native vegetation becomes established.

The Solomon Islands National Minerals Policy, Objective 10 states that an environmental bond (by lodgement of a letter of credit) is required to cover the cost of mine rehabilitation. The rehabilitation plan includes the estimated cost of rehabilitation. The letter of credit is required by the Ministry of Mines, Energy and Rural Electrification before a mining agreement is finalised.

4.9 Expected project schedule

Axiom commenced exploration in the San Jorge Tenement in September 2015 under prospecting licence (PL 01/15). The mine construction phase is planned to start in 2018.

The mine will initially operate for about five to ten years (operations phase), within 12 months of the development consent being granted. Exploration will continue and it is expected that sufficient ore will be mapped to allow mining to continue after this initial phase. The completion of all mining will be followed by a decommissioning and closure period of one to three years. This will be described in the mine rehabilitation plan.

Current projections indicate that the mine will export the first shipment of ore within 12 months of the development consent being granted.

5 Environmental impact assessment

5.1 Assessment approach

5.1.1 Background information and data collection

The south of Santa Isabel Island has been extensively studied, including during preparation of the EIS for Sumitomo Metal Mining's (SMM 2012) proposed development of Isabel tenements D and E. These tenements are adjacent to the Kolosori Tenement and close to the San Jorge Tenement, and share similar geology, geography and climate (see Figure 1.1).

This EIS uses the existing environment information in SMM (2012), which has been validated for the San Jorge Tenement deposit by site-specific technical assessments (including field surveys), and to provide further site specific data on the following:

- soils and rehabilitation (Appendices A and B);
- freshwater environment (Appendix C);
- physical marine environment (Appendix D);
- terrestrial and marine ecology (Appendices E and F);
- noise (Appendix G); and
- stakeholder consultation (Appendix H).

The technical assessments included consultation with local people within or associated with the tenement; site inspections; water and soil sampling; flora and fauna surveys; analysis of results; and a site-specific assessment of potential impacts.

5.2 Environmental and social values

Environmental and social values need to be defined prior to an impact assessment taking place. An environmental value is a quality or characteristic of the environment that is required for ecological health, amenity or safety, or one protected by legislation. Social values usually relate to sensitive receptors, such as a home or school.

5.3 Impact assessment method

There are three commonly used methods of impact assessment; these are risk assessment, significance assessment and compliance assessment.

A risk assessment enabled the development of scopes for the technical studies presented in this EIS and referenced in the EMM (2017) San Jorge Scoping Report.

The significance and compliance assessment methods are used in this EIS.

5.3.1 Significance assessment method

The significance of an impact is assessed by calculating the sensitivity or susceptibility to change of a social or environmental value, and the worst-case magnitude of the impact that will affect it. The residual significance of the impact is then calculated based on successful implementation of mitigation measures.

The matrix in Table 5.1 shows how the significance of an impact is calculated.

Table 5.1 Significance assessment matrix

		Sensitivity of value		
		Low	**Moderate**	**High**
Magnitude of impact	**Low**	**Negligible**	**Low**	**Moderate**
	Moderate	**Low**	**Moderate**	**High**
	High	**Moderate**	**High**	**Major**

Following the application of mitigation measures, the significance of an impact is recalculated to give the residual impact, and the change in significance is an indication of how appropriate the mitigation measure is.

5.3.2 Compliance assessment method

The compliance assessment method is used for situations where the impact is governed by relevant legislation, usually for emissions or discharges. Where relevant legislation is not available, appropriate equivalent legislation can be used, or the significance risk assessment method used. The results of a compliance risk assessment are either compliant or non-compliant. The compliance assessment method has been used for the noise impact assessment.

5.4 Impact prioritisation and assessment

The issues with the greater potential impacts as defined by the San Jorge Scoping Report (EMM 2017) are considered in greater detail in this EIS than impacts that are minor or easily managed as part of routine mine operations. The most significant issues are largely associated with the high rainfall and erodibility of soils in the region, as well as cultural and social sensitivities.

The higher risk environmental issues are briefly described in Table 5.2, including a description of how they have been addressed in the EIS. The issues are described in detail in the following assessment sections.

Table 5.2 Key issues

Environmental issue	EIS approach	EIS section
Erosion of lateritic soils	Lateritic soils are prone to erosion, particularly in the high rainfall environments that they form. The specialist soil assessment determined the soil characteristics, erosion potential and appropriate management measures. The water assessments determined the likely impacts of sediment on surface water bodies and the marine environment.	Chapter 7
Rehabilitation of lateritic soils	As lateritic soils have low fertility and are easily eroded, they can be difficult to rehabilitate. The specialist soils assessment provides a robust rehabilitation method, with reference to sites where these soils have successfully been rehabilitated.	Chapter 7
Ecology	The lateritic soils support a type of ebony tree that is endemic to Santa Isabel Island while the coastal and marine environment supports important fisheries for the surrounding communities. The specialist terrestrial, aquatic and marine ecological assessments characterised existing ecological conditions, impacts to ecology and the significance of these impacts.	Chapter 8
Resources and livelihoods	The use of the land and sea required for the Project, and the potential loss of terrestrial and marine natural resources, which is under customary collective ownership and use rights is expected to be an emotive and economic issue. The socio-economic impacts of the mine in terms of job distribution, financial distribution (eg of royalty profits) and community benefits is addressed in the social chapter.	Chapters 11, 12 and 13.
Water management	Water management, including the requirement to hold water for treatment prior to discharge, has been a contentious issue in the Solomon Islands. The EIS highlights that unlike a gold mine, no process chemicals are required at the San Jorge Nickel Project. There will be no tailings, pits will be free draining and erosion and sediment controls will be implemented. The specialist surface water assessment outlines the water management that will be used to minimise impacts.	Chapter 9
Cultural heritage	The specialist assessment determined traditional cultural heritage values of the project area to identify cultural sites and work with local communities on the management of such sites.	Chapter 14

The EIS also addresses the marine environment (Chapters 10 and 11), noise and amenity (Chapter 12) and socio-economic issues (Chapter 13) which are lower risk environmental issues than those described in Table 5.2.

The following assessment sections predict impacts in accordance with the requirements of the Environment Act and the Environment Regulations, with the following specific requirements from the Environment Act:

- assess primary, secondary, short-term, long-term, adverse and beneficial impacts;
- assess time period, boundaries and significance of impacts; and
- describe residual impacts which cannot be mitigated or can only be mitigated partially.

The assessment chapters describe the following for each environmental aspect:

- assessment methods;
- existing environment, which is used to predict the potential values and sensitivities;
- impact assessment;
- primary environmental management measures; and
- residual impacts after implementation of management measures.

The method used to determine the residual impacts is described below.

1. Method

The baseline characterisation, field survey (if relevant), and assessment method is described.

2. Existing environment

Baseline characterisation of the study area describes features of the existing environment relevant to each environmental value.

3. Impact assessment

Impacts are predicted based on the assessment requirements defined by the Environment Act, which are described in Table 5.3.

Table 5.3 Impact prediction

Criteria	Rating
Status of impact	• Beneficial • Neutral • Adverse
Boundaries of impact	• Local – project area and immediate surrounds • Regional – southern section of Santa Isabel Island and adjacent marine waters • National – Solomon Islands
Duration of impact	• Short term – 0 to 5 years • Medium term – 6 to 15 years • Long term – 16 to 30 years • Permanent – ongoing social, cultural and/or natural impacts
Extent of impact	• Direct impacts – where a stressor impacts directly on the ecosystem component of interest • Indirect impacts – where a stressor impacts supporting components of an ecosystem or ecosystems downstream of the primarily impacted ecosystem
Severity	• Low – minimal social, cultural and environmental impacts from project • Medium – society, cultural aspects and the environment are adversely impacted but can continue in a modified way • High – society, cultural aspects and the environment are adversely impacted and temporarily or permanently cease or are substantially affected

Table 5.3 Impact prediction

Criteria	Rating
Residual impacts	The net impacts remaining with the mitigation measures in place
Confidence level	The specialist's level of confidence that the impacts are likely to be known, unpredictable or irreversible: • Low • Medium • High

Impacts to the environmental values are assessed as described in Section 1.3 using the significance assessment method or the compliance assessment method where relevant.

4. Primary environmental management measures

Primary environmental management measures that are part of the mine design or the planned management of the mine that will be implemented to address the key issues are described.

5. Residual impact prediction

Residual impacts are predicted based on the implementation of the management measures. Additional management measures are described for impacts which remain unacceptable after the implementation of the primary environmental management measures.

Due to the lack of development in the area, any cumulative impacts from other projects are negligible.

6 Physical setting

6.1 Physical setting

6.1.1 Location and topography

The Solomon Islands are an archipelago of islands and coral atolls in the Pacific Ocean. The islands are mountainous and form a double chain separated by the New Georgia Sound. They are aligned north-west to south-east, stretching approximately 1,400 km from Bougainville to the Santa Cruz Islands.

The land area of the Solomon Islands is 28,446 km^2, comprising six major islands and about 992 small islands, atolls and reefs. The major islands are Choiseul, New Georgia, Santa Isabel, Guadalcanal, Malaita, and Makira. The capital of the Solomon Islands, Honiara, is on Guadalcanal.

San Jorge Island is situated in the central part of the Solomon Islands, immediately offshore from the south-east edge of Santa Isabel Island, in Isabel Province (Figure 1.1). Honiara is approximately 102 km south-south-east of San Jorge Island.

San Jorge Island is approximately 22 km long from north-west to south-east, and between 15 km and 6 km wide from north-east to south-west. San Jorge Island is separated from Santa Isabel by a large bay in the south-east named Thousand Ships Bay, which is approximately 6 km wide at its entrance. The bay narrows over the next 14 km then forming the narrow Ortega Channel, which separates San Jorge Island from Santa Isabel Island by only 330 m in the far north. San Jorge Island has topography characteristic of the Solomon Islands, with vegetated slopes reaching a maximum height of 420 metres above mean sea level (m AMSL) to the north-west of the island.

The prospecting licence area (PL 01/15) is located on the south-eastern part of San Jorge Island, where the elevations range from sea level to 360 m AMS. The tenement measures approximately 9 km west to east and 4 km north to south, and approximately 30% of the tenement is sea. The proposed main access road will go from the proposed port location to Camp Bungusule in the centre of the tenement at an elevation of approximately 180 m AMSL.

6.1.2 Climate and weather

The Solomon Islands experience an equatorial climate influenced by the El Niño Southern Oscillation. There is generally a dry season from May to October, and a wet season from November to April.

The following climate data are derived from a weather station (IWS01) installed by SMM in the south of Santa Isabel Island, with data reported from 2008 to 2012 (SMM 2012).

i Temperature

Over the four years of measurement (2008-2012) the minimum temperatures ranged from 20.4°C to 23.4°C and maximum temperatures from 31.5°C to 35.9°C. The monthly average temperature was between 25.5°C and 26.9°C. The warmest months are November to April and the coolest months are May to October (MET 2015).

ii Humidity

Relative humidity varies greatly over the course of the day, but has little seasonal variation. Over the four years of measurement (SMM 2012), the minimum average monthly humidity ranged from 64% to 72% and average monthly maximum humidity ranged from 97% to 99%.

iii Rainfall

Annual rainfall in the Solomon Islands ranges from 3,000 mm to 5,000 mm with significant variation between locations due to prevailing winds and topography. Rainfall generally increases with elevation, with the highest rainfalls occurring on the sides of the highest slopes facing prevailing winds.

Rainfall measurements at IWS01 show no seasonal rainfall pattern, that is, no dry or wet season. This is due to the monsoonal influence from December to April and the south-easterly prevailing winds during the remainder of the year.

Based on the four years of measurement (SMM 2012), the minimum rainfall generally occurs between April and June, and the maximum rainfall occurs between December and April. The lowest recorded rainfall (100 mm) was in June 2010 and the highest recorded rainfall 650 mm was in January 2010.

iv Wind

Wind direction was recorded at IWS01. West south-westerlies predominate during January, which shift to the north-west during February and March. Wind directions shift to the northeast during June then back to the northwest in October. The average yearly wind speed is between 1.33 m/s and 2.41 m/s with maximum wind speed between 4.14 m/s and 8.93 m/s.

v Natural hazards

Common natural hazards in the Solomon Islands are tropical cyclones, floods and droughts. Cyclones are not common (averaging one to two per year, across the whole of the Solomon Islands), but can occur during the wet season. Six cyclones were recorded within 500 km of San Jorge between 2005 and 2015, but none came within 100 km of the island (BOM 2017). Cyclones and tropical storms which affect the Solomon Islands are often in the early stages of their life cycle, and relatively small; however they can still be destructive to buildings and water supplies, and have caused flooding and loss of life in the past. Thunderstorms are common over Santa Isabel and San Jorge islands between December and March and may cause damage from flash flooding and high winds.

Drought is associated with La Niña and El Niño, and may cause water and food shortages.

The Solomon Islands archipelago is at the boundary of the Australian and Pacific continental plates. The Australian and Woodlark plates are moving north-east at a rate of 7 cm per year towards and underneath the Pacific plate, resulting in earthquakes and volcanic activity (Smithsonian/USGS 2013). The Santa Isabel and San Jorge islands form part of a linear north-west to south-east trending chain of islands in the New Georgia Group (Berly 2006).

7 Soil assessment

7.1 Assessment objectives

The objectives of this assessment are to:

- describe the soil types and their location;
- describe the characteristics of the different soil types;
- describe potential management practices to preserve soil based on soil type and characterisation; and
- assess the suitability of the different soil types for rehabilitation.

7.2 Assessment method

A desktop and field survey of the soil in the San Jorge Tenement was conducted by EMM in September 2017 to identify soil types and collect samples for laboratory characterisation. All field and desktop assessment methodology for the survey was conducted with regard for the following guidelines:

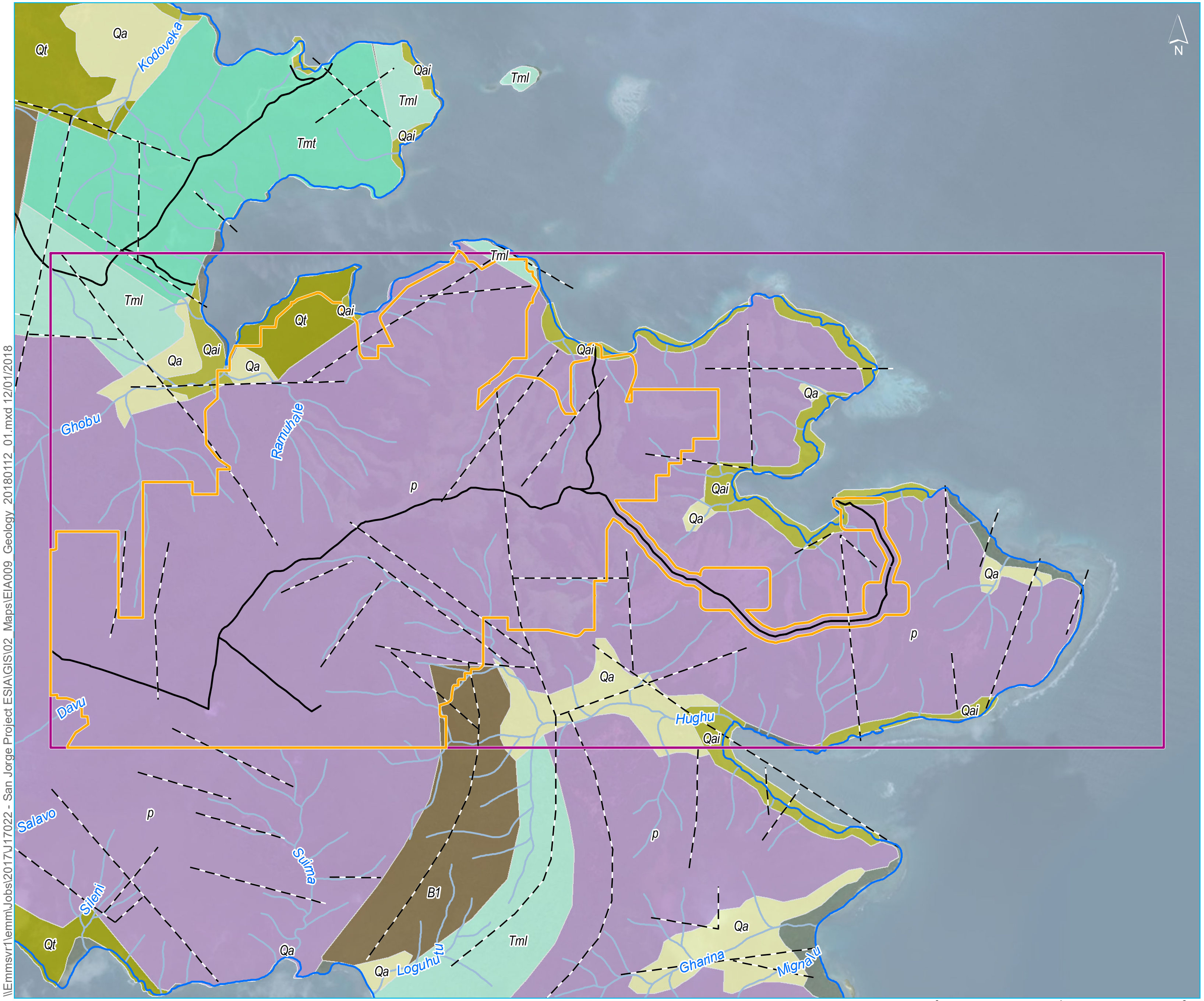
- *Soil Data Entry Handbook* (Milford et al. 2001);
- *Australian Soil And Land Survey Book* (NCST 2009); and
- *The Australian Soil Classification* (Isbell 2002).

7.2.1 Field surveys

The sampling rationale of the survey is defined in the *Australian Soil and Land Survey Field Handbook* (NCST 2009). Indicative locations were chosen based on visual assessment of access areas and topography. Two types of sites were surveyed, check sites and detailed sites; 12 detailed sites and 25 check sites were located across the project area. Check sites underwent a field assessment to describe the soil type only, no samples were taken and there was no laboratory analysis. Detailed sites included a description of the soil type, compared to a check site, including soil texture, structure, colour, pH and EC. Samples of the soil profile were taken for laboratory assessment. Detailed sites were selected to give a representative sample of soil overlaying the deposits and the surrounding land. Photos were taken of the soil surface and surrounding area at each site. A hand auger was used to extract a disturbed soil profile to a depth of 1 m bgs. A description of the soil type for each profile was completed before collecting samples at detailed sites only.

7.3 Existing environment

The Solomon Islands is an archipelago, forming part of the Greater Melanesian arc system. San Jorge Island overlays Late Cretaceous ultramafics, which are rocks with low silica content. The nickel laterite deposits on the island have formed via the weathering (largely rainfall) and decomposition of these ultramafic rocks. This leads to the enrichment of nickel, cobalt and iron in the laterite profile. Many nutrients have been leached by this weathering particularly in flat areas. Where the topography is ridged, soils are immature due to erosion rates exceeding soil formation rates. The profile above the ultramafic rocks can be broken down to four main layers - the soil, limonitic zone, transition zone and saprolitic zone.



Source: EMM (2017); Axiom Mining Limited (2017)

0 1 2 km
WGS 1984 UTM Zone 57S

KEY

- Prospecting licence boundary
- Potential area of disturbance
- San Jorge Island coastline
- Access road
- Watercourse / drainage line
- Fault

Geology

- B1 - San Jorge Volcanics
- Qa - Alluvium
- Qai - Mangrove swamp deposits
- Qt - Mt Tohebakala Conglomerate
- Tml - Loguhutu Formation
- Tmt - Albatross Bay Limestone Member
- p - Kolomola Ultramafic - Serpentinized

Geological setting

Axiom Mining Limited
San Jorge Nickel Project
Environmental impact statement
Figure 7.1

7.3.1 Soil

The soil is highly weathered with high levels of iron. The depth varies from 0.1 to 0.3 m below ground surface (m bgs).The majority of the nutrients in the profile are contained in this thin layer. The upper section of the layer is dominated by organic matter (mainly roots) and varies in depth depending on the landform such as ridges and slopes.

7.3.2 Limonitic zone

The topsoil is underlain by the limonitic zone. This zone extends from the topsoil down to a depth of 8-10 m bgs. Magnesium and silicate minerals have been largely leached from this layer with iron oxides being the dominant component. Pore space and moisture is relatively high. This zone has a reddish brown colour at the top before transitioning to yellowish brown. The texture also changes down this layer from a silty clay to a silty soil-like weathered rock. Residually enriched, lower-grade nickel ore was present in the lower area of limonite.

Under the limonitic zone there is a transition zone which shares characters from the limonitic zone above and the saprolite below.

7.3.3 Saprolitic layer

The final layer in geology is the saprolitic layer and extends down to a depth of 12-15 m bgs. The saprolite consists of sandy or clayey soils with bedrock textures. Fragmented ultramafics are also found lower down in the saprolite. Higher grades of nickel occurred in the upper part of this layer, and it is the saprolite layer that is the focus of mining operations.

Photograph 7.1 Soil sampling on San Jorge

7.4 Impact assessment

An area of up to 1348.4 hectares (ha) of land will be disturbed throughout the life of the mine. Land disturbance will largely be from the construction of infrastructure, including open-cut pits, out-of-pit emplacement areas, roads for haul trucks and light vehicles, and run-of-mine (ROM) pads for ore stockpiling. Without effective mitigation measures, the project has the potential to impact on soils and land in the project area in a number of ways. These include:

- loss of soil stability; and
- loss of soil function (fertility).

Table 7.1 summarises the potential impacts and their severity.

Table 7.1 Summary of unmitigated impacts and their significance

Impact	Value	Status	Boundary	Duration	Direct /indirect	Confidence	Sensitivity of value	Severity of impact	Significance of impact
Direct disturbance of project area reducing the stability of landforms	Soil stability	Adverse	Local	Medium (five to ten years)	Direct	High	Moderate soil stability and slope steepness, therefore soil stability is moderately sensitive.	High	High
Erosion and sedimentation of disturbed area reducing the stability of landforms	Soil stability	Adverse	Local	Medium (five to ten years)	Direct	High	Moderate soil stability and slope steepness, therefore soil stability is moderately sensitive.	High	High
Exposure of acid sulphate soils reducing the soil's ability to support an ecosystem	Soil function	Adverse	Local	Medium (five to ten years)	Direct	Low	Nutrient poor soils, but support an ecosystem therefore soil function is moderately sensitive.	Low	Low
Contamination from hazardous spills and leaks reducing the soil's ability to support an ecosystem	Soil function	Adverse	Local	Medium (five to ten years)	Direct	High	Nutrient poor soils, but support an ecosystem therefore soil function is moderately sensitive.	Moderate	Moderate
Uncontrolled discharge of solid and liquid waste reducing the soil's ability to support an ecosystem	Soil function	Adverse	Local	Medium (five to ten years)	Direct	Medium	Nutrient poor soils, but support an ecosystem therefore soil function is moderately sensitive.	Moderate	Moderate

7.4.1 Loss of soil stability

While soil erodibility was shown to be low, it is important to note that this is only one component of the overall erosion hazard. The climate in the region has a high erosive force due to the high quantity and intensity of rainfall. The slopes that connect to the ridges are also much more prone to erosion than the ridges themselves due to an increase in runoff speed. Once vegetation is removed the erosion hazard will increase greatly due to increased runoff velocity which increases the potential for rill and gully erosion. Due to the high rainfall and the nature of the mining activities, there is the potential to create unstable surfaces that could be prone to collapse or landslip; however much of this risk can be mitigated prior to construction with mine design.

The potential impact of the project on soil stability without any mitigation measures will be high.

7.4.2 Loss of soil function

The soils on the tenement have moderate to low fertility, with strong acidity and nutrient deficiencies with could restrict plant growth; however, the soils in their current state support the existing ecosystem. The nature of the mining activity (ie removal of vegetation and strip mining) will significantly impact soil function, and its ability to support ecosystems or potential agriculture during construction and operation. The soils on the tenement have strong acidity, but there is the potential to expose acid sulphate soils through the process of excavation and exposure, which would increase the acidity of the soil. There is a significant potential for contamination of soils to take place from spills and leaks of chemicals and hydrocarbons from plant and equipment during construction, operation and rehabilitation of the site. In addition, litter and waste associated with the project could impact soil function if not appropriately managed.

Rehabilitation will aim to restore the soil function, but until this takes place, the potential impact on soil function will be high.

7.5 Management plans and mitigation measures

Many issues relating to surface water flow (ie the effects of erosion and sedimentation) will be managed through the implementation of a water management strategy in the design of the mine. The water management strategy is discussed in Chapter 9. This will significantly control the movement of water around the project area, and reduce the significance of impacts on geology and soil.

7.5.1 Management plans

The following plans and mitigation measures will also be implemented to reduce impacts to soil stability and function.

- Erosion and sediment control plan containing procedures and information on the management of:
  - catchment areas and drainage lines;
  - proposed mining, stockpiles and disturbance areas;
  - the extent and nature of riparian protection zones;
  - the alignment and geometries of all drainage;
  - the location and size of all sedimentation dams;

- waterway crossings; and
- drainage lines that require scour protection.

- Hazardous materials plans, containing procedures for:
  - documentation: storage and currency of safety data sheets (SDSs);
  - regulatory authority guidelines for the safe handling, transport and storage of all hazardous materials used; signage; and document review;
  - storage and use of hazardous materials: locations and quantities; containers; labelling; leakage testing; bunding and capacity of bunded areas; and spill response;
  - transportation of hazardous materials: staff training in handling; clean-up and remediation of spills; storage of materials; and excavation and treatment of contaminated soil; and
  - monitoring: document currency; vehicle and hazardous material storage inspections; and spill response preparedness.
- Liquid and solid waste management plan, containing procedures and designs for:
  - disposal of solid and liquid wastes to prevent leaching and contamination of surface water;
  - treatment and disposal of domestic wastewater to prevent spills, leaks and contamination of surface water;
  - treatment and disposal of wastewater from the MIA and fuel storage areas including spacing of facilities from watercourses and the shoreline; and
  - monitoring such as daily inspections of storage areas and weekly review of waste generation.
- A water quality monitoring plan, containing procedures for:
  - Regular sampling for water quality parameters such as pH, turbidity, TSS, dissolved oxygen, turbidity and electrical conductivity.
- If required, an acid sulphate soils management plan, containing procedures for:
  - Specialised handling for potentially acid sulphate soils; and
  - additives such as limestone, organic materials or bactericides used on potentially acid generating waste rock.

A full list of mitigation measures for each plan is included in Chapter 15, Management plans and mitigation measures.

7.5.2 Rehabilitation

A rehabilitation plan has been prepared as part of this EIS, which includes management measures to manage the rehabilitation of the site. This plan contains procedures for:

- surface management (including compaction, filling and ripping) of rehabilitated areas including open-cut pits and slopes, mine infrastructure and building areas, haul roads, stockpiles and laydown areas.
- soil grading, stockpiling and spreading;
- re-establishment of vegetation on rehabilitated soils using selected native plants;
- long term erosion and sediment control measures; and
- maintenance and monitoring programs to confirm successful rehabilitation.

The rehabilitation plan is included in Appendix B.

7.6 Residual impacts

Table 7.2 outlines the significance of residual impacts from each potential impact of the project following the application of management plans and mitigation measures.

Table 7.2 Summary of residual impacts

Impact	Potential significance prior to implementation of mitigation measures	Residual significance after implementation of mitigation measures
Direct disturbance of project area reducing the stability of landforms	High	Moderate
Erosion and sedimentation of disturbed area reducing the stability of landforms	High	Low
Exposure of acid sulphate soils reducing the soil's ability to support an ecosystem	Low	Low
Contamination from hazardous spills and leaks reducing the soil's ability to support an ecosystem	Moderate	Low
Uncontrolled discharge of solid and liquid waste reducing the soil's ability to support an ecosystem	Moderate	Low
Direct disturbance of project area reducing the stability of landforms	Moderate	Low

7.7 Conclusion and summary

The soils and geology found on San Jorge Island within the project area are vulnerable to impacts from project activities. The implementation of management plans and the application of management measures will reduce the significance of these impacts from moderate, to low to moderate. Impacts are most likely to occur during significant rainfall events when the design capacity of the erosion and sediment controls is exceeded.

8 Terrestrial ecology

8.1 Assessment objectives

The objectives of this assessment are to provide:

- a description of existing terrestrial ecological values at the project area, using existing literature and data gathered during field surveys;
- an assessment of the potential impacts of the project on the terrestrial ecological values; including any-cumulative impacts, taking into consideration any relevant guidelines, policies, plans and statutory provisions; and
- a description of the actions that would be taken to avoid, minimise the potential impacts of the project.

8.2 Assessment method

The first component of the assessment was a desktop review comprising:

- review of literature relevant to the south of Santa Isabel Island, particularly from the Sumitomo Projects (SMM 2012, 2014) and the Kolosori Project (unpublished);
- a search for local threatened species on the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (the Red List); and
- information related to nickel mining methods, impacts and rehabilitation.

Ecological experts from EMM and Pacific Horizons Consulting Group surveyed the flora and fauna in the project area in September 2017. Initially, vegetation was mapped based on forestry mapping and satellite imagery, which was confirmed in the field. Data collected during the surveys was used to define the dominant canopy species and community structure, with reference to published community descriptions.

The methods used to assess the vegetation throughout the San Jorge mine tenement included a rapidly walked transect survey totalling 80 transects. This enabled coverage of the area in the least amount of time, in preference to slower quadrating methods and strip transects. Major species were recorded for canopy, mid-layer and ground-layer species as a running life-form list for each vegetation type observed, and foliage project cover calculated. All plant species identified were also verified against the National Herbarium (Honiara, Solomon Islands) using photographs and specimens collected in the field. The conservation importance of the vegetation was noted in addition to its rarity on Isabel and within the Solomon Islands. Comments were also provided on the important factors influencing vegetation structure and floristic composition.

The mapping of the vegetation and marine environments used recent Google Earth Images of San Jorge Island. This was then digitised to provide location of the various environments and area they occupy within the mining tenement.

The site was also surveyed for birds, reptiles and amphibians. Birds were surveyed by walking existing paths and roads through a variety of habitats including primary forest on the upper ridges, secondary forests, valley forest, fernlands and coastal areas. All birds seen or heard were identified and where possible photographed. Shy, rare and species which occur at low densities were surveyed using call playback to attempt to detect their presence. Incidental records of mammals were also made during the various surveys.

Two sites within the tenement were surveyed for reptiles and amphibians on San Jorge Island, over two days and two nights in August, 2017. At each site, a visual encounter surveys (VES) was conducted for frogs and reptiles. This involved randomly walking the two sampling sites, observing and recording each species of reptiles and frogs in the area. Randomized walks are normally used for rapid sampling where time and conditions do not allow for placement of quadrats or transects. However, this technique (VES), has many advantages for rapid surveys, which includes, providing "hands on experience", the observation of cryptic species and juveniles, and sampling multiple species within "heterogeneous habitats" (Pikacha et al. 2016). As a result, we were able to obtain a checklist, species richness, and abundance record of some common reptiles and frogs in the area.

During the survey, the surveyors walked around the area of interest, at site 1 (next to the spring/stream near the camp), and site 2 (at the junction of the road in the centre of the island), over 3 hours each night, and for a distance of about 1 km at each site. To improve the accuracy of visual identifications, 20 sticky board traps were set up around the sites to increase the chances of capturing cryptic reptiles, particularly skinks. Traps were placed mostly at Site 1 (14 sticky boards), with the rest placed randomly at Site 2 (6 sticky boards). They were placed approximately eight meters apart.

8.2.1 Limitations of surveys

The surveys that were undertaken had the following limitations:

- The site was visited during August and September 2017, and therefore, no seasonal or annual variations have been accounted for;
- The surveys were of a short duration and thus rare, shy and cryptic species may be under represented; and
- Habitats on the ridgelines were relatively thick and inaccessible and due to health and safety issues, field surveyors stayed on known paths and tracks.

Despite these limitations, the survey work undertaken, combined with the desk study of ecological field work in southern Santa Isabel Island has given us a sufficient understanding of the ecological communities and values of the area.

8.3 Existing environment

8.3.1 Flora

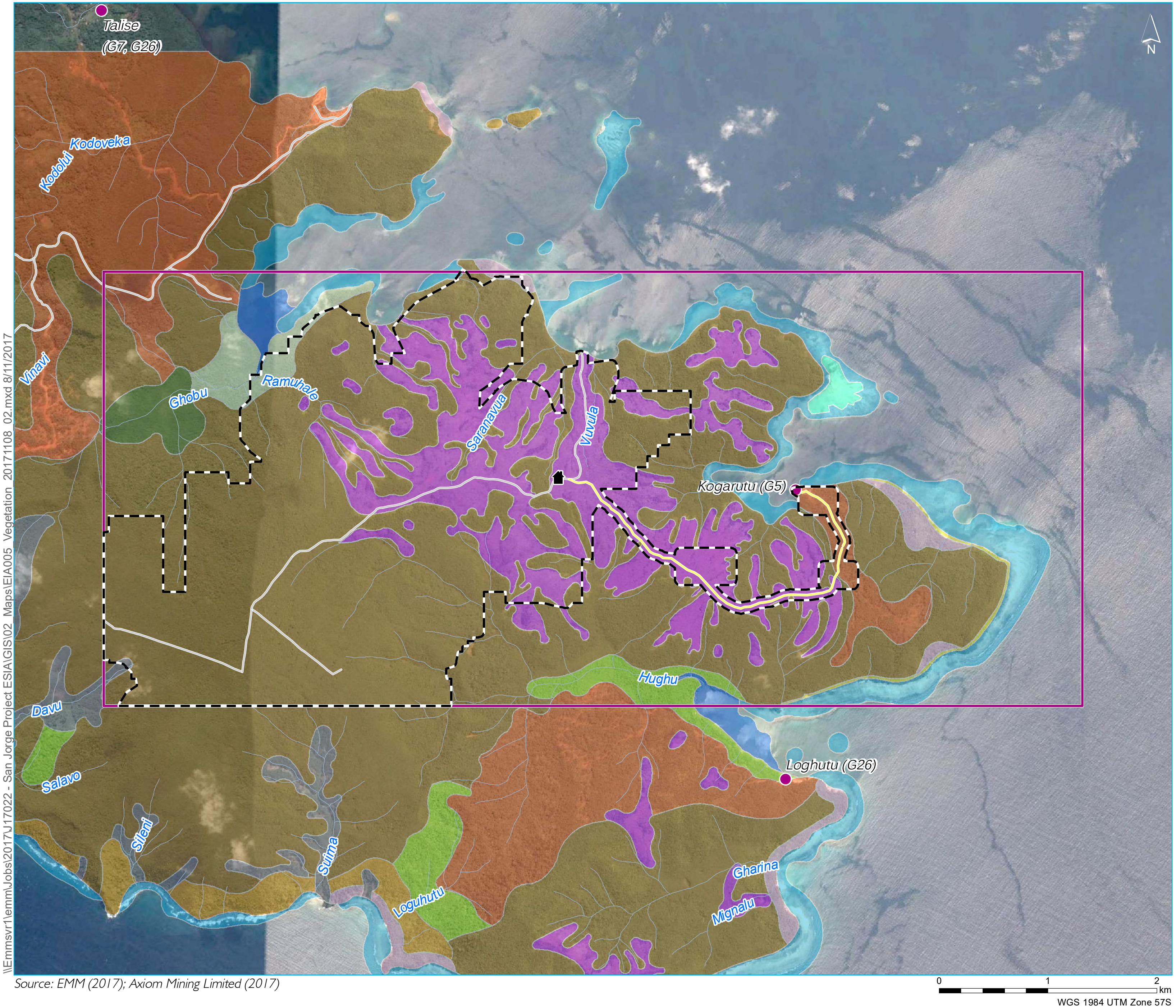
The terrestrial habitats within the tenement are described below and illustrated on Figure 8.1. Photograph 8.1 shows the higher areas of the mining tenement showing the extent of the ultamafic forest in this area, with Santa Isabel Island visible in the distance.

Photograph 8.1 The higher area of San Jorge showing the extent of ultramafic forest on the two closer ridgelines. Santa Isabel Island can be seen in the far distance.

i Coconut plantation

Agricultural activity in the tenement and in the surrounding vegetation is limited to a few old coconut stands along the east and southern coasts. This is due to the poor nature of the soils in the ultramafic areas confining coconut planting to flat areas where nutrients have accumulated. They are collectively no more than a hectare in size and occur as narrow plantings near the edge of the sea.

Photograph 8.2 Coconut plantation



Source: EMM (2017); Axiom Mining Limited (2017)

Habitat mapping

Axiom Mining Limited
San Jorge Nickel Project
Environmental impact statement
Figure 8.1

EMM

ii Fernlands (including Fern Scrubland and Fern Woodlands) on ultramafic soils

Fernlands, Fern Shrublands and Fern Woodlands occur on the slopes and ridges of the lower hills in the east of the mine tenement being the second most dominant vegetation, covering 326.6 hectares. On Santa Isabel Island it is uncommon, having a land area of c.26 km². These plant communities frequently inter-grade with each other on San Jorge Island. Species composition of the herb, shrub and tree layers is determined by fire intensity and frequency, resulting from deliberate burning of the vegetation. These would have begun as small fern 'balds' on the top of ridge-lines where soil depth was shallow and nutrients were reduced by sheet erosion and leaching from high rainfall. Over time the frequent deliberate fires have expanded these plant communities in the tenement area, and it has now become the largest area of this vegetation type within Isabel Province. The Conservation Status listed is '*Human induced fernlands that are not threatened'*. However, species restricted to ultramafic soils in the Solomon Islands are also commonly found here such as *Myrtella baccarii, Xanthostemon melanoxylon, Gymnostoma papuana* and *Hydriastele hombronii*. Customary reserves and land management planning are therefore recommended due to the uncommon occurrence of these species in the Solomon Islands.

Photograph 8.3 Fernland habitat

These communities commonly have a foliage cover of between 85-100% being determined by the dense cover created by the fern *Dicranopterus linearis*. In the case of the 'Fernlands' the height may range from between 0.5-1m, the Fern Shrublands 1-5m, while for the Fern woodlands the canopy height may reach 5-10m.

Common native tree species associated with this vegetation includes *Hydriastele hombronii, Gymnostoma papuana, Dillenia crenata, Myrtella beccari, Xanthostemon melanoxylon, Pandanus spiralis, Euodia hortensis, Planchonella firma, Trema orientalis, Commersonia bartramia and Syzygium* spp.

The most common native shrub species included *Melastoma affine* and *Myrtella beccarii*. Herbaceous plants associated with the groundlayer are *Dicranopterus linearis, Lycopodium cernum, Scleria polycarpa*, *Spathoglotis plicata* and *Dianella ensifolia*. The native vine *Flagellaria gigantea* and the epiphyte *Hydnophytum formicorum* were also sporadically present.

iii Logged Forest

Logged forest areas are located to the north and south of the tenement mainly in valley depressions where larger trees have grown due to higher nutrient levels. Within the tenement area, logged forest occupies an area of 10.3 hectares in the south. The main species removed have been *Callophyllum vitiense* and *Dysoxylum excelsum*, but also *Xanthostemon melanoxylon* and *Diospyros insularis* have been logged. The area is now in a state of regeneration being conspicously covered by *Macaranga* spp. and the vine *Merremia peltata*. Logged forests in their current state have a low conservation value although there is potential value as they will regrow over time.

iv Mangrove Forest

Within Isabel Province mangrove forest covers c.211 km² (Hansell and Wall 1977) and occurs commonly in river and stream deltas as well as in protected coastal or islands environments. They cover an area of 13.3 hectares of the tenement. The largest areas of mangrove occur mainly at the mouths of two streams along the eastern coast, although scattered smaller stands occur along the entire seashore. It is typified by large stands of *Rhizophora apiculata* ranging from a few metres to several metres in height. Occasionally, the larger mangrove *Bruguieria gymnorrhiza* is found behind the *Rhizophora* as large trees reaching a height of 20m.

Photograph 8.4 Coastal mangroves

Other mangrove trees associated with this forest include *Barringtonia racemosa, Bruguiera hainsii, Bruguiera parviflora, Ceriops tagal, Nypa fruticans, Inocarpus fagiferus, Dolichandron espathacea, Quassia indica, Lumnitzera littorea, Rhizophora stylosa, Rhizophora mucronata, Xylocarpus granatum, Excoecaria agallocha, Rhizophora x lamarckii, Scyphiphora hydrophyllacea, Aegicerus corniculatum* and *Heritiera littoralis.*

The scandent shrub *Acanthus ebracteatus* and the mangrove fern *Acrostichum speciosum* also occur sporadically in the understorey.

The canopy is often open and ranges from 20-80% depending on the size of the mangrove stand. The understorey layer is either absent or composed of germinating mangroves and leaf litter. The community enters the mouths of streams in the area and can be adjacent to beach forest or riparian forest. The conservation status is '*Native forest that is not listed as threatened'*. The mangrove forest is important to maintain in the mining operation as it will help mitigate sediment release to reef areas when that occurs.

v Riparian and valley forest on ultramafic soils including areas of landslips and erosion

Riparian forests are restricted to small low-lying pockets of wetter soils found near the mouths of rivers and streams particularly on the eastern side of the tenement. This is also a restricted vegetation type on Isabel having a total area of 65 km² and is found primarily near river mouths and larger streams containing wet peaty soils where nutrient accumulation has occurred. It is characterised by higher diversity than the ultramafic forest, the presence of plank buttresses, additional palm species, lianas and an abundance of *Freycinetia* spp. on tree trunks. Canopy closure ranges between 75-85% and canopy height may reach 20-30m.

It is identified as a 'Native forest that is not listed as threatened'. Management planning is recommended to keep roads, machinery and log removal away from these areas as this forest type may play an important role in sediment entrapment. This will help mitigate possible sediment discharge that might occur from upstream in the mining area.

The major tree species include *Terminalia calamansanai, Xanthostemon melanoxylon, Calophyllum obscurum, Gymnostoma papuana, Canarium liguliferum, Vitex coffasus, Macaranga* spp.*, Ficus* spp.*, Euodia* spp.*, Syzygium* spp. and the palms *Crytostachys kisu, Heterospathe minor* and *Heterospathe solomonensis.*

The understorey consists of seedlings and juveniles of the canopy species as well as the climbers *Calamus hollrungii, Calamus stipitatus, Rhapidophora* sp.*, Freycinetia solomonensis, Freycinetia decipiens* and *Merremia peltata.*

The groundlayer is patchy with large areas of leaf litter interspersed with ferns *Selaginella rechingeri* and *Dicranopterus linearis*, germinating seedlings, *Dianella ensifolia* and *Scleria* sp.

Some areas of valley forest, particularly on the south-western side of the tenement and areas just outside the tenement have been subject to erosion and minor landslips.

vi Beach Forest

Beach forest occurs as a narrow vegetation community along most of the coastline and often located behind pockets of mangroves. It is very common throughout coastal Santa Isabel often forming large stands around islands and along the coast. The floral composition of these forests is typical of that found throughout the Indo-Malesia region (Whitmore 1969).

The trees and shrubs are a strand flora consisting of *Barringtonia asiatica, Callophyllum inophyllum, Casuarina equisetifolia, Terminalia catappa, Cerbera manghas, Heritiera littoralis, Hibiscus tiliaceus, Morinda citrifolia, Timonius timon, Pandanus tectorius, Pandanus compressus, Intsia bijuga, Neiospermum oppositifolium, Cordia subcordata, Cocos nucifera, Bikkia* sp.*, Premna corymbosa, Trema orientalis, Clerodendron buchanani* and *Sararanga sinuosa.*

Photograph 8.5 Beach Forest

The vines and trailers present in this community are *Milletia pinnata, Dalbergia* sp.*, Scaevola taccada* and *Ipomoea pes-caprae.*

The forbs in the ground-layer include *Alpinia oceanica, Wollastonia biflora* and the fern *Dicranopterus linearis* in rare scattered patches being limited by the shade from an often dense canopy.

These are mostly widely dispersed species due to their seeds being transported long distances by the sea. The canopy closure is approximately 90% and trees reach a height of 20-30m. The forest is in a relatively untouched state except for some log removal and where small areas of coconuts have been planted. The understory in the vegetation contains mainly seedlings and saplings of the canopy species but may include germinating coconuts. Due to its common nature it is identified as '*Native forest that is not listed as threatened*'.

vii Ultramafic Forest and Swamp Forest in ultramafic soils

Two associations of ultramafic forest occur in the project area on the ultramafic soils, and they represent the dominant vegetation. On the slopes and ridges where drainage is not impeded, *Gymnostoma papuana* is dominant in the upper canopy with the palm *Hydriastele hombronii* as an emergent, covering 969 hectares of the tenement. A small area also occurs in the north of the site in a swampland depression which is distinctive from ultramafic forest on the slopes and covers an area less than a hectare in size. It is dominated also by *Gymnostoma papuana* but also containing *Calophyllum vitiense* as a co-associate, identifying a separate ultramafic association (Lees, 1991). These forests intergrade with fernlands, and riparian areas which are also on ultramafic soils and a collective species list is presented for these ultramafic areas. A full list of species recorded is given in Appendix E.

Photograph 8.6 Ultramafic forest

The conservation status of this forest type is 'Native *forest that is not threatened'*. However, these forests are uncommon in the Solomon Islands, particularly ultramafic forest in swampland. These forests only occur in confined and scattered locations on southern Isabel Island, San Jorge Island and southern Choiseul with smaller areas occurring on Guadalcanal at Marau, Wanderer Bay on Makira and the Nggela Islands (Whitmore 1969).

Whitemore (1988) also noted that the ultramafic forests are the most distinctive plant assemblage in the Solomon Islands and are even more distinctive than those found in South-East Asia. He further noted that these forests are often sharply demarcated from adjoining forest, as they are in this project area. Whitemore (1988) further discusses that this variation does not result from the high levels of nickel and chromium but from low concentrations of potassium and phosphorus in the soils, which reduce forest height to 15-25m as well as species diversity at the project site. Whitmore (1988) and Lee (1969) suggest that in the Solomon Islands, it is the absence of soil nutrients except magnesium and not high concentration of heavy metals that have lowered the tree species diversity and simplified forest structure. Anacker (2014), Kay et al. (2011) and Rajakaruma (2004) indicate that the depauperate nature of ultramafic soil generates selective processes promoting speciation and the evolution of ultramafic endemism which results in distinctive plant communities. San Jorge is no exception to this influence and does visually and floristically appear distinct from other forest types in the Solomon Islands. In South-East Asia, this forest is becoming threatened and is regarded as having a high conservation value (Wolf 2001).

The ultramafic assemblages cover a large area of the San Jorge mining tenement and were found to be in a relatively undisturbed condition except for some selective removal of timber trees. Hansell and Wall (1977) found that this forest type occupies 232 km² on southern Isabel and San Jorge for the hill-forests, and 16 km² for the swamp-forest association. This makes it an uncommon vegetation type in this part of the Solomon Islands. There has been some sporadic removal of larger trees in the past for timber especially *Xanthostemon melanoxylon* (Queen Ebony), *Diospyros insularis* (Ebony) and *Calophyllum* spp; but overall the forest is structurally and floristically intact. Due to the uncommon nature of this forest, particularly the swamp-forest, logging impacts, and potentially mining impact on its distribution and conservation status will increase. This is especially relevant should the nickel reserves be mined across Isabel Island and other areas of the Solomon Islands. Customary reserves and land management planning are therefore recommended.

The canopy is also fairly open in many areas being 60-80% foliage cover. Whitmore (1988) suggests that the presence of *Gymnostoma papuana* and its dominance in the vegetation of the project area is due to the ability of this species to fix nitrogen allowing it to have a competitive advantage in the nutrient poor soils, making it a species worth considering for mine reclamation.

Some tree species are confined to this forest type in the Solomon Islands and these include on San Jorge, *Xanthostemon melanoxylon*, *Gymnostoma papuana*, *Hydriastele hombronii* and *Dacridium solomonensis* (Whitmore 1988). Large climbers, shrubs, the common smaller vine *Hoya affinis* and ground forbs are also notably absent in this forest type. Plank buttressed trees are also conspicuously absent. Orchids are infrequent but do occur low down on tree trunks due to the open nature of the forest in some areas.

The main native canopy trees include *Gymnostoma papuana, Elaeocarpus sphaericus, Cryptocarya* sp., *Calophyllum obscurum, Calophyllum vitiense, Syzygium* sp, *Diospyros insularis, Xanthostemon melanoxylon, Dacridium solomononensis, Hydriastele hombronii, Pandanus spirallis,* and *Podocarpus* spp.

The native mid-layer species mostly comprised young canopy species but also sporadically *Myrtella beccarii,* with young palms of *Hydriastele hombronii* very conspicuous. Occasionally, young *Pandanus spiralis* and the vine *Flagellaria gigantea* also enter the understorey.

The native groundlayer species include seedlings of the canopy trees and palms, a common covering by *Flagellaria indica* and patches of *Dicranopterus linearis* and *Lycopopdium cernum* in addition to a deep leaf litter.

viii Overall values of habitats

The ultramafic forests in the ridge areas and in the swampy lowlands, as well as some of the valley forest are of regional significance within the Santa Isabel Province due to their diversity and natural scarcity in this region and across the Solomon Islands. The fernlands are also of regional significance due to their scarcity.

8.3.2 Fauna

The majority of the terrestrial fauna species recorded in previous surveys undertaken on Santa Isabel Island adjacent to San Jorge Island (Golder (2014) and SMM Solomon Limited (2012) are common and most are associated with forested areas. This section sets out the species recorded on San Jorge Island during the 2017 studies and identifies other species which are likely to occur, or could possibly occur based on range and habitat.

i Mammals

No specific mammal surveys were undertaken on San Jorge Island although opportunistic sightings did occur while surveying for other animals. The desk study has revealed that a number of species of mammal occurred on adjacent areas of Santa Isabel Island (SMM, 2014) and therefore are likely to occur on San Jorge. These species are listed in Table 8.1. Northern blossom bat *Macroglossus minimus* and Sanborn's Flying Fox *Pteropus mahaganus* were noted on site in September 2017 during other surveys.

Seven species of mammal listed under the IUCN Red List of Threatened Species (2013) have been recorded during detailed surveys in areas near to the project area on Santa Isabel. These species and their habitat requirements are detailed in Table 8.2.

Table 8.1 Mammal species recorded by SMM (2014) on adjacent parts of Santa Isabel Island

Common name	Scientific Name
Northern blossom bat	*Macroglossus minim us nanus*
Solomon tube nose bat	*Nyctimene bougainville*
Solomon Island Tube nose	*Nyctimene major*
Sanborn's Flying Fox	*Pteropus mahaganus*
Pacific Rat	*Rattus exulans*
Rousette Bat l	*Rousettus amplexicaudatus*
Eastern Bent-winged Bat	*Miniopterus schreibersii*
Large-footed Myotis	*Myotis adversus*
Fawn Leaf-nosed Bat	*Hipposideros cervinus*
Naked-rumped Sheathtail Bat	*Saccolaimus saccolaimus*
Umboi Tube-nosed Bat	*Nyctimene vizcaccia*

Table 8.2 Mammal species recorded from the vicinity of the project area

Common Name	Scientific Name	Status	Habitat Requirements
Bougainville Monkey-faced Bat	*Pteralopex anceps*	EN	Flannery (1995) suggests that this species inhabits mature tropical forest (preferentially high elevation mossy forest).
Guadalcanal Monkey-faced Bat	*Pteralopex atrata*	EN	Flannery (1995) observed animals feeding upon un-ripe mangos in an old garden. The species is probably dependent on undisturbed, old growth forests, and seems to roost in tree hollows.
Greater Monkey-faced Bat	*Pteralopex flanneryi*	CR	This species appears to be entirely dependent on old-growth, lowland forest. It probably roosts solitarily in foliage, though it might also utilize hollows or cavities of large Ficus trees.
Sanborn's Flying Fox	*Pteropus mahaganus*	VU	This species is found in coastal lowlands in coconut plantations and lowland tropical forest.
Dwarf Flying Fox	*Pteropus woodfordi*	VU	Has been recorded from lowland gardens, through to mature forest.
Bougainville Giant Rat	*Solomys salebrosus*	EN	Has been collected in nests of leaves within hollow trees, presumably within tropical moist forest.
Isabel Giant Rat	*Solomys sapientis*	EN	This species is associated with tropical moist forest. It is reportedly arboreal, and may rely on large forest trees for nesting sites.

Notes: CR – Critically Endangered, EN – Endangered, VU - Vulnerable

Based on the desk study assessment, the mammal community on the site is considered to be of local to regional value.

ii Birds

Forty one species of bird were recorded within the tenement from the higher forests, through degraded open areas, to the coastal and marine zone. The species richness within each habitat is described below. A full list of species and their status on the site and within the Solomon Islands is given in Appendix E.

Primary forest held the most species diversity. Twenty-four species were recorded in primary forest including the lower valley gulley forests, within the tenement. The community included seventeen (17) regional endemics, and three species which are considered near threatened by IUCN: Red-knobbed Imperial-Pigeon, Solomons Frogmouth and Solomons Pied Monarch. Of these, the records of Solomons frogmouth are the most significant. This species has a small range in which the area, extent and quality of habitat are known to be in decline, with a corresponding decline in the population suspected as a result. However, its population is not severely fragmented and it occurs at more than 10 locations. Its global population size is estimated to be 1500-7000 individuals.

Photograph 8.7 The endemic Solomons Pied Monarch

Table 8.3 Primary / valley (gulley) forest

Species	Scientific name
Melanesian Scrubfowl	*Megapodius eremita*
Superb Fruit-Dove	*Ptilinopus superbus*
Claret-breasted Fruit-Dove	*Ptilinopus viridis*
Red-knobbed Imperial-Pigeon	*Ducula rubricera*
Island Imperial-Pigeon	*Ducula pistrinaria*
West Solomons Boobook	*Ninox jacquinoti*
Solomons Frogmouth	*Rigidipenna inexpectata*
North Solomons Dwarf-Kingfisher	*Ceyx meeki*
Ultramarine Kingfisher	*Todiramphus leucopygius*
Solomon's (Ducorps's) Cockatoo	*Cacatua ducorpsii*
Finsch's Pygmy-Parrot	*Micropsitta finschii*
Song Parrot	*Geoffroyus heteroclitus*
Cardinal Lory	*Chalcopsitta cardinalis*
Red-capped (Scarlet-naped) Myzomela	*Myzomela lafargei*
Barred Cuckooshrike	*Coracina lineata*
Oriole Whistler	*Pachycephala orioloides*
Chestnut-bellied Monarch	*Monarcha castaneiventris*
Solomons Pied Monarch	*Symposiachrus barbatus*
Steel-blue Flycatcher	*Myiagra ferrocyanea*
White-billed Crow	*Corvus woodfordi*
Yellow-throated White-eye	*Zosterops metcalfii*
Long-tailed Myna	*Mino kreffti*
Midget Flowerpecker	*Dicaeum aeneum*
Olive-backed Sunbird	*Cinnyris jugularis*

Secondary forest and open areas of fernland held a distinctly different avifaunal community although a few species were seen in both habitat types including Ultramarine Kingfisher, Olive-backed Sunbird and White-billed Crow. In total twelve (12) were recorded in the open, more degraded areas, and lower diversity compared to primary forest would be expected. Two of the species recorded were regional endemics.

Photograph 8.8 A pair of the endemic Ultramarine Kingfishers

Table 8.4 Open areas of woodland / Fernland

Species	Scientific name
Red-knobbed Imperial-Pigeon	*Ducula rubricera*
Uniform Swiftlet	*Aerodramus vanikorensis*
Moustached Treeswift	*Hemiprocne mystacea*
Ultramarine Kingfisher	*Todiramphus leucopygius*
Sacred Kingfisher	*Todiramphus sanctus*
Dollarbird	*Eurystomus orientalis*
Cardinal Lory	*Chalcopsitta cardinalis*
White-bellied Cuckooshrike	*Coracina papuensis*
White-billed Crow	*Corvus woodfordi*
Pacific Swallow	*Hirundo tahitica*
Long-tailed Myna	*Mino kreffti*
Olive-backed Sunbird	*Cinnyris jugularis*

Coastal areas held the least diversity with no endemic or rare species recorded there. There are however good numbers of seabirds feeding offshore of the fringing reefs.

Table 8.5 Coastal and Marine areas

Species	Scientific name
Rufous Night-Heron	*Nycticorax caledonicus*
Eastern Osprey	*Pandion cristatus*
Whimbrel	*Numenius phaeopus*
Common Sandpiper	*Actitis hypoleucos*
Black Noddy	*Anous minutus*
Bridled Tern	*Onychoprion anaethetus*
Roseate Tern	*Sterna dougallii*
Great Crested Tern	*Thalasseus bergii*
Common Kingfisher	*Alcedo atthis*
Beach Kingfisher	*Todiramphus saurophagus*

Five other relevant species of bird listed under the IUCN Red List of Threatened Species (2013) have been recorded during detailed surveys in areas near to the project area on Santa Isabel. None of these species were seen or heard on San Jorge although they could occur in the area. These bird species and their habitat requirements are detailed in Table 8.6.

Table 8.6 Bird species recorded from the vicinity of the project area

Common Name	Scientific Name	Status	Habitat Requirements
Imitator Goshawk	*Accipiter imitator*	VU	Collected and sighted in lowland forest or forest edge to at least 400 m and, possibly, 1,000 m
Solomon's Nightjar	*Eurostopodus nigripennis*	VU	Occurs in forests and woodland alongside beaches and is confined to coasts, occurring from sea level to 300 m.
Sanford's Sea-eagle	*Haliaeetus sanfordi*	VU	It prefers forested coastal areas.
Fearful Owl	*Nesasio solomonensis*	VU	Occurs in old-growth lowland and hill forest, usually in primary forest but also in adjacent secondary forest and forest edge to at least 2,000 m
Black-faced Pitta	*Pitta anerythra*	VU	Found in primary forest, and also small forest remnants and regrowth thickets within a patchwork of gardens between 400-600 m. Here it is more common in the secondary thickets of the gardened areas and less common in large tracts of primary forest.

Note: VU - Vulnerable.

Targeted surveys of these five species were undertaken on site using call playback for Imitator Goshawk, Fearful Owl and Black-faced Pitta, and visual surveys in the right time of day for Sanford's Sea-eagle and Solomon's Nightjar. None of these species were recorded during the 5 days of survey.

The bird community of the primary forest is considered to be of regional value (provincial) based on the diversity of species and the occurrence or likely occurrence of a range of regional endemic species.

The bird communities in the open / fernland areas and the coastal zone are considered to be of local value.

iii Reptile and Amphibians

Fourteen species were recorded out of a possible 34 known species of herpetofauna at the two sites sampled (see Table 8.7). All but three species, *Cornufer (Discodeles) guppyi*, *Nactus multicarinatus* and *Emoia flavigularis*, were common, occurring throughout the Solomon Islands. The largest tree frog in the archipelago, *Cornufer hedigeri* was found commonly on both survey sites. *Palmatorappia solomonis*, a vulnerably listed species (IUCN Redlist) found on mainland Isabel was not heard calling on San Gorge. However, the surveys were not intensive enough to prove their absence. The large water frog, *Cornufer guppyi*, was found along the stream adjacent to the Axiom camp site (Site 1). They were absent at Site 2, on the ridge. An endemic goanna, *Varanus spinulosus*, occurs on San Jorge. This also was not recorded during field surveys. Table 8.7 details a list of species either recorded during the survey or suspected to occur at this site from previous studies or literature.

Photograph 8.9 **Solomon Islands Eyelash Frog (*Cornufer guentheri*)**

Photograph 8.10 **Weber's Wrinkled Ground Frog (*Cornufer weberi*)**

Table 8.7 Amphibians and Reptiles recorded on the tenement

Family	Species (Scientific name, common name (where available))	Relative Abundance Site 1	Relative Abundance Site 2
Frogs			
	Cornufer bufoniformis	u	u
	Cornufer guppyi	r	r
	Cornufer elegans	a	a
	Cornufer gigas	u	u
	Cornufer hedigeri	c	c
	Cornufer neckeri	u	u
	Cornufer guentheri	a	a
	Cornufer trossulus	u	u
	Cornufer vertebralisi	c	c
	Cornufer wolfi	u	u
	Cornufer (Discodeles) guppyi	r	u
	Litoria thesaurensis	a	c
	Litoria lutea	u	u
	Palmatorrapia solomonis	u	u
	Cornufer solomonis	c	c
	Cornufer weberi	a	a
	Rana kreffti	u	u
	Rhinella marianus	a	a
Reptiles			
Agamidae			
	Hypsilurus macrolepsis, Solomon Forest dragon	u	u
Gekkonidae			
	Gehyra oceanica, Oceanic Gecko	c	u
	Hemidactylus frenatus, Common House Gecko	c	u
	Lepidodactylus guppyi Guppy's Gecko	u	u
	Nactus multicarinatus, Solomons Slender-Toed Gecko	r	r
Scincidae			
	Corucia zebrata, Prehensile-Tailed Skink	u	u
	Emoia atrocostata, Reef Skink	u	u
	Emoia cyanogaster, Green-Bellied Tree Skink	u	u
	Emoia flavigularis, Yellow-Throated Skink	r	r
	Eugongylus albofasciolatus, White-Banded Sheen Skink	u	u
	Lamprolepis smaragdina, Emerald Tree Skink	u	u
	Sphenomorphus concinnatus, Elegant Forest Skink	c	c
	Sphenomorphous cranei, Crane's Skink	c	c
	Sphenomorphous solomonis	u	u
	Tribolonotus ponceleti, Poncelet's Crocodile Skink	u	u

Table 8.7 Amphibians and Reptiles recorded on the tenement

Family	Species (Scientific name, common name (where available))	Relative Abundance Site 1	Relative Abundance Site 2
Varanidae			
	Varanus indicus, Pacific Monitor	u	u
	Varanus spinulosus, Isabel Monitor	u	u
Typhlopidae			
	Ramphotyphlops depressus, Blind Snake	u	u
Boidae			
	Candoia paulsoni, Solomons Ground Boa	u	u
Acrochordidae			
	Acrochordus granulatus, Little File Snake	u	u
Colubridae			
	Boiga irregularis, Brown Tree Snake	u	u
	Dendelaphis calligaster, Solomons Tree Snake	u	u
Elapidae			
	Loveridgelaps elapoides, Solomons Black-Banded Krait	u	u
	Salomonelaps par, Solomons Red Krait	u	u

Relative abundance: a = abundant (recorded daily in large numbers; c = common (encountered regularly); r = rare (encountered less than five times), and u = unknown (not recorded during surveys, but possibly present given proximity to, and a faunal assemblage affinity to the mainland – Isabel Island).

Photograph 8.11 Fauro sticky-toed Frog (*Cornufer vertebralis*)

Photograph 8.12 An Elegant Forest Skink (Sphenomorphous concinnatus) caught with a sticky-board trap

Based on the desk study assessment and the field work, the reptile and amphibian community on the site is considered to be of local to regional value.

8.4 Impact assessment

8.4.1 Land clearance

Land clearance will lead to the direct loss of up to 1321.3 of habitat for the base case and 1348.4 ha for the alternative case. The latter is the worst case scenario should the alternative case be taken. A full breakdown of land clearance by habitat type is given below in Table 8.8 for the base case.

Table 8.8 Land clearance by habitat type (ha) (base case scenario)

Habitat type	Area of loss (ha)
Coconut plantation	1.0
Fernlands	326.6
Large landslips and erosion in valley forest	0.8
Logged Forest	10.3
Mangrove Forest	13.2
Riparian and valley forest	0.0
Freshwater swamp forest	0.0
Beach Forest	0.0
Ultramafic Forest	969.0
Other	0.4
Total	1321.3

The habitat loss will also lead to a decline in populations of mammals, birds, reptiles and amphibians across the site. Areas of forest left are likely to see a decline in true interior forest species such as Solomons Frogmouth and Solomon Pied Monarch.

The impacts of land clearance can include:

- loss of vegetation communities or individual threatened species;
- reduced species abundance and biodiversity;
- loss of habitat, loss of connectivity between habitat areas and associated diminished fauna movement; and
- loss of land stabilisation and riparian filtration functions.

Siting of the project to minimise impacts on native vegetation is difficult when dealing with an open cut resource, as alternative options do not exist. The extent of the resource determines the boundary of the mine which in turn determines the location of processing and transport facilities. Associated infrastructure will be located as efficiently as possible while still meeting the needs of each component such as location (especially significant for dams and water storage), proximity (drying and storage facilities) and landform (for access roads). Where possible, infrastructure will be located to avoid sensitive environmental areas in light of these constraints.

Impacts will be minimised as far as possible and it is necessary for mitigation measures to be implemented to reduce the extent of environmental impacts resulting from land clearance. Post-mining rehabilitation of the project site will return a stable landform similar to those surrounding the project site, although this will take many years.

8.4.2 Habitat fragmentation and edge effects

A significant impact of the project on terrestrial flora and fauna will be habitat fragmentation... Habitat fragmentation occurs when large areas of forest (or other habitats) are divided into smaller areas. The ecological effects of habitat fragmentation include:

- an increase in the ratio of forest edges to interior forest;
- plant and animal populations being isolated from each other;
- the overall loss of habitat reduces the average size of forest patches;
- it leads to changes in micro-climates (sunlight, humidity, temperature etc); and
- it can alter ecological balances whereby for example edge species dominate the area, or predators become more efficient at hunting.

Habitat fragmentation affects biodiversity by reducing the amount of available habitat as it invariably involves some amount of habitat removal. Plants and other sessile organisms are usually directly removed, while most mobile animals (especially birds and mammals) retreat into remnant patches of habitat (Lindenmayer and Fischer 2006). This can lead to crowding and increased competition between individuals and species.

Habitat fragmentation also results in barrier effects, which occur where particular species are either unable, or are unwilling, to move between suitable areas of fragmented habitat. Species most vulnerable to barrier effects include smaller ground-dwelling species and species with low mobility that find it difficult to traverse altered landscapes. Species least vulnerable to barrier effects tend to be those that are highly mobile and can traverse altered landscapes such as birds, bats and large ground-dwelling mammals (Bennett 1990).

Connectivity across the project area has been considered in terms of local habitat connections and broader corridors which sit in a regional context. Within the site connectivity is linked to the riparian areas which will be retained.

On a regional scale, vegetation and watercourses extend from the ridgelines to the ocean. These linkages will allow the movement of fauna from the upland areas to the south and west of the project area to the coastal fringes. This potentially forms an important corridor for fauna groups that utilise a variety of foraging habitats. Habitat across the project area is also strongly linked to riparian vegetation and adjoining remnant Lowland Forest, and it is essential that riparian corridors are maintained.

On a local scale, connectivity will potentially be disturbed by the construction of haul roads that cut the riparian vegetation types. Riparian vegetation along the watercourses within the project area contain habitat for a number of mammal and amphibian species which may be impacted to varying degrees, depending on their mobility and specific habitat requirements. These impacts will be immediate and suitable mitigation measures will be required to counter impacts. Other more mobile species, such as bird or bat species, are less constrained and are less affected by minor breaks in connectivity.

8.4.3 Water quality impacts

Surface water impacts resulting from the project which could potentially affect conservation values are:

- the alteration of water flows;
- impacts on water quality and flow volumes; and
- diminished water quality can impact aquatic fauna and indirectly impact terrestrial species by reducing food sources. Within the project site, amphibian, bird and mammal species are likely to be affected by reduced water quality.

8.4.4 Direct and indirect mortality

Some mobile species (eg. birds) will move away from areas as they are cleared for mining and move into adjacent areas that are suitable. These species will survive initially, however they will then be competing with other resident populations in the new habitat and either they or their competitors will survive, leading to an overall population decline.

Immobile species such as small mammals, reptiles and amphibians will generally suffer mortality during the clearance process or shortly afterwards as habitats and food sources are lost. Mitigation measures are discussed under Traffic in the Management Measures section below.

8.4.5 Noise and vibration

Increased noise from vehicles, extraction and processing can disturb fauna species and impact on feeding and breeding behaviour. Mitigation measures are set out in the noise section of the Amenity Chapter (Chapter 12).

8.4.6 Artificial light

Key sources of light generation within the project site will be the mine pits, infrastructure areas and access roads. Headlights and flashing lights associated with vehicle movements will also contribute. These sources combined can also result in a general lightening of the night sky. Light spill has the potential to impact on nocturnal species by disrupting feeding behaviour and reducing effective home ranges. It can also impact on breeding behaviour of species. Increased light will attract insects which may be beneficial to insectivorous nocturnal feeders. Impacts are not considered likely to be significant within the project site.

8.4.7 Traffic

Traffic generation associated with the project has the following potential impacts on fauna:

- Direct mortality resulting from vehicle collision; and
- Dust generation which has the potential to smother road side plants thereby reducing available habitat and food resources.

Direct fauna mortality has the potential to impact on ground dwelling species such as mammals, reptiles and ground foraging or nesting birds. Reptile species which may utilise road side verges as habitat are susceptible to vehicle collision as they are less mobile than other species.

8.4.8 Dust and air quality

Dust generation has the potential to smother plants, resulting in loss of vegetation, and the resultant indirect loss of food resources and habitat for fauna species.

8.4.9 Increased risk of fire

The project has the potential to increase the risk of fire from the operation of vehicles and through site personnel activities (e.g. welding, cigarette butts). Uncontrolled fires have the potential to alter ecosystem characteristics and directly and indirectly impact flora and fauna.

8.4.10 Erosion and sedimentation

There is potential for erosion and sedimentation during most phases of the project. Extraction of the resource, transportation from the site to the boat ramp and stockpiling of material all create conditions where material can be eroded and transported from the site in surface water flows, or as dust in dry conditions. Sediment can accumulate in watercourses and smother aquatic plants including freshwater macrophytes and mangroves. Increased turbidity in water courses and receiving environments can impact on water quality, ecosystem health and biodiversity. Serious erosion and siltation can threaten terrestrial and marine biodiversity, and the ecological functions of local water and coastal systems. Loss of surface sediments can also impact on the success of rehabilitation and future uses of the rehabilitated site for agriculture or forestry.

8.4.11 Invasive weeds

Weeds have the potential to impact on revegetation of the mine as well as spreading into areas adjacent to movement corridors and stockpile areas. Weeds reduce biodiversity and can reduce the habitat and food resources available for certain species. They can also impact on the productivity of the site once remediated.

8.4.12 Introduction of Invasive species

The following feral animal species have been identified within the Solomon Island:

- *Bufo marinas* (cane toad);
- *Oryctolagus cuniculus* (rabbits);
- *Capra hircus* (goats);
- *Felis catus* (cats); and
- *Sus scrofa* (pigs).

The impacts of these species are likely to include the following:

- predation on native species;
- toxicity to native species;
- competition for food resources, which may decrease abundance of prey for native predator species;
- habitat changes due to destruction of plants; changed floristic composition;
- reduced regeneration of plants; alteration of soil structure; increased invasion and spread of weeds;
- increased access for non-native predator species; and
- reduced water quality and availability.

Table 8.9 Summary of unmitigated impacts and their significance

Impacts	Ecological Communities affected	Beneficial / Adverse	Severity	Geographical boundaries	Duration	Confidence of occurrence	Ability to recover	Value / sensitivity	Significance of the effects
Land clearance	Most habitats including ultramafic forests and fernlands. Mammals, birds, reptiles and amphibians etc.	adverse	high	local	medium-long term	certain	low	moderate	Moderate
Habitat fragmentation and edge effects	Most habitats including ultramafic forests. Mammals, birds, reptiles and amphibians	adverse	moderate	local	medium-long term	certain	low	moderate	Moderate
Water quality impacts	Stream dwelling species	adverse	moderate	local	short to medium	highly likely	high	low - moderate	Moderate / low
Direct and indirect mortality	Reptiles, amphibians, possibly some birds, mammals especially if they are breeding	adverse	low	local	short to medium	likely	low	low-moderate	low
Noise and vibration	Sensitive species of mammal and birds	adverse	low	local	short to medium	likely	high	Low – moderate	low
Artificial light	Sensitive species of mammal and birds. Also insects and reptiles.	adverse	low	very localised	short to medium	likely	high	Low – moderate	low
Traffic	Reptiles, amphibians, possibly some mammals	adverse	low	very localised	short to medium	likely	high	Low – moderate	low
Dust and air quality	Vegetation, some insects	adverse	low	very localised	short to medium	likely	high	Low – moderate	low
Increased risk of fire	Loss of remaining habitats on site and possible off-site losses	adverse	moderate	local	short	possible	moderate	Low – moderate	low
Erosion and sedimentation	Stream dwelling species	adverse	moderate	local	short to medium	highly likely	high	low - moderate	low
Invasive weeds	All habitats on site and possibly offsite. Individual plant species may also be impacted	adverse	low	local	Possibly long term	possible	moderate	low - moderate	low
Introduction of Invasive animal species	This could affect a variety of habitats and plant / animal species	adverse	low	local	Possibly long term	possible	moderate	low - moderate	low

8.5 Management plans and mitigation measures

8.5.1 Habitat loss / land clearance

Vegetated corridors and buffers should be maintained across the project site and the site will be progressively rehabilitated, minimising exposed areas and encouraging the re-establishment of habitat throughout the project life. General mitigation measures intended to reduce the impacts of vegetation clearance include:

- clearly delineate areas of native vegetation to be removed or retained to equipment operators and supervisors before clearance;
- retain vegetation along watercourses (min 20m buffer either side) in order to maintain bank stability, habitat connectivity and movement corridors for terrestrial fauna species and a habitat refuge for fauna seeking shelter and water;
- install appropriate erosion and sediment controls to prevent sediment deposition in remaining habitat and to maintain the integrity of vegetated land that is not cleared. Maintenance of retained areas of existing vegetation could also provide a source of seed for mine rehabilitation works;
- prepare a site rehabilitation management plan which incorporates rehabilitation monitoring and trials;
- use native species for rehabilitation;
- monitor rehabilitation success at locations representative of the range of conditions on the rehabilitating areas. Conduct annual reviews of monitoring data to assess trends and monitoring program effectiveness;
- fence riparian vegetation communities off from stock where possible to assist in maintaining and improving native groundcover species, as well as preventing the spread of weed seeds and assist in erosion control; and
- manage pests and weeds in accordance with a site-specific pest and weed management plan.

8.5.2 Habitat fragmentation and edge effects

The following design features and mitigation measures are proposed across the project area to maintain connectivity:

- reinstate and enhance disturbed areas to maintain linkages between areas of habitat as outlined in the Rehabilitation Management Plan;
- retain and restore riparian vegetation to support fauna habitats and movement corridors through the project area; and
- stage vegetation clearance in a staged manner to allow fauna to migrate to adjacent habitats.

Habitat fragmentation also leads to “edge effects”, which is the term given to impacts that occur at the interface between natural habitats, especially forests and disturbed or developed land. When an edge is created between forest and a cleared area, changes to ecological processes within the retained vegetation occur which can extend between 10 m and 100 m from the edge (Yahner 1988). These include microclimatic changes in light, temperature, humidity and wind, which can favour a suite of different species and therefore cause significant changes to the ecology of the patch (Lindenmayer and Fischer, 2006). These changes include; invasion by weeds, increase in feral animals, reduction in tree health and barriers to dispersal or distribution (Yahner 1988). Edge effects are especially pronounced in small habitat fragments where they may extend throughout the patch.

Clearing of vegetation and construction of infrastructure corridors and open cut mining pits can result in fragmentation and the creation of smaller, more disturbed patches of vegetation. The increased surface area of these remnants increases exposure to weeds, light and wind penetration (which can alter microclimate features). Plant species can become more susceptible to disease due to stress and over time community composition can change due to changes in structure and weed encroachment. Associated fauna habitats can deteriorate as vegetation community’s change with fauna needing to seek alternative roosting or foraging areas.

It is difficult to quantify the impact of edge effects as they occur gradually over time. Rehabilitation of disturbed areas and the provision of buffers around undisturbed areas of retained vegetation will help to minimise edge effects.

8.5.3 Water quality

The following design features and mitigation measures are proposed across the project area to reduce impacts on water courses and receiving environments:

- control surface water drainage to prevent ponding of water and associated logistical and management problems;
- place stockpiles appropriately to avoid any drainage lines or depressions;
- re-profile drainage paths to stabilise banks and use contour banks, rock armouring, etc. to manage concentrated flows and reduce sediment load increase;
- use sediment traps to settle sediment; and
- adopt best practice erosion and sedimentation controls and pollution control measures across the project site.

Measures for the management of fuels, chemicals, wastes and effluent within the facility will be implemented through a hazardous materials plan and a waste management plan.

8.5.4 Artificial light

The following mitigation measures are proposed to lessen the effects of light spill if night works are undertaken:

- use low glare and directional lighting to reduce light spill; and
- orientate workshop buildings within the project site to reduce light spill.

8.5.5 Traffic

Fauna numbers were limited across the project site and in studies of surrounding areas and no immediate mitigation measures are proposed. Rather, a precautionary approach has been adopted and the following measures proposed:

- monitor fauna collision rates to identify high mortality areas with a view to incorporating additional protective measures where required. This is to include the main access roads within the project site; and
- restrict vehicle speeds on access and haul roads to 20 km/h.

8.5.6 Dust and air quality

The following design features and mitigation measures are proposed across the project site to reduce impacts associated with dust generation:

- limit vehicle movements to designated trafficable areas;
- spray unsealed road areas, short-term soil stockpiles and other exposed areas susceptible to wind erosion with freshwater to reduce dust generation when required; and
- mine and rehabilitate the resource progressively to reduce exposure.

An air quality management plan will be prepared and implemented to monitor dust levels and identify appropriate additional control actions.

8.5.7 Fire control

All components of the project will implement appropriate management systems to prevent accidental ignition of fires. This can include active watering, orientation of stock and waste piles based on wind directions, and wind breaks. Bushland areas retained on site will also be managed for fuel load and have appropriate fire regimes put in place to maintain biodiversity values whilst reducing risk from bushfire.

8.5.8 Erosion and sedimentation

Erosion and sedimentation is addressed in details in Soils and Geology (Chapter 7) and Water Resources (Chapter 9). The following design features and mitigation measures are proposed across the project area to reduce impacts associated with erosion and sedimentation:

- mine and rehabilitate the resource progressively to reduce exposure; and

- implement appropriate erosion and sediment control measures to reduce erosion and sedimentation.

An erosion and sediment control plan will be prepared and implemented to monitor erosion and sedimentation and identify appropriate additional control actions.

8.5.9 Invasive weeds

The following weed management measures will be implemented within the project site:

- construct wash down facilities at access points for vehicles arriving and departing from the project site (the Port in Honiara). These facilities will be bunded and located away from drainage lines to reduce the risk of weed spread;
- wash down all vehicles entering the project site and leaving areas known to contain declared weeds, ensuring wheels, wheel arches and the undercarriage are free of mud and plant material;
- limit vehicle movements to designated trafficable areas;
- use native plants for revegetation;
- identify and control weeds of management concern on site in accordance with local best management practices;
- monitor treated areas to assess the success of declared weed eradication; and
- include weed management in the site inductions to promote the awareness of weed management issues.

A site-specific pest and weed management plan will be prepared. The plan will describe how the weeds are to be managed.

8.5.10 Introduction of invasive species

The following general mitigation measures are proposed for the management of feral species:

- management of wastes on site; and
- ensuring pest species are not deliberately or accidentally brought onto the site.

8.6 Residual impacts

Table 8.10 Residual impacts following the implementation of proposed management measures

Impacts	Ecological Communities affected	Residual impacts
Land clearance	Most habitats including ultramafic forests. Mammals, birds, reptiles and amphibians etc.	Moderately significant. Implementation of the management measures detailed above would reduce the significance of the residual impacts of habitat clearance. However, due to the scarcity of the ultramafic forests and fernland habitat, the impact of the mine is still considered moderately significant. The fernlands should recover relatively quickly; however, the loss of the forested areas and associated flora and fauna will be long term.
Habitat fragmentation and edge effects	Most habitats including ultramafic forests. Mammals, birds, reptiles and amphibians	Moderately significant. Implementation of the management measures detailed above would reduce the significance of the residual impacts of habitat fragmentation and edge effects. However, due to the scarcity of the ultamafic forest and associated communities, this is still considered a moderately significant impact.
Water Quality Impacts	Stream dwelling species	Low significance. Implementation of the management measures detailed above and in the soils and water sections will prevent significant impacts.
Direct and indirect mortality	Reptiles, amphibians, possibly some birds, mammals especially if they are breeding	Low / negligible significance. Implementation of the management measures detailed above will prevent significant impacts.
Noise and vibration	Sensitive species of mammal and birds	Low / negligible significance. Implementation of the management measures detailed in the Noise report will prevent significant impacts.
Artificial light	Sensitive species of mammal and birds. Also insects and reptiles.	Low / negligible significance. Implementation of the management measures detailed above will prevent significant impacts.
Traffic	Reptiles, amphibians, possibly some mammals	Low / significance. Implementation of the management measures detailed above will prevent significant impacts.
Dust and air quality	Vegetation, some insects	Low / negligible significance. Implementation of the management measures detailed above will prevent significant impacts.
Increased risk of fire	Loss of remaining habitats on site and possible off-site losses	Low / negligible significance. Implementation of the management measures detailed above will prevent significant impacts.
Erosion and sedimentation	Stream dwelling species	Low / negligible significance. Implementation of the management measures detailed above and in the soils and water sections will prevent significant impacts.
Invasive weeds	All habitats on site and possibly offsite. Individual plant species may also be impacted	Low / negligible significance. Implementation of the management measures detailed above will prevent significant impacts.
Introduction of Invasive animal species	This could affect a variety of habitats and plant / animal species.	Low / negligible significance. Implementation of the management measures detailed above will prevent significant impacts.

8.7 Conclusion and summary

The site contains a number of relatively unusual habitats including ultramafic forests, ultramafic swamp forest and fernlands. These habitats and their associated flora and fauna (birds, mammals reptiles and amphibians) are considered to be of regional value. Impacts upon these ecological resources would include: land clearance; habitat fragmentation and edge effects; water quality impacts in streams; direct and indirect mortality of fauna; increased noise; artificial light at night; possible fires; traffic; increased dust; soil erosion; and the potential for introduced weeds and animal pests to enter the area.

A wide range of mitigation measures have been proposed to minimise these impacts including, but not limited to: progressive rehabilitation; retaining as much natural vegetation as possible, especially in gullies; erosions and sediment controls; development of a site-specific pest and weed management plan; and development of an air quality management plan.

Whilst the implementation of these mitigation measures will reduce the significance of the impacts, the overall impacts are considered moderately significant due to the long term loss of a large area of ultramafic forest.

9 Fresh water environment

9.1 Assessment objectives

A fresh water assessment was prepared by EMM for the project and is provided in Appendix C. This chapter provides a summary of the assessment.

The objectives of the assessment were to provide:

- a description of the existing fresh water values at the project area, using existing literature and data gathered during field surveys;
- an assessment of the potential impacts of the project on the fresh water values; including any-cumulative impacts, taking into consideration any relevant guidelines, policies, plans and statutory provisions; and
- a description of the actions that would be taken to avoid, minimise the potential impacts of the project.

9.2 Assessment method

The assessment was informed by a literature review, site inspections, field sampling and physical and chemical analysis. Experts from EMM surveyed and sampled the watercourses in the project area in September 2017.

The assessment describes the existing environment and provides water management strategies for mining areas, access roads and the ore handling facility. It is expected that the proposed strategies will be further developed into detailed Water Management Plans for each mining area as part of the mine plan development process.

9.3 Existing environment

9.3.1 Climate

The Solomon Islands have a climate that is typical of most tropical bioregions, with warm to hot temperatures, high humidity and abundant rainfall in most months. Average annual rainfall has historically ranged between 3,000 to 5,000 mm. Monthly variations in rainfall, prompted by the north-west tropical monsoon and the equatorial trough, respectively coincides with increased monthly rainfall totals between January and March, and drier months between June and September.

The Solomon Islands lies at the northern limit for cyclone prevalence, however typically experiences between one and two tropical cyclones per year. Cyclone prevalence and strength is strongly influenced by the north-west tropical monsoon. Given the northern location of San Jorge Island and the distinct lack of wet and dry climate seasonality, it is reasonable to assume cyclone intensity is likely to be low.

Further information on climate is provided in Section 6.1.2.

9.3.2 Vegetation and soils

Vegetation remains relatively intact with over 50% of the project area covered with Ultramafic Forest. Some portions of the project area have been cleared for commercial forestry. The remaining project area is covered with ferns and new tree growth (see photograph 9.1).

Soils have an overall low level of erodibility. However, once vegetation has been removed and soils are exposed, they are much more prone to erosion, and require rehabilitation to restore to a state of low erodibility. This is evident in areas of vegetation clearance, for example logged areas.

Photograph 9.1 View from project area facing north-west

9.3.3 Watercourses

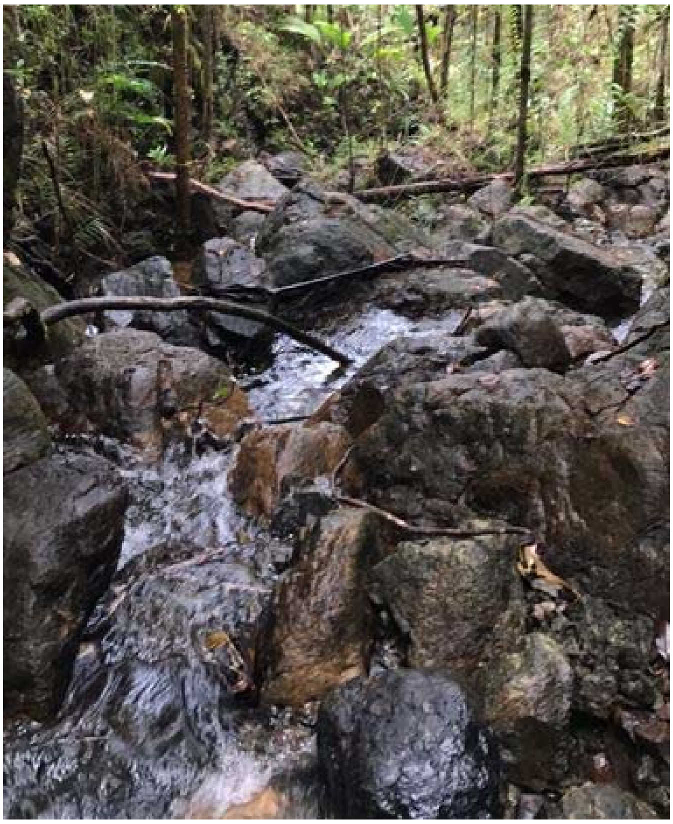
The project area is located within the southern part of San Jorge Island. This part of the island is characterised by rolling hills and steeply incised watercourses. The project area drains into eight separate catchments, which have areas ranging from 148 ha to 1234 ha.

Catchment areas and watercourses alignments are shown in Figure 9.1.

Watercourses in the project area are broadly divided into two groups:

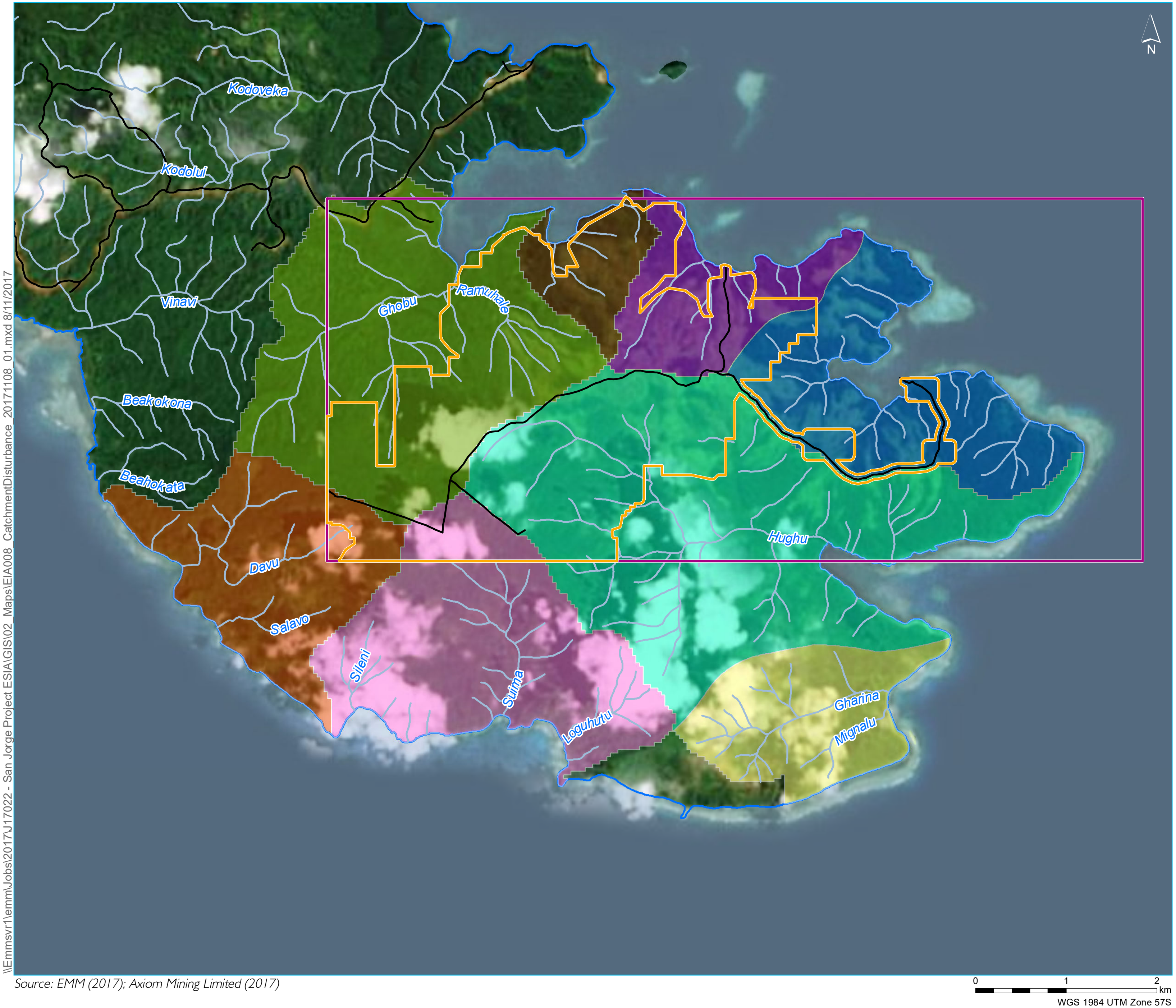
- smaller, fast flowing watercourses at higher elevations in upper catchments which are characterised by steep drainage lines in rugged, steep terrain and coarser grained sediments in well defined gullies (see photograph 9.2); and
- larger, slower watercourses at lower elevations which have gentler channel gradients, fine grained sediments and densely vegetated floodplains. The lower reaches have tidal influences and are occupied by mangroves (see photograph 9.3).

All watercourses, with the exception of Davu Creek, have low sinuosity, and limited meander. This is typical of an erosional environment with steeply incised valleys and defined channels.



Photograph 9.2 Typical higher reach watercourse (Sumia Creek)

Photograph 9.3 Typical lower reach watercourse



Source: EMM (2017); Axiom Mining Limited (2017)

Existing Catchments and Watercourses

Axiom Mining Limited
San Jorge Nickel Project
Environmental impact statement
Figure 9.1

EMM

9.3.4 Hydrogeology

Groundwater was detected in auger holes, and at groundwater fed springs across the project area. The springs are located below the southern San Jorge ridgeline. Typical spring flows were estimated to vary between <0.01 L/s and 2 L/s. Groundwater flow reflects the local topography, flowing from ridgelines to watercourses or coastal recharge areas. Spring flows and groundwater seepage into the watercourses are expected to be the primary source of stream base flows.

9.3.5 Water quality

The project area is generally undeveloped with the exception of some existing facilities and infrastructure from logging activities and previous exploration including haul roads and lay down areas that Axiom will upgrade, replace and maintain for use by the project.

i Soil disturbance

Photograph 9.4 was taken from Davu Creek and shows a logging area in the background. Sediment laden water was observed in watercourses downstream of logging areas or logging roads. Photograph 9.5 shows the confluence of a watercourse with logging disturbance in the catchment and a watercourse with no disturbance in the catchment. The photograph shows the impact of logging, vegetation clearance and soil disturbance on water quality.

Photograph 9.4 Davu Creek with logging in the background after a rainfall event

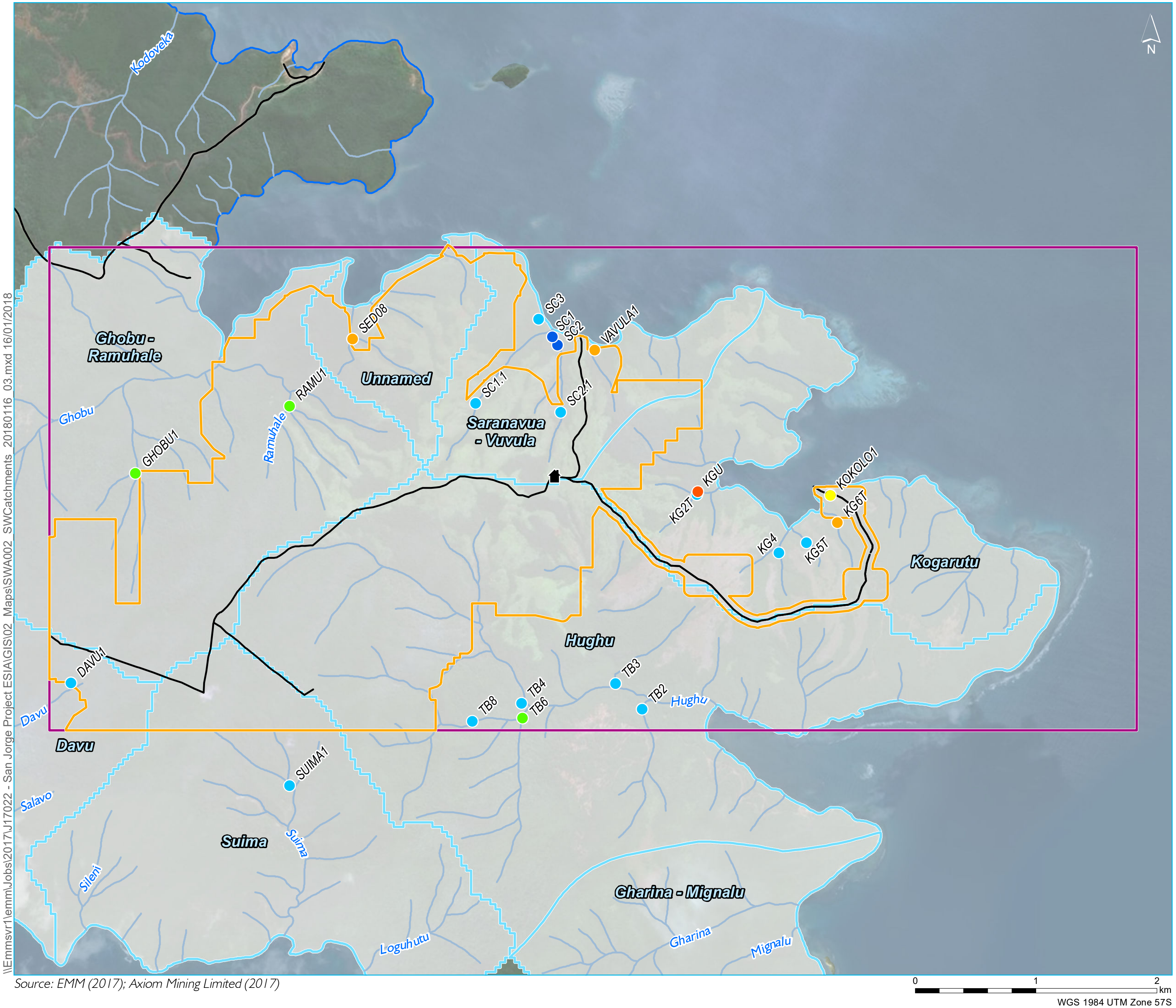
Photograph 9.5 Confluence of two watercourses showing the impacts of soil disturbance from logging operations

ii Water quality sampling

Freshwater quality samples were collected from watercourses across the project area with the objective of establishing baseline conditions. Water quality samples were collected from 21 monitoring locations over a period of 10 months between October 2016 and August 2017. Sampling was typically undertaken during base flow conditions. Water samples were analysed for a comprehensive suite of physical and chemical parameters, broadly including physicochemical properties, major ions, alkalinity, heavy metals and nutrients. Samples were compared to the ANZECC (2000) water quality guideline values. Sample locations are presented in Figure 9.2.

This analysis found that:

- pH was generally neutral which is consistent with typical values for an undisturbed watercourse;
- salinity indicated freshwater conditions;
- elevated levels of some dissolved heavy metals were consistently present in watercourses across the project area. These are likely to be naturally occurring, having been leached from the weathered saprolite and limonite within the surface water catchments. Elevated metals included chromium, nickel and zinc; and
- nutrient levels were consistent with typical values for an undisturbed watercourse.



KEY

- Camp Bungusule
- San Jorge Island coastline
- Prospecting licence boundary
- Potential area of disturbance
- Catchment boundary
- Access road
- Local road
- Watercourse / drainage line

Surface water and sediment quality monitoring location

- Sediment
- Sediment, water
- Sediment, particle size distribution
- Sediment, water, particle size distribution
- Water
- Water, particle size distribution

Surface water and sediment quality monitoring locations

Axiom Mining Limited
San Jorge Nickel Project
Figure 9.2

EMM

Source: EMM (2017); Axiom Mining Limited (2017)

\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps\SWA002_SWCatchments_20180116_03.mxd 16/01/2018

9.3.6 Sediment characteristics and quality

i Physical characteristics and particle size distribution

Streambed sediment samples were collected at seven locations and analysed for particle size distribution. The following trends were noted:

- samples taken from Ramuhale Creek and Hughu Creek had a high proportion of large gravels representative of high energy, fast flowing environments; and
- samples taken downstream of an existing access road were found to have high proportions of very fine sand and silt indicative of low energy, depositional environments.

ii Chemical characteristics

Sediment samples were obtained from creek beds in each of the surface water catchments expected to be impacted by the project. Samples were analysed for major ions and metals, and compared to ANZECC (2000) sediment quality guideline values. The following characteristics were noted:

- samples contained significantly elevated concentrations of chromium and nickel, indicating that the soils in the contributing catchment areas are naturally elevated in these metals;
- some samples contained slight elevations of cadmium and copper; and
- heavy metals and chloride and sodium concentrations were consistently higher at a sampling location immediately down-gradient of an established access road (owned by a neighbouring landowner) which is substantially eroded and has little to no sediment and erosion controls.

9.3.7 Freshwater resource use

It is understood that there are no material freshwater users in the vicinity of the project area.

9.4 Impact assessment

An area of up to 1348.4 ha of land will be progressively disturbed during the life of the mine. Land disturbance will largely be from the construction of infrastructure, including open-cut pits, out-of-pit emplacement areas, roads for haul trucks and light vehicles, and stockpiles. Local receiving waters will be impacted by the mining activities. Potential impacts include:

- increased sedimentation in receiving waters;
- impacts on aquatic ecology due to increased turbidity;
- localised impacts on aquatic ecology if concentrations of metals and other pollutants increase above existing levels or known toxicity thresholds;
- changes to the existing hydrologic regimes due to alterations to catchment areas; and
- erosion of drainage lines due to direct disturbance of watercourses and changes to hydrologic regimes.

Table 9.1 summarises the potential impacts and their significance.

Table 9.1 Summary of unmitigated impacts and their significance

Impact	Value impacted	Status	Boundary	Duration	Direct /indirect	Confidence	Sensitivity of value	Severity of impact	Significance of impact
Erosion of disturbed areas leading to increased sediment laden runoff and watercourse sedimentation	Stable watercourse	Adverse	Local	Medium (five to ten years)	Direct	High	Moderate	Medium	Moderate
Construction of mine and infrastructure causing changes to catchment areas and hydrologic regimes	Stable watercourse	Adverse	Local	Medium (five to ten years)	Direct	High	Moderate	Medium	Moderate
Construction of mine and infrastructure leading to changed hydrologic regimes and watercourse erosion	Stable watercourse	Adverse	Local	Medium (five to ten years)	Direct	High	Moderate	Medium	Moderate
Erosion of disturbed areas leading to increased sediment laden runoff and physical changes to water quality	Water quality	Adverse	Local	Medium (five to ten years)	Direct	High	Moderate	Medium	Moderate
Spills and leaks of hazardous materials causing contamination of surface and groundwater	Water quality	Adverse	Local	Medium (five to ten years)	Direct	Medium	Moderate	Medium	Moderate

9.5 Management plans and mitigation measures

Management of potential impacts on the freshwater environment will be a key consideration in the detailed design of the project. This will be informed by the implementation of a water management strategy. In addition to the strategy, a number of management and monitoring plans will be implemented during the life of the project. An overview of the strategy, and management and monitoring plans is provided below.

9.5.1 Water management strategy

The water management strategy included in Appendix C describes the key water management principles that will be applied to manage surface water within mining areas. It is proposed to further develop this strategy into a detailed Water Management Plan for each mining area as part of the mine plan development process.

The objectives of the water management strategy are to:

1. Minimise the mining disturbance areas to reduce the volume of runoff that requires management.

2. Establish Riparian Protection Zones around major watercourses to:

    a) avoid direct disturbance of watercourses.

    b) reduce the need to reconstruct watercourses; and

    c) provide conduits for clean water drainage through mining areas.

3. Where possible, divert clean water around mining areas to reduce the volume of runoff from mining areas that requires management.

4. Construct sedimentation basins to treat runoff from mining areas.

5. Progressively monitor water quality and implement further water treatment if poor water quality is identified.

Further details of the water management strategy including site specific water management principles and an example water management plan are included in Appendix C, Freshwater Assessment.

9.5.2 Management plans

i Erosion and sediment control plan

As part of the implementation of the water management strategy, an erosion and sediment control plan for the whole project will be prepared. This will include provision for the preparation of site specific water management plans to be developed in conjunction with mining plans. The erosion and sediment control plan will apply the water management principles discussed in the water management strategy, and will provide detailed site specific information on:

- catchment areas and drainage lines;

- proposed mining, stockpiles and disturbance areas;

- the extent and nature of riparian protection zones;
- the alignment and geometries of all drainage;
- the location and size of all sedimentation dams;
- waterway crossings; and
- drainage lines that require scour protection.

ii Other management plans

In addition to the erosion and sediment control plan, the following plans and mitigation measures will also be implemented to reduce impacts to freshwater:.

- hazardous materials plans, containing procedures for:
  - documentation: storage and currency of safety data sheets (SDSs);
  - regulatory authority guidelines for the safe handling, transport and storage of all hazardous materials used; signage; and document review;
  - storage and use of hazardous materials: locations and quantities; containers; labelling; leakage testing; bunding and capacity of bunded areas; and spill response;
  - transportation of hazardous materials: staff training in handling; clean-up and remediation of spills; storage of materials; and excavation and treatment of contaminated soil; and
  - monitoring: document currency; vehicle and hazardous material storage inspections; and spill response preparedness.
- liquid and solid waste management plan, containing procedures and designs for:
  - disposal of solid and liquid wastes to prevent leaching and contamination of fresh and marine water;
  - treatment and disposal of domestic wastewater to prevent spills, leaks and contamination of fresh and marine water;
  - treatment and disposal of wastewater from the MIA and fuel storage areas including spacing of facilities from watercourses and the shoreline; and
  - monitoring such as daily inspections of storage areas and weekly review of waste generation.
- if required, an acid sulphate soils management plan, containing procedures for:
  - specialised handling for potentially acid sulphate soils; and
  - additives such as limestone, organic materials or bactericides used on potentially acid generating waste rock.

A full list of mitigation measures for each plan is included in Chapter 15, Management plans and mitigation measures.

iii Monitoring plan

A fresh water monitoring and inspection plan will be implemented over the life of the project. The plan will include:

- establishment of an on-site weather station to record rainfall and other climatic conditions;
- quarterly monitoring of water quality in select sedimentation dams and receiving water locations; and
- quarterly inspection of water management controls.

Implementation of this monitoring and inspection plan will enable the project's fresh water impacts to be progressively assessed and underperforming or high risk components of the water management system to be identified and improved. The monitoring and inspection plan will identify measures (including water treatment) that could be implemented to improve the performance of the water management system if required.

9.6 Residual impacts

The proposed management plans and mitigation measures will reduce the potential significance of the fresh water impacts. However, given the scale of disturbance, residual impacts are expected to occur during construction and operation.

Table 9.2 outlines the significance of residual impacts from potential impact of the project following the application of management plans and mitigation measures.

Table 9.2 Residual impacts following the implementation of proposed management measures

Impact	Potential significance prior to implementation of mitigation measures	Residual significance after implementation of mitigation measures
Erosion of disturbed areas leading to increased sediment laden runoff and watercourse sedimentation	Moderate	Moderate to Low
Construction of mine and infrastructure causing changes to catchment areas and hydrologic regimes	Moderate	Low
Construction of mine and infrastructure leading to changed hydrologic regimes and watercourse erosion	Moderate	Low
Erosion of disturbed areas leading to increased sediment laden runoff and physical changes to water quality	Moderate	Low
Spills and leaks of hazardous materials causing contamination of surface and groundwater	Moderate	Low

9.7 Conclusion and summary

The project area supports a number of small freshwater streams (3-4 km long) that flow into the sea. These streams are vulnerable to impacts from project activities. The main impact of the project will be to increase sedimentation in the streams from soil erosion. Soil erosion will be most likely in heavy rainfall events following vegetation clearance. Other potential impacts include changes to hydrologic regimes and riverbed erosion, and contamination of freshwater from sediment and hazardous materials.

The implementation of the water management strategy and related management plans and mitigation measures will reduce the significance of these impacts from high, to low to moderate. Impacts are most likely to occur during significant rainfall events when the design capacity of the erosion and sediment controls is exceeded.

10 Physical marine environment

10.1 Assessment objectives

A high level marine assessment of the receiving waters of San Jorge Island was undertaken as part of this EIS. The objectives of this assessment are to provide:

- a description of existing physical marine environment surrounding the project area, using existing literature and data gathered during field surveys;
- an assessment of potential impacts of the project on the marine environment; including impacts from sedimentation entering the sea from watercourses and the shipment and trans-shipment of ore as it is exported; and
- a description of the actions that would be taken to avoid, reduce potential impacts of the project.

10.2 Assessment method

This assessment used existing data, as well as results from site surveys to establish a baseline for metocean and water quality conditions. This baseline information was used to predict the impact of dispersion of sediment from project-related activities into the marine environment.

Baseline surveys of the physical marine environment focused on metocean and water quality monitoring. Metocean monitoring measured physical processes such as tides, currents, wind and waves to gain an understanding of water movement in Thousand Ships Bay.

A monitoring program was established in January 2016 which recorded directional waves and currents at the entrance to Tanatola Bay on the southern shore of San Jorge Island. This site also included a sub-surface buoy attached to a mooring equipped with a logger to measure near-surface turbidity.

Two monitoring locations were also established in watercourses on San Jorge Island. Hughu1 was located upstream in Hughu Creek feeding into Tanatola Bay, and Ghobu1 was located upstream in Ghobu Creek feeding into Albatross Bay on San Jorge's eastern shore. These locations monitored the water for flow rates, water level and suspended sediment.

Due to instrument damage, not all the data for the monitoring program was recoverable, but a sufficient amount was used to characterise the metocean conditions for the purposes of the physical marine assessment.

Numerical hydrodynamic modelling was used to predict the potential distribution and magnitude of sedimentation on water quality of the receiving marine waters. The numerical modelling suite used for this project simulates flows, waves and sediment transport in rivers, lakes, estuaries, bays, coastal areas and seas in two dimensions. The numerical models were used to predict the advection, dispersion and deposition of sediment discharged into the marine environment. This model was used to predict impacts from sediment discharge in watercourses, as well as marine loading of ore into barges and bulk carriers.

10.3 Existing environment

10.3.1 Metocean

Thousand Ships Bay is a submerged valley which comprises mangrove fringed shorelines, fringing coral reefs and small islands. It is up to 50 m deep at the entrance to the Ortega Channel and the ocean floor drops rapidly to depths greater than 1,000 m south of San Jorge Island.

The project area is largely sheltered from open ocean swells as it is protected from northerly Pacific Ocean swells by Santa Isabel Island. Additionally, Guadalcanal and Puavuvu Islands protect it from Coral Sea swells to the south. However, the area does experience persistent trade winds.

Thousand Ships Bay is a micro-tidal environment with a tidal plane of less than 1.5 m. On average, it has two high and two low tides per day making its tidal signal semi-diurnal.

The main drivers of current within the project area during the deployment period were tide and wind, with waves having a much smaller influence.

10.3.2 Marine water quality

Limited turbidity data was recovered from the Hughu1 site. The data showed that periods of increased turbidity occur regularly and are likely linked to surface water runoff events.

During the wet season, high runoff rates with increased turbidity and high sediment loads are frequent. Discoloured water discharges into Thousand Ship Bay, and it is therefore likely that the resident aquatic flora and fauna in streams, and discharge zones, are adapted to the variation in flows and water quality that occur naturally.

Figure 10.1 Digital imagery showing increased sediment concentrations in the receiving waters from freshwater sources (imagery date 7 July 2013)

10.3.3 Marine resource use

The marine environment is the main source of protein (fish) and a source of income for local islanders. Customary fishing rights to both local and commercial fishing industries exist within Thousand Ships Bay. Locals fish for reef fish, shellfish, turtles, crabs, crayfish, oysters and snapper which are either sold at markets or used for themselves. During stakeholder consultation, local villagers stated that they do not use the bay to fish after periods of heavy rainfall as waters become turbid and discoloured.

10.4 Impact assessment

10.4.1 Surface water runoff

The high and frequent rainfall in the project area and proximity to the coast means that site activities during construction, operation and rehabilitation could impact water quality in runoff and consequently, the marine environment, if not appropriately managed.

To assess the potential impacts of increased sediment load caused by the project, three simulations were modelled to reproduce a range of likely sediment discharge conditions into Thousand Ships Bay. These simulations were:

1. Typical rain event (120 mm over five days), average wind conditions, no development.

2. Extreme rain event (250 mm over five days), strong wind conditions, no development.

3. Extreme rain event (250 mm over five days), strong wind conditions, project development with surface clearance, but no mitigation measures.

The following figures show the 99th percentile 'worst-case' scenario for each simulation showing discharge of sediment into Thousand Ships Bay from the project area.

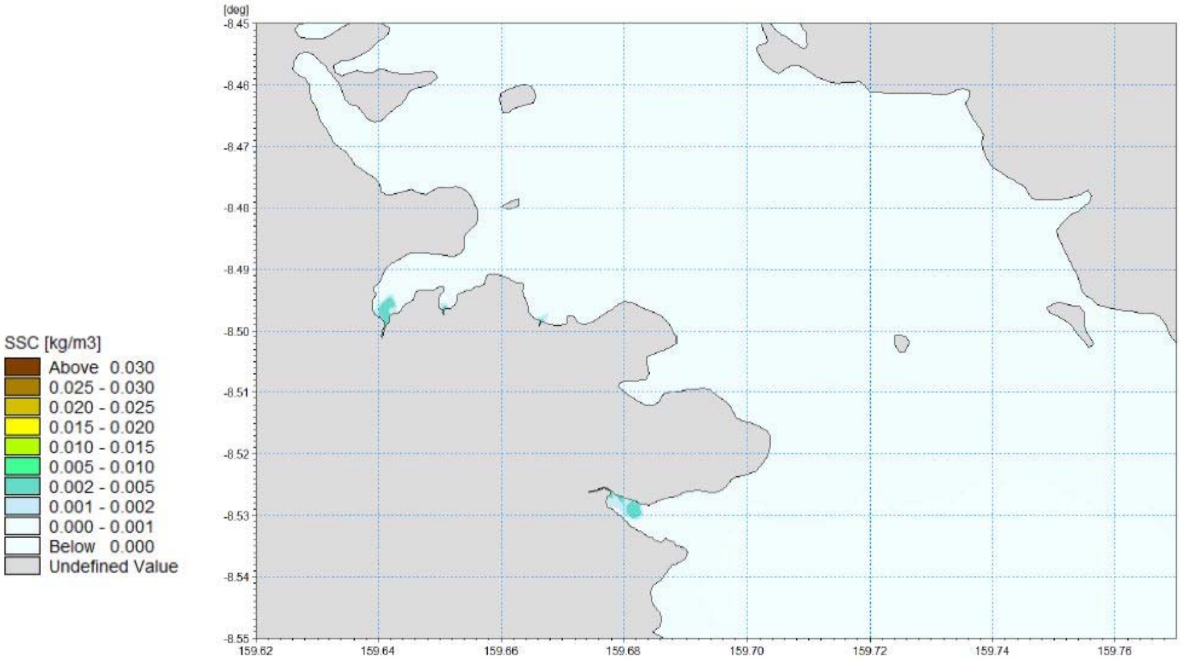


Figure 10.2 **Scenario SW1: Typical rain event (120 mm over five days), average wind conditions, no development**

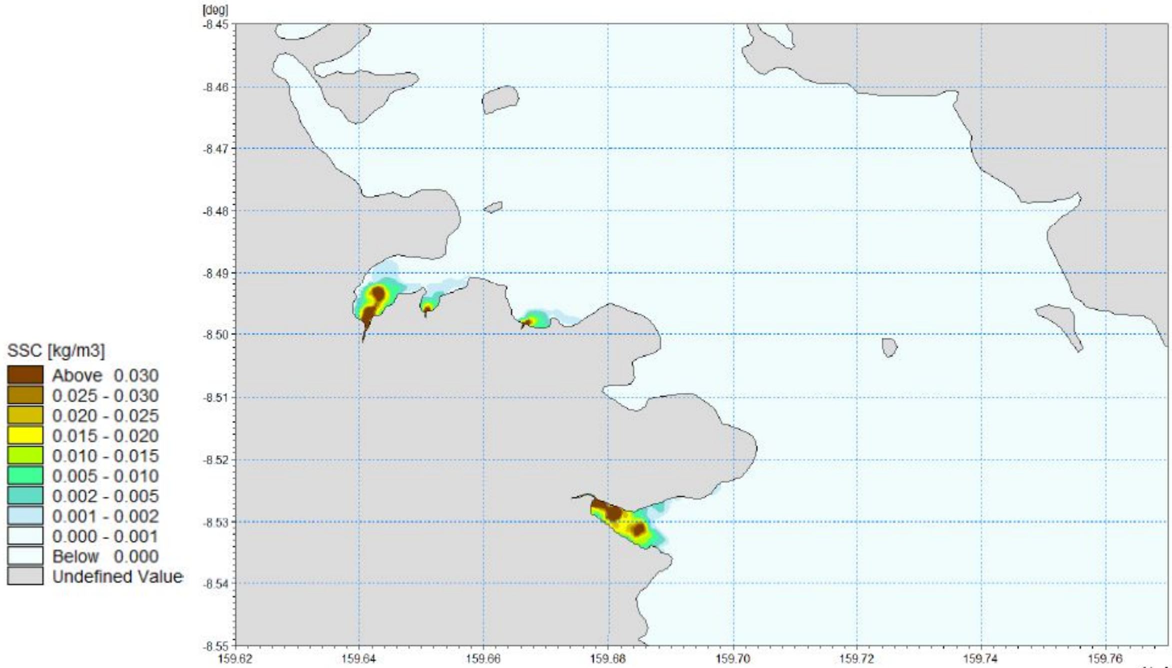


Figure 10.3 **Scenario SW2: Extreme rain event (250 mm over five days), strong wind conditions, no development**

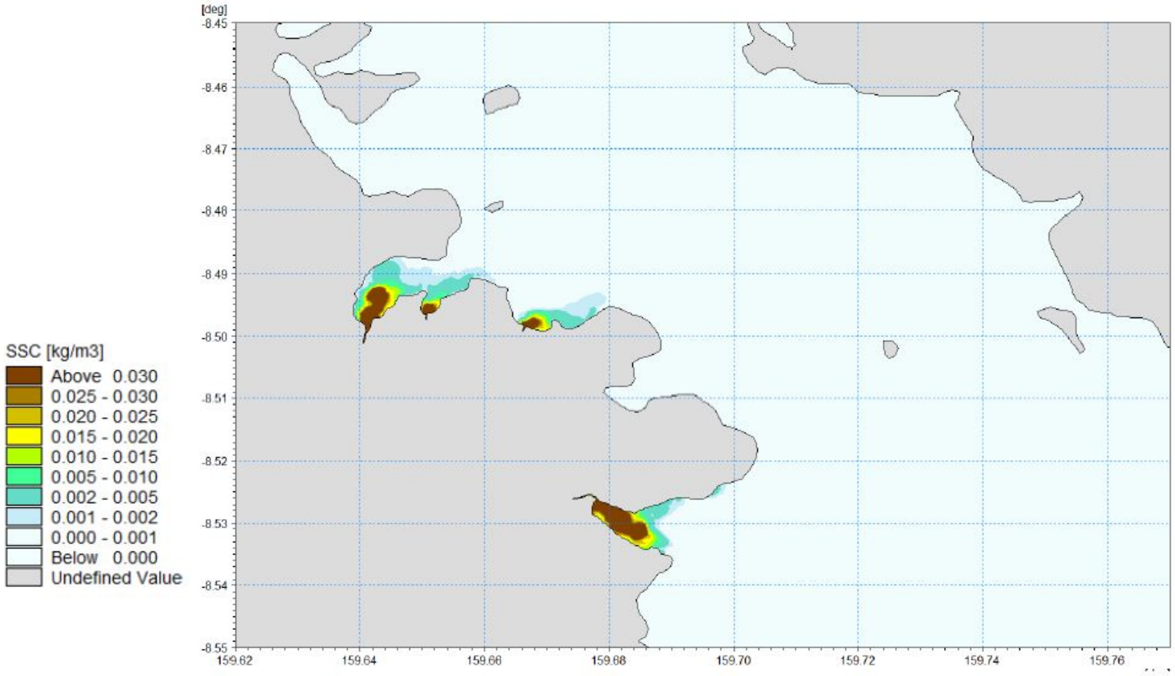


Figure 10.4 **Scenario SW3: Extreme rain event (250 mm over five days), strong wind conditions, project development with surface clearance**

The results of the surface water run-off modelling show increases in total suspended sediment and sediment deposition predominantly confined to the individual bays where the various creeks discharge. The circulation in these bays is relatively weak (ie low current speeds) and the sediment discharged is deposited locally before reaching the deeper waters of Thousand Ship Bay.

The difference in sediment deposition between scenarios 2 and 3 shows that any increase in project-related sedimentation would be mostly confined to the local bays it enters. All of these bays are already depositional environments comprising estuaries fringed with mangroves. Sensitive environmental receptors (eg coral reefs) are mainly outside these impacted areas. In extreme events, the nearest parts of the reefs may be slightly impacted by these predicted increases in suspended sediment and sediment deposition, but receptors out of this area, in deeper water would be largely unaffected.

10.4.2 Marine loading impacts

To assess the potential unmitigated impacts of direct spillage of ore on the marine receiving waters during ore loading operations, three simulations were modelled to reproduce a range of likely sediment dispersion conditions into Thousand Ships Bay. These simulations were:

1. Wet season conditions, typical (1%) direct spillages.

2. Wet season conditions, high (2%) direct spillages.

3. Dry season conditions, high (2%) direct spillages.

The following figures show the 99th percentile 'worst-case' scenario for each simulation showing discharge of sediment into Thousand Ships Bay from marine loading.

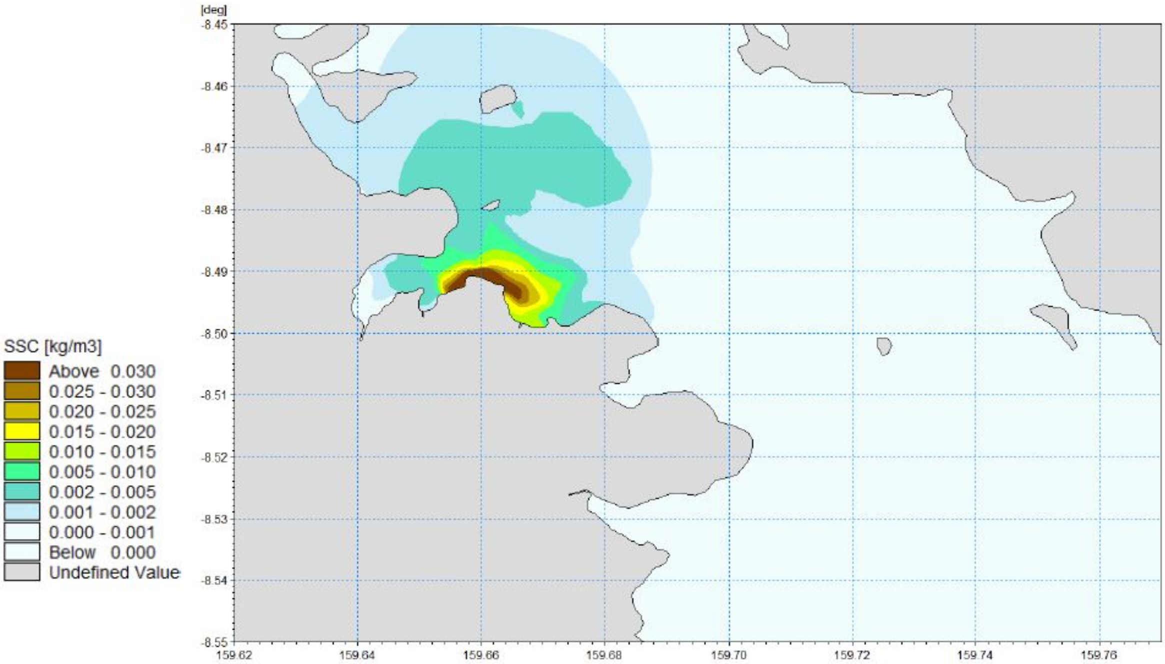


Figure 10.5 Scenario ML1: Wet season conditions, 1% direct spillage over one month

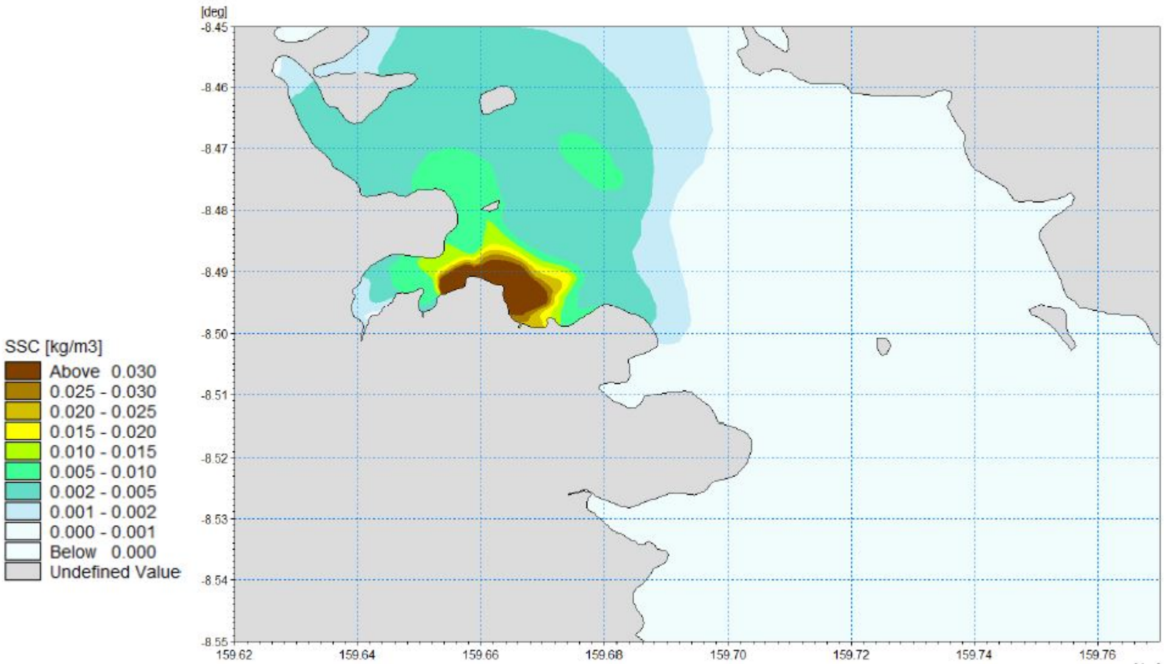


Figure 10.6 Scenario ML2: Wet season conditions, 2% direct spillage over one month

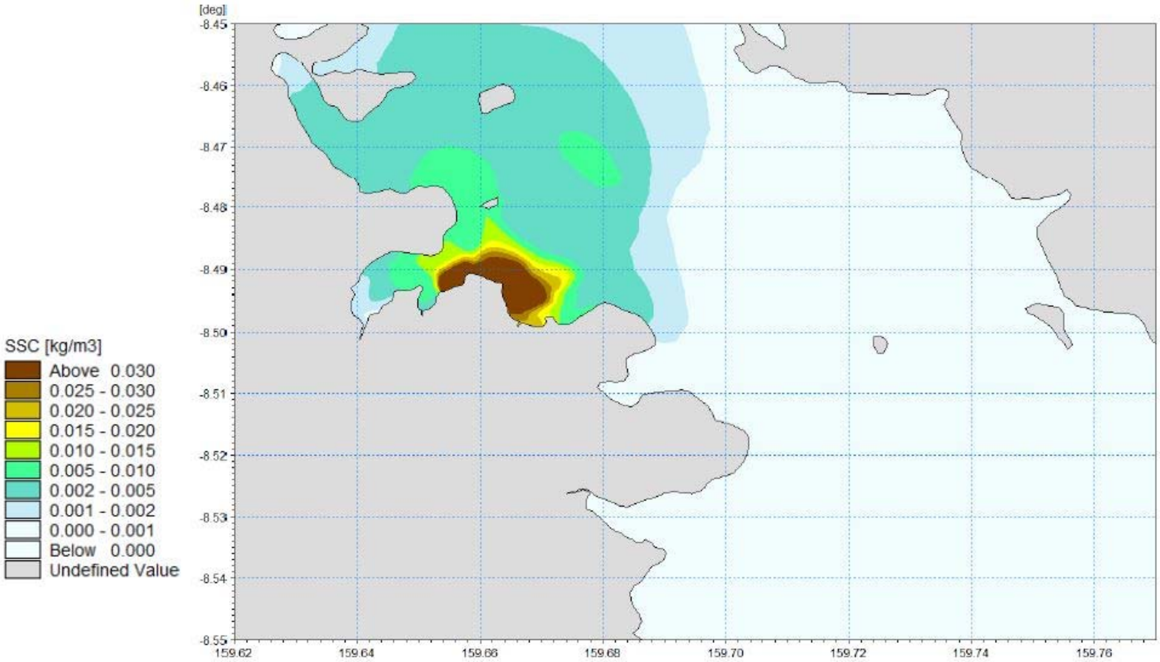


Figure 10.7 Scenario ML3: Dry season conditions, 2% direct spillage over one month

Based on a conservative assumption that all ships visiting in a year carry 72,000 t of ore, the annual increase in the sediment loads due to direct spillage are expected to be:

- 52,000 t for the typical spillage scenarios (ie 1% spill rates); and
- 104,000 t for the high spillage scenarios (ie 2% spill rates).

When considering that half of this spillage is assumed to occur at the ore loading facility and the other half at the transhipment, these are comparable to the increase in sediment loads from the surface water runoff due to mining disturbance in the project area.

The sediment distribution and deposition for ore spilt at the ore loading facility is higher than that modelled for the surface water runoff scenarios. This increase is due to the finer sediments that are modelled as part of the spillage, as well as the longer length of time of the model. These fine particles remain suspended in the water column for longer periods of time than coarse particles, and are therefore much more susceptible to wind-driven currents. The large water depth at the transhipment site means that sediment concentrations are expected to be low when averaged over the water column.

10.4.3 Summary of potential impacts

The potential impacts are summarised in Table 10.1 below.

Table 10.1 Summary of unmitigated impacts and their significance – physical marine environment

Impact	Value impacted	Status	Boundary	Duration	Direct /indirect	Confidence	Sensitivity of value	Severity of impact	Significance of impact
Erosion of disturbed areas leading to increased sediment laden runoff and marine sedimentation	Stable coastal form	Adverse	Local	Medium (five to ten years)	Direct	High	Moderate	Medium	Moderate
Erosion of disturbed areas leading to increased sediment laden runoff and physiochemical changes to water quality	Stable coastal form	Adverse	Local	Medium (five to ten years)	Direct	High	Moderate	Medium	Moderate
Ore spillage during barge and ship loading causing marine sedimentation	Stable coastal form	Adverse	Local	Medium (five to ten years)	Direct	High	Moderate	Medium	Moderate
Spills and leaks of hazardous materials causing contamination of marine waters	Marine water quality	Adverse	Local	Medium (five to ten years)	Direct	Medium	Moderate	Medium	Moderate
Ore spillage during barge and ship loading causing contamination of marine waters	Marine water quality	Adverse	Local	Medium (five to ten years)	Direct	Medium	Moderate	Medium	Moderate

10.5 Management plans and mitigation measures

An important consideration in the mine design is the avoidance or minimisation of sedimentation impacting the physical marine environment. These design measures are outlined in Chapter 15. In addition, a comprehensive suite of management measures will be implemented to avoid or minimise potential impacts on the physical marine environment. These measures are reflected in the management plans outlined in the following section.

10.5.1 Management plans

- Erosion and sediment control plan containing procedures and information on the management of:
  - catchment areas and drainage lines;
  - proposed mining, stockpiles and disturbance areas;
  - the extent and nature of riparian protection zones;
  - the alignment and geometries of all drainage;
  - the location and size of all sedimentation dams;
  - waterway crossings; and
  - drainage lines that require scour protection.
- hazardous materials plans, containing procedures for:
  - documentation: storage and currency of safety data sheets (SDSs);
  - regulatory authority guidelines for the safe handling, transport and storage of all hazardous materials used; signage; and document review;
  - storage and use of hazardous materials: locations and quantities; containers; labelling; leakage testing; bunding and capacity of bunded areas; and spill response;
  - transportation of hazardous materials: staff training in handling; clean-up and remediation of spills; storage of materials; and excavation and treatment of contaminated soil; and
  - monitoring: document currency; vehicle and hazardous material storage inspections; and spill response preparedness.
- the development of an appropriate boat ramp design and ore loading procedures to minimise ore spillage. These measures would include:
  - ensuring the boat ramp design facilitates easy barge docking and vehicle access;
  - training for staff on how to tip on to barges;
  - protocols in weather events (eg heavy rain and strong winds) and when to stop loading;
  - transhipment grab operation procedures; and

- keeping the boat ramp clean from spillages and accumulations of ore.

- liquid and solid waste management plan, containing procedures and designs for:
    - disposal of solid and liquid wastes to prevent leaching and contamination of fresh and marine water;
    - treatment and disposal of domestic wastewater to prevent spills, leaks and contamination of fresh and marine water;
    - treatment and disposal of wastewater from the MIA and fuel storage areas including spacing of facilities from watercourses and the shoreline; and
    - monitoring such as daily inspections of storage areas and weekly review of waste generation.
- A water quality monitoring plan, containing procedures for:
    - Regular sampling for water quality parameters such as pH, turbidity, TSS, dissolved oxygen, turbidity and electrical conductivity.
- if required, an acid sulphate soils management plan, containing procedures for:
    - specialised handling for potentially acid sulphate soils; and
    - additives such as limestone, organic materials or bactericides used on potentially acid generating waste rock.

A full list of mitigation measures for each plan is included in Chapter 15, Management plans and mitigation measures.

10.6 Residual impacts

Table 10.2 outlines the residual impacts following the implementation of the management measures described above.

Table 10.2 Residual impacts following the implementation of proposed management measures

Impact	Potential significance prior to implementation of mitigation measures	Residual significance after implementation of mitigation measures
Erosion of disturbed areas leading to increased sediment laden runoff and marine sedimentation	Moderate	Low
Erosion of disturbed areas leading to increased sediment laden runoff and physiochemical changes to water quality	Moderate	Low
Ore spillage during barge and ship loading causing marine sedimentation	Moderate	Low
Spills and leaks of hazardous materials causing contamination of marine waters	Moderate	Low
Ore spillage during barge and ship loading causing contamination of marine waters	Low	Low

10.7 Conclusion and summary

The marine waters around San Jorge Island are vulnerable to sedimentation impacts from local watercourses and impacts from the spillage of ore during the export process. The impacts of sedimentation and loading at the boat ramp have been modelled using a hydrodynamic model. Modelling predicts that during mine operations, water quality impacts will largely be confined to the local bays, which are generally depositional environments; estuaries surrounded by mangroves. In extreme rainfall events, the closer parts of some fringing reefs may be slightly affected, but the deeper water reefs should not be impacted. Transhipment of the ore at sea should have limited impacts due to the depth of water and the effects of dilution.

The implementation of management measures prescribed in this chapter will reduce the significance of these impacts from moderate, to low. Impacts are most likely to occur during significant rainfall events when the design capacity of the erosion and sediment controls is exceeded.

11 Marine ecology

11.1 Assessment objectives

The objectives of this assessment are to provide:

- an assessment of the potential impacts of the project on any marine threatened species, populations, ecological communities or their habitats; and
- a description of the actions that would be taken to avoid and reduce the potential impacts of the project to marine biodiversity.

11.2 Assessment method

Technical field assessments for marine ecology were not conducted for the San Jorge Nickel Project, however data and information have been sourced from studies which were carried out in 2015 on adjacent areas of Thousand Ships Bay (for the Kolosori Nickel Project), which is only 5 km away. This information is considered to be representative of the San Jorge site and has been used for this assessment.

The 2015 surveys of marine waters in Thousand Ships Bay determined the habitats and species occurring in the project area and identified threatened marine species, populations and ecological communities present or potentially occurring in the project area. This assessment is summarised in this section. This assessment has been carried out in accordance with the following acts and regulations:

- *Environment Act 1998;*
- *Environment Regulations 2008;*
- *Wildlife Protection and Management Act 1998;*
- *Wildlife Protection and Management Regulations 2008; and*
- *Protected Areas Act 2010.*

In addition to using the 2015 field survey information, a desktop assessment was undertaken to assess the potential impacts of the project on marine ecology. Desktop assessments consisted of literature reviews and database searches. Field surveys were limited to visual assessments via field observations and photographic surveys due to logistical limitations.

11.2.1 Desktop assessments

A literature review was undertaken to assess the marine flora and fauna likely to be found in the study area. Studies investigating the biodiversity of areas close to the project site were reviewed along with documents on the marine biodiversity of the Solomon Islands.

The International Union for Conservation of Nature (IUCN) Red List was used to source information regarding threatened species potentially found within the study site, including details of their preferred habitat. In conjunction with information found from the literature review, information on preferred habitats was used to undertake a 'likelihood of occurrence' assessment for any species listed as threatened.

11.2.2 Field surveys

Due to logistical and time limitations, field survey data from 2015 from Kolosori Nickel Project site on Santa Isabel Island, approximately 5 km from the San Jorge tenement, was used. Due to the proximity of the sites in Thousand Ships Bay, the marine ecology will be highly similar in both areas. These field surveys were limited to visual assessments in the form of field observations and photographic surveys. Photographic surveys were undertaken near the mouth of Vuavula, Beahutu and Hugithehe streams on Santa Isabel Island, in addition to the foreshore areas near the Kolosori camp office and near the end point of an existing track to the north-west of the Beahutu stream mouth. Photographic surveys took place on 19 December 2015 and consisted of:

- land based observations of foreshore conditions;
- snorkelling in the shallow coastline edges (maximum depth ~3 m); and
- observations of habitats in deeper waters during boat journeys between photographic survey locations.

11.2.3 Habitat mapping

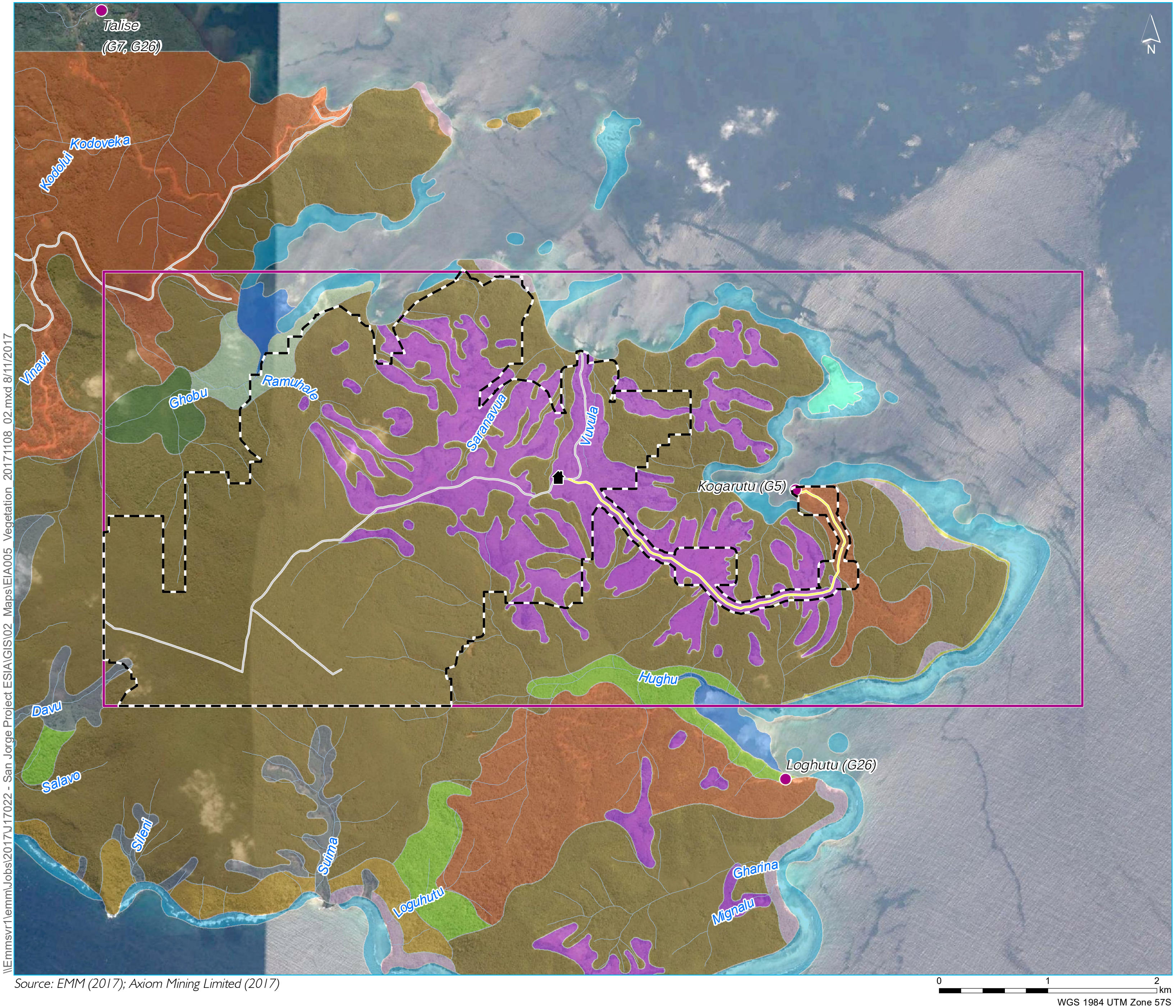
Marine habitats found in the study area were mapped based on field observations and aerial photograph analysis. As detailed delineation of marine habitats was limited by the resolution of available aerial imagery, the habitats were mapped as a broad mosaic of habitats (see Figure 11.1).

11.3 Existing environment

Coastline vegetation is dominated by fringing coral reefs, with a mangrove forest to the north of the project area, and estuarine mudflats surrounding the mangroves. Shallow water habitats consist of a mosaic of soft sediment benthos and rocky patch reefs. Seagrass, sandy benthos and rock mosaics were evident in small patches near the project site. The shallow water habitats extend seaward to a distance of approximately 250-300 m from the foreshore before the shelf drops leading to deeper offshore waters. These ecosystems hold high environmental value and support diverse flora and fauna communities. Generally, the marine habitats were in good condition; however some degradation from anthropogenic activities (eg mangrove clearing and siltation of reefs due to runoff from logging tracks) was evident.

11.3.1 Overview

The following sections describe the marine habitats, flora and fauna of the territory surrounding the project area.



KEY
- Potential area of disturbance
- Project area
- Accommodation camp
- Village (owner)
- Main access road
- Local road
- Watercourse / drainage line

Degraded vegetation and agriculture
- Coconuts
- Fernland
- Large landslips and erosion in valley forest
- Logged forest

Marine environment
- Sandy foreshore
- Seagrass meadows
- Soft-sediment benthos (estuarine mudflat)
- Reef

Natural vegetation
- Mangrove forest
- Riparian and valley forest
- Freshwater swamp forest
- Beach forest
- Ultramafic forest

Habitat mapping

Axiom Mining Limited
San Jorge Nickel Project
Environmental impact statement
Figure 11.1

Source: EMM (2017); Axiom Mining Limited (2017)

\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps\EIA005_Vegetation_20171108_02.mxd 8/11/2017

11.3.2 Marine habitats

The following marine habitats have been identified in the project area:

- mangrove forests;
- seagrass meadows;
- soft sediment benthos;
- sandy foreshore;
- open bay waters; and
- shallow coral reefs.

i Mangrove forests

Mangroves are one of the most extensive wetland habitats in the Solomon Islands and are present in the north-west area of the project area. Of the 20 mangrove species found on the Solomon Islands, 12 were recorded in proximity to the project area. *Rhizophora stylosa, Rhizophora apiculata, Bruguiera gymnorrhiza, Bruguiera parviflora* and *Bruguiera exaristata* appear to be the most dominate mangrove species identified.

Mangroves are an integral component in coastal habitats as they stabilise channel banks and protect shorelines from erosion by storing and dissipating the energy of floodwaters. They also provide structural complexity in the intertidal habitat and enhance refuge habitats.

ii Seagrass meadows

A total of ten species of seagrass were recorded in small patches around the project area. This represents approximately 80% of the total seagrass species diversity in the Indo-Pacific region. *Thalassia hemprichii* and *Enhalus acoroides* are the most dominant species of the study area. Other seagrass species found within the project area are *Cymodocea rotundata* and *Cymodocea serrulata*.

Seagrass meadows are an important food source for threatened species such as the green sea turtle (*Chelonia mydas*) and dugong (*Dugong dugon*) which are found throughout the Solomon Islands.

iii Soft-sediment benthos

Benthic infaunal communities are dominated by polychaete worms, bivalves (mussels), gastropods (snails) and crustaceans (crabs and shrimp). Burrowing crab species such as mud crabs (Xanthidae) and fiddler crabs (Ocypodidae) are commonly found in mangroves whilst shore crabs (Grapsidae) frequently inhabit unvegetated soft-sediment benthos.

In the study area, muddy soft-sediment benthos were mainly present on the seaward side of mangrove vegetation. This habitat may be an artefact of surface run-off and sedimentation as the concentration of this habitat around stream discharge points as opposed to a natural unvegetated, soft-sediment habitat.

iv Sandy foreshore

Sandy foreshores were limited to strips on the southern parts of the coastline. Seagrasses were generally present only in the sandier areas of the foreshore.

v Coral reefs

Coral reefs dominate the coastline of the site area. They are one of the most extensive marine habitats in the Solomon Islands and range from narrow fringing reefs along shorelines to offshore barrier reefs, atolls and patch reefs. The Solomon Islands form part of the Coral Triangle which is recognised as a global coral biodiversity hotspot, nurturing nearly 600 coral species. Four hundred and ninety described coral species are found in the Solomon Islands, giving it the second highest coral species diversity in the world.

Seven types of coral community across two main groups (shallow water communities and deep/mixed depth communities) have been identified in the Solomon Islands including:

- Type A –acropora, pocilloporid, massive favid and millepora exposed shallow water communities;
- Type B – acropora, massive favid, millepora and alcyonacea shallow water communities;
- Type C – mixed merulinid, fungid, sponge and alcynoacean communities with very high species richness;
- Type D – mixed astreopora, lobophyllia, alcyonacea and sponge sheltered water communities;
- Type E – massive favid, pocilloporid, acropora and alcyonacea clear deep water communities;
- Type F – agaricid, massive favid, plating pectinid and gorgonian communities on steep deep reef slopes; and
- Type G – porites, massive Favid, fungid, agaricid, alcyonacea and sponge communites of mixed depth and low species richness.

Type A shallow water communities and Type E deep water communities were recorded in survey sites close to the project area.

Coral communities in the survey region are dominated by hard corals, with soft corals occurring occasionally in this area. Hard coral families are dominated by Acroporidae, Poritidae and Faviidae families while soft corals are dominated by Alcyoniidae. Macroalgal cover in coral reefs was low (< 15% cover) and mainly consisted of Caulerpa spp and Sargassum spp.

Overall the reefs and associated marine ecology adjacent to San Jorge Island Coast and in Thousand Ships Bay is considered to be of regional or moderate value.

11.3.3 Marine flora

A comprehensive list of marine flora that may potentially occur within the habitats present in this study can be found in marine ecology species lists (Appendix F).

11.3.4 Marine fauna

A comprehensive list of marine fauna that may potentially occur within the habitats present in this study can be found in marine ecology species lists (Appendix F).

11.3.5 Species of conservation significance

The IUCN database search indicated a total of 171 listed threatened species occur or have potential to occur within the Solomon Islands. This included:

- two mammals;
- four reptiles;
- twelve fish;
- seven rays/sharks;
- ten echinoderms;
- two molluscs; and
- one hundred and thirty four coral species.

Of these species:

- one is listed as critically endangered;
- eleven are listed as endangered; and
- one hundred and fifty six are listed as vulnerable.

Several species are listed as Data Deficient and could potentially constitute further threatened species.

Due to limited field data, a conservative approach was taken and threatened species were considered likely to occur if any potential habitat was present within the study area. As a result a total of 164 species, mainly corals, have been assessed as having some potential to occur within the project area. A detailed assessment of the likelihood of occurrence of these species within the study area is provided in Appendix F.

11.4 Impact assessment

Mining projects can result in the direct clearance and removal of marine habitats for development of infrastructure. Additionally, they can indirectly harm marine environments by a variety of means, particularly erosion and sedimentation.

Without effective mitigation measures, the project has the potential to impact on marine biodiversity in the study area in a number of ways. These include:

- erosion and sedimentation;
- hazardous spills and leaks;

- acid sulphate soils;
- ballast dumping in deeper waters;
- litter and waste; and
- vessel collisions with fauna.

Table 11.1 summarises the potential impacts and their severity.

11.4.1 Erosion and sedimentation

Clearing of forest and fernland areas for the project site increases the likelihood of erosion and sedimentation which affects the quality and quantity of water within streams and ultimately increases sedimentation within the marine environment. The proposed methodology for resource extraction will result in a significant amount of soil disturbance, with an associated increase in the potential for erosion and sedimentation of the freshwater streams that discharge into the marine environment.

11.4.2 Increased turbidity

An increase in turbidity in aquatic and marine environments due to sedimentation is closely connected with rainfall and surface runoff, with spikes in turbidity typically occurring after rain events and reducing as flows return to normal. Although marine ecosystems are likely to be adapted to natural peaks in high turbidity during some periods, an increase in the magnitude or the frequency of these peaks of turbidity due to destabilisation of soil through mining activity has the potential to have a detrimental effect on marine ecosystems.

Increased concentrations of suspended sediment and associated turbidity could also occur due to construction related activities. Vegetation clearing and earthworks is required for the construction phase of the project resulting in the mobilisation of soils from disturbed areas. Sediment control structures, roads, ore stockpiles areas, boat ramp facilities and accommodation camps are areas which will be subjected to earthworks and may cause increased sedimentation and turbidity to marine waters.

The primary impact from an increase in turbidity is the reduction in light penetration which affects primary production in marine flora and the symbiotic algae (zooxanthellae) present in coral. Impacts of increased turbidity on corals and seagrasses vary from subtle changes in reef structure or seagrass meadows to total mortality. Increased turbidity and sedimentation could impact the feeding, locomotive and reproductive behaviours of marine biota. It could also affect the abundance and diversity of habitats available to marine biota. These changes in the structure of coral reefs and seagrass communities is likely to impact on marine fauna as these communities provide important habitat for many invertebrate and vertebrate species. The impacts on fauna, in turn, could affect the productivity of fisheries in the locality. Seagrasses and corals are particularly vulnerable to impacts associated with turbidity and sedimentation.

Sedimentation can be reduced by mangrove roots as they tend to retain sediments and consolidate soil; however the possible removal of mangroves for the project has the potential to locally increase erosion and sedimentation into the marine environment.

11.4.3 Eutrophication

Sediment movement can mobilise nutrients and pollutants to marine habitats. Excess nutrients in the marine habitat can lead to eutrophication, which can cause loss of diversity, reduced growth and changes in the ecological structure of marine communities, including fisheries. This can also increase the growth of algae on surface waters can reduce light penetration in the water resulting in reduced growth of seagrasses and zooxanthellae. Seagrass beds and coral reefs are particularly vulnerable to damage from eutrophication and nutrient enrichment. The sediments in the project area are low in nutrients, so any eutrophication that may occur is likely to be on a localised scale.

11.4.4 Hazardous spills and leaks

There is a risk of contamination of marine water by spills and leaks of chemicals and hydrocarbons from plant and equipment during construction of the mine and upgrade of the roads. The substances could enter marine waters directly or through the movement of stormwater. Contamination from stormwater runoff could adversely affect water quality, subsequently impacting the diversity and abundance of marine biota. The implementation of the hazardous materials plan will reduce the likelihood of spills occurring and/or impacting the marine environment.

11.4.5 Acid sulphate soils

Dredging and other activities associated with port construction could disturb marine sediments and potentially expose acid sulphate sediments (ASS) to oxidising conditions. This could reduce the pH, locally, of surrounding marine waters potentially causing fish-kills, disease and other disturbances to marine biota. Many local communities depend on marine biota as sources of food and income. Therefore, detrimental effects of ASS to marine communities, especially fish, may impact the livelihood of local communities. The implementation of the acid sulphate soil plan would reduce the likelihood of ASS affecting marine communities.

11.4.6 Ballast water dumping

Ballast water has the potential to cause a serious ecological threat to marine habitats by facilitating the introduction of invasive marine species and disease. Ballast water also contains sediments which have the potential to accelerate channel sedimentation and increase sediment loads in adjacent marine communities, such as coral reefs, seagrasses and mangrove forests. Implementation of a ballast water treatment system will be required during the active phase of the shipping port to include monitoring of ballast water in ships, barges and other marine transport.

11.4.7 Litter and waste

Litter and waste associated with the construction of port area and infrastructure could degrade water quality and impact marine biota. Entanglement and ingestion of debris may hinder feeding, moving and reproductive capabilities of marine fish and mammals, and could be fatal. A waste management plan, for both solid and liquid waste, will be implemented in order to minimise waste impacts on the marine habitat.

11.4.8 Vessel collisions with fauna

During the construction and operational phases of the project, there is risk of vessels colliding with marine mammals and turtles. Green sea turtles *Chelonia mydas* and dugongs *Dugong dugon* are known to occupy waters of the Solomon Islands. As both species are listened as threatened, collisions with vessels could be significant. This can be avoided by limiting vessel speeds in the vicinity of the project area and maintaining diligent lookout by training vessel crew to monitor and report marine fauna sightings.

Table 11.1 Summary of unmitigated impacts and their significance – marine ecology

Impact	Impacted value	Status	Boundary of impacts	Duration	Direct/indirect	Confidence	Sensitivity of value	Severity of impact	Significance of impact
Erosion of disturbed areas causing increased sediment runoff and marine sedimentation	Marine ecosystems	Adverse	Local	Medium (five to ten years)	Direct	High	Moderate	Moderate	Moderate
Erosion of disturbed areas causing eutrophication	Marine ecosystems	Adverse	Local	Medium (five to ten years)	Direct	High	Moderate	Low	Low
Ore spillage during barge and ship loading causing marine sedimentation	Marine ecosystems	Adverse	Local	Medium (five to ten years)	Direct	High	Moderate	Moderate	Moderate
Spills and leaks of hazardous materials causing contamination of marine waters	Marine ecosystems	Adverse	Local	Medium (five to ten years)	Direct	Medium	Moderate	Moderate	Moderate
Ore spillage during barge and ship loading causing contamination of marine waters	Marine ecosystems	Adverse	Local	Medium (five to ten years)	Direct	High	Low	Moderate	Low
Disturbance of acid sulphate soils causing acidification of marine waters	Marine ecosystems	Adverse	Local	Short (during construction phase)	Direct	Low	Moderate	Low	Moderate
Dumping of ballast water introducing invasive pests and disease	Marine ecosystems	Adverse	Regional	Medium (five to ten years)	Direct	Medium	Moderate	Moderate	Moderate
Litter and waste causing degraded marine waters and entanglement or ingestion of debris by marine fauna	Marine ecosystems	Adverse	Local	Medium (five to ten years)	Direct	Medium	Moderate	Moderate	Moderate
Project-related vessels colliding with fauna and causing mortality	Marine ecosystems	Adverse	Local	Medium (five to ten years)	Direct	Medium	Moderate	Low	Low

11.5 Management plans and mitigation measures

There are several methods to reduce the impact of the project on marine ecology. Many issues relating to surface water flow (ie the effects of erosion and sedimentation) will be managed through the implementation of a water management strategy in the design of the mine. The water management strategy is discussed in Chapter 9; and this will significantly control the movement of water around the project area, and reduce the significance of impacts on marine ecology.

i Management plans

The following management plans will be prepared and implemented to prevent impacts to marine ecosystems:

- erosion and sediment control plan containing procedures and information on the management of:
    - catchment areas and drainage lines;
    - proposed mining, stockpiles and disturbance areas;
    - the extent and nature of riparian protection zones;
    - the alignment and geometries of all drainage;
    - the location and size of all sedimentation dams;
    - waterway crossings; and
    - drainage lines that require scour protection.
- hazardous materials plans, containing procedures for:
    - documentation: storage and currency of safety data sheets (SDSs);
    - regulatory authority guidelines for the safe handling, transport and storage of all hazardous materials used; signage; and document review;
    - storage and use of hazardous materials: locations and quantities; containers; labelling; leakage testing; bunding and capacity of bunded areas; and spill response;
    - transportation of hazardous materials: staff training in handling; clean-up and remediation of spills; storage of materials; and excavation and treatment of contaminated soil; and
    - monitoring: document currency; vehicle and hazardous material storage inspections; and spill response preparedness.
- the development of an appropriate boat ramp design and ore loading procedures to reduce ore spillage. These measures would include:
    - ensuring the boat ramp design facilitates easy barge docking and vehicle access;
    - training for staff on how to tip on to barges;
    - protocols in weather events (eg heavy rain and strong winds) and when to stop loading;

- transhipment grab operation procedures; and
- keeping the boat ramp clean from spillages and accumulations of ore.

- liquid and solid waste management plan, containing procedures and designs for:
  - disposal of solid and liquid wastes to prevent leaching and contamination of fresh and marine water;
  - treatment and disposal of domestic wastewater to prevent spills, leaks and contamination of fresh and marine water;
  - treatment and disposal of wastewater from the MIA and fuel storage areas including spacing of facilities from watercourses and the shoreline; and
  - monitoring such as daily inspections of storage areas and weekly review of waste generation.
- a ballast water management plan, containing procedures for:
  - use of low risk ballast water (such as fresh potable water, high seas water or fresh water from an on-board fresh water production facility);
  - ballast water exchange to be conducted in a designated area; and
  - discharge to an approved ballast water reception facility.
- if required, an acid sulphate soils management plan, containing procedures for:
  - specialised handling for potentially acid sulphate soils; and
  - additives such as limestone, organic materials or bactericides used on potentially acid generating waste rock.
- a water quality monitoring plan, containing procedures for:
  - regular sampling for water quality parameters such as pH, turbidity, TSS, dissolved oxygen, turbidity and electrical conductivity.
- biodiversity monitoring plan, containing procedures for:
  - Appropriate education and awareness about the environment, biodiversity and landscape function.
  - Key performance indicators against which to measure biodiversity progress and will specify review periods where progress is reviewed.
  - Consultation with local communities to ensure their traditional knowledge of biodiversity and cultural values are acknowledged and incorporated into the management plan.
  - Regular sampling for marine fauna diversity, abundance and community structure.

A full list of mitigation measures for each plan is included in Chapter 15, Management plans and mitigation measures.

11.6 Residual Impacts

Table 11.2 outlines the residual impacts from each potential impact of the project.

Table 11.2 Residual impacts following the implementation of proposed management measures

Potential impacts	Potential significance prior to implementation of mitigation measures	Residual significance after implementation of mitigation measures
Erosion of disturbed areas causing increased sediment runoff and marine sedimentation	Moderate	Low to Moderate
Erosion of disturbed areas causing eutrophication	Low	Low
Ore spillage during barge and ship loading causing marine sedimentation	Moderate	Low
Spills and leaks of hazardous materials causing contamination of marine waters	Moderate	Low
Ore spillage during barge and ship loading causing contamination of marine waters	Low	Low
Disturbance of acid sulphate soils causing acidification of marine waters	Moderate	Low
Dumping of ballast water introducing invasive pests and disease	Moderate	Low
Litter and waste causing degraded marine waters and entanglement or ingestion of debris by marine fauna	Moderate	Low
Project-related vessels colliding with fauna and causing mortality	Low	Low

11.7 Conclusion and summary

While coastline habitats show some signs of disturbance from current land uses eg logging, the wider marine environment within the study area appears to be in good condition with clear, well oxygenated waters and a range of habitats that support a healthy diversity of corals and fish. Although limited field data was collected, desktop analyses indicate that marine biodiversity within the study area and wider locality is likely to be high, especially as the Solomon Islands form part of the highly diverse 'Coral Triangle'.

Issues that may arise without acceptable preventative management measures include:

- turbidity and sedimentation from stormwater and construction methods;
- hazardous spills and leaks from the project plant and equipment;
- acid sulphate soils from the construction of the boat ramp;
- ballast water dumping from vessels entering the project area;
- litter and waste created from the project; and
- vessel collisions with marine fauna.

These issues can be prevented or reduced by implementing various management plans. These include:

- Erosion and sediment control plan;
- Hazardous materials management plan;
- Liquid and solid waste management plan;
- Acid sulphate soils plan;
- Ballast water management plan;
- Marine monitoring plan; and
- Biodiversity monitoring plan.

Provided that these measures are implemented and monitoring takes place to ensure control of key issues such as sedimentation, the impacts of the project should be sustainable and should not trigger long term damage to the marine environment in the project area.

12 Amenity

Environmental amenity is defined as 'pleasantness', or more commonly the absence of unsightliness, dust and odours, and noise. Visual amenity, air quality and noise are environmental characteristics as perceived by people, and to a lesser degree flora and fauna. Therefore, for the purposes of these assessments, sensitive receptors have been used. These are locations from where the lack of amenity would be significantly noticeable, and are usually dwellings and homes, or public areas such as schools or hospitals.

The site specific assessments for visual amenity, noise and air quality for the San Jorge Nickel Project are based on background data and information from studies which were carried out on Tenements D and E and the Kolosori site on Santa Isabel (SMM, 2012 and EMM, 2015) which are considered to be representative of the San Jorge site.

12.1 Visual amenity

The project will comprise components visible from some areas on the southern part San Jorge Island, and parts of Santa Isabel Island. Project components include:

- open mine pits;
- haulage routes;
- mining equipment and vehicles;
- infrastructure and buildings; and
- barges and ships.

This sensitive describes the nearby sensitive locations and impacts on them from potentially visible project components.

12.1.1 Assessment method

The visual assessment method comprised:

- identification of viewpoints around the project area;
- description of the view type and landscape context;
- description of visual absorption capacity and view quality; and
- assessment of the significance of impacts.

i Viewpoints

Four viewpoints were chosen for the assessment. Viewpoint 1 is from Talise, the closest inhabited village to the project area, and the location most sensitive to changes in visual amenity. Viewpoints 2, 3 and 4 are from the island of Santa Isabel, from the villages of Suma, Thathaje and Sepi respectively. The locations of Kogarutu and Loghutu are not permanently settled, so were not considered further for this assessment.

ii View type and context

View type and context is the existing landscape character, particularly the built environment, topography, and screening provided by topography, vegetation or other elements of the environment.

The context is a primary factor in the visual absorption capacity of the view; sites with higher contrasting landscapes generally have greater ability to absorb change, whereas sites within a uniform or highly ordered landscape have lower absorption capacity.

iii Existing view quality

View quality rates the existing aesthetic quality based on its relationships with the landscape setting and with its visual interest and contrast. This has been determined by using a rating of low, medium or high.

iv Significance of impact

Significance of impact from the viewpoints has been determined by considering the above. The line of sight from the villages to project components was considered based on intervening topography to determine the level of visual change. Visual change was informed by visual sensitivity, the nature of the landscape, topography, the distance between the viewpoint and the project components, as well as the type of view experienced.

12.1.2 Existing environment

The landscape of southern San Jorge Island is characterised by inshore reefs and mangrove forest along the shoreline; heavily forested lowlands and hill slopes; and lower ridges devoid of vegetation over near-surface nickel deposits. The majority of forest is old growth with a tree canopy up to 40 m high and a dense understorey dominated by young trees, saplings, small palms and ferns.

There is one village on southern San Jorge Island; Talise located approximately 2 km north of the tenement boundary, and 3.5 km from the closest area which may be affected by mining. Talise has approximately 500 inhabitants.

On the western coast of Santa Isabel Island there are several villages of varying sizes including Suma, Sesedo, Thatheje, Vulavu, Lepi and Sepi. Suma is located to the north east, 5.6 km from the tenement boundary, and 7.5 km from closest area which may be affected by mining. Thatheje is located to the east, 8.2 km from the tenement boundary, and 12.8 km from the closest area which may be affected by mining. Sepi is located to the south east, 10.2 km from the tenement boundary, and 14.8 km from the closest area which may be affected by mining. The view of the villages on Santa Isabel towards San Jorge is over Thousand Ships Bay.

Photograph 12.1 View of Thousand Ships Bay from San Jorge (L) to Santa Isabel (R)

Photograph 12.2 View of San Jorge from Thousand Ships Bay

12.1.3 Impact assessment

The project will comprise components which could be visible from nearby sensitive locations such as villages. Such project components will include:

- open mine pits;
- haulage routes;
- mining equipment and vehicles;
- infrastructure and buildings; and
- barges and ships.

Talise is located within a valley running south west to north east to the north of the San Jorge Tenement. The views from the village in all directions are the local built environment and then fairly uniformly of forested slopes and mangroves to the east. There are no coastal views from the village itself as it is inland from the coast along a small river. The uniformity and low contrast of the views indicates low visual absorption capacity.

The villages of Suma, Thatheje and Sepi have similar viewpoints, being on the west coast of Santa Isabel Island overlooking Thousand Ships Bay. Suma is located on the coast; the view to the north and east is of the partially forested hills and valleys of Santa Isabel with a number of ridges and valleys. The view to the south and west is of Thousand Ships Bay, with the promontories of Santa Isabel visible to the south, and the partially forested hills of the island of San Jorge to the south west and west. The variation in views indicates a moderate visual absorption capacity.

Thatheje is located on the coast; with views of the partially forested hills and valleys of Santa Isabel to the north, north west, east and south east. The view to the south west is of Thousand Ships Bay, with distant islands on the horizon. The view to the west and north west is of the partially forested slopes of San Jorge Island. The variation in views indicates a moderate visual absorption capacity.

Sepi is also located on the coast; the views to the north and east are of the partially forested hills and valleys of Santa Isabel in the background, with the buildings of Sepi in the foreground. The view to the south and west is over Thousand Ships Bay with distant islands on the horizon. The view to the north west is of the distant partially forested slopes of San Jorge Island, partially obscured by a headland of Santa Isabel Island. The variation in views indicates a moderate visual absorption capacity.

The quality of existing views at Talise is moderate, with limited topography and forest views.

The quality of the existing views at Suma and Thatheje are high due to the varied topography; water and forest views; and lack of surrounding development.

The quality of the existing view at Sepi is moderate due to presence of surrounding development.

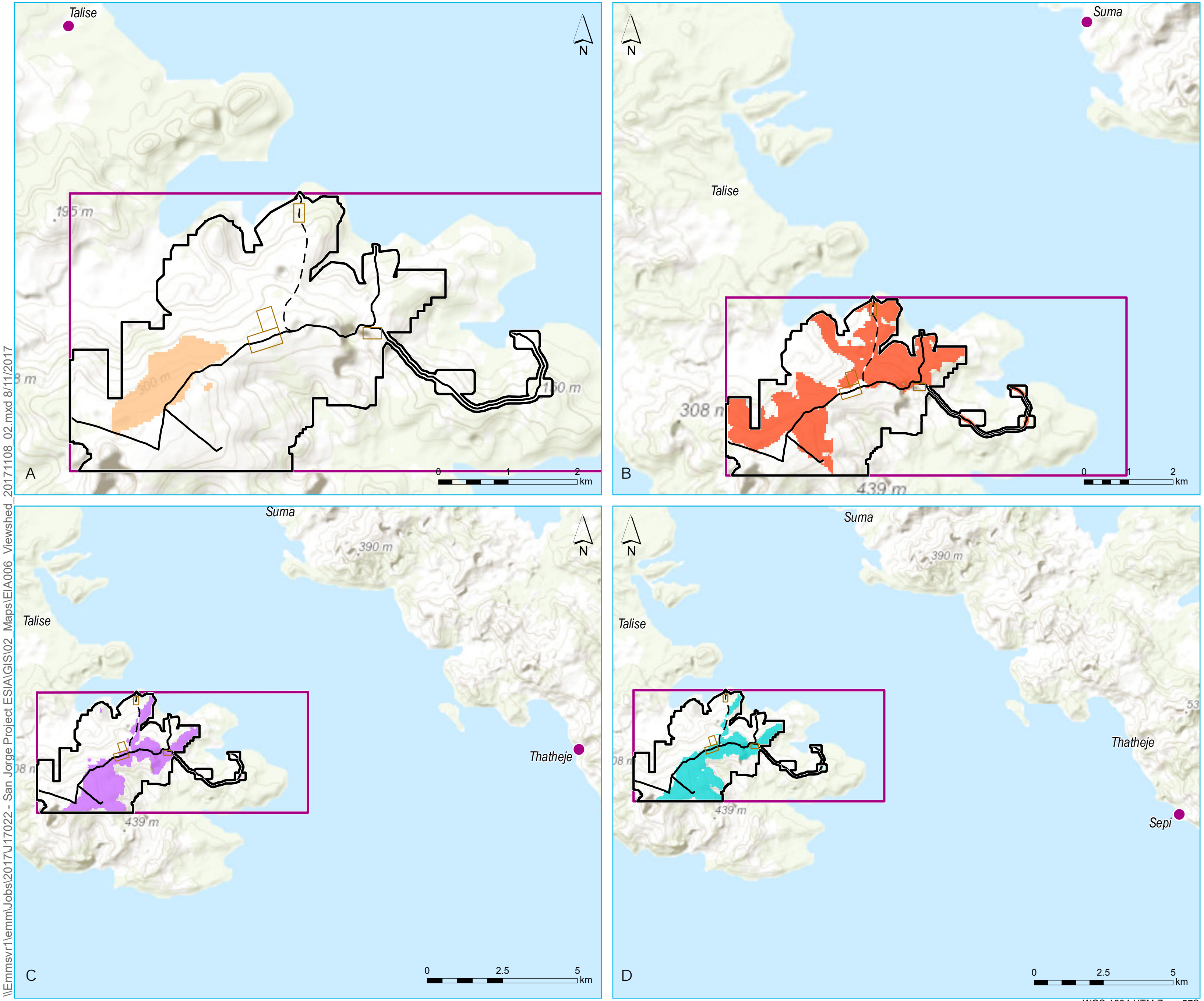
Few project components are likely to be viewable from Talise during construction and operations as there is a high ridge between the deposits, ore loading facility/MIA, other infrastructure and the village which will shield views.

Many project components are likely to be viewable from Suma, Thatheje and Sepi; however these will be located a significant distance away (minimum of 7 km distant). Ocean going vessels in Thousand Ships Bay will be visible from the villages on Santa Isabel; however, they will not be a significant feature of the viewscape as they will be in deep waters at least 4 km from the villages. Large logging ships are also a regular feature of the seascape in Thousand Island Bay.

The project will include some night time working, but as the site will use local generators and will not be fully electrified, the quantity and intensity of the lighting will be relatively low. Directional lighting will be used on working vehicles, and other lighting will be of a low to moderate intensity.

Given the above, adverse impacts will be minor, as project components may be visible at a distance from Suma, Thatheje and Sepi. Potential impacts will be localised and short to medium term as only a small area of the project may be visible from the villages on Santa Isabel and the proposed project duration is estimated at five to ten years.

The viewshed analysis for these four sites is presented in Figure 12.1.



KEY
- Project area
- Potential area of disturbance
- Village (viewshed assessment location)
- Surface infrastructure and stockpile locations
- Access road
- Proposed access road
- A - Viewshed from Talise
- B - Viewshed from Suma
- C - Viewshed from Thatheje
- D - Viewshed from Sepi

Viewshed analysis

Axiom Mining Limited
San Jorge Nickel Project
Environmental impact statement
Figure 12.1

EMM

Source: EMM (2017); Axiom Mining Limited (2017)

WGS 1984 UTM Zone 57S

12.1.4 Mitigation measures

Specific mitigation measures are not required as the unmitigated impacts will be minor, however the following mitigation measures to manage other impacts will also reduce visual impacts:

- the resource will be mined progressively to reduce exposure;
- the site will be progressively rehabilitated and revegetated;
- areas disturbed for construction, but not required for further operations, will be rehabilitated and revegetated as soon as possible;
- vegetation clearing will be reduced as far as is practicable;
- vegetation strips will be retained where practicable, particularly along drainage lines; and
- low glare and directional lighting will be used to reduce light spill where practicable.

12.1.5 Residual impacts

Visual impacts prior to mitigation are minor. By considering the topography and distance between villages and project components there is high confidence that there will be a minor residual impact.

12.2 Air

12.2.1 Assessment method

The south of Santa Isabel Island and San Jorge Island have been extensively studied, including during preparation of the EIS for Sumitomo Metal Mining's (SMM 2012) proposed development of Isabel tenements D and E, and Axiom's developments at the Kolosori Tenement (EMM, 2015). These tenements share similar geology, geography and climate to San Jorge and are considered to be representative of the site.

Potential air quality impacts on sensitive locations from the project have been inferred from tenements D and E as the mining methods and localities will be similar. Potential pollutants assessed for tenements D and E using the CALPUFF model were TSP, PM_{10}, $PM_{2.5}$, exhaust particulates and heavy metals (arsenic, copper, lead, zinc, chromium, cadmium and nickel). The villages near the tenements were taken as the sensitive locations.

The ambient air quality parameters in Table 12.1 were used in the model, with predictions compared to criteria in the Queensland *Environment Protection (Air) Policy 2008* (EPP Air) and the NSW Department of Environment and Conservation (DEC) (2005).

Table 12.1 Air quality criteria

Pollutant	Averaging period	Criteria	Source
$PM_{2.5}$	24 hours	25 µg/m^3	EPP Air
	Annual	8 µg/m^3	EPP Air
PM_{10}	24 hour	50 µg/m^3	EPP Air
	Maximum	30 µg/m^3	DEC (2005)
TSP	Annual	90 µg/m^3	EPP Air
Deposited dust	Annual	4 (total) g/m^2 month	DEC (2005)
	Annual	2 (maximum increase) g/m^2 month	DEC (2005)
Arsenic	Annual	6 µg/m^3	EPP Air
Cadmium	Annual	5 µg/m^3	EPP Air
Chromium VI	1 hour	90 µg/m^3	DEC (2005)
Copper	1 hour	18,000 µg/m^3	DEC (2005)
Nickel	Annual	20 µg/m^3	EPP Air
Zinc	1 hour	90,000 µg/m^3	DEC (2005)

This report compares the proximity of villages near the project to those near tenements D and E and infers impacts on the air quality in those villages from the study for tenements D and E.

For the purposes of the air quality assessment for the San Jorge Nickel Project, the village of Talise located 2 km to the north of the tenement; the garden sites at Kogarutu (within the tenement) and Loghutu (0.5 km south of the tenement) have been used as sensitive receptors.

As modelling of air quality data was not undertaken for the San Jorge Nickel Project, the air quality impact assessment has been undertaken using the significance method rather than the compliance method.

12.2.2 Existing environment

There are few air pollution sources in Solomon Islands, with the main source being emissions from combustion of solid fuels. Results of ambient air quality monitoring in tenements D and E for SMM (2012) are in Table 12.2, which are below the project specific criteria adopted for that study (Table 12.1).

Table 12.2 Ambient air quality in tenements D and E

Parameter	Time period	Concentration
Particulate matter 10 micro metres or less in diameter (PM_{10})	24 hour peak	27.7 µg/m^3
	Annual average	25 µg/m^3
Particulate matter 2.5 micro metres or less in diameter ($PM_{2.5}$)	24 hour peak	10.1 µg/m^3
	Annual average	10 µg/m^3
Total suspended particulates 100 micro metres or less (TSP)	Annual average	69.2 µg/m^3

Climatic conditions which influence the transport of atmospheric pollutants in Solomon Islands are:

- diurnal variation in winds, with wind speeds increasing during the morning and peaking in the afternoon, and lighter winds or calm conditions at night;
- katabatic wind flow, with cool and dense air flowing off mountains at night leading to offshore winds up to 20 km/h in the early morning; and
- increased calm conditions between the two seasons.

12.2.3 Impact assessment

The following air quality impacts could occur during construction and operation of the project without effective mitigation measures:

- generation of dust (TSP, PM_{10} and $PM_{2.5}$) which could migrate from the project area to sensitive locations from:
    - ground disturbance during vegetation clearing;
    - removal of overburden and extraction of ore;
    - transportation of overburden and ore;
    - ore dumping, stockpile management and barge loading; and
    - wind blowing over dry exposed surfaces.
- generation of particulates from combustion of fossil fuels which could migrate from the project area to sensitive locations.

The previous assessment of a similar project in the nearby Santa Isabel Tenement E only predicted one exceedance of the dust deposition amenity criterion of 90 $\mu g/m^3$ in a village approximately 700 m from mining areas. This is a significantly closer than the distance from Talise, Kogarutu or Loghutu to the potential area of disturbance. Therefore, it is unlikely that if the base case port scenario is developed, any significant impacts will occur at Talise, Kogarutu or Loghutu. If the alternative case port scenario is developed, the owner of the site at Kogarutu will need to be compensated, and the site would be included in the mine development, therefore will not be considered as a sensitive receptor. No impacts are expected at other villages on the mainland due to their distance from the project area.

Initial modelling for the previous assessment predicted a number of exceedances of PM_{10} and $PM_{2.5}$ criteria at villages surrounding tenements D and E from handling of overburden and ore, and vehicle generated dust. Additional analysis determined that there was a low likelihood of exceedances due to the mitigating effect of the wet season, when generation of particulates is less likely to occur due to the moisture of the soil and ore profiles.

Given the above, impacts are unlikely during the wet season and will be minor at Talise, Kogarutu or Loghutu during the dry season. Impacts will be medium term as the proposed project duration is estimated to be five to ten years. Primary impacts will be minor dust deposition on plants and the ground surface in the local area during the dry season, which could be a minor stressor on affected ecosystems or plants. There will be no secondary impacts.

12.2.4 Mitigation measures

An air quality management plan will be prepared prior to project construction, which will be implemented during construction and operations and will contain the following dust and particulate management measures:

- reduce the amount of exposed soil to lessen dust generation from exposed surfaces;
- progressively rehabilitate and revegetate disturbed areas;
- restrict vehicle speeds on access and haul roads. Vehicle speeds will be further restricted when it is windy;
- limit vehicle movements to designated trafficable areas;
- spray unsealed road areas, short-term soil stockpiles and other exposed areas susceptible to wind erosion with freshwater to reduce dust generation if required;
- reduce drop heights when dumping material from excavators and loaders;
- reduce surface disturbance activities, excavation, dumping and stockpile management during dry or high wind conditions;
- appropriately service and maintain vehicles and equipment to reduce generation of particulates associated with combustion of fossil fuels; and
- switch off vehicles and equipment when not in use to reduce generation of particulates and greenhouse gases associated with combustion of fossil fuels.

12.2.5 Residual impacts

i Construction phase

The construction phase will involve some surface disturbance as the existing roads will need to be upgraded. Some clearing will be required at the MIA, which will involve surface disturbance and associated dust generation. Equipment and vehicles will be used during construction; therefore, particulates will be generated.

The management measures discussed in Section 12.2.4 will be implemented during construction and residual impacts will be minor.

ii Operations phase

Air quality impacts will be of greater concern during operations as overburden and ore are removed, transported, stockpiled and overburden placed into the mine voids and ore placed on barges. Implementation of management measures will reduce dust generation, however, some residual dust is expected to be generated.

iii Summary

The impacts of the construction phase and operations phase are likely to be similar; therefore they have been grouped for the consideration of the residual impacts.

The severity of impacts will be low, with minimal social, cultural and environmental impacts. Residual impacts will be low after implementation of management measures.

12.3 Noise

12.3.1 Assessment method

The assessment has been prepared with reference to the following standards and guidelines:

- ISO (International Standards Organisation), Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation, ISO9613-2:1996, 1996; and

- IFC (International Finance Corporation) 2007, *Environmental, health and safety (EHS) guidelines - Section 1.7 Noise*.

The following noise criteria for the project was established based on the IFC (2007) noise level guidelines, which recommend that noise levels at a sensitive location not exceed an increase of 3 dB over the ambient levels, or, that the following maximum noise levels not be exceeded:

- Residential, institutional and educational locations – 55 $dBA_{LAeq(1hr)}$ (Daytime - 07:00-22:00) and 45 $dBA_{LAeq(1hr)}$ (Night time - 22:00-07:00).

- Industrial and commercial locations – 70 $dBA_{LAeq(1hr)}$ (24hrs).

The criteria of 55 $dBA_{LAeq(1hr)}$ for daytime and 45 $dBA_{LAeq(1hr)}$ for night time were adopted for this assessment.

The acoustic assessment was completed using the noise prediction algorithm provided in ISO 9613-2:1996(E) *Acoustics -- Attenuation of sound during propagation outdoors -- Part 2: General method of calculation*. It is an engineering method for calculating the attenuation of outdoor sound propagation and has been used to predict environmental noise levels from the mine to nearest noise sensitive receivers. It predicts the equivalent continuous A-weighted sound pressure level under noise enhancing meteorological conditions from sources of known noise emission.

The model has considered factors such as:

- the location of the noise source;

- distance from the source to nearest potential receptor; and

- topography of the project site and surrounding area.

Noise modelling was based on the typical worst case scenario, this assumed:

- 24 hours/day, 7 days/week operations;
- all plant and equipment operating at the nearest point of the disturbance area of the San Jorge Nickel Project (ie the closest practical location to each noise-sensitive receiver);
- all mine equipment and plant operating concurrently;
- no barrier/shielding effects from the surrounding topography;
- no ground effects or air absorption; and
- downwind propagation to the receivers.

Potential noise levels from project operations were predicted using the noise modelling method discussed above. The A-weighted sound power level (L_w) for each of the operational plant and equipment items has been sourced from an EMM database of similar equipment. Two port options have been modelled; with a base port option at the north of the project site and an alternative port option to the east of the project site.

The primary plant and equipment on site and their corresponding sound power levels can be seen below in Table 12.3.

Table 12.3 Operational plant and equipment sound power levels

Plant and equipment	Quantity	Sound power level, $L_{Aeq1\ hour}$, dB
70t excavator	1	107
90t excavator	3	116
24t dump truck	12	105
40t articulated dump truck	10	108
Small water cart	1	96
Track dozer	3	119
Soil compactor	1	116
Front end loader	5	115
Motor grader	1	108
Lighting plant	10	107
Pit dewatering pump	3	111
Service truck	1	110
Light vehicle / 4WD	10	76
Mobile crusher	1	114

12.3.2 Existing environment

No baseline noise monitoring was undertaken at the San Jorge Tenement; however ambient noise was measured as part of studies on the Tenements D and E and at the Sumitomo site on Santa Isabel (SMM, 2012) which are considered to be representative of the San Jorge site.

The noise monitoring found that average daytime ambient noise levels were 34 dBA at both tenements, and average night time ambient noise levels were 39 dBA and 40 dBA at Tenements D and E respectively. Background noise mostly comprised natural sounds such as birds, insects, domestic animals and weather effects. There were short periods of noise from mechanical sources such as boats, helicopters and generators. Ambient noise was higher at night due to higher levels of insect noise.

12.3.3 Impact assessment

The modelling results have been predicted at three noise-sensitive receivers; the nearest dwelling within the Talise village and one location at each of the temporary settlements at Kogarutu and Loghutu. The noise modelling results are summarised in Table 12.4.

Table 12.4 Noise modelling results

Receiver	Port Option	Noise level, $L_{Aeq,1\ hour}$, dB	Criteria, $L_{Aeq,1\ hour}$, dB	Exceedance, dB
R1 - Talise (Nearest dwelling)	Base	31	$L_{Aeq,1\ hour}$ 55 dB (Daytime) $L_{Aeq,1\ hour}$ 45 dB (Night-time)	Nil
	Alternative	31		Nil
R2 - Kogarutu (Garden)	Base	37	$L_{Aeq,1\ hour}$ 55 dB (Daytime) $L_{Aeq,1\ hour}$ 45 dB (Night-time)	Nil
	Alternative	N/A[1]		Nil
R3 - Loghutu (Coconut plantation)	Base	35	$L_{Aeq,1\ hour}$ 55 dB (Daytime) $L_{Aeq,1\ hour}$ 45 dB (Night-time)	Nil
	Alternative	45		Nil

Notes: 1. Under the alternative port option, this location is part of the project area and would be removed as a noise-sensitive receiver.

For operation, under the base port option and the alternative port option there were no exceedances of the noise criteria at any of the sensitive receptor locations, therefore the project is compliant. Construction noise impacts are expected to be lower than operational impacts, and are therefore also expected to be compliant.

12.3.4 Management measures

As there are no exceedances predicted from the modelling, there is no need to prepare a noise management plan or to implement mitigation measures to reduce the noise. However, some of the mitigation measures for other impacts such as air quality may reduce the noise levels further.

12.3.5 Residual impacts

Noise impacts from the construction and operation of the project will be compliant with the noise criteria for daytime and night time periods at all sensitive receptors.

13 Socio-economics

13.1 Assessment objectives

This assessment aims to:

- characterise the social and economic conditions of communities potentially affected by the development of the project, being proposed by Axiom;
- identifies direct and indirect social and micro (local) economic impacts, and
- provides management measures to address key issues, enhance benefits and reduce impacts.

13.2 Assessment method

The socio-economic assessment was undertaken using two methods of data collection:

- desk study research; and
- baseline field studies and consultation in 2016 and 2017.

The desk study used data from the Solomon Islands Government, in particular from the Solomon Islands National Statistics Office (http://www.statistics.gov.sb/). In addition, baseline studies from the Sumitomo (SMM) EIS reports from 2012 and 2014 were also used to gather background information from southern Isabel Province.

The most detailed field studies undertaken on San Jorge, and more specifically, Talise, occurred in 2016 as part of the social assessment for the Kolosori project. These reports are currently unpublished. Given this data was collected recently, this study did not repeat that work. Consultation undertaken in September 2017 as part of the EIS process for San Jorge, visited Talise as part of a public consultation process as well as a number of settlements on Santa Isabel and two other settlements on San Jorge which are not permanently settled.

For the purposes of this assessment, the study area comprises the project area (the San Jorge Tenement) and surrounding villages whose residents use the project area, and are customary owners of the project area. These villages are shown on Figure 13.7.

Additional information has been used from Axiom's on-going consultation process (see Appendix H).

13.3 Existing socio-economic context

13.3.1 Country setting

The Solomon Islands has a complex history. Archaeological evidence suggests that the Solomon Islands have been inhabited since 10,000 BC, with Europeans first arriving in 1568. The first explorer was Spaniard Alvaro de Mendana, and believing that gold would be found in the islands, he named them the Solomon Islands after the legendary King Solomon's mines. It was not until the 19th century that interaction between the Solomon Islands and Europe intensified, as naval ships began to stop in the area and missionaries and traders arrived.

In 1893, the United Kingdom established a protectorate over the eastern group of islands, with Germany controlling most of the western islands. An Anglo-German Agreement signed in 1899 extended the UK protectorate to all nine island groups which now comprise Solomon Islands, while Buka and Bougainville became part of German New Guinea (later to be incorporated into Papua New Guinea). The Solomon Islands was granted internal self-government in 1976 and gained independence in 1978. It is a member of the Commonwealth and Queen Elizabeth II is the head of state, represented by a Governor-General.

13.3.2 Governance and society

The Solomon Islands has a unicameral national parliament comprising 50 members elected for a four-year term under a first-past-the-post voting system. The prime minister is elected by simple majority of members of parliament.

Provincial Governments were envisaged under the Solomon Islands Constitution and were established in law through the 1981 Provincial Government Act. The act also envisaged a third tier of government, allowing Provincial Assemblies to create Area Councils for local administration, however Area Councils were abolished in the late 1990s, resulting in a gap between Provincial Administration and the village level.

The Solomon Islands has experienced major security concerns in the past twenty years. In December 1998, existing ethnic tensions on Guadalcanal rapidly escalated. The tension was predominantly caused by resentment from Guadalcanal people of the influence of settlers from other islands and their occupation of undeveloped land in and around Honiara. The settlers were mostly from Malaita, and violent clashes resulted, destabilising the Solomon Islands and undermining national institutions. The tensions continued for a period of four years. In 2003, The Solomon Islands Prime Minister (Sir Allan Kemakeza) requested assistance from Pacific countries to address the violence. In response to this request, the Regional Assistance Mission to Solomon Islands (RAMSI) was established, with a view to creating the conditions necessary for a return to stability, peace and a growing economy. In 2013, RAMSI's military component was withdrawn, and in 2016, RAMSI is focussed on building the capacity of the Solomon Islands Police Force.

The three institutions of Solomon Islands life are traditional governance (kastom), the Church and the State. Kastom is a major part of life, including customary land tenure and traditional norms which influence gender relations, decision-making, property rights and division of labour. Respect is another over-riding influence on life in the Solomon Islands. The focus on respect helps to support the traditions and maintain a controlled conservative community in rural areas; however it can also lead to the stifling of dissent and differing views.

The Solomon Islands has both matrilineal and patrilineal societies. In a matrilineal society, rights of land and other clan assets are inherited from the mother, and equivalently in patrilineal societies, these rights are inherited through the father. Even within matrilineal societies, gender relations are considered to be heavily male-dominated. It is argued that male roles in traditional governance, ritual and warfare have been undermined by modern influences, resulting in more negative forms of masculinity, including binge drinking, sexual promiscuity and denigration of women, taking their place. Violence against women is one of the biggest challenges to development in the Solomon Islands, as it prevents women from contributing to and benefiting from the development process.

Female participation in leadership and decision-making at senior levels is considered to be low (women make up 40% of civil servants but mostly fill junior positions, with only 5% of senior public servant positions occupied by women). The Asian Development Bank's gender assessment went on to note that the key constraints for women to enter leadership positions include: low levels of education, high burden of family care responsibility, high levels of violence and underlying discriminatory attitudes.

At a national level, the voice of the youth is channelled through the Solomon Islands National Youth Congress (established by Government White Paper in 1980). The Congress reports through the Ministry of Women, Youth and Children Affairs, with the vision of encouraging young people to participate more fully in the nation’s development.

13.3.3 Demographics

Settlement in the area that now constitutes the Solomon Islands can be traced back to as early as 10,000 BC. Initial waves of immigrants came from Papua New Guinea, followed by Melanesian settlers arriving in approximately 4000 BC. Groups of Polynesian islanders began to arrive in the Solomon Islands from around 1500 AD, typically occupying smaller outlying islands which were relatively uninhabited. The declaration of the area as a British Protectorate in 1893 brought with it an increase in the number of Europeans. World War II marked a significant period in the history of the Solomon Islands, with almost all of the country captured by Japan. Chinese traders arrived in the 1950s and 1960s and a group of Gilbertese who were resettled from Kiribati arrived shortly afterwards. The 1990s brought with it the arrival of refugees from Bougainville, most of who were repatriated prior to 1999.

A lack of comparable census data makes it difficult to assess the growth of the population over time. It is considered likely that the population declined in the 19th century linked to the introduction of epidemics brought to the islands by European traders. Head-hunting practices which prevailed in the first half of the century are also likely to have suppressed population growth.

The nine island groups are mostly inhabited by Melanesians; however population groups of Polynesians dominate some outlying islands, such as Rennell and Bellona, Ontong Java (in Malaita) and Tikopia, Anuta and the Reef and Duff Islands in Temotu (see Figure 13.1). Honiara was established as the country’s administrative and commercial hub after World War II, triggering a large-scale influx into that area of Guadalcanal Island. Displacement caused by ethnic conflict during the 1990s and 2000’s (known as the “tensions”) resulted in a large movement of people from Honiara to Malaita (predominantly). In 2003, the countries of the Pacific region supported the formation of a regional assistance mission (RAMSI) to assist the Solomon Islands to address civil unrest and lawlessness, economic decline, corruption and a dramatic decline in service delivery and government administrative standards. The transition away from RAMSI began in 2013 and as of 2016 only the policing mission aspects remain.

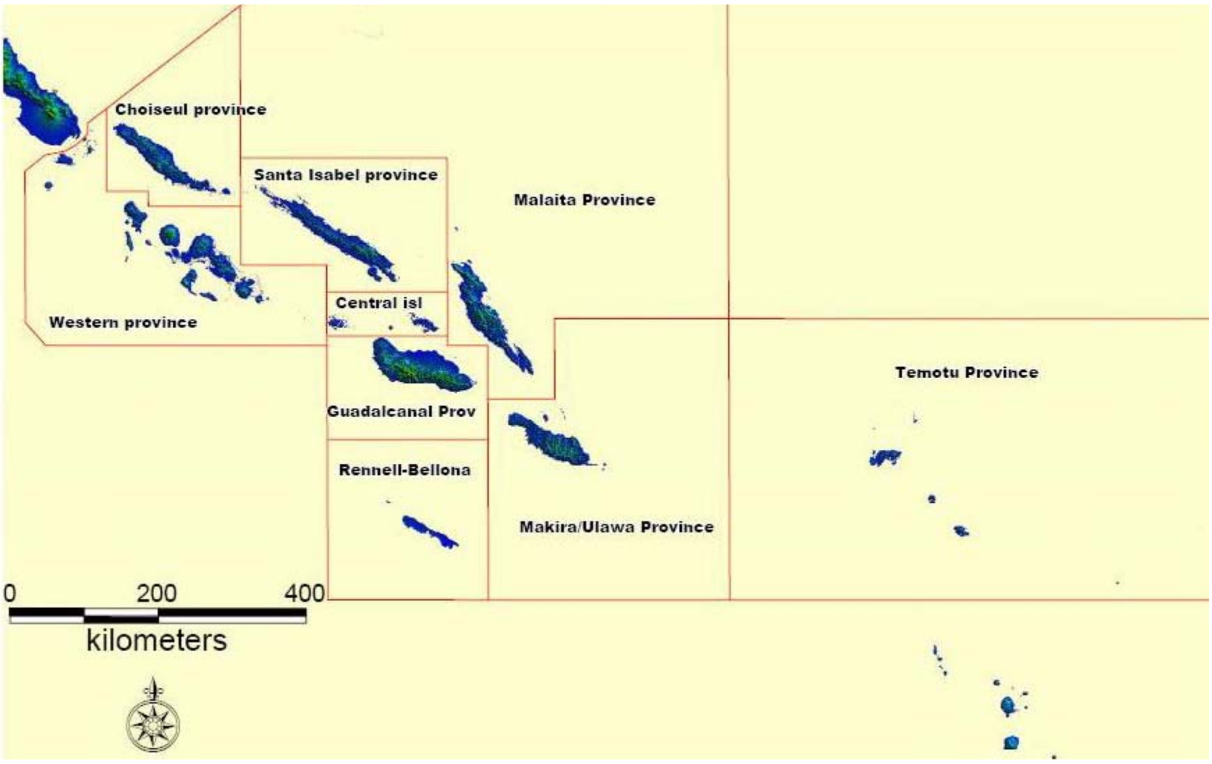


Figure 13.1 Solomon Islands provinces

The population of each of the provinces is indicated in Table 13.1. The 2009 census, which is still the most up to date information, generated a population estimate of 515,870, however it was noted that this included an under-count of approximately 8.3%, and as such, total population was more likely to be approximately 558,000 at that time. As a result of the under-count, all of the population statistics for the Solomon Islands taken from the 2009 survey are likely to under-represent the real population.

Forecast population growth is shown in Table 13.2. By 2017, the population of the Solomon Islands is forecast to be 653,248.

Table 13.1 Population Indicators Solomon Islands 2009

Indicator	Solomon Islands	Choiseul	Western	Isabel	Central	Rennell-Bellona	Guadalcanal	Malaita	Makira-Ulawa	Temotu	Honiara
Total population	515,870	26,372	76,649	26,158	26,051	3,041	93,613	137,596	40,149	21,362	64,609
Males	264,455	13,532	39,926	13,328	13,261	1,549	48,283	69,232	20,879	10,466	34,089
Females	251,415	12,840	36,723	12,830	12,790	1,492	45,330	68,364	19,630	10,896	30,520
Average annual population growth rate 1999-2009 (%)	2.3	2.8	2.0	2.5	1.9	2.5	4.4	1.2	2.6	1.2	2.7
Population density (# people/km2)	17	7	10	6	42	5	18	33	13	25	2,953

Source: http://www.statistics.gov.sb/statistics/social-statistics/population

Table 13.2 Projected population by province 2010 – 2025

Year	Choiseul	Western	Isabel	Central	Rennel	Guadalcanal	Malaita	Makira	Temotu	Honiara	Total
2010	28,480	82,187	28,150	27,852	3,274	103,059	146,143	43,627	22,679	70,002	555,453
2011	29,293	83,931	28,876	28,392	3,361	107,979	147,905	44,832	22,970	72,079	569,620
2012	30,106	85,650	29,597	28,912	3,449	112,988	149,573	46,020	23,250	74,168	583,714
2013	30918	87,344	30,311	29,415	3,539	118,078	151,152	47,190	23,520	76,260	597,726
2014	31,731	89,015	31,020	29,902	3,632	123,239	152,647	48,344	23,779	78,346	611,656
2015	32,548	90,673	31,728	30,375	3,726	128,479	154,079	49,489	24,032	80,424	625,554
2016	33,370	92,319	32,434	30,837	3,823	133,790	155,457	50,625	24,278	82,485	639,418
2017	34,197	93,953	**33,139**	31,289	3,923	139,164	156,787	51,755	24,520	84,522	**653,248**
2018	35,030	95,579	33,843	31,732	4,026	144,592	158,076	52,880	24,757	86,529	667,044
2019	35,869	97,197	34,548	32,168	4,131	150,067	159,333	54,001	24,991	88,501	680,806
2020	36,719	98,820	35,257	32,603	4,239	155,605	160,583	55,126	25,227	90,441	694,619

Table 13.2 Projected population by province 2010 – 2025

Year	Choiseul	Western	Isabel	Central	Rennel	Guadalcanal	Malaita	Makira	Temotu	Honiara	Total
2021	37,581	100,448	35,970	33,039	4,351	161,197	161,832	56,257	25,463	92,344	708,482
2022	38,453	102,083	36,688	33,476	4,465	166,838	163,085	57,396	25,701	94,206	722,392
2023	39,336	103,724	37,410	33,915	4,582	172,520	164,345	58,545	25,940	96,026	736,343
2024	40,227	105,367	38,135	34,358	4,701	178,237	165,613	59,705	26,180	97,802	750,325
2025	41,131	107,023	38,866	34,809	4,822	184,002	166,908	60,886	26,422	99,544	764,412

Source: http://www.statistics.gov.sb/statistics/social-statistics/population)

13.3.4 Livelihoods and employment

The following overview of the Solomon Islands' economy is from the following government publication: *Solomon Islands, Demographic and Health Survey 2015* (2017).

> Most Solomon Islanders depend predominantly on agriculture, fishing, and forestry for at least part of their livelihood. Because the country's economy is small and depends on imports, it is often vulnerable to external shocks such as the volatility in world commodity prices and extreme weather patterns. The islands are rich in undeveloped mineral resources such as lead, zinc, nickel and gold. During 1998 to 2003 the country experienced severe ethnic violence, resulting in the closure of key business enterprises, and an almost empty government treasury that led to serious economic disarray, and near collapse. Tanker deliveries of crucial fuel supplies have become sporadic due to the government's inability to pay for the fuel and due to attacks against ships. Telecommunications are threatened by the non-payment of bills and by the lack of technical and maintenance staff, many of whom have left the country. Post-tension stability has meant that many of these activities have recovered and are now in operation.
>
> A per capita gross domestic product of USD 1,612 ranks Solomon Islands as a lesser developed nation. Two-thirds of the country's labour force is engaged in the primary sector, which consists of subsistence crop and animal production, hunting and related service activities, and fishing. Until 1998, when world prices for tropical timber fell steeply, timber was Solomon Islands' main export product and, in recent years, Solomon Islands' forests were overexploited. Other important cash crops and exports include copra and palm oil. In 1998 Ross Mining of Australia began producing gold at Gold Ridge on Guadalcanal. Mineral exploration in other areas continued. However, in the wake of the ethnic violence in June 2000, exports of palm oil and gold ceased while timber exports fell. It was later in 2010 when Allied Gold Ltd took over the mine and started production. In 2012, St Barbara Limited acquired the operations from Allied Gold until 2014 when the mine ceased due to severe weather and flooding.
>
> With the economy growing at 2% (in 2014), prospects for sustaining growth remains a challenge. Exploitation of Solomon Islands' rich fisheries offers potential for further export and domestic economic expansion. However, a Japanese joint venture, Solomon Taiyo Ltd., which operated the only fish cannery in the country, closed in mid-2000 as a result of ethnic disturbances. The plant has reopened and is currently in full operation.
>
> Tourism, particularly diving, is an important industry for Solomon Islands. Growth in that industry is, however, hampered by a lack of infrastructure, transportation limitations and security concerns. Solomon Islands' economy was particularly affected by the Asian financial crisis that occurred before the ethnic violence and immediately after by the Global Financial Crisis, affecting exports particularly timber and other primary commodities. The government continues to progress timber harvesting policies with the aim of reforming the industry so that it is sustainable.
>
> The arrival of the Regional Assistance Mission to Solomon Islands (RAMSI) in mid-2003 and the reengagement of other donors provided Solomon Islands with an opportunity to rebuild and expand its struggling economy. The Solomon Islands government was seen as the driving force of any fundamental reforms for long-term change. Reforming the bureaucracy and inefficiencies of the past, and providing a stable environment for private business was an integral part of these reforms. Previous government domination of the small economy, both through state businesses and regulation, had hindered the development of a robust private sector.

> With stability returning, the government continues to progress structural reforms through fiscal policy reforms (e.g. the Pubic Finance and Audit Act of 2013) and the National Development Strategy to tackle a range of medium- to long-term challenges, especially in the areas of improving rural service delivery, alleviating poverty, improving health and education, and driving economic growth. The key longer-term challenge will continue to be in the area of land tenure. For Solomon Islands to prosper, the government must address this divisive and delicate issue. The size of Solomon Islands' market and the inherent difficulties and costs due to geography and relative isolation do not mean that Solomon Islands cannot be prosperous. Facilitating an open and flexible business-friendly economy will help Solomon Islands' economy grow and its businesses to compete in international markets.

Overall, the Solomon Islands is considered a lower middle income country, with a $1.202 billion USD GDP in 2016, when it grew 3% year on year. It is currently ranked joint 176th out of 196 countries by the World Bank (https://data.worldbank.org/data-catalog/GDP-ranking-table Index), placing it just above Guinea-Bissau. The GDP has been growing at an average of 3% in recent years (excluding a dip in 2014 due to flooding) and this trend is expected to continue.

It is estimated that 22.7% of the population were living below the poverty line in 2015. This ranks the Solomon Islands moderately better than Papua New Guinea (28%) and slightly worse than Tonga (22.5%) and Kiribati (21.8%). Although a relatively high percentage of Solomon Islanders aged twelve or over (63%) were considered economically active in the 2009 census, only 20% of these individuals received a regular paid income. Subsistence livelihoods, comprising fishing and gardening, were the main activity of 20% of males and 31% of females aged 12 or over. This statistic is strongly biased towards rural areas, with only 2% of the same age group in urban areas working at subsistence activities, compared to 32% in rural areas.

13.3.5 Land tenure

Under the Constitution of the Solomon Islands 1978, only "Solomon Islanders" may hold a perpetual interest in land. A Solomon Islander in this context is considered to be a person born in the Solomon Islands who has two grandparents who were members of a group, tribe or line indigenous to Solomon Islands. The Constitution recognises customary law as a general source of law which can evolve and develop.

The majority of land (87%) in the Solomon Islands is customarily held. Land is owned by tribes and passed down through lineage. Both matrilineal and patrilineal societies exist across the Solomon Islands. Only a small percentage of customary land has been registered (12% in 2002), and where registration has taken place it is normally achieved through the Land and Titles Act 1996. Registration of land under this Act can provide for group ownership of land, through appointment of a maximum of five trustees. As part of the land registration process, a genealogical assessment of the proposed claim area is undertaken, as per the Land and Titles Act 1996.

Where disputes over land ownership occur, they must be submitted to the local chiefs for adjudication before the matter can be referred to the courts. Local courts assess the dispute on the basis of customary law relevant to their location. A decision made by a local court can be appealed to the Customary Land Appeal Court (CLAC), whose members are appointed by the Chief Justice and which also applies customary law. A right of further appeal to the High Court exists in situations where state law or procedure is at question, but not for matters of customary law.

13.3.6 Education

The Ministry of Education and Human Resource Development (MEHRD) oversees, leads and develops educational services in the Solomon Islands. Education services themselves are delivered through 31 Education Authorities (EAs), ten of which are provincial or city council EAs. The remainder are independent, private or faith-based, although some are very small, consisting of only one or two schools. The vast majority of children attend provincial or city council schools (73.6% primary and 69.6% secondary).

Children start primary school at age six, which extends for six years. This is followed by three years of junior secondary and three years of senior secondary school. Primary and junior secondary combined are considered to make up basic education. MEHRD monitor five categories of school (Table 13.3):

- Early childhood centres (ECCs) – Also known as kindergartens, ECCs tend to be village based;
- Primary schools (PS) – Formal education commences at primary school. The purpose of primary education is to introduce children to the skills needed for writing, reading, mathematics, community studies, science, agriculture, art, music, physical education and religion;
- National secondary schools (NSS) – The schools are the original high schools operated by the Government and by Churches, with student enrolments coming from across the country;
- Provincial secondary schools (PSS) – These schools were initiated by the Government but are run by the Provinces, drawing students from the province only; and
- Community high schools (CHS) – These schools started as primary schools and the secondary sections were added to them. They are typically built and managed by communities and assisted by the Church or Provincial Education Authorities.

Table 13.3 Number of Schools by Type, 2007

School Type	Number of Schools in 2007
Early Childhood Centres	526
Primary Schools	515
Community High Schools	154
Provincial Secondary Schools	16
National Secondary Schools	8
Total	1219

Note: MEHRD (2008) Solomon Islands Digest of Education Statistics www.spc.int (accessed 22 February 2016)

Eighty-four percent (84%) of children aged between 6-15 years were enrolled in schools in 2009, with female enrolment rates (83.9%) slightly higher than male enrolment rates (83.2%). School enrolment rates decline rapidly after 13 years of age, with approximately 20% of 15 year olds not attending school. Typically enrolment rates are higher in urban areas compared to rural areas.

The 2009 census collected data on the highest education level attained indicates that 56% of the population 15 years or older had only a primary level of education, with 21% of males and 16% of females completing secondary education. Six percent (6%) of males and 3% of females had tertiary level education. Eleven percent (11%) of males and 21% of females had either never been to school or only attended pre-school. Figure 13.2 illustrates the comparative level of school attendance across provinces.

The Solomon Islands has over 80 indigenous languages. In addition to indigenous languages, English and Pidgin are also spoken. The 2009 census indicated that 69% of the population aged 5 years or older were proficient in English, followed by Pidgin (67%) and local languages (66%). At a national level, amongst people aged 15 years or older, 84% were considered to be literate (88.9% males and 79.2% females). Higher literacy levels are recorded in urban areas (94% for people above 15 years of age) compared to rural areas (81%). Literacy rates also decline with age: 90% of the population aged 10-34 is literate, compared to 80% of population aged 45-49, and 60% of population aged 70 or above.

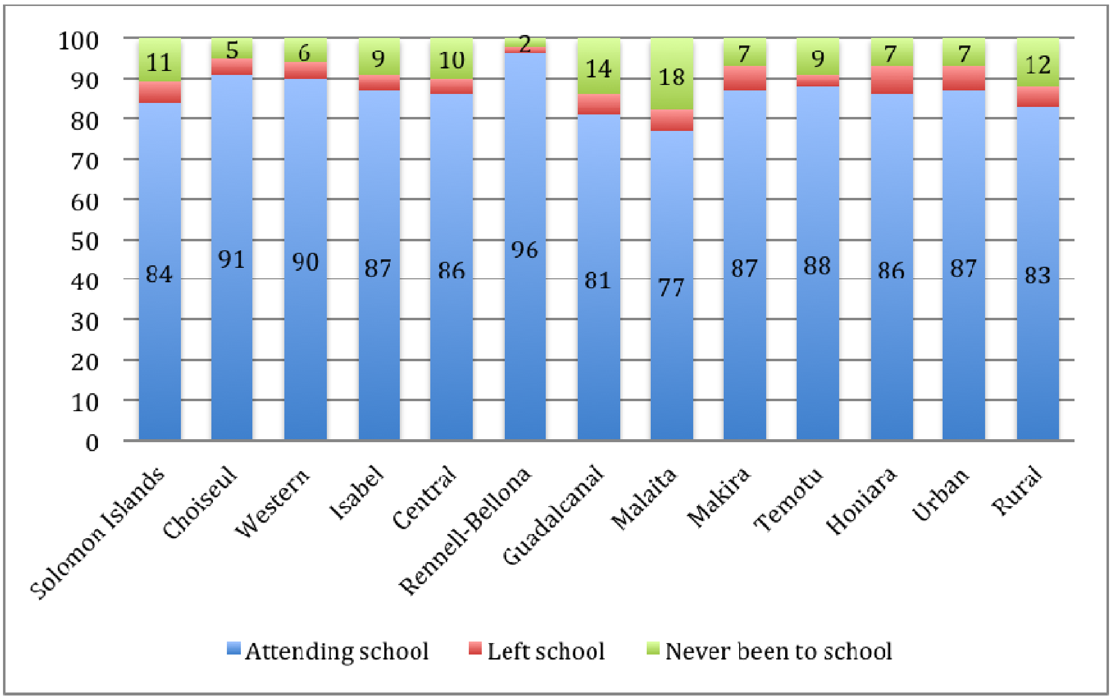


Figure 13.2 Percentage of Children Aged 6-15 Attending School Across Provinces, 2009

13.3.7 Community health

Health care delivery is made complex in the Solomon Islands by the geographically dispersed predominantly rural (80%) population. This complexity is amplified by the "epidemiological transition" which is occurring in the Solomon Islands requiring it to control the level of infectious diseases while also managing an increasing incidence of non-communicable diseases, with limited resources.

Life expectancy in the Solomon Islands was estimated in 2012 to be 66 and 69 for males and females respectively. The total fertility rate (TFR) estimates the average number of births per woman. The TFR reduced from 5.0 in 1999 to 4.7 in 2009 and a marked difference was seen between the TFR in rural areas (4.8) and in urban areas (3.6). The median age of first birth for women aged 25-29 years is 21.6 years of age, linked to a median age of first marriage for women of 20.6 years for women in the same age group.

The maternal mortality ratio has fluctuated between 100 and 150 deaths per 100,000 live births between 1990 and 2012, although the general trend is seen to be decreasing. The infant mortality rate (IMR) was reported to be approximately 24 infant deaths per 1000 in the 2007 DHS, although caution was expressed about the validity of this figure. It is estimated that over 90% of expectant mothers receive at least one antenatal care visit and in 2013, 90% of births were reported as being attended by skilled health personnel.

Table 13.4 Mortality and health indicators, selected years 1980-2012

Indicator	1980	1990	2000	2009	2010	2011	2012
Life expectancy at birth, total (years)	59	67	69	71	67	67	68
Life expectancy at birth, male (years)	58	65	67	69	66	66	66
Life expectancy at birth, female (years)	60	69	71	72	68	69	69
Total mortality rate, adult male (per 1000 adult males)	-	250	205	206	202	197	-
Total mortality rate, female (per 1000 adult females)	-	188	151	166	161	157	-

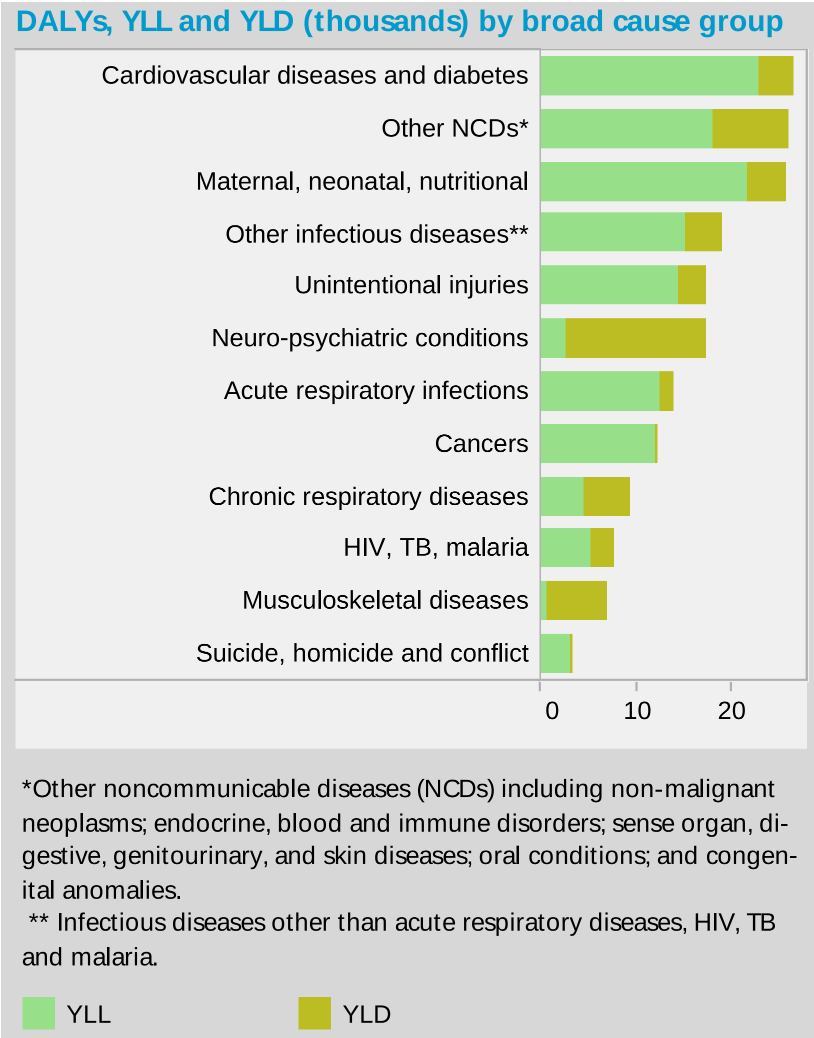
Note: Hodge, N, Slayter, B & Skiller, L 2015, Solomon Islands Health System Review, prepared by Asia Pacific Observatory on Health Systems and Policies.

Table 13.5 Cause of death

Cause of Death	Number of deaths (000s) in 2012
Stroke	0.3 (9.3%)
Diabetes mellitus	0.2 (8.3%)
Lower respiratory infections	0.2 (8%)
Ischaemic heart disease	0.2 (6.3%)
Diarrhoeal diseases	0.1 (3.7%)
Road injury	0.1 (2.8%)
Asthma	0.2 (2.7%)
Tuberculosis	0.1 (2.7%)
Preterm birth complications	0.1 (2.5%)

Source: WHO (2015) Solomon Islands: WHO statistical profile, www.who.int (accessed 3 February 2016).

In order to understand the health profile of a country, it is necessary to understand the burden of disease, summarised in terms of disability-adjusted life years (DALYs) which are the sum of years of life lost due to premature mortality (YLL) and years of healthy life lost due to disability (YLD). Figure 13.3 clearly illustrates the transition being experienced in the Solomon Islands, with health burdens created by both infectious and non-communicable diseases. In 2012, the WHO estimated that 51% of years of life lost could be attributed to the broad cause of communicable disease with 41% being attributable to non-communicable diseases and the remainder (8%) to injuries. Between 2005-2006, the WHO conducted a survey to better understand the risk factors for non-communicable disease in the Solomon Islands, and discovered that 31% of the population reported daily smoking, 94% reported consuming less than five combined servings of fruit and vegetables per day, and more than 25% of the male population reported consuming five or more alcohol beverages per day within the previous week.



Source: WHO (2015) Solomon Islands: WHO statistical profile, www.who.int (accessed 3 February 2016)

Figure 13.3 DALYs for Solomon Islands 2012

The 2007 Demographic and Health Survey (DHS) indicated that approximately 77% of 12-23 month old children were fully vaccinated.

The Solomon Islands has an HIV prevalence of approximately 0.004%, corresponding to 22 known HIV positive cases in 2013. Eight people have died of AIDS-related causes. These figures are expected to under-report the number of cases, as less than 0.3% of Solomon Islanders know their HIV status and the cases which have been recorded have typically been symptomatic at the time of diagnosis. Access to HIV testing services is low (9 testing centres across the country with three located in Honiara). While the HIV prevalence is very low, the level of sexually transmitted infections is considered to be high. In 2013, 11% of pregnant women were tested for HIV and 39% were tested for syphilis, and among those women, 14% tested positive for syphilis, while none tested positive for HIV.

The Ministry of Health and Medical Services (MHMS) is the central actor in the Solomon Islands heath system. NGOs and faith-based service providers also play a role (albeit small) and the private sector has very little role in health service delivery. Five different levels of care are offered in the Solomon Islands:

- Level 1: nurse aide post – Usually located in remote areas and staffed by local nurses providing: basic first aid care including treatment of mild ailments and injuries; immunizations and stabilisation of patients until transport is available. Some nurse aides also conduct deliveries;

- Level 2: rural health clinic (RHC) – Play a supervisory role to multiple nurse aide posts. Usually staffed by a registered nurse and a nurse aide;

- Level 3: area health centre (AHC) – Both inpatient and outpatient care is offered at an AHC; however inpatient care is often limited by bed availability. AHC's provide specific birthing facilities. Usually staffed by at least two registered nurses and one or two nursing aides;

- Level 4: provincial hospital – Provide the highest standard of care logistically available outside of Honiara; and

- Level 5: national referral hospital (NRH) – Based in Honiara is the highest level of care available in the Solomon Islands.

The Government of the Solomon Islands spends approximately 8% of GDP on health.

The Solomon Islands ranks highly amongst the countries most affected by malaria in the Asia-Pacific region. Recent improvements at a national level have seen the annual parasite incidence (API) rate decrease from 131/1000 in 2007 to 77/1000 in 2009. Reductions in the API have been particularly successful in Isabel and Temotu Provinces, with Isabel achieving a reduction from 64.1/1000 in 2003 to 2.6/1000 in 2009. This success has been achieved through a combination of treated nets, indoor insecticide sprays, rapid diagnosis and appropriate treatment and widespread community engagement. With this low level of malaria now achieved in Isabel Province, it now needs to "hold the line" (maintain or further reduce this level) and prevent the introduction of malaria cases from surrounding areas.

13.3.8 Houses and accommodation

The majority of households (74%) reside in owner-occupier dwellings, and the majority of households (75%) live on land classified as "freehold". In the rural areas, most households live on customary land owned by tribes. Across the Solomon Islands, the average household size is 5.5 people, although this varies between 7.0 in Honiara and 4.4 in Rennell-Bellona.

The 2009 census also assessed the type of building lived in by households. Seven types of building were identified:

- one family house detached from any other house;

- one family house attached to one or more houses;

- building with two or more apartments;

- building with 2 or more households which share a kitchen/toilet;

- lodging house;

- dwelling attached to a shop or other non-residential building; and
- other.

The overwhelming majority (92%) of households in the Solomon Islands reported living in a one family house detached from any other house. Materials used for house construction vary across the country, with wood and traditional materials dominating.

The Solomon Islands lags behind other Pacific nations in relation to rural water access. It is estimated that between 35-40% of rural communities have easy access to potable water, and only 20% have access to sanitation. Most people in rural areas practice open defecation.

In 2009, the main source of energy for lighting was the kerosene lamp (used by 75% of all households). While statistics are not available at a national level, large changes have occurred in the electrification field since 2009, with significant investments being made by the Solomon Islands Government and others in small-scale solar panels.

The main source of energy for cooking was reported to be wood/coconut shells.

13.4 Isabel Province and the San Jorge Study Area

13.4.1 Governance and society

i Isabel Province

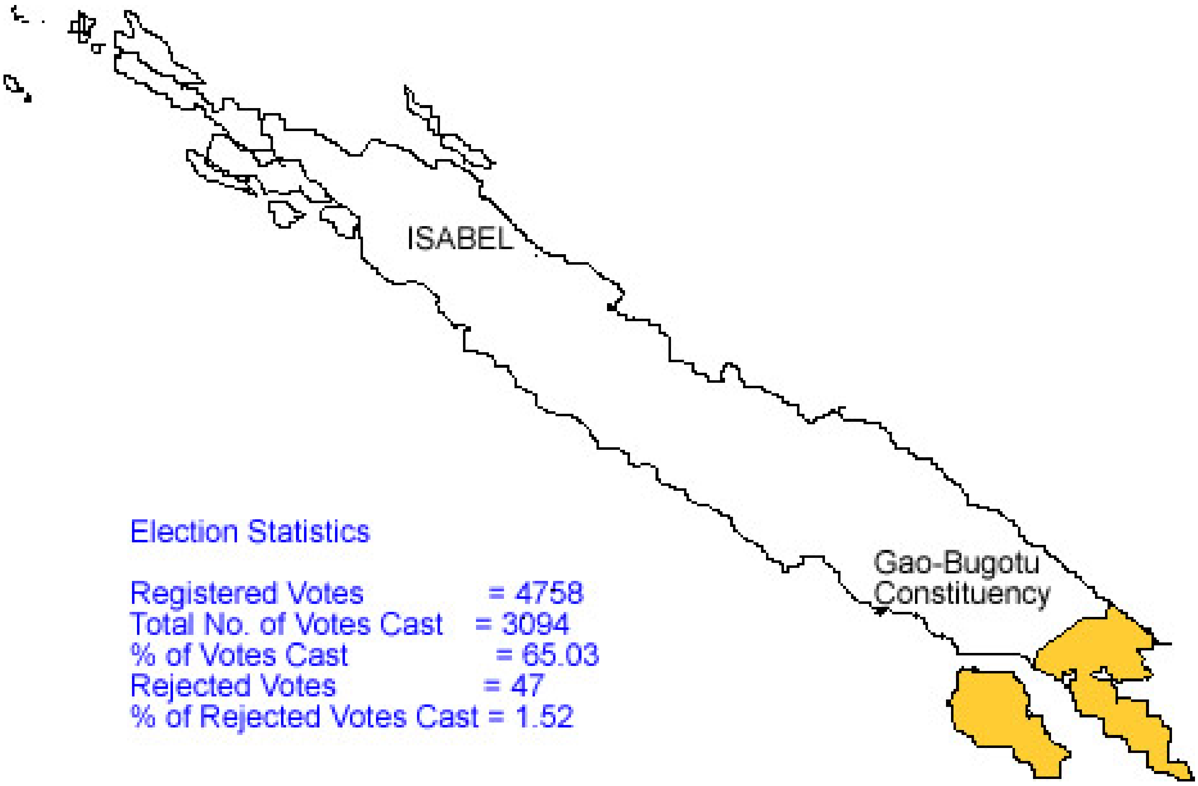
Formally, Isabel Province is governed by the Provincial Government, which is the administrative arm of the National Government. However, Isabel Province is well-known for its tri-partite (or tripod) approach to governance integrating the Provincial Government; the Isabel Council of Chiefs and the Church of Melanesia.

- Provincial Government – Isabel Province comprises three constituencies; Gao-Bugotu; Maringe-Kokota; and Hograno-Kia-Havelei. Each constituency has one parliamentary representative who sits in the National Parliament for a period of up to four years.
- Isabel Council of Chiefs – The Isabel Provincial Assembly passed a resolution in 1984 creating the Isabel Council of Chiefs as an advisory body. Each district (Gao, Bugotu, Maringe, Katova, Kokota, Hograno, Kia and Havulei) has a House of Chiefs, and each of the district level House of Chiefs select two members to sit on the Council of Chiefs which is led by the Paramount Chief. The role of Paramount Chief is understood to have existed in various forms for over 100 years.

  In 2003, the UNDP launched a project in Santa Isabel aimed at strengthening the level of local and provincial government (the Isabel Province Development Project (IPDP)) which was driven in part to support efforts of traditional leadership in Isabel. As described by the inaugural Paramount Chief (the late Dudley Tuti) the key issues managed by the Council of Chiefs include: promoting unity; taking care of land and custom; organising feasts and celebrations and promoting the work of the church and government.
- Church – The Anglican Church of Melanesia is the dominant church of Isabel Province (followed by 96% of population).

The tripod integrates all three institutions represented by the Provincial Premier, Paramount Chief and the Diocesan Bishop respectively.

The San Jorge study area is located in the southern end of Isabel Province, in the Gao-Bugotu Constituency (Figure 13.4). The study area is primarily located in Japuana ward, with a population of 2,163 according to the 2009 census.



Source: http://www.parliament.gov.sb/index.php?q=node/2680

Figure 13.4 The location of the Gao-Bugotu Constituency, Isabel Province

ii San Jorge and southern Isabel Province

In addition to the structures described above, villages have two further layers of governance: village chiefs and tribal chiefs. Isabel Province comprises three tribes: Vihuvunaghi, Posamogho and Thanokama. Most villages have members of all three tribes, and land is owned at a tribal level. The tribal leader inherits decision-making powers due to being born into a land owner lineage. The role is for life and is generally (although not always) held by men.

Village chiefs are appointed (in general) through a majority vote process and are usually selected on the basis of leadership skills and personal characteristics. Village chiefs can be male or female; however most the villages had male chiefs during the time of baseline data collection in 2016.

Within the villages in the study area it is common for there to be two Village Chiefs and three Tribal Chiefs per village. According to a Chiefs Leadership Development Program held in Buala in 2013, the role of a chief in society is:

- "to maintain public tranquillity and law and order in society;
- to prevent and combat crime; and
- to provide assistance and service functions to the public".

Village Chiefs play an important role in law and order. They counsel people informally while also mediating and hearing minor crimes and civil matters. Village chiefs will liaise with police (located in Buala) for advice on criminal and civil matters. A code of penalty and compensation has been developed for Village Chiefs to help ensure consistency of punishment across Isabel Province.

Village Chiefs can sit on Local Courts. Local Courts have unlimited jurisdiction on customary matters such as bride price disputes and customary land cases. In civil matters, local courts have powers to hear cases up to $1000 Solomon Dollars in value. Local courts have maximum sentencing powers of 6 months imprisonment or a $200 Solomon Dollar fine.

No formal youth groups were identified during the social baseline studies in 2016. In the event that the youth want to influence decision-making in the village, they, like women, present their views to the village chief and elders. Given the importance of respect in society across the Solomon Islands, if an initiative is not immediately picked up by village leaders it will only normally be raised once or twice, before being dropped.

13.4.2 Demographics

In 2009, the population of Isabel Province was 26,158. Table 13.2 shows the predicted growth in populations across the Solomon Islands since the last census in 2009. According to this, the population of Isabel Province has increased to 33,139 in 2017.

As is evident from Table 13.1 and Table 13.2, Isabel Province is one of the smaller provinces, by population, in the Solomon Islands. With Isabel Provence's current population, it has a low population density of 6 people/km^2 compared to the national average of 17 people/km^2, with 96.3% of it considered rural.

Isabel Province is divided into wards, as illustrated in Figure 13.5. Buala is the capital of Isabel Province and is the only urban area recorded in the Province (ward population of 2,813 with an urban population of 971).

Ward populations across Isabel Province are detailed in Table 13.7.

Table 13.6 Population in five-year age groups: 1 Jul 2017

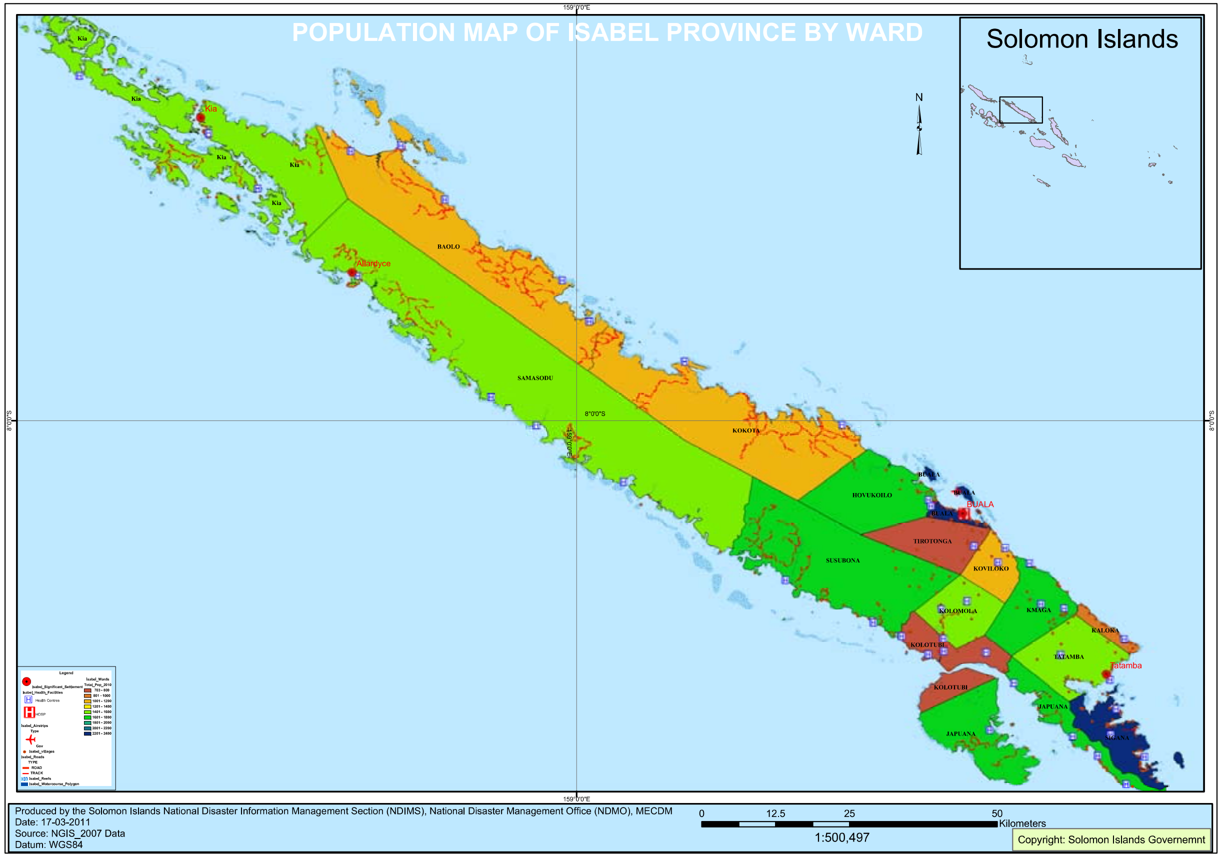
Age	Absolute Numbers		
	Males	Females	Total
0	2,092	1,955	4,047
5	2,069	1,952	4,021
10	2,044	1,951	3,995
15	1,821	1,702	3,523
20	1,487	1,340	2,827
25	1,193	1,172	2,365
30	979	1,115	2,094
35	1,016	1,039	2,055
40	996	982	1,977
45	809	764	1,573
50	569	566	1,136
55	497	509	1,006
60	413	398	811
65	338	305	643
70	229	226	455
75	144	166	310
80+	131	169	300
Total	16,827	16,312	33,139

Source: http://www.statistics.gov.sb/statistics/social-statistics/population

Table 13.7 Isabel Province Ward Populations (2009)

Ward	Kia	Baolo	Kokota	Hovikoilo	Buala	Tirotongana	Koviloko	Kmaga	Kaloka	Tatamba	Sigana	Japuana	Kolomola	Kolotubi	Susubona	Samasodu
Population	1929	1148	1177	1988	2813	683	1240	1862	959	1404	2397	2163	949	1671	1907	1868

Notes: *SINSO (2009) Population and Housing Census, Volume 1.*



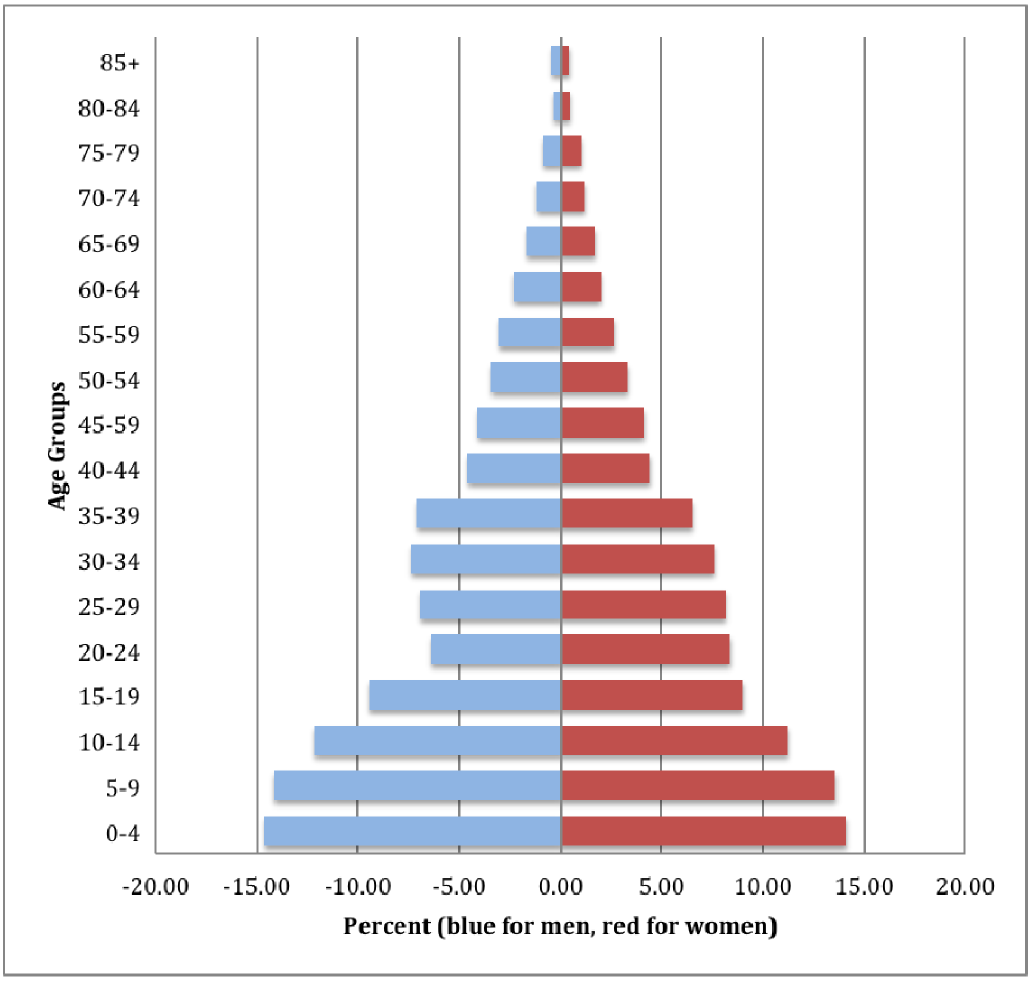
Source: *http://reliefweb.int/map/solomon-islands/solomon-islands-population-map-isabel-province-ward-17-mar-2011*

Figure 13.5 Population Map of Isabel Province by ward

Isabel's population is reported to be 99% Melanesian and 1% Polynesian. Forty percent (40%) of the population is aged 14 years or younger. Figure 13.6 demonstrates the population pyramid for Isabel Province, indicating a typical developing country demographic with a large youth population and small aged population. It is also evident that there is a narrowing of population between the ages 20-34, especially men, indicative of a population loss to urban centres in this age range.

The dependency ratio is the number of non-working aged people (0-14 years and > 59 years) who are supported by those within the working age range (15-59 years of age). According to the 2009 census, Isabel Province has a dependency ratio of 88, which is slightly higher than the national average of 85. This means that for every 100 people of working age, 88 people are in the dependent age category, with the majority being children. The sex ratio (proportion of males to females) is 105 across the Solomon Islands, and 104 in Isabel Province. The sex ratio data presented in the 2009 census should be applied with some caution, as the 2012/13 Household expenditure and income survey generated a significantly different result for Isabel Province (113 on Isabel Province compared to a national average of 106).

Average life expectancy at birth across the Solomon Islands is 66.2 for men and 73.1 for women. On Isabel Province, life expectancy is slightly lower at 65.7 for men and 72.5 for women.



SINSO (2009) Population and Housing Census, Volume 1

Figure 13.6 Population Pyramid, Isabel Province (2009)

Talise is the only settlement on San Jorge which is close to the proposed mine. The nearest potential active mining area is just over 3.5 km from the village. Talise has a population of around 500 people and is currently experiencing rapid growth.

Villages in this area, speak either one of two indigenous languages: Bugotu and Chekeholo, as well as English and Pidgin to varying extents. Many of the villages who identify as speaking one language are equally fluent in the other. In Talise, Chekeholo is the most commonly spoken language.

There has been a high level of mobility of population across the study area. There have been a number of drivers for population movement within the study area (and more broadly), including:

- Movement away from the coast to the highland areas during the headhunting period (19th Century);
- Movement from the highland areas to the coast during the establishment of the British Protectorate (early 20th Century);
- Movement from remote small villages to larger population groupings due to the construction of a church;
- Movement to areas of flat-land identified as potential cattle-grazing zones by the Solomon Islands Government in the 1950s; and
- Movement to areas with more accessible garden land linked to population growth.

Talise has been occupied for around 70 years. The people in Talise previous came from Piregha. People from Piregha moved to Talise and Leleghia due to a shortage of land in Piregha. Talise was established after a church was constructed there.

13.4.3 Livelihoods and employment

Isabel Province supported the second highest number of logging operations in the Solomon Islands, with approximately 32,000 ha logged (as at 2012) out of a possible logging area of 71,600 ha. In 2008 alone, it is estimated that SBD$23 million was paid to land owners on Isabel Province as a royalty for logging activities. In 2012, it was estimated that logging contributed approximately 60% of the provincial budget.

On average, wages/salaries are the primary household income for 24% of the population of Solomon Islands. This figure is lower in Isabel Province (18%), however the proportion of households receiving remittances is higher (31% in Isabel compared to a national average of 22%). For 56% of the population of Isabel Province, the main source of household income was from the sale of fish, crops or handicrafts. The following statistics were reported in the 2009 census about Isabel Province:

- only 4% of households were not involved in growing any crops;
- 65% of households grew crops for the purpose of their own consumption as well as sale;
- 31% grew crops solely for the purpose of consumption;
- less than 1% of households grew crops solely for the purpose of sale;
- over 72% of all households in Isabel raised livestock (41% pigs and 61% raised poultry);

- 81% of households were engaged in fishing activities: 29% for their own consumption and 52% fished for personal consumption and sale of their catch; and
- less than 1% of households fished for the sole purpose of selling their catch.

The detailed household income and expenditure survey conducted in 2012/13 provides a breakdown of income distribution taking into account subsistence income (see Table 13.8). It highlights some clear differences between the income structure of Isabel Province compared to urbanised Honiara as well as rural Choiseul. Notably, Isabel has a significantly smaller proportion of business income (13.8% compared to 38.4% in Choiseul) and a much higher proportion of home production is consumed (28.7% in Isabel, compared to 0.8% in Honiara and 12.1% in Choiseul). Finally, it is also clear that Isabel benefits from a considerably higher level of royalties than other provinces. Unfortunately, the nature of these royalties was not defined in the 2012/13 HIES, however, it is expected that they are linked to logging activities.

Table 13.8 Percentage (%) distribution of income by sub-category in provinces

Main/sub-category of income	Solomon Islands	Choiseul	Isabel	Honiara
Wages & Salaries	21.1	12.4	17.5	36.0
Public	9.1	6.3	8.7	14.0
Private	11.0	5.6	7.7	21.0
Other (NGO etc)	1.0	0.6	1.0	1.0
Wages & salaries (income in-kind)	2.7	1.1	0.04	5.8
Business income (non-subsistence)	21.5	39.4	13.8	31.1
Subsistence incomes (market oriented)				
Agriculture activities	6.3	4.9	6.0	0.6
Fishing activities	1.9	1.7	1.4	0.4
Livestock activities	2.4	2.1	2.7	0.4
Handicraft activities	2.0	1.3	0.6	1.6
Home production consumed	19.1	12.1	28.7	0.8
Total employment income	77.0	75.1	70.7	76.7
Home rental	1.3	0.4	1.6	3.7
Royalties	1.4	2.0	9.0	0.2
Other property income	1.2	0.8	0.03	3.9
Total property income	3.9	3.2	10.7	7.8
Remittances from Solomon	0.7	1.6	1.9	0.2
Remittances from overseas	0.2	0.4	0.01	0.2
Pension	0.4	0.3	0.01	1.1
Other transfer or benefit	0.0	0.1	0.02	0.0
Total regular transfers income	1.3	2.4	2.0	1.6
Irregular cash income	1.1	1.8	0.4	1.1
Bought items received	1.0	0.9	0.8	0.6
Home produced item received	0.8	0.9	1.2	0.01
Total casual income	2.9	3.7	2.5	1.8
Total income (excl. imputed rents)	85.1	84.4	85.8	87.9
Imputed rents	14.9	15.6	14.2	12.1
TOTAL INCOME	**100**	**100**	**100**	**100**

Note: SINSO (2013) Solomon Islands 2012/13 – Household income and expenditure survey – National Analytical Report (Volume 1).

The 2012/13 HIES also provided a breakdown of the types of goods consumed as part of home production (which comprised close to 29% of income in Isabel). Table 13.9 demonstrates that the goods produced and consumed in Isabel are very similar to those produced in other provinces; however the reliance upon them for consumption is much greater.

Table 13.9 Percentage (%) distribution of home production by selected goods by province

	Solomon Islands	Choiseul	Isabel	Honiara
Meat	2.8%	1.3%	2.9%	2.5%
Fish	13.2%	18.1%	16.0%	3.9%
Seafood	6.0%	3.8%	9.7%	2.3%
Fruit	16.0%	16.9%	12.6%	21.5%
Vegetables	10.7%	9.9%	9.3%	11.9%
Tuber	46.4%	45.9%	43.6%	54.3%
Other	4.9%	4.1%	6.0%	3.6%
Total	100%	100%	100%	100%

Note: SINSO (2013) Solomon Islands 2012/13 – Household income and expenditure survey – National Analytical Report (Volume 1).

Table 13.10 summarises data collected though the 2012/13 HIES related to expenditure patterns in Isabel Province. Food and non-alcoholic beverages comprise nearly 50% of total expenditure, of which 65% was from home production. It is clear that expenditure is almost completely related to consumption items (93%), as compared to non-consumption items and investments.

Table 13.10 Annual Expenditure Distribution by Category and Type, Isabel Province

Main Expenditure Category	Cash (%)	Home production (%)	Imputed Rents (%)	Total (%)
Consumption Expenditure				
Food and non-alcoholic beverages	17	32	0	49
Alcoholic beverages, tobacco and illicit substances	6	2	0	8
Clothing and footwear	2	0	0	2
Housing and utilities	4	0	14	18
Furnishings, equipment & maintenance	3	0	0	3
Health	0	0	0	0
Transportation	8	0	0	8
Communication	1	0	0	1
Recreation & culture	1	0	0	1
Education	1	0	0	1
Restaurants & Hotels	0	0	0	0
Misc. goods & services	1	0	0	1
Total consumption expenditure	44%	34%	14%	93%

Table 13.10 Annual Expenditure Distribution by Category and Type, Isabel Province

Main Expenditure Category	Cash (%)	Home production (%)	Imputed Rents (%)	Total (%)
Non-consumption expenditure				
Ceremonies	1	0	0	1
Cash donations to households	1	0	0	1
Cash donations to church	1	0	0	1
Cash donations to village	0	0	0	0
Taxes and fines	0	0	0	0
Cash donations to associations	0	0	0	0
Other charitable	0	0	0	0
Total non-consumption expenditure	4%	0%	0%	4%
Investment expenditure				
Purchase of land or house	0	0	0	0
House construction	2	0	0	2
Major improvements to house	0	0	0	0
Plant or equipment	1	0	0	1
Mortgage payment	0	0	0	0
Total investment expenditure	4%	0%	0%	4%
TOTAL	52%	34%	14%	100%

The villages within the San Jorge Study Area predominantly undertake subsistence livelihood activities. These activities include:

- gardening and plantation crops;
- fishing;
- hunting (for special occasions only and not in all villages); and
- community projects.

Gardening activities are typically undertaken by women, although men may play a larger role in the development of plantation crops. Fishing activities involving a boat are predominantly undertaken by men; however, collection of shoreline seafood (mud crabs etc) is undertaken by women.

Few differences in gardening and fishing activities were noticed across the villages. In general, the villages reported growing the following resources:

- kumara (sweet potato);
- cassava;
- cabbage;
- yam;
- coconuts;

- kakake (swamp taro);
- sago palm;
- sugarcane;
- bananas;
- pineapples;
- melons;
- peanuts;
- betel nut;
- tomatoes;
- capsicum; and
- lettuce.

Gardens are tended every day on average (typically in the morning). Talise village has recently been working with a non-government organisation (Kastom Garden Association) to improve the diversity of their gardens. The program has introduced new seeds and a workshop on how to build resistance and diversity within a “kastom garden”.

Fishing is predominantly undertaken by wooden canoe and, where available, by motorised boat. The frequency of fishing varies across the area.

Some of the villages reported small level hunting activities. Hunting does not appear to be a regular activity and is linked to special occasions. Hunting activities are understood to primarily target wild pigs and birds.

Community projects are typically defined by the Village Chief or Elders and require the contribution of all villagers. They may include road clearing, rehabilitation of community facilities, construction of new facilities etc. The amount of time dedicated to community projects varies across villages; however it can be as high as two mornings per week.

In addition to the subsistence activities described above, some of the villages also undertake commercial activities, including:

- Sale of garden products;
- Community logging;
- Commercial logging; and
- Sale of fish and seafood.

Historically, there has been a limited market for the sale of garden produce in the study area due to a combination of factors: most households were growing the same items, minimising demand; and few households had access to cash to purchase items. The development of the Axiom and Sumitomo exploration camps has generated a new demand for garden produce, with villages increasingly growing produce with a view to selling it to the camps for cash income. This demand may also be influenced in the future by an increase in the number of jobs available for villagers, reducing their availability to grow their own crops. The sale of fish and seafood items is limited by both demand and transport logistics to a market.

As noted in the previous section, logging has played an important role in the Isabel Province economy. Talise residents indicated that commercial logging ceased recently, as the resource has been exhausted. Previously, this had provided employment for a number of villagers. Some community logging is now being undertaken, but only on a small-scale.

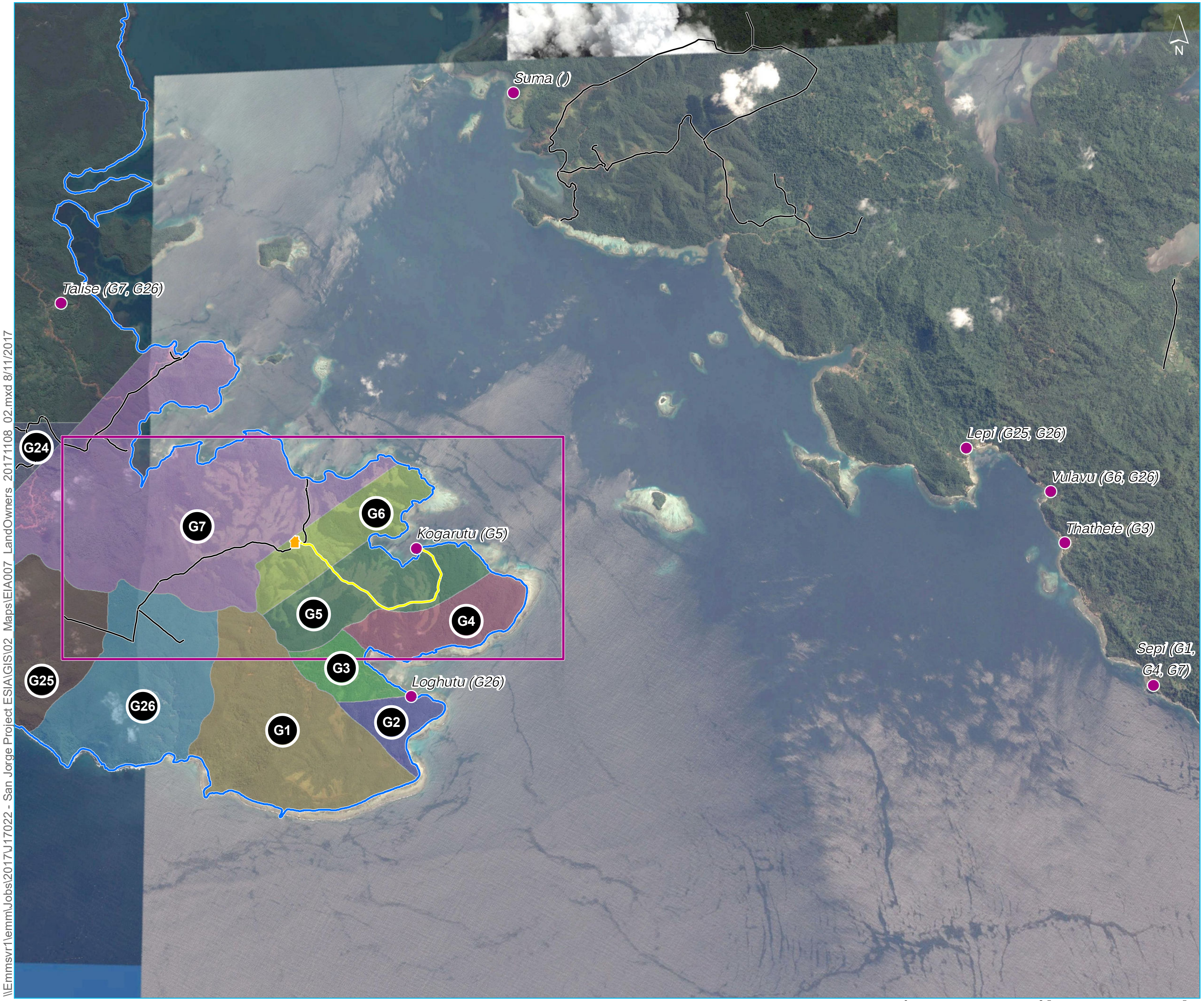
The Study Area is already experiencing an increase in the amount of paid employment through the exploration activities of Axiom KB (and to a lesser extent, SMM). Unskilled and semi-skilled job openings on the Axiom project are allocated via coordinators working with landowners (Trustees). Table 5.4 provides a summary of the employment status within the villages as at December 2015.

13.4.4 Land tenure

There are no permanent settlements on Axiom's tenement area. The closest village on San Jorge Island is Talise which is approximately 2 km north of the tenement boundary, and 3.5 km from the closest area which may be affected by mining. There is a small settlement within the tenement at Kogarutu which is regularly used by a family from Sepi. In addition, Loghutu, which sits on the coast just to the south of the tenement, is used regularly by people from Thathaje to collect coconuts. This site was previously used as a base for logging.

Land tenure on San Jorge is mostly customary with most land owned by tribes and clans. Land use mostly comprises traditional subsistence living including hunting (pigs) and fishing, with such activities providing an important source of protein. Logging on or adjacent to the tenement has ceased, and the only area of significant cultivation is around Talise, all of which is outside the tenement. Crops grown by local villages include coconut, taro, melons, pineapple, banana, sugarcane and a variety of vegetables. Some customary owners harvest coconuts from a variety of locations around the coast adjacent to Axiom's tenement.

Ten landholder groups (G) are located within and adjacent to the tenement area. These groups are referred to locally as G1, G2, G3, G4, G5, G6, G7, G24, G25 and G26. The landholder groups share customary rights to the area covered by the tenement, and Axiom has signed two Surface Access Agreements with the land's customary owners: one for G7 and one for all of the remaining groups. Some of these landholder groups are located in villages on Santa Isabel Island, namely Lepi, Vulavu, Thatheje and Sepi (See Figure 13.7).



\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps\EIA007_LandOwners_20171108_02.mxd 8/11/2017

KEY

- Project area
- Accommodation camp
- Village (owner)
- Main access road
- Local road
- San Jorge Island coastline

Customary landowner

- G1
- G2
- G3
- G4
- G5
- G6
- G7
- G24
- G25
- G26

0 2.5 5 km

WGS 1984 UTM Zone 57S

Source: EMM (2017); Axiom Mining Limited (2017)

Land ownership plan

Axiom Mining Limited

San Jorge Nickel Project

Environmental impact statement

Figure 13.7

EMM

13.4.5 Education

Education statistics for Isabel Province indicate it is broadly in-line with national averages. For example, in 2009, 87% of children aged 6-15 years were enrolled in school (52% in primary, 16% in secondary and 25% in preschool). Less than 1% of all students attended a tertiary institution or vocational institution, however 6% of students were attending a trade school or undertaking an apprenticeship. Literacy rates for males and females aged 15-24 years of age were recorded as 89.3% and 89.2% respectively, making them slightly lower than the national average. Language skills were almost identical to those recorded at a national level.

Two Educational Authorities operate schools in Isabel province: Isabel Provincial Government and the Seventh Day Adventist Church, however as evidenced in Table 13.11, the Church operates only a single primary school.

Table 13.11 Isabel Province schools by type, 2007

Education Authority	ECE	PS	CHS	PSS	NSS	Total
Isabel Provincial Government	57	25	4	2	0	88
Seventh Day Adventist Church	0	1	0	0	0	1
Total	57	26	4	2	0	89

Note: MEHRD (2008) Solomon Islands Digest of Education Statistics www.spc.int (accessed 22 February 2016).

Many of the smaller villages within the study area do not have schools, requiring students to travel to other villages to attend primary and secondary school. Most primary school students commute daily, however it is common for secondary school students to live in dormitory accommodation at the location of their school during weekdays/term time. School locations are summarised in Table 8.3. Within the Solomon Islands, entry into secondary school is controlled by the grade achieved in a Level 6 exam (end of primary school). Anecdotally, it is relatively common for school students in the Study Area to fail to meet the required standard to allow entry to secondary school.

Talise has a primary school (105 pupils). Some primary school students also go to Lelegia (70+ students). Secondary school students travel to Kalenga and Mauna.

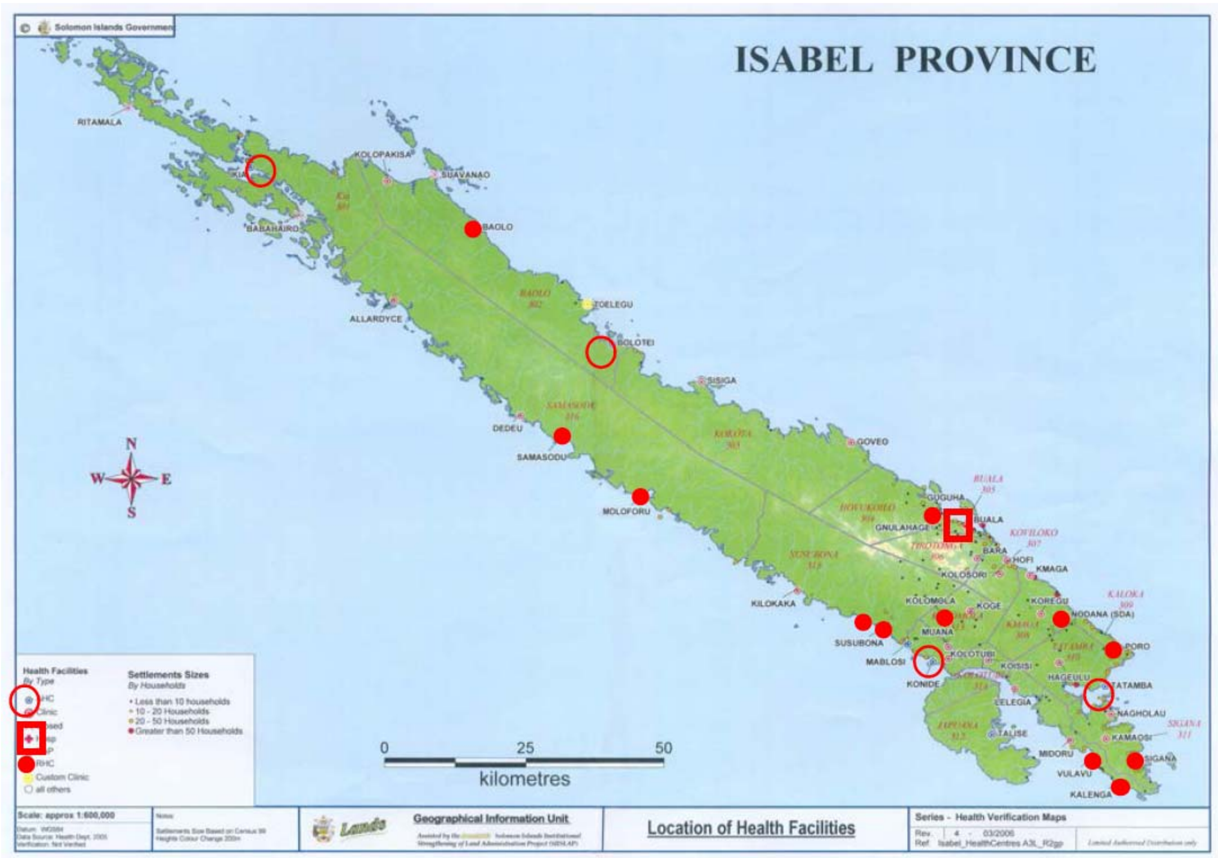
13.4.6 Health care

Isabel Province is served by 32 different health facilities, as indicated in Table 13.12. The location of these facilities is illustrated in Figure 13.8, where open circles represent Area Health Clinics (AHCs), square boxes represent provincial hospitals and filled circles represent rural health centres (RHCs). This information is also presented in Table 13.13. The Provincial Hospital is located in the capital of the province, Buala.

Table 13.12 Health facility network by province

Health Facility	Central	Choiseul	Guadal -canal	Isabel	Malaita	Makira	Temotu	Rennell & Bellona	Western	Total
Faith based hospital	0	1	1	0	1	0	0	0	1	4
National referral hospital	0	0	1	0	0	0	0	0	0	1
Provincial hospital	1	1	0	1	1	1	1	0	1	7
Area health centre	3	1	6	4	4	5	1	1	3	38
Rural health centre	5	10	10	9	25	17	6	2	23	102
Nurse aide post	14	13	20	18	43	16	8	0	31	187

Source: Hodge, N, Slayter, B and Skiller, L (2015) Solomon Islands Health System Review, Health Systems in Transition Vol. 5, No. 1, 2015 page 48



MHMS (2015) Health Facility Locations, Ministry of Health and Medical Services http://prdrse4all.spc.int/production/system/files/mhms_portfolio_aug_2015_ver2.pdf (accessed February 22, 2016)

Figure 13.8 Health facilities in Isabel Province, 2015

Table 13.13 Health facility status Isabel Province, 2015

Health Facility Name	MHMS Classification	Operational Status	Comment
Buala Hospital	Provincial Hospital	Open	Some development works underway
Tatamba	Area Health Centre	Open	New clinic under construction without MHMS and IPC involvement
Konide	Area Health Centre	Open	Termite infested, needs renovation
Kia	Area Health Centre	Open	Clinic in good condition
Bolotei	Area Health Centre	Open	Clinic in good condition Low pressure water supply
Gughua	Rural Health Centre	Open	Renovation near completion
Nodana	Rural Health Centre	Open	SDA mission functioning as Nurse Aide Post
Poro	Rural Health Centre	Open	Old clinic newly renovated for maternity
Tasina	Rural Health Centre	Open	Termite infested, internal walls removed
Vulavu	Rural Health Centre	Open	Clinic in good condition with good water supply
Kalenga	Rural Health Centre	Open	Needs termite treatment and minor renovation
Kolomola	Rural Health Centre	Open	Building under full renovation
Susubona	Rural Health Centre	Open	Clinic and houses in good condition
Biluro	Rural Health Centre	Open	SDA mission (functioning as Nurse Aide Post)
Moloforu	Rural Health Centre	Open	Isolated location. Poor access for catchment
Samasodu	Rural Health Centre	Open	Clinic and staff houses in good condition
Baolo	Rural Health Centre	Open	Clinic has termite infestation
Hoffi	Nurse Aide Post	Open	Functioning as RHC
Bara	Nurse Aide Post	Open	Newly renovated permanent building
Kmaga	Nurse Aide Post	Open	Renovations near completion
Visena	Nurse Aide Post	Open	Leaf roof with timber walls – under renovation
Kamaosi	Nurse Aide Post	Open	School clinics serving nearby communities
Lelegia	Nurse Aide Post	Open	Newly built clinic. Ablution yet to be built
Koge	Nurse Aide Post	Open	Permanent clinic generally in good condition
Kolotubi	Nurse Aide Post	Open	Old permanent clinic building
Goveo	Nurse Aide Post	Open	Newly built clinic with water supply to facility
Kilokaka	Nurse Aide Post	Closed	Newly built clinic
Hageulu	Nurse Aide Post	Closed	No staff
Koisisi	Nurse Aide Post	Closed	New facility awaiting staffing
Nagolau	Nurse Aide Post	Closed	Under early stages of construction
Dedeu/Deva	Nurse Aide Post	Closed	Newly built
Allardyce	Nurse Aide Post	Closed	School dispensary. No water clinic. No toilet
Babahaero	Nurse Aide Post	Closed	Newly established.
Kolopakisa	Nurse Aide Post	Closed	Currently non-existent
Sisiga	Nurse Aide Post	Closed	Land site under preparation for relocation

Table 13.14 summarises the distribution of health personnel per province, and demonstrates that Isabel Province has a level of service similar to the national median. In order to understand the level of service, however, it is necessary to also consider the distance between villages and the nearest health centre, which can be quite extreme in the northern end of Isabel Province. Health services are more abundant in the south-eastern portion of the Province which is also where the population density is higher.

Table 13.14 Distribution of health personnel and facilities by province, 2010

Province	Population	Health Facilities	Health personnel	Ratio: health workers to population
Central	27 928	26	127	1: 220
Choiseul	25 870	28	110	1: 235
Guadalcanal	78 290	40	184	1: 425
Honiara	63 311	14	124	1: 511
Isabel	26 310	35	123	1: 214
Makira	40 386	38	139	1: 291
Malaita	159 923	73	370	1: 432
Rennell and Bellona	3 025	3	22	1: 138
Temotu	24 412	17	119	1: 205
Western	81 214	60	333	1: 244
Total	530 669	334	1 651	1: 321

Source: Hodge, N, Slayter, B and Skiller, L (2015) Solomon Islands Health System Review, Health Systems in Transition Vol. 5, No. 1, 2015 page 57

Figure 13.8 shows that the health facilities in closest proximity to the San Jorge study area are:

- Lelegia Nurse Aide Post;
- Vulavu Rural Health Centre; and
- Kalenga Nurse Aide Post.

Additional information about these facilities is given in Table 13.13.

During the baseline surveys in 2016, questions around health access, common illnesses and the place where women give birth were asked. While all villages indicated that women try to gain access to a health facility when giving birth, they also acknowledged that some children are born in the village due to a combination of: distance; timing and belief that birth can be managed within village (particularly if the mother has already given birth to previous children with no concerns). Talise's nearest health centre is at Lelegia. There is a half-completed health centre in Talise (funded by Government Rural Development Project) but the staff house has not been completed. The key health concerns identified in Talise were:

- diarrhoea;
- pneumonia;
- influenza;
- limited malaria;

- skin diseases;
- high blood pressure; and
- diabetes.

Women from Talise travel to Lelegia to give birth, however this is not always possible due to lack of money. Of the 8-10 new babies born each year, approximately 50% are born in Talise.

13.4.7 Houses and accommodation

The size of households in Isabel Province is smaller than the national average (4.5 in Isabel compared to 5.7 across the Solomon Islands). Most houses are constructed using traditional materials and wood for the floor, walls and roof. In 2009, 64% of dwellings were connected to a communal standing pipe for drinking water, while another 11% used a river or stream as their source of drinking water. These figures may have improved since 2009 through the efforts of rural water and sanitation programs led by the Solomon Islands Government and non-governmental and faith-based organisations.

Consistent with the findings at a nation level, 74% of households in Isabel used a kerosene lamp for lighting with 17% receiving energy from solar panels in 2009. Unfortunately, more recent data for electrification is not available for Isabel Province, but it is considered likely that the proportion of solar panel usage has increased considerably since 2009.

i Study area

A mixture of housing types is evident in the study area. A large proportion of houses are constructed of traditional materials (Photograph 13.1) however there is also a trend towards more permanent style housing in some villages (Photograph 13.2).

Photograph 13.1 Traditional housing Talise

Photograph 13.2 Village shop / house Talise

13.4.8 Stakeholder engagement

The over-riding feedback during consultation was that people appear to want development and they want the mine to be developed, as they believe it will bring employment, social prosperity and increase the standards of living. For many years various organisations have discussed developing mines in southern Isabel Province and the local residents seem to be becoming impatient; the message was '*they want to see something actually happen*'. However, the local residents are understandably nervous about the development because they have never seen a mine and they do not fully comprehend the possible beneficial and adverse impacts. A summary of Stakeholder engagement interactions undertaken as part of the EIS process is set out in Table 13.15.

Table 13.15 Stakeholder engagement summary

Village / Location Name	Key challenges facing/concerns held by community
Talise (San Jorge)	**2016 Consultation** Village experiencing rapid population growth. Anticipating a land shortage if growth continues at same pace. Primary concern relates to lack of sources of income for village. Women were concerned that increased development will increase access to alcohol amongst the youth. **2017 Consultation** (Meeting with village leaders joint male/ female) Concern about pollution from the mine going into the sea. Concern was expressed about what had happened at Goldridge mine. [It was explained that no mineral processing would occur on san Jorge]. There was great concern over their customary fishing grounds. Concern was expressed about the distribution of money and who gets the money from share income and royalties. A point was raised that all money should be shared equally amongst customary owners for education, healthcare and community infrastructure. Others said that the government should ensure money is spread fairly Concern was raised about sediment control and river pollution, and how topsoil would be preserved. Villagers asked how the land would be rehabilitated and what it would look like afterwards A question was asked "if something goes wrong – who do they tell? Who do they call? They asked "who would ensure that environmental protection measures are implemented?" Many villagers expressed a desire to see the mine happen to increase jobs and increase wealth in the area, but overall they are nervous about the impacts of the mine, what will be left behind and how money will be distributed.
Kogarutu (temporary settlement)	**2017 Consultation** (Consultation with Mr Bako, who is from Sepi on Isabel Island) Mr Bako is generally positive about the project and he wants to see the landowners working together. Mr Bako first starting discussions with Axiom in 2015. Mr Bako sees benefits of the project for landowners as: • royalties / income; • being able to supply services such as boats; and • being able to provide products from his store and fuel. Mr Bako said he's never seen a mine and did not know what to expect. He was concerned about the environment impacts and thought that should be looked at very carefully. My Bako got his food locally from Isabel and some from San Jorge and fish (coral trout and king fish) came from the sea. He also uses the customary fishing nets for Bonito.

Table 13.15 Stakeholder engagement summary

Village / Location Name	Key challenges facing/concerns held by community
Loghutu – used occasionally by people from Thathaje	**2017 Consultation** (consultation with James Vasethe (Wilson Lusia is his Uncle) and five other men from Thathaje). No one lives permanently at Loghutu – they visit from Thathaje mainly to collect coconuts. This has been going on for 50-60 years. The settlement was originally set up to support the logging industry, but all logging has now ceased. Discussions with Axiom began in early 2017. They did not know what to expect from a mine. They thought it would: • destroy the land; • destroy the trees; • they were concerned about chemicals [it was explained that no processing would take place and they thought this was much better]; • they thought the mine would bring financial benefits; • possible jobs; and • they want something to happen soon – people are just waiting expecting something to happen.
Vulavu	**2017 Consultation** (consultation with Carlos Stevenson, Elder Chief John Edwards, Senior Chief John Francis and others) The land owners are worried that the Government is giving out PLs to too many companies. They are worried what will be left when the mining is finished and how will the land be rehabilitated. They have seen prospecting damage the environment. Axiom has been bulldozing roads and clearing the land whilst exploring. Sumitomo didn't damage the land in the same way. They asked who has the power to stop the mining company if the mine damages the environment. They asked what would happen after the EIS is submitted. They wanted to know if the government would visit them. They were not sure about the project and needed to understand what the environmental impacts might be. They were worried about how the mine would affect the rivers and the sea. They thought some mining should be allowed, but it has to be done properly.
Lepi	**2017 Consultation** It was not possible to visit the village of Lepi during the site visit.
Sepi	**2017 Consultation** (Consultation was with Susan Gnacho, Chief Wilson, Susan's husband - Philemon Gnelemane) Consultation was limited as Philemon took over the meeting and prevented discussion about the San Jorge Nickel EIS study.
Thathatje	2017 Consultation See above under Loghutu

i Public Consultation undertaken by Axiom

Axiom has been engaging with the local people on San Jorge Island and associated areas of Santa Isabel Island since January 2016. A complete record of their consultation meetings is given in Appendix H of this Environmental Impact Statement (EIS). The following gives a brief overview of the consultation process undertaken to date.

Initial consultation regarded the deployment of monitoring equipment such as water monitoring devices and land access. In late February to early March 2016, Axiom undertook initial consultation with representatives from the following villages regarding the establishment of a Surface Access Agreement (SAA): Nagolau, Suva, Sepi, Lepi, Kamaosi, Vulavu, Sigana, Thathaje, Midoru, and Japuana for the San Jorge Tenement (study area).

In June 2016, Axiom visit Talise and Sepi village to update people on the current status of Axiom's mining tenements in south Isabel Province. The update informed local people that the Government (via the recent court ruling) had confirmed that Axiom has a valid Prospecting License (PL) on south San Jorge and that they planned to secure a SAA and to carry out prospecting work on San Jorge in the near future.

In August 2016, Axiom presented in the Heritage Park Hotel (Honiara) and later in Sepi Village regarding their proposed exploration program, social and environmental impacts, tambu site identification, employment opportunities and road and landing development.

Consultation through the rest of 2016 and early 2017 was a continuous process culminating with the signing of a legal Surface Access Agreement with most customary landholders in February 2017, and an updated agreement signed with the Bungusule Clan in May 2017.

More recently, as set out above, Axiom staff have assisted with consultation as part of the Environmental Impact Assessment process in Talise and a number of villages on southern Santa Isabel Island. Axiom's full consultation process is documented in the table in Appendix H

Photograph 13.3 Public consultation meeting – Talise September 2017

Photograph 13.4 Public consultation meeting – Vulavu September 2017

Photograph 13.5 Public consultation meeting – Loghutu September 2017

Photograph 13.6 The recent settlement at Kogarutu

13.5 Impact assessment

The following potential impacts have been identified as potential issues which could arise without appropriate social and environment management measures (mitigation):

13.5.1 Beneficial impacts

i Increased Jobs

As previously described, southern Isabel Province suffers from a lack of paid employment with the majority of workers undertaking subsistence activities. This project will have a major beneficial effect on direct and indirect employment. It will generate approximately 300 jobs during construction and the operational phase will provide approximately 120-140 direct jobs. The flow on effects in the local economy will also increase the number of jobs eg. in service industries and suppliers.

The construction roles will include specialised civil engineering and mine planning roles as well as semi-skilled construction and unskilled labourer roles.

Operational jobs will range from skilled mine manager and mine geologist roles to semi-skilled driving roles, rehabilitation specialists and unskilled labour.

Axiom will looked to recruit locally where possibly, particularly from villages with customary ownership of the land, thereby ensuring the mine benefits locally communities.

ii Increase regional revenue

The mine's presence will increase regional income by:

- employing local people during construction thus increasing their spending power;
- employing local people during operation thus increasing their spending power;
- purchasing goods from local people such as fresh fruit and vegetables where available;
- purchasing services from local people such as boat journeys around the local area and accommodation where available;
- the Axiom Mining KB Company is structured to give 10% share ownership (of the company) to the customary owners of the San Jorge Nickel Project tenement. This will give the owners a share of profits gained from the sale of nickel ore. This money will be spent in the local economy directly and indirectly and if used wisely should benefit the local economy; and
- some of the royalties generated from the project which will go directly into the central government's coffers, should be used to benefit the local community in the San Jorge area.

iii Increased transport to the region

With all of the additional boat traffic to the area, local people are likely to be able to benefit from increased access to boats travelling to and from Honiara. At this stage it is not possible to quantify the number of boats coming to and from San Jorge to Honiara.

iv Increase standard of living

Overall the project should improve the standard of living in the San Jorge area and surrounding villages, particularly in the villages with customary ownership of the site. This will stem from all of the positive impacts set out in points a to c above. Benefits will be maximised to the local community if the profit shares and royalty benefits are used for social infrastructure and social development such as education, healthcare and other long term community projects.

13.5.2 Adverse impacts

i Disruption of village life / tranquillity

Although there are no permanent settlements on the San Jorge settlement, the activity of a mine, marine traffic during construction and operation, changes to the landscape and changes in environmental parameters such as noise levels will lead to some disruption of village tranquillity. This could be exacerbated by the fact that the area is currently totally undeveloped with no roads or industry other than logging.

ii Social inequality / money distribution

Should the mine be developed, this will lead to customary landowners being financially compensated and money being received into the community via profit shares and royalties. This could lead to an immediate social divide with some receiving payments and others not. Likewise, some villagers may get jobs on the project during construction and operation and other may be unsuccessful at obtaining employment. Again, this could lead to divisions within the community creating tension and jealousy.

iii Inter and Intra village conflict

The overall effects of payments coming into the community in various forms, and jobs being given out across the various villages could unsettle villages and potentially lead to jealously related conflict within villages and between villages.

iv Gender inequality

As noted my SMM (2012) Isabel women are not generally included in village governance or public decision making. It is therefore likely that given the types of roles on offer on this project during construction and operation, and the more dominant role men play in village life, that more men are likely to secure jobs directly from the mine than women. This could lead to an economic gender divide within the local area.

v Increased demand on social infrastructure

With an increase of people visiting the area for work, particularly in the short term during construction, there could be an increase demand for local services. This will depend on where the workforce originates from, but healthcare facilities, schools, policing and other demands on social infrastructure in the project area could increase.

vi Increase in anti-social behaviour

SMM (2012) documented that villagers on Santa Isabel had reported that the logging industry and the employment of exploration workers on their (SMM's) project had had a negative impact on village lifestyle and brought some anti-social behaviours, including:

- increased alcohol consumption and drunkenness;
- increases in single mothers as local women become involved with workers who do not take responsibility of their children;
- an increase in sexually transmitted diseases; and
- erosion of traditional values as youths are influenced by mine workers and money.

vii Customary fishing grounds

Impacts from the mine could lead to sediment and nickel ore entering the marine environment around the traditional customary fishing nets. Increased volumes of sediment could enter the water following heavy rainfall. Nickel ore could enter the sea around the loading boat ramp and during the transhipment process. In addition, this area could be disturbed by port traffic.

viii Loss of hunting areas

Once the mining area is active during construction, large areas of land will be in accessible to residents of San Jorge and visitors to the island for hunting pigs. It should be noted that the area is apparently only occasionally used for hunting.

ix Water pollution / sedimentation (increased metals) in food chain

SMM (2012) and SMM (2014) documented detailed investigations into potential human health issues from naturally occurring heavy metals entering the food chain and affecting local people.

This could potentially occur where:

- areas of soil or ore with elevated levels of heavy metals are disturbed during mining;
- precipitation causes the soil / ore to be washed into water courses and then into marine environment, where the sediment filters onto the seabed and becomes part of the seabed (the benthic zone);
- the sediment is then ingested by bottom-feeding invertebrates such as worms and molluscs;
- larger invertebrates (crabs and lobsters) and fish eat the worms/mollusc etc and the metals bioaccumulate in the larger predators in the food-chain; and
- local residents catch crabs/ lobsters and fish and ingest elevated concentrations of heavy metals.

This potential human health issue was thoroughly investigated by SMM (2014). These assessments are documented in SMM's EIS in Appendix C (Human Health) and Appendix F (Arsenic Food Study).

The human health assessment looked at exposure to naturally occurring metals and other chemicals in groundwater, freshwater, soil and sediments. The key findings of the human health assessment were:

> As the population density in the Project area is low and potential emission sources are scarce (e.g., household fuel use and transport), the existing air quality concentrations for key urban air pollutants are within levels for the protection of ecosystems and human health.
>
> Baseline conditions for soil, fresh and marine water, and marine sediment indicate natural background elevation from some metals and nutrients. It is likely that the regional ecology is naturally adapted to these background levels. In addition the elevated levels are within safe exposure levels for humans.
>
> Baseline aquatic and terrestrial foods were sampled to enable estimates of dietary exposure for humans eating locally grown vegetables and locally caught seafood. There were few concentrations of metals in aquatic foods greater than human food guidelines (where available). Three samples were above food guidelines (two samples with elevated cadmium

The SMM (2014) report

The Arsenic Study, which was carried out by the University of Queensland, Executive summary stated:

> This study provides an assessment of existing arsenic content in marine resources across the Jejevo region of Santa Isabel Island, Solomon Islands. It informs the Environmental and Social Impact Assessment for the Solomon Islands Nickel Project planned by SMM Solomon Ltd (SMM Solomon) in the Jejevo / Isabel B tenements region.

Arsenic (As) is a natural element that is present in the tissues of marine and terrestrial organisms While arsenic is required for cellular processes, high concentrations can cause negative outcomes for human health. Arsenic exists in a range of forms with differing toxicity, from the highly toxic inorganic forms (As III, V) to the relatively harmless organic forms such as Arsenobetaine (AsB). Some countries have set a food safety guideline of 2 mg/kg for the toxic inorganic forms of arsenic in seafood. Previous studies in Solomon Islands found that some marine resources commonly consumed by humans contained total arsenic concentrations of over 50 mg/kg. This study aimed to confirm if a broader range of species contained similar concentrations and to investigate the relative contribution of inorganic and organic forms to further the understanding of arsenic's potential toxicity to humans

Thirty-one organisms (69 samples) were investigated. Results confirmed previous findings of high levels of arsenic in seafood with total arsenic concentrations of 22 to 61 mg/kg in crayfish. Some fish species (e .g., midnight snapper, sweetlips and amberjack) had total arsenic concentrations of between 5 and 12 mg/kg, but the majority of fish species had low concentrations of total arsenic (below 2 mg/kg). Mud crabs, clam shells and brown algae also contained total arsenic above 2 mg/kg, with average concentrations of 2.6, 2.6 and 8.1 mg/kg, respectively. Concentrations of arsenic in the range of that found in seafood groups in this study have previously been recorded for uncontaminated seafood worldwide.

No inorganic forms of arsenic were detected in any of the 32 fish samples analysed and all arsenic detected in fish was the non-toxic AsB form. Similarly, only AsB was found in all Crayfish and other marine invertebrate seafood sampled, with the exception of mangrove shells and clam shells, which contained 0.06 mg/kg of AsIII and 0.09 mg/kg of dimethylarsinic acid (DMA), respectively. These amounts of AsIII and DMA are more than twenty times lower than international guideline levels of inorganic arsenic content in seafood considered safe for human consumption.

Marine algae and seagrass contained a mixture of inorganic and organic forms of arsenic, and the brown alga *Sargassum* sp. contained 4.6 mg/kg of toxic AsV, which is more than twice the international food safety guideline level. However, as humans in the Jejevo region do not consume this alga, it should not pose a human health risk. High levels of inorganic arsenic are commonly found in seaweed (algae) worldwide and values recorded in the Jejevo region were not above those found elsewhere.

The edible green alga *Caulerpa racemosa* had a relatively low total arsenic concentration (0.77 mg/kg) and only contained AsB, the non-toxic organic form. Sea grass species (not consumed by humans) also had relatively low total arsenic concentrations (less than 0.5 mg/kg), although this was predominately toxic AsV.

In summary, none of the seafood investigated in this study contained more arsenic than has previously been recorded in the same food groups elsewhere, and all concentrators were below international food safety guidelines for inorganic arsenic.

To assess the potential sources of arsenic to marine organisms and their surrounding environment in the Local Study Area (LSA), the existing conditions of arsenic concentrations in the marine environment were evaluated. Arsenic concentrations in marine surface waters were low across the LSA (less than 2.1µg/L). Concentrations of total arsenic in marine sediments, however, ranged from 1.6 to 50.3 mg/kg and were particularly high in inshore areas. At 3 inshore sites, the total arsenic concentration were above the international water quality guideline value of 20 mg/kg (ANZECC & ARMCANZ 2000). Sediment porewater (i.e., water occupying the spaces between sediment particles) generally contained higher concentrations of dissolved arsenic (3.0 to 8.2µg/L).) than marine surface water, suggesting that sediments could be a source of arsenic to surface waters. It is possible that terrestrial soil input from adjacent catchment areas leads to higher concentrations of total arsenic in marine sediments of inshore areas near river mouths.

> An incubation experiment was conducted to assess the potential for arsenic mobilisation from terrestrial soils in marine sediments into marine waters. Samples of topsoil. limonite ore and deeper transitional soils were mixed with seawater and inshore marine sediments under anoxic and oxic conditions for a period of six months. After this incubation, arsenic concentrations within all incubation chambers were below international water quality guideline values for surface marine waters (ANZECC and ARMCANZ 2000). Results from the incubation experiment do not support the hypothesis that addition of terrestrial soils to marine sediments will increase seawater arsenic concentrations above guideline levels under the existing conditions.

Given that San Jorge Island is located only 45 km from the Jejevo / Isabel B project and it has very similar geology and soils, the results of this study are considered valid for the project.

x Air pollution / Noise

In dry windy conditions, exposed areas of soil, stockpiles and roads could be a source for fugitive dust emissions. Elevated levels of dust, particularly small fragments of particulate matter (PM10 and PM2.5) can cause respiratory issues. In addition, in certain conditions, noise from the mine may be audible at the nearest village (Talise).

Table 13.16 and Table 13.17 summarise the likely impacts of the project, their scale, their likely duration, their severity and the likelihood of occurrence.

Table 13.16 Summary of potential beneficial impacts

Impact	Scale / Extent	Duration	Severity / significance	Probability of occurrence without appropriate management
a. Increased Jobs	Local	During construction, operation and rehabilitation (8 years +)	Moderate	Certain if the project is implemented.
b. Increase regional revenue	Local / national	During construction and operation. Most revenue will flow during operations.	Moderate	Certain if the project is implemented.
c. Increased transport to the region	Local	During construction and operation.	Minor	Likely if the project is implemented.

Table 13.17 Summary of potential adverse impacts

Impact	Scale / Extent	Duration	Severity	Probability of occurrence without appropriate management
a. Disruption of village life / tranquillity	Local	During construction, operation	Low	Likely in very local areas
b. Social inequality / money distribution	Local	During construction, operation and possibly beyond	Moderate	Likely if the project is implemented
c. Inter and Intra village conflict	Local	During construction, operation and possibly beyond	Moderate	Possible if the project is implemented
d. Gender inequality	Local	During construction, operation and possibly beyond	Moderate	Likely if the project is implemented
e. Increased demand on social infrastructure	Local	During construction, operation	Low	Possible
f. Increase in anti-social behaviour	Local	During construction, operation	Moderate	Possible if the project is implemented
g. Customary fishing grounds	Local	During construction, operation and possibly beyond	Moderate / High	Likely if the project is implemented
h. Loss of hunting areas	Local	During construction, operation and beyond	Low	Certain if the project is implemented
i. Water pollution / sedimentation (increased metals) in food chain	Local	During construction, operation and possibly beyond	Moderate	This is considered unlikely to occur
j. Air pollution / Noise	Local	During construction, operation	Low	Significant air pollution and noise levels are unlikely to reach local residents who are remote from the site

13.5.3 Socio-economic mitigation measures

There are a number of potential social and economic impacts of this project which could have a variety of beneficial and adverse effects on the community. In order to increase and enhance the positive benefits and reduce or negate the potential negative effects the following management measures (mitigation) are proposed (see Table 13.18).

Table 13.18 Social-economic management measures

Potential impacts	Proposed community engagement /management measure(s)	Commitment
a. Disruption of village life / tranquillity	Communication with village chiefs and leaders Education about the mine The establishment of a complaints / feedback procedure Noise and air pollution controls (see below)	[S001] Establish a working group with village chiefs and leaders to communicate information about the project, including updates and changes. [S002] Establish a complaints and feedback procedure that responds to project related complaints, issues, comments and suggestions. [S003] Consider flexible working hours and rosters to promote a family friendly culture. [S004] Develop and implement a health, safety and environmental management plan for all project activities. [S005] Restrict access to local villages for workers who are not members of landowning tribes. [S006] Prohibit hunting and fishing for workers who are not members of landowning tribes. [S007] Collaborate with local leaders, government and NGOs to develop awareness training on health issues (including communicable diseases), workplace health and safety, cultural awareness and appropriate worker behaviour that is included in the workplace induction program.
b. Social inequality / money distribution	The establishment of a working group with the national government, regional government and community leaders to agree how jobs, service agreements, royalties and profits are shared between the communities and how the money is used to benefit them is essential. The establishment of a trust fund is one potential method, for holding and distributing funds as long as the correct governance procedures are in place to ensure the money went to appropriate projects to help community development e.g. for education, healthcare, community infrastructure projects, grants for small businesses.	[S008] Establish a working group with the national government, regional government and community leaders to agree how benefits such as jobs, service agreements, royalties and profits are managed and shared between the communities. [S009] Investigate methods for holding and distributing funds appropriately to maximise community rather than individual benefits. [S010] Investigate sustainable supply agreements with local businesses. [S011] Recruit local people from San Jorge and south Santa Isabel where possible.

Table 13.18 Social-economic management measures

Potential impacts	Proposed community engagement /management measure(s)	Commitment
c. Inter and Intra village conflict	It will be important to establish a working group (as set out above under point b) of key leaders from the communities affected by the project (the customary land owner groups). Axiom will work with the Government and these key leaders to agree how the benefits of the project are shared and how community harmony can be maintained to avoid conflicts within and between villages. By ensuring social equality and a fair distribution of the benefits of the project, this will go a long way in preventing conflict.	[S012] Establish a working group with key community leaders to manage and avoid potential conflicts within and between villages that may arise as a result of the project.
d. Gender inequality	Establish a working group with senior female leaders from the community. They should consider: • targeted employment for women; • training for women; and • accommodation for women.	[S013] Establish a working group with senior female leaders from the community to promote the involvement of women in the project. [S014] Provide employment and training opportunities for women. [S015] Develop an equal opportunity policy and investigate accommodations and provisions for employing women on the site.
e. Increased demand on social infrastructure	The mine should be self sufficient for key services including healthcare and any education requirements.	[S016] Provide health services to the workforce by establishing an on-site first aid post to prevent overloading of the local healthcare system. [S017] Provide opportunities for appropriate training and up-skilling to the workforce.
f. Increase in anti-social behaviour	This issue should be addressed in collaboration with senior leaders from the villages. The camp should be dry (no alcohol / drugs on site)	[S018] Collaborate with local leaders to develop and enforce a workforce code of conduct including disciplinary procedures to reduce anti-social behaviour. [S019] Prohibit alcohol and non-prescribed drugs on site.
g. Customary fishing grounds	The fishing ground should be protected using an erosion and sediment control plan. In addition Axiom will: Liaison over the location of the l boat ramp Liaison over the route for the barges to get to/from the ship exporting the ore.	[S020] Establish a working group with village chiefs and leaders to safeguard the existing fishing sites and liaise on locations of marine infrastructure and shipping routes.

Table 13.18 Social-economic management measures

Potential impacts	Proposed community engagement /management measure(s)	Commitment
i. Water pollution / sedimentation (increased metals) in food chain	Sedimentation will be controlled an erosion and sediment control plan. Axiom will also develop a full mine drainage plan to assist with water management and mine planning.	See mitigation measures [E001] to [E025] from the erosion and sediment control plan.
j. Air pollution	Dust emissions on site will be minimised by: • undertaking progressive vegetation; • imposing speed limits on the site; • spraying roads and stockpiles with water during dry weather; and • keeping machinery well maintained • switching machinery off when not in use.	[E016] Restrict vehicle speeds on access and haul roads to 20 km/h. Vehicle speeds will be further restricted when it is windy. [AQ001] Reduce drop heights when dumping material from excavators and loaders. [AQ002] Reduce surface disturbance activities, excavation, dumping and stockpile management during dry or high wind conditions. [AQ003] Appropriately service and maintain vehicles and equipment. [AQ004] Switch off vehicles and equipment when not in use.
k. Noise	Noise emissions on site will be minimised by: • low impact reversing alarms; • speed limits on the site; • engine exhausts fitted with silencers or mufflers; • keep machinery well maintained; and • switch machinery off when not in use.	[E016] Restrict vehicle speeds on access and haul roads to 20 km/h. Vehicle speeds will be further restricted when it is windy. [AQ003] Appropriately service and maintain vehicles and equipment. [AQ004] Switch off vehicles and equipment when not in use. [G013]Use low impact reversing alarms on mobile equipment. [G014] Fit engine exhausts with suitable silencers or mufflers. [G015] Include noise-sensitivity training in worksite inductions.

13.6 Residual impacts

As set out above, with appropriate community engagement and social management measures in place, the project is likely to have a number of significant beneficial impacts on the local communities. These will stem from employment and additional revenue flowing into the southern Isabel Province economy. Conversely, the project is unlikely to have many adverse social impacts assuming appropriate management and community engagement measures are in place. Table 13.19 below sets out the residual effects of the project.

Table 13.19 Residual impacts following the implementation of proposed management measures

Potential impacts	Residual impacts
a. Disruption of village life / tranquillity	With appropriate management measures in place the residual impacts on village tranquillity will be low. This is primarily due to Talise, the only permanently occupied village close to the proposed mine on San Jorge being approximately 3.5 km from the active mining area. Some disturbance (visual and noise) will be detected in the Loghutu and Kogarutu, but these locations are not permanently settled, and people using these sites will become accustomed to the mine in time. No village resettlement is required for this project. However, if the 'Alternative' port option is pursued, the house used (on occasions) at Kogarutu will need to be vacated.
b. Social inequality / money distribution	Assuming money and jobs being distributed into the local communities are managed in conjunction with the Government and community leaders, this impact should not have residual effects. It is essential that the money is not given to individuals. The money has to be given to communities to benefit everyone.
c. Inter and Intra village conflict	Assuming money, royalties and jobs are shared equitably and discussed and agreed with community leaders, conflicts within villages and between villages should be manageable. It is essential that village elders engage with their own communities and with each other to avoid jealousy issues creating disharmony and conflict.
d. Gender inequality	Assuming the proposed management measures are implemented and specific roles are created for woman on the project, gender equality will be achieved. Overall this should a significant beneficial effect.
e. Increased demand on social infrastructure	With appropriate management measures implemented, there should not be a significant impact on local community infrastructure and services. Axiom will be self sufficient in this regard.
f. Increase in anti-social behaviour	Assuming the proposed management measures are implemented anti-social behaviour should be managed to acceptable levels. It is essential that village elders engage with their own communities and with each other to avoid anti-social behaviours getting traction in their respective villages.
g. Customary fishing grounds	Further discussion and consultation is required with the landowners who use the customary fishing nets and the fishing grounds. Assuming the proposed management plans are implemented, impacts on the fishing grounds should be minimised, however, there could be effects from sedimentation and disturbance of the area from barge / ship traffic.
i. Water pollution / sedimentation (increased metals) in food chain	Assuming appropriate management measures are in place to manage sedimentation, and based on the studies undertaken by SMM (2012, 2014) no human health issues should arise from this project. No residual impacts are anticipated.
j. Air pollution	With appropriate dust control measures in place, there should be no residual impacts from fugitive dust emissions from the site.
k. Noise	With appropriate noise control measures in place, there should be no residual impacts from noise emanating from the site.

13.7 Conclusion and summary

This socio-economic assessment reviews the current situation in the Solomon Islands and more specifically the southern Isabel Province and San Jorge Island regarding: governance and society; demographics; livelihood and employment; land tenure; education; healthcare; and housing. The introduction of a mine in southern Isabel Providence will have both positive and negative impacts on these socio-economic attributes.

On the beneficial side, the project will have significant positive benefits: it will increase revenue to the Solomon Island's government through royalties; it will increase jobs; and it will increase regional revenue via both direct spend from jobs and services being provided to the mine from local businesses. In addition, it will increase transport to the region making the area more accessible to and from the capital, Honiara. All of these beneficial effects will help to increase standards of living and assist in community development.

There are also some potential adverse impacts: disruption of village life / tranquillity; social inequality regarding money distribution; inter- and Intra-village conflict; gender inequality; increased demand on local social infrastructure; increases in anti-social behaviour, potential impacts on customary fishing grounds, the loss of hunting areas, water pollution / sedimentation causing increased heavy metals in food chain, and increased air pollution and noise.

The assessment sets out a range of social management and community engagement measures to mitigate potential adverse impacts which in many cases can make them a positive benefit of the project. Assuming a well considered social management plan, addressing all the issues is implemented, most, if not all of the potential negative impacts can be mitigated. The positive impacts of the mine have the potential to grow the area economically and should have significant benefits on education, healthcare and the livelihoods of the local communities.

14 Cultural and historical heritage

14.1 Introduction

Santa Isabel is the largest island in the Isabel Province, with San Jorge a substantial contiguous island in the south and several smaller islands extending out around Kia in the north (Malakobi, Bates, Ghaghe, Barora Fa, Baroar Ite, Nidero and Omona). The highest point of Santa Isabel Island is Mt. Kubonitu (Sasari at 1,220 m), situated near (west of) Buala. San Jorge Island has an area of c.184 km^2 and between 600-800 inhabitants most of whom live in the village of Talise. Thousand Ships Bay is located to the east of the island, between San Jorge (Moumolu Naunitu) and Santa Isabel.

This chapter outlines the known cultural heritage values within the project area on San Jorge Island, and describes the potential impacts to the cultural and historical heritage values that may result from the project.

Axiom has already begun implementation of mitigation measures for protecting the cultural heritage values within the project footprint; these measures and their implementation are discussed to demonstrate Axiom's commitment to protecting and enhancing cultural and historical heritage values.

14.2 Solomon Island legislative framework

The legislative framework that governs the protection of Solomon Islands cultural and historical heritage values provides several mechanisms within enacted legislation, in particular where an EIS is required for a development. These mechanisms also make reference to matters concerning National Heritage items or traditional artefacts, though it is acknowledged that cultural and historic heritage values extend beyond material items.

The following section provides a review of the key Solomon Islands legislative instruments and the mechanisms included within to address the risks from development to cultural and historical heritage values.

14.2.1 Solomon Islands Legislation

i Environment Act 1998

The Environment Act (see also Chapter 2) contains numerous provisions that promote environmental protection, regulate environmental impacts associated with development activities, and safeguard the life supporting capacity of air, water land and ecosystems.

Recognition of cultural heritage values is provided in the definition of environment, as follows:

- *includes all natural and social systems and their constituent parts, and the interactions of their constituent parts, including people, communities and economic, aesthetic, culture and social factors*.

Recognition of cultural heritage values is also included within the definition of sustainable development as follows:

- *means the management or the human use, development, conservation, protection, maintenance and enhancement of the natural, physical and cultural resources of Solomon Islands in a way or at a rate, which enables people and communities to provide for their social, economic and cultural well-being and for their health and safety while -*

  (a) sustaining the potential of natural and physical resources to meet the needs of future generations;

  (b) using, developing or protecting renewable natural and physical resources so that their ability to yield long-term benefits is not endangered;

  (c) using, developing or protecting non-renewable natural resources so as to lead to an orderly and practical transition to adequate substitutes including renewable resources;

  (d) safeguarding the life-supporting capacity of air, water, soil and ecosystem; and

  (e) avoiding, remedying or mitigating any adverse effects of development on the environment.

Section 23 of the Environment Act lists the required content of EISs prepared to support development applications, pertaining to proposed and existing prescribed development. The list includes the following in regard to cultural matters:

- *(l) justify the prescribed development in terms of environmental, economic, culture and social considerations.*

ii Environment Regulations 2008

Division 2, Section 10 (6, (b), (v)) of the Environment Regulations 2008 (Environment Regulations) lists matters that need to be taken into account for processing of development applications where a Preliminary Environmental Review (PER) or EIS is dispensed with. These matters include the following:

- *any effect on a locality, place, building having aesthetic, anthropological, archaeological, architectural, cultural, historical, scientific or social significance or other special value for present or future generations.*

Though an EIS is provided to support the proposed development application, it is noted that the legislative requirements set expectations for studies that extend to matters that provide special value for present or future generations.

iii Mines and Minerals Act 1996

Part II (Administration) of the *Mines and Minerals Act 1996,* (Section 4, 2, (a)) makes reference to reserved and protected areas and states:

- *Reconnaissance, prospecting and mining are prohibited in or on any village, place of burial, tambu or other site of traditional significance, inhabited house or building, except with the consent in writing of the owner or occupier thereof, and within such distance as may be prescribed by the Minister.*

Though there are no recognised or gazetted “reserved or protected areas” within the project footprint, it is acknowledged that the marine environment plays an essential role in the customary lifestyle of the people of the Solomon Islands.

The *Mines and Minerals Act 1996* also provides that these sensitive environments can be declared (by the Minister) to be reserved or protected areas if it is found they are at risk from development.

Section 6 of this Part (Part ll) of the *Mines and Minerals Act 1996* describes the power of the Minister (upon advice of the Board), to undertake the following:

> *(iv) to protect sites of archaeological, historical, or geological significance.*

Axiom has established strategies to identify and protect the archaeological, historical, and geological values within the project footprint including surveys of the proposed impacted areas in the company of the traditional landowners and the appointed trustees.

vi National Minerals Policy 2017

Objective 16 in the National Minerals Policy outlines the rights of landholders and communities that are affected by mining. The *General Principle* relating to Objective 16 states that:

> *All landholders and impacted communities have the right to culturally appropriate free, prior, and informed consent about whether mining takes place on their land. Landholders have the power of veto over exploration activities. To protect investor confidence, however, this consent cannot be revoked after is has been given at exploration stage, provided the Company has complied with all their legal obligations in respect of the community.*

Axiom has consulted with the customary landholders and has consent through a Surface Access Agreement with the landholders to access the San Jorge tenement.

iv Protected Areas Act 2010

The *Protected Areas Act 2010* provides that the Minister may, on the recommendation of the Director, declare by order in the Gazette any area as a protected area of biological diversity significance if the area:

a) possesses significant genetic, cultural, geological or biological resources;

b) constitutes the habitat of species of wild fauna and flora of unique national or international importance;

c) merits protection under the Convention Concerning the Protection of World Cultural and Natural Heritage; or

d) requires special measures to be taken to conserve biological diversity.

As mentioned above, there are no recognised or gazetted “reserved or protected areas” within the project footprint.

v The Isabel Province Preservation of Culture Ordinance

This ordinance outlines the process which must be abided by in relation to development in the province and cultural heritage. Section 8 (1), of this Provincial Ordinance dictates that the register of protected places must be consulted and that an inspection of the proposed development area must be carried out prior to the development of the area.

14.3 Assessment method

14.3.1 Overview

The existing cultural and historical heritage values within the Project area have been identified and assessed with the assistance of:

- Axiom project staff, some of whom are from San Jorge Island and the surrounding island group;
- appointed trustees representing landowners within the San Jorge Tenement; and
- landowners who hold customary ownership of parts of the tenement but reside outside its boundaries.

14.3.2 Community Consultation

Axiom consulted the trustees representing landowners within its tenement to find and consult people with knowledge of the tambu sites and other sites of cultural significance in the area. This was followed by clearly identifying the tenement boundaries and the areas Axiom was interested in for its exploration program. The landowners then met and recommended the people with most knowledge on the tambu and cultural sites. These people (all men) then led the Axiom team, comprised of the Community Affairs team and the Environment Manager on to the land to identify the locations of all tambu sites which were then recorded on GPS and clearly marked.

14.4 Project area demography and cultural groups

There are a number of landholders within the San Jorge Tenement who were identified during Axiom's consultation process. Axiom was able to gain access to all villages within landholdings over the tenement to negotiate access and discuss areas of cultural heritage importance. Land use and tenure of the Project is detailed in Chapter 9 of the EIS.

14.5 Existing cultural and historical heritage values

In the Solomon Islands, cultural heritage sites may include, but are not limited to the following: burial sites, places of worship, archaeological remains, sacred sites (including spiritual sites), caves, traditional boundary markers, tribal warfare areas, cultivation areas, etc.

Careful scrutiny of proposed drilling areas were undertaken by the community affairs representatives in company with landowners and appointed trustees. This approach has reduced the likelihood of damage or destruction of cultural and or historic items or places that hold heritage values, and as well, has increased Axiom's knowledge of which areas represent significant cultural heritage values to the local people for consideration in the mine's design and EIS.

The field visits were carried out in the San Jorge Tenement with Batholomew Ramau, Joel Voda and Chief Ellison Bako (Kokolo Thaba) who represent the customary landowners of the tenement.

14.6 Non indigenous cultural aspects

The following section provides a review of the European historical aspects of Santa Isabel Province. Though there is also a significant amount of material describing events during the period of World War ll, the review has focused on the pre-war period, concentrating on those events that may have influenced life on the island, in particular the southern portion. The information is largely taken from a review of the Solomon Islands Historical Encyclopaedia 1893-1978.

14.6.1 Santa Isabel Province 1500 – 1900

On the 19th of November, 1567 an expedition lead by the Spanish explorer Álvaro de Mendaña y Neira set off from the Peruvian city of Callao to study and conquest the unknown southern land. The island was named Santa Ysabel (Isabel) after the saint's day on which the Mendaña expedition first sighted the island on 9 February 1568. On April 28 1568, San Jorge Island was first sighted by the same expedition through a local voyage of the area.

Figure 14.1 Alvaro Mendaña

The expedition recorded Bilebau-Arra as the local name for the Santa Isabel Island. Mendaña and his party spent some months on the island, building a small vessel to use to survey the Solomon Islands.

Mendaña observed 'chiefs' who commanded warring and trading expeditions in western Isabel.

These were probably Kia leaders who had close alliances with groups in the Roviana Lagoon in New Georgia through kin, trade and war alliances, a consequence of which was attacks on the Bugotu people of southern Isabel.

There was never a local name for the whole island (White 1991, 83-84; Aswani and Sheppard 2003).

The next foreign visitors did not reach the island until 1769, when French explorer Jean-François-Marie de Surville rediscovered Isabel at Port Praslin, near present-day Kia. Then, beginning in the 1820s, whaling and trading ships sailed past and occasionally contacted the people of Isabel in their search for whales, turtle shell and bêche-de-mer (sea cucumber). The primary trade locations were near Kia (Port Praslin) and the Bugotu area (White 1991a, 84-85; Bennett 1987, 350-355).

European traders did attempt to establish themselves on Isabel but none managed to do so permanently during the nineteenth century. One early castaway, George Hezekiah Spurgeon from the whaler Georgia, was put ashore because it was believed he had leprosy (Horton 1965, 144-149).

Christianity's permanent presence was brought about by the Anglican Melanesian Mission. Earlier, in 1845, the Marist Catholic Church had tried to settle on Isabel but Bishop Jean-Baptiste Epalle was killed upon landing and the endeavour was abandoned. Anglican Bishop Patteson visited Bughotu on the Southern Cross in 1861 and then and throughout the decade was able to persuade some young men to leave for training in New Zealand and on Norfolk Island.

14.6.2 Santa Isabel Province 1900 – 2000

Santa Isabel Island was claimed between 1886 and 1899 as part of German New Guinea but then transferred to the British Protectorate (Pacific Order in Council 1893). Originally attached to Western District, the first District Officer was appointed there in 1918. The District Station was at Tatamba (Tunnibulli), a natural harbour on the southeast coast. D. C. Horton, District Officer there in 1937-1938, reported that he ran the island with the help of several Headmen, a corporal and five police, a prison warder and an auxiliary schooner of around 15 tons. The Russell Islands were included in its administrative area. (Horton 1965, 33-70).

There were moves in the 1930s to establish stores on Isabel and by 1936 there were five European-owned stores and one Chinese-owned one. (Bennett 1987, 251-252). There were several small plantations on the island before the Second World War, at Ravihana (Kia), Papatura, Suavanao, Ghatere, Estrella Bay, Huhurangi, Ghojoruru (Gozoruru), Goronga, Guguha, Hivo, Fera, Haevo, Floakora, Papari, and Maranatabu, as well as one on San Jorge Island. (Horton 1965, 144-149; Bennett 1987, 251; Golden 1993, 311-312). Sidney Philip Palmer, an English war veteran, set up a plantation on San Jorge Island in 1914. At this time, there was no population present on the island due to earlier head hunting raids and beliefs that spirits of ancestors occupied the island.

The Japanese established a garrison on Isabel during the Second World War with a seaplane base at Rekata Bay. The Allies considered creating a major base there to help retake Rabaul, but decided that Isabel was not important enough strategically. Isabel was finally cleared of Japanese during the allies move through the Western Solomons (Cline and Michel 2002, 247-248). However, some Japanese soldiers were hiding and living in the centre of San Jorge Island.

In 1956 Isabel was transferred to Central District, and in 1978 it became a separate Province. The administrative headquarters was established at Buala on the southeast coast, consisting of Jejevo station where the Church of Melanesia has its diocesan headquarters, and Buala village, which became the centre for provincial administration. The town is close to the airfield on Fera Island.

14.7 Impact assessment

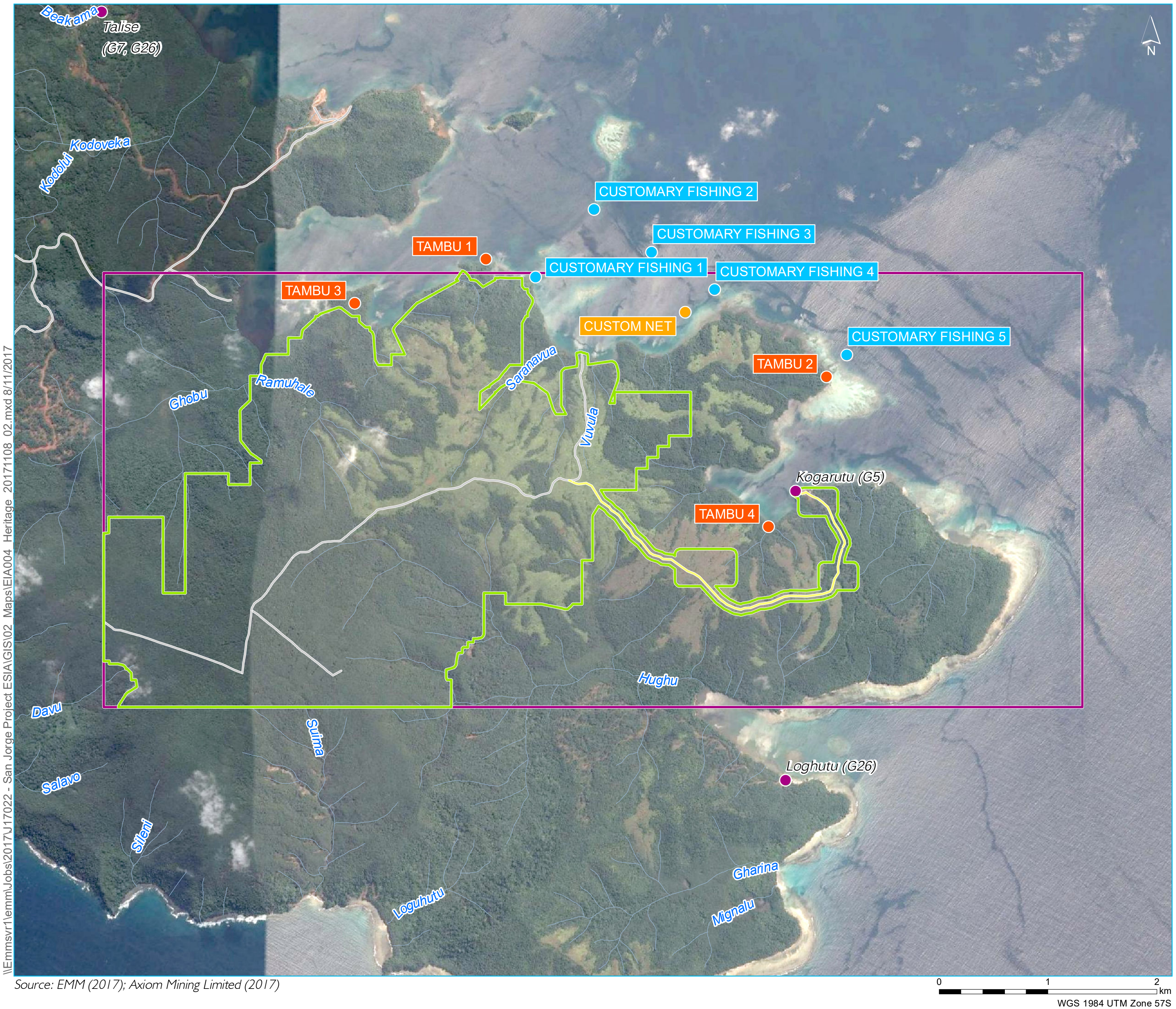
Surveys to identify cultural heritage (archaeological and oral tradition) sites, materials and values have been undertaken in consultation with the community, elders and appointed trustees. This has included consultation regarding the management of cultural heritage sites and preparation of any protocols required for ongoing consultation with community representatives prior to land disturbance.

Outcomes of the cultural heritage surveys have included:

- GPS registered cultural heritage constraints/sensitivities for avoidance;
- further research of appropriate archives, where relevant and required;
- consultation and liaison with the Solomon Islands National Museum; and
- landowner (Trustee) concurrence for cultural heritage management approach.

It is important to note that cultural heritage salvage methods, which prescribe standards and procedures for archaeological salvage, (through surface collection and excavation) will be undertaken before and during construction. This includes Axiom's Cultural Heritage Chance Finds Protocol, described further in this section and within the EMP. The location of the sites of cultural heritage importance are shown on Figure 14.2.

Table 14.1 lists the potential impacts upon cultural and historical heritage items within and around the project area. Four tambu sites were identified, three of which are in the project area. None of the tambu sites are within the project's disturbance area. All of the tambu sites identified are considered to be of local value and importance to the customary landowners.



Source: EMM (2017); Axiom Mining Limited (2017)

Sites of cultural heritage importance

Axiom Mining Limited
San Jorge Nickel Project
Environmental impact statement
Figure 14.2

Table 14.1 Potential unmitigated impacts and their significance

Description	Location		Significance	Likely adverse impacts
	Easting	Northing		
Tambu site 1 contains skulls	572618	9061376	Local value. Culturally significant to the local people	Will not be directly affected as the site is outside the potential area of disturbance and prospecting licence boundary. Access to the site and its setting (surrounding landscape) will be disturbed during construction and operation.
Tambu site 2 Johnson Point	575750	9060291	Local value. Culturally significant to the local people	Will not be directly affected as the site is outside the potential area of disturbance. Access to the site for local people and its setting (surrounding landscape) will be disturbed during construction and operation.
Tambu site 3	571412	9060967	Local value. Culturally significant to the local people	Will not be directly affected as the site is outside the potential area of disturbance. Access to the site for local people and its setting (surrounding landscape) will be disturbed during construction and operation.
Tambu site 4 contains crocodiles	575215	9058910	Local value. Culturally significant to the local people	Will not be directly affected as the site is outside the potential area of disturbance. Access to the site for local people and its setting (surrounding landscape) will be disturbed during construction and operation.
Custom net used for traditional fishing practices	575215	9058910	Local value. Culturally significant to the local people	Will not be directly affected as the site is outside the potential area of disturbance and prospecting licence boundary. Access to the area may be affected by ore barge traffic and the area may be affected by periodic sedimentation following heavy rainfall.

.

14.8 Mitigation measures

14.8.1 Overview

As set out in the previous section, no culturally significant heritage sites will be directly affected by the project.

In the event that unexpected finds are made a chance finds procedure will be implemented as set out below.

14.8.2 Chance finds protocol

A cultural heritage awareness package will be developed and issued to all staff, contractors and sub-contractors prior to their participation in work activities, either during induction training or in tool box talks. Axiom will consult with trustees regarding this plan. Axiom will also consult the Solomon Islands National Museum and Cultural Centre if sites of potential cultural heritage are identified.

The site contractor/s will monitor ground disturbance works and report possible cultural heritage chance finds to the Mining Operations Manager. Should items or artefacts be identified, the site will be marked and GPS position of the item noted for future reference. In the event that a site or item of potential cultural heritage significance is discovered, all contractors will immediately stop work within an approximate distance of five metres of the site. The contractors will demarcate and secure the area.

An archaeologist will be engaged to determine if the site or item has cultural heritage value and the significance of the site or item. If it is of high significance, Axiom will notify the Solomon Islands National Museum and Cultural Centre, describing the type of find.

i Management of chance finds

Should the archaeologist determine that the cultural heritage site is a highly significant archaeological site, the archaeologist, in consultation with Axiom, will determine the appropriate action. The following management options will be considered:

Avoidance: This option minimises the impact to the site through partial or complete project redesign or relocation. This is the preferred option from a cultural resource management perspective.

Salvage excavation: This data recovery option is site destructive and can delay construction. If required, salvage excavation will be conducted in accordance with the requirements of the trustees.

In-situ management: This option includes the application of site protection measures, such as fencing or barricades, or capping the site area with fill. Appropriate protection measures will be identified and agreed between the contractors, Axiom and the trustees.

If this option is the best, but is likely to involve some damage to a significant site (eg in process of capping site area with fill), it may be combined with limited salvage excavation.

Surface collection: If a site is assessed as having limited salvage excavation potential but contains significant surface archaeological items, those surface finds may be individually mapped and collected in accordance with the wishes of the trustees.

Destruction: If a site is assessed as having limited archaeological significance, it may be destroyed once a complete photographic record has been made and a report has been completed (see Appendix A).

ii Reporting and notification

Any cultural heritage finds during the bulk sampling will be recorded using the chance find report form (Attachment A of this chapter). Data from this form will be transferred to the Project GIS database. The site supervisor will request guidance from the community affairs manager to determine the nature and significance of individual finds (where appropriate).

All documentation of significant finds will be kept by Axiom and supplied to the Solomon Islands National Museum and Cultural Centre upon request. These reports will include the following as appropriate:

- cultural heritage assessments;
- recording and mapping of the cultural heritage sites/finds and oral traditions and additions to GIS mapping database;
- further research of appropriate archives where relevant and required;
- engagement of specialists such as social anthropologists, archaeologists (including marine) and cultural heritage specialists;
- preparation of site-specific cultural heritage plans for all proposed disturbance areas in consultation with Solomon Islands National Museum and Cultural Centre and relevant specialists, where necessary;
- implementation of the cultural awareness initiatives; and
- implementation of the cultural heritage chance finds protocol.

All Axiom personnel and contractors will report chance finds to Axiom as per (Attachment A of this chapter). All sites where items have been found should be marked to identify origin.

14.9 Residual Impacts

The residual impacts on areas of cultural heritage significance are set out below in Table 14.2. As there is no direct disturbance, the residual impacts are considered negligible to minor.

Table 14.2 Cultural heritage – residual impacts following the implementation of proposed management measures

Description	Location		Significance	Residual Impacts
	Easting	Northing		
Tambu site 1 contains skulls	572618	9061376	Culturally significant to the local people	The site should be undisturbed however the surrounding landscape will be changed due to the mining resulting in a minor residual impact.
Tambu site 2 Johnson Point	575750	9060291	Culturally significant to the local people	The site should be undisturbed. The surrounding landscape will be changed although this will not be visible due to the local ridgeline resulting in a negligible residual impact.
Tambu site 3	571412	9060967	Culturally significant to the local people	The site should be undisturbed however the surrounding landscape will be changed due to the mining resulting in a minor residual impact.
Tambu site 4 contains crocodiles	575215	9058910	Culturally significant to the local people	The site should be undisturbed however the surrounding landscape will be changed due to the mining resulting in a minor residual impact.
Custom net used for traditional fishing practices	575215	9058910	Culturally significant to the local people	The site should be undisturbed and fishing should be able to continue, however the surrounding landscape will be changed due to the mining resulting in a minor residual impact.

14.10 Conclusion and summary

Axiom has undertaken continuous consultation with local villagers who have customary land holdings within the tenement (study area). Part of this process has included the identification of culturally important sites, including tambu (forbidden) sites and other cultural features on or adjacent to the study area.

A total of four tambu sites and one other culturally important site were identified in conjunction with local leaders within or adjacent to the study area. These included: a tambu site where skulls were known to be sited; 2 tambu sites important because of their location and views; a tambu site important for crocodiles; and lastly the area’s customary fishing nets.

None of the sites will be directly affected by the proposed development. However some indirect adverse effects have been noted: access to all of the tambu sites may be affected during the construction and operation of the mine. In addition, the setting (surrounding landscape) at all of the sites may be affected. The customary fishing nets may be affected by disturbance from barges and shipping and by sedimentation from adjacent rivers during storm events.

The assessment set out a range of management measures to address potential impacts and to deal with chance finds. Overall the impacts are considered to be of negligible to minor significance, with issues being resolved through consultation, communication and possible compensation, particularly regarding the customary fishing nets.

Attachment A

Chance Finds Report Form

Please contact: ______________________________

To discuss find, on: ______________________________

Initial Detail:

Location of Find: Date of Find: Person who identified find:

___________________________ ___________________________ ___________________________

Description of Initial Find:

____

Was work stopped in the immediate vicinity of the find? □ Yes □ No

Was an archaeologist contacted? □ Yes □ No

Contact details:____

Archaeological Detail:

Date of inspection: ____________ Reporting Archaeologist: ____________

GPS coordinates: Photo Record:

Zone: ______ N: ______________ E: ______________ □ Yes □ No

Description of Find (fill in applicable information) (use additional pages if required):

Artefact type: ____________

Max artefact length (in mm): ______________ Max artefact width (in mm): __________________

Max artefact thickness (in mm): ____________ Max artefact platform width (in mm): ____________

Approximate number of artefacts at site:

□ 1

□ 2 to 10

□ > 10

□ >50

Other: ____________

Approximate size of site:

Site area: ___________ m^2

Site length: __________ m

Site height (max) (for rock shelters/caves): _______ m

Brief description of site and vegetation (eg, surface sediment type, ground surface visibility, distance to nearest freshwater source, attach site sketch if necessary):

____

Brief description of find(s):

____

Statement of Significance (scientific, spiritual, historical, aesthetic and emotive and any evidence of stratification):

____

Level of Significance:

Low □ Medium □ High □ Skeletal □

Impact Assessment:

Is site destroyed? □ Yes □ No

Can further impacts to the chance find be avoided? □ Yes □ No

Avoidance and mitigation measures discussed:

____

Impact to Find:

Avoidance and mitigation outcome:

____

Date completed form lodged: Person who lodged form: Signature:

_________________________ _________________________ _________________________

15 Management plans and mitigation measures

This chapter collates the mitigation measures that have been developed to reduce or avoid the potential adverse impacts of the project and enhance its benefits. The mitigation measures are derived from the work of technical specialists, international leading-practice standards, and design features from Axiom. The mitigation measures will generally form the basis of management plans that will be prepared prior to the project's construction.

The management plans which will be prepared for this project include:

- Erosion and sediment control plan;
- Rehabilitation plan*;
- Hazardous materials and spill response plan;
- Waste management plan;
- Acid sulphate soils plan;
- Ballast water management plan;
- Pest and weed management plan;
- Air quality management plan;
- Marine monitoring plan; and
- Biodiversity monitoring plan.

* Rehabilitation plan has already been prepared.

The proposed management plans and the mitigation measures have been summarised in Table 15.1. Additional measures that will be implemented but do not form the basis of a management plan are summarised in Table 15.2.

Table 15.1 Proposed management plans and mitigation measures

Management plan	Number	Mitigation Measure
Erosion and sediment control plan	E001	Install leading-practice erosion and sedimentation controls measures across the project site.
	E002	Design infrastructure to reduce the amount of vegetation clearance required.
	E003	Regularly maintain erosion and sediment control measures during and immediately after heavy rainfall.
	E004	Maintain sediment structures around recently rehabilitated areas until stabilised.
	E005	Rehabilitate and revegetate areas disturbed for construction, but not required for further operations as soon as possible.
	E006	Preferentially use water captured in sedimentation basins for dust suppression.

Table 15.1 Proposed management plans and mitigation measures

Management plan	Number	Mitigation Measure
	E007	Implement the monitoring and mitigation plan that is detailed in the surface water assessment.
	E008	Divert upslope runoff around mine blocks, stockpiles and storage areas.
	E009	Establish riparian protection zones around watercourses.
	E010	Retain strategic vegetation strips where practicable.
	E011	Mine and rehabilitate the resource progressively to reduce exposure.
	E012	Determine grubbing requirements on a site by site basis to maintain soil stability where practicable.
	E013	Limit the use of grubbing at temporary laydown areas.
	E014	Clear vegetation and overburden immediately prior to mining to reduce surface exposure.
	E015	Engineer diversion channels to direct surface water from disturbance areas to sedimentation basins.
	E016	Construct sedimentation basins to treat sediment laden runoff from disturbance areas. Sedimentation basins are to be sized to capture runoff from an 85th Percentile 5 day rainfall event.
	E017	Engineering designs will be prepared for all sedimentation basins that have earthen fill embankments. The designs will include appropriately designed spillways and consider geotechnical risks
	E018	Design and engineer waterway crossings and interfaces to reduce the risk of scour damage to the waterway.
	E019	Prepare detailed water management plans in conjunction with mine plan development.
	E020	Where practicable, construct roads along ridge lines to minimise cut and fill batter footprints and the need for watercourse crossings.
	E021	Stabilise cut and fill batters with vegetation and / or rock armouring. Where required, establish clean water diversions along the top of the cut batter (up-gradient of the road) to divert runoff from up-gradient areas into designated transverse drainage systems.
	E022	Transverse drainage (or cross drainage) systems will be appropriately designed to convey clean water under the access roads. Apply scour protection at inlet and outlets as required.
	E023	Configure and size longitudinal road drainage for the contributing catchment area, local topography and road design (i.e. single or double cross fall roads). The length of longitudinal drainage will be minimised to prevent excessive flows. Incorporate scour protection such as rock armouring into the design as required.
	E024	Establish small sedimentation basins (commonly referred to as pocket ponds) at longitudinal drainage outlets to provide sedimentation treatment.
	E025	Engineering designs of Primary Haul Roads will consider all transverse and longitudinal drainage.
	E026	Sheet road surfaces with appropriate material.
	E027	Limit vehicle movements to designated trafficable areas
	E028	Restrict vehicle speeds on access and haul roads to 20 km/h. Vehicle speeds will be further restricted when it is windy.
	E029	Spray unsealed road areas, short-term soil stockpiles and other exposed areas susceptible to wind erosion with freshwater when required.

Table 15.1 Proposed management plans and mitigation measures

Management plan	Number	Mitigation Measure
	E030	Grade the ore handling facility to drain inland so that all surface water drains away from the marine environment. Direct water into water management system for treatment if required. Use water captured in the basins for haul road dust suppression.
	E031	Shelter stockpiles from prevailing winds, leave in a coarse condition and revegetate as soon as practicable.
	E032	Cover stockpiles with tarpaulins during rainfall events to prevent rainfall ingress into and seepage from stockpiles.
Rehabilitation Plan (will also include measures E001 to E032 from the erosion and sediment control plan)	R001	Follow soil management procedures detailed in the Rehabilitation Plan.
	R002	Stockpile topsoil and overburden for use in revegetation.
	R003	Chip, compost and stockpile cleared vegetation for use in rehabilitation where appropriate.
	R004	Place soil and overburden in separate stockpiles close to the mined areas in previously cleared areas where practicable.
	R005	Place stockpiles away from operational areas to avoid disturbance.
	R006	Place stockpiles appropriately to avoid any drainage lines or depressions.
	R007	Limit topsoil stockpiles to a height of 2 m to encourage infiltration and limit the potential for anaerobic conditions to develop.
	R008	Ensure a suitable embankment slope of the stockpile (less than 2:1) and divert drainage from higher areas around stockpiles to avoid erosion.
	R009	Chemically improve topsoil to maintain fertility and physical integrity.
	R010	Establish a vegetative cover of native, species via seeding in order to stabilise the stockpile.
	R011	Use native species for revegetation.
	R012	Follow soil management procedures detailed in the Rehabilitation Plan.
	R013	Reinstate and enhance disturbed areas to maintain linkages between areas of habitat.
Hazardous materials and spill response plan	H001	Apply appropriate industry standards and codes of practice for the handling of hazardous materials including fuels, oils, lubricants and chemicals.
	H002	Cover and bund all fuel storage and refuelling areas to reduce the risk of hydrocarbons entering soils and the drainage system.
	H003	Store hazardous materials in designated areas, with appropriate bunding where required.
	H004	Keep relevant, up to date hazardous materials information (including SDS) on site and accessible in the event of a spill.
	H005	Develop and implement spill response and reporting procedures to reduce the impacts of a potential spill.
	H006	Ensure appropriate spill response equipment for containment and recovery is present on site, and accessible in the event of a spill.
	H007	Detail spill response procedures in site inductions.

Table 15.1 Proposed management plans and mitigation measures

Management plan	Number	Mitigation Measure
Waste management plan (will also include measures H001 and H002 from the Hazardous Materials and Spill Response Plan)	W001	Manage solid and liquid waste from construction, operation and rehabilitation so that they are contained, transported, handled and disposed of in such a manner as to reduce impacts to human health and the environment.
	W002	Design and construct appropriate waste management infrastructure for the recycling and disposal of solid and liquid waste generated by the project.
	W003	Maintain a waste stream inventory to identify the type, classification, storage and disposal requirements for the waste.
	W004	Identify opportunities to reduce, reuse and recycle waste where possible.
	W005	Treat waste water and sewage to a standard adequate for discharge in accordance with the National Water Quality Management Strategy: Australian Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000).
	W006	Dispose of sludge from the waste water plant at the project landfill.
	W007	Dispose of hazardous waste at an accredited and registered waste disposal facility.
	W008	Cover ore on barges from rain and sea spray, and use a runoff system to collect, manage and appropriately dispose of waste water from barges.
	W009	Dispose of food scraps in bins that prevent animal access.
Ballast water management plan	B001	Ships will comply with the International Convention of Pollution from Ships (MARPOL) as established by the International Maritime Organisation.
	B002	Establish procedures for the management of ballast water.
	B003	Use low risk ballast water such as fresh potable water or high seas water.
	B004	Exchange ballast water in the designated area, and treat or dispose of appropriately.
Acid sulphate soils management plan	A001	Establish procedures to manage potential or actual acid sulphate soils.
	A002	Establish handling procedures for potential and actual acid generating materials.
	A003	Add appropriate additives to neutralise potential or actual acid generating waste rock.
Pest and weed management plan	P001	Make sure all vehicles entering the site have been appropriately washed down, ensuring wheels, wheel arches and the undercarriage are free of mud and plant material.
	P002	Identify and control pests and weeds of management concern on site in accordance with local best management practices.
	P003	Monitor treated areas to assess the success of declared weed eradication.
	P004	Include pest and weed management in the site inductions to promote the awareness of weed management issues.
Air quality management plan (will also include measures E001, E002, E011, E014, E026, E027, E028, and E029 from the erosion and sediment control plan)	AQ001	Reduce drop heights when dumping material from excavators and loaders.
	AQ002	Reduce surface disturbance activities, excavation, dumping and stockpile management during dry or high wind conditions.
	AQ003	Appropriately service and maintain vehicles and equipment.
	AQ004	Switch off vehicles and equipment when not in use.

Table 15.2 General mitigation measures

Relevant chapter	Number	Mitigation measure
General	G001	Adhere to all applicable legislation and regulations.
General	G002	Mark trees that are to be removed that can be used by the project or community, and keep separate from other cleared vegetation.
General	G003	Remove trees by chainsaw rather than bulldozer so they can be used as a community resource.
General	G004	Develop an appropriate training and induction program for all employees, contractors and visitors to site.
Terrestrial ecology	G005	Clearly delineate areas of native vegetation to be removed or retained to equipment operators and supervisors before clearance.
Terrestrial ecology	G006	Retain and restore riparian vegetation to support fauna habitats and movement corridors through the study area.
Terrestrial ecology	G007	Undertake vegetation clearance in a manner that allows fauna to migrate to adjacent habitats.
Terrestrial ecology, amenity	G008	Use low glare and directional lighting to reduce light spill.
Terrestrial ecology, amenity	G009	Orientate workshop buildings within the project site to reduce light spill.
Amenity	G010	Use low impact reversing alarms on mobile equipment.
Amenity	G011	Fit engine exhausts with suitable silencers or mufflers.
Amenity	G012	Include noise-sensitivity training in worksite inductions.
Cultural heritage	G013	Develop a cultural heritage awareness package (including chance finds protocol) and include it in worksite inductions.
Cultural heritage	G014	Prohibit disturbance of Tambu sites.
Cultural heritage	G015	All workers to report chance finds as detailed in the chance find protocol.
Social	S001	Establish a working group with village chiefs and leaders to communicate information about the project, including updates and changes.
Social	S002	Establish a complaints and feedback procedure that responds to project related complaints, issues, comments and suggestions.
Social	S003	Consider flexible working hours and rosters to promote a family friendly culture.
Social	S004	Develop and implement a health, safety and environmental management plan for all project activities.
Social	S005	Restrict access to local villages for workers who are not members of landowning tribes.
Social	S006	Prohibit hunting and fishing for workers who are not members of landowning tribes.
Social	S007	Collaborate with local leaders, government and NGOs to develop awareness training on health issues (including communicable diseases), workplace health and safety, cultural awareness and appropriate worker behaviour that is included in the workplace induction program.
Social	S008	Establish a working group with the national government, regional government and community leaders to agree how benefits such as jobs, service agreements, royalties and profits are managed and shared between the communities.
Social	S009	Investigate methods for holding and distributing funds appropriately to maximise community rather than individual benefits.
Social	S010	Investigate sustainable supply agreements with local businesses.
Social	S011	Recruit local people from San Jorge and south Santa Isabel where possible.

Table 15.2 General mitigation measures

Relevant chapter	Number	Mitigation measure
Social	S012	Establish a working group with key community leaders to manage and avoid potential conflicts within and between villages that may arise as a result of the project.
Social	S013	Establish a working group with senior female leaders from the community to promote the involvement of women in the project.
Social	S014	Provide employment and training opportunities for women.
Social	S015	Develop an equal opportunity policy and investigate accommodations and provisions for employing women on the site.
Social	S016	Provide health services to the workforce by establishing an on-site first aid post to avoid putting pressure on the local healthcare system.
Social	S017	Provide opportunities for appropriate training and up-skilling to the workforce.
Social	S018	Collaborate with local leaders to develop and enforce a workforce code of conduct including disciplinary procedures to reduce anti-social behaviour.
Social	S019	Prohibit alcohol and non-prescribed drugs on site.
Social	S020	Establish a working group with village chiefs and leaders to safeguard the existing fishing sites and liaise on locations of marine infrastructure and shipping routes.

The following monitoring plans will be prepared and implemented to monitor impacts to marine ecosystems:

- Marine monitoring plan, containing procedures for:
  - regular sampling for water quality parameters such as temperature, pH, turbidity, dissolved oxygen, turbidity and electrical conductivity.
- Biodiversity monitoring plan, containing procedures for:
  - appropriate education and awareness about the environment, biodiversity and landscape function;
  - key performance indicators against which to measure biodiversity progress and will specify review periods where progress is reviewed;
  - consultation with local communities to ensure their traditional knowledge of biodiversity and cultural values are acknowledged and incorporated into the management plan; and

    regular sampling for marine fauna diversity, abundance and community structure.

16 Summary and conclusions

The EIS has been prepared to accompany the application for a nickel mine on San Jorge Island in southern Isabel Province in the Solomon Islands. The project will comprise extraction, by shallow strip mining, of approximately 2 million tonnes per annum (Mtpa) of nickel laterite deposits, over a period of five to ten years. The ore will be directly shipped overseas for processing.

There is a continuous global demand for nickel: when added to other metals eg iron and copper, it creates strong, versatile alloys including stainless steel; and it is used in rechargeable batteries eg in electric cars.

The economy of the Solomon Islands is predominantly based on forestry and agriculture, which makes it vulnerable to changing climate and market forces. This project aligns with government policy of diversification to increase jobs and revenue streams.

Axiom is committed to an enduring partnership with traditional land owners and development of mining that benefits the local community and wider region. This is reflected in its ownership structure, with this project being 10% owned by the customary land owners of the San Jorge tenement.

The project will create a significant number of jobs – projected to be 300 during construction and 120 to 140 during operations. Axiom will aim to recruit locally where possibly, particularly from villages with customary ownership of the land, thereby ensuring the mine benefits locally communities. Not only will this significantly increase income, but the training will provide ongoing benefits such as attainment of new skills that can be taken back to home villages. The project will generate significant revenue through taxes and royalties for the government. It is anticipated that taxes and royalty benefits will be used for social infrastructure and social development such as education, healthcare and other long term community projects.

The EIS sets out relevant legislation in the Solomon Islands, and includes a summary of project-related stakeholder consultation. It also describes the EIS methodology setting out how impacts have been identified, described and quantified. For each social and environmental aspect, the EIS sets out: the existing environment; an impact assessment method; potential impacts; environmental management measures; and residual environmental impacts assuming environmental management measures are implemented. The key issues described in the EIS are related to:

Geology/Soils: the shallow, red soils are susceptible to erosion during heavy rainfall, once vegetation is cleared. A rehabilitation plan has been prepared to reduce soil erosion and associated impacts.

Terrestrial ecology: the clearance of ultramafic forests and fernlands, including flora and fauna (over 1000 ha in total) will reduce the area's ecological value. Whilst environmental protection measures and a rehabilitation plan will reduce impacts, the site will still be adversely affected over a long term period.

Freshwater environment: the project area supports a number of small freshwater streams (3-4 km long) that flow into the sea. The main impact of the project will be to increase sedimentation in the streams from soil erosion. The rehabilitation and erosion and sediment control plans will assist in reducing adverse impacts, although some increase in sedimentation and turbidly will not be completely preventable.

Marine ecology and environment: the marine water quality and ecology will be locally affected by stream sedimentation. In addition, loading of barges and ships with ore and the boat ramp construction may have local adverse water quality impacts. A variety of management plans are proposed to reduce impacts.

Amenity: this assessment considered impacts of the project relating to visual amenity, air quality and noise on local villages. The nearest receptors are in Talise, 3.5km from the project. The three assessments (visual, air quality and noise) all concluded that impacts would all be minor / negligible due to the distance between the mine and receptors.

Socio-economic and cultural heritage: there are a number of significant socio economic benefits that would arise from the development of the mine: direct revenue to the Government; jobs during construction and operation; revenue into the local economy via the share ownership model; and indirect economic benefits from associated industries and services to supply the mine. The project does not directly impact any villages or settlements and therefore no resettlement action plan is required. The project could have some indirect, adverse social impacts, however a range of social management measures have been suggested to reduce or eliminate these issues. Four culturally sensitive tambu sites and a customary fishing area have been identified by local residents for protection should the project proceed. None of these are directly affected by the project, and indirect impacts are considered to be minor.

References

Anacker, BL 2014, The nature of serpentine endemism *American Journal of Botany,* 101, pp. 219-224.

ANZECC/ARMCANZ 2000a, *National Water Quality Management Strategy: Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment and Conservation Council/ Agriculture and Resource Management Council of Australia and New Zealand.

ANZECC/ARMCANZ 2000b, *National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting*, , Australian and New Zealand Environment and Conservation Council/ Agriculture and Resource Management Council of Australia and New Zealand.

Bennett, A 1990, Habitat Corridors and the Conservation of Small Mammals in a Fragmented Forest Environment *Landscape Ecology*, 4, pp. 109-122.

Berly, TJ, Hermann, J, Arculus, R, & Lapierre, H 2006, Supra-subduction zone pyroxenites from San Jorge and Santa Isabel (Solomon Islands) *Journal of Petrology* 47, pp. 1531-1555.

BOM (Bureau of Meteorology) 2017, *Southern Hemisphere Tropical Cyclone Data Portal*, viewed 12 October 2017, http://www.bom.gov.au/cyclone/history/tracks/

DEC 2005, *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales*, prepared by Department of Environment and Conservation NSW.

EHP 2008, *Environmental Protection (Air) Policy 2008*, Department of Environmental and Heritage Protection.

EMM 2015, *Kolosori Project Solomon Islands*, prepared by EMM Consulting Pty Ltd.

EMM 2017, *Environmental Impact Assessment: Scoping Report*, prepared for Axiom Mining Limited by EMM Consulting Pty Ltd.

EPP/DEHP 2013, *Queensland Water Quality Guidelines 2009*, prepared by Environmental Policy and Planning/ Department of Environment and Heritage Protection.

Flannery, TF 1995, *Mammals of the South-West Pacific and Moluccan Islands,* Cornwell University Press, Ithaca.

Golder 2014, *Jejevo/Isabel B Project Terrestrial Ecology Baseline Report*, Prepared for inclusion in EIS for the Jejevo/Isabel B Project for SMM Solomon Limited by Golder and Associates.

Hansell, JRF & Wall, JRD 1977, *Land Resource Study 18: Land Resources of the Solomon Islands,* Land Resources Division, Surrey.

Hodge, N, Slayter, B & Skiller, L 2015, *Solomon Islands Health System Review*, prepared by Asia Pacific Observatory on Health Systems and Policies.

IFC 2007, *Environmental, Health, and Safety Guidelines: Noise Management*, International Finance Corporation.

IMC 2016, *San Jorge Technical Study*, prepared by IMC Mining Pty Ltd for Axiom KB Limited.

International Nickel Study Group 2017, *Production, usage and prices*, viewed 11 October 2017, http://www.insg.org/prodnickel.aspx

Isbell, RF 2002, *The Australian Soil Classification*, CSIRO Publishing, Collingwood.

ISO 1996, *Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation ISO 9613-2:1996*, International Organization for Standardization.

IUCN Red List of Threatened Species (International Union for Conservation of Nature) 2013, *Red List of Threatened Species*, viewed 12 October 2017, http://www.iucnredlist.org/

Kay, KM, Ward, KL, Watt, LR & Schemske, DW 2011, Plant speciation, In *Serpentine: Evolution and Ecology in a Model System*, eds SP Harrison & N Rajakaruna, University of California Press, Berkley.

Lee, KE 1969, Some Soils of the British Solomon Islands Protectorate *Philosophical Transactions of the Royal Society of London*, 255, pp. 211-257.

Lees, A 1991, *A Representative Protected Forests System for the Solomon Islands*, Maruia Society, Nelson.

Lindenmayer, DB & Fischer, J 2006, *Habitat Fragmentation and Landscape Change: An Ecological and Conservation Synthesis,* Island Press, Washington DC

MEHRD 2008, *Digest of Education Statistics*, prepared by Solomon Islands Government Ministry of Education and Human Resource Development.

MET (Meteorological Services Division) 2015, *Solomon Islands Meteorological Services*, viewed 12 October 2017, http://www.met.gov.sb/

Milford, HB, McGaw, AJE & Nixon, KJ 2011, *Soil Data Entry Handbook 3rd edition*, NSW Department of Land and Water Conservation, Sydney.

NCST (National Committee on Soil and Terrain) 2009, *Australian soil and land survey field handbook 3rd edition*, CSIRO Publishing, Collingwood.

Nickel Institute 2017, *First uses of nickel*, viewed 11 October 2017, https://www.nickelinstitute.org/NickelUseInSociety/AboutNickel/FirstAndEndUsesofNickel.aspx

Price, S, Beeson, A, Fardin, J & Radford, J 2015, *Environmental law in Solomon Islands*, Solomon Islands Government.

Rajakaruna, N 2004, The edaphic factor in the origin of species *International Geology Review*, 46, pp. 471-478.

ResEval 2016, *San Jorge Technology Study Geology*, prepared by ResEval Pty Ltd for Axiom KB Limited.

Sagapoa, CV, Imai, A & Watanabe, K 2011, Laterization process of ultramafic rocks in Siruka, Solomon Islands *Journal of Novel Carbon Resource Sciences* 3, pp. 32-39.

SINSO (Solomon Islands National Statistics Office) 2017, *Projected population by province 2010 – 2025*, viewed 12 October 2017, http://www.statistics.gov.sb/statistics/social-statistics/population

SINSO/SIMoHMS/SPC 2017, *Solomon Islands Demographic and Health Survey 2015*, prepared by Solomon Islands National Statistics Office/ Solomon Islands Ministry of Health and Medical Services/ Pacific Community.

Smithsonian/USGS (United States Geological Survey) 2013, *Smithsonian/USGS Weekly Volcanic Activity Report*, viewed 12 October 2017, http://volcano.si.edu/reports_weekly.cfm

SMM Solomon Limited 2012, *Environmental Impact Statement Santa Isabel Island*, prepared by SMM Solomon Limited.

SMM Solomon Limited 2014, *Jejevo Isabel B Environmental and Social Impact Assessment*, prepared for SMM Solomon Limited.

The Economist Intelligence Unit, *Solomon Islands: The government plans to diversify the economy*, viewed 11 October 2017, http://country.eiu.com/article.aspx?articleid=1997730584&Country=Solomon%20Islands&topic=Economy&_2

Whitmore, TC 1969, Vegetation of the Solomon Islands *Philosophical Transactions of the Royal Society of London*, 255, pp. 259-270.

Whitmore, TC 1988, *Tropical rain forests of the Far East 2nd edition*, Oxford University Press, Oxford.

WHO (World Health Organization) 2015, *Solomon Islands: WHO Statistical Profile*, viewed 3 February 2016, http://www.who.int/countries/slb/en/

Wolf, A 2001, Conservation of endemic plants in ultramafic landscapes *Biological Conservation*, 100, pp. 35-44.

Yahner, RH 1988, Changes in Wildlife Communities Near Edges, *Conservation Biology*, 2(4), pp. 333-339

Study team

The San Jorge Nickel Project Environmental and Social Impact Statement has been a collaborative effort by multiple people from varying companies.

EMM Consulting is the proponent for the project. The EMM Consulting team listed in Table S.2 worked collaboratively with the technical team, listed in Table S.1, to prepare this report. Individuals from Royal HaskoningDHV, Ecological Solutions, Institute of Applied Technology and The Ministry of Fisheries and Marine Resources were commissioned by EMM Consulting as technical specialists.

Table S.1 EMM project team

Team Member	Project Role	Qualifications	Years of Experience
Philip Towler	Project Director	BSc (Chemistry)(Hons), PhD Environmental Chemistry	20
Robert Morris	Project Manager and EIS Author	BSc (Ecology)(Hons), MSc (Environmental Assessment and Management), GAICDs	25
Luke Stewart	Senior Reviewer	BAppSc (Hons)	19
Ellie Thackray	EIS Author	BSc (Environmental Geology)(Hons)	8
Chagi Weerasena	EIS Author	BEnvSc (Natural Resource Science)(Hons)	1

Table S.2 Technical specialists

Team Member	Project Role	Company	Qualifications	Years of Experience
Kylie Drapala	Soil and Rehabilitation	EMM Consulting	BEnvSc (Natural Resource Science), PhD, Dip Quality Auditing, Cert IV Project Management, Cert III Frontline Management, Cert IV Training and Assessment	12
Nicholas Jamson	Soil and Rehabilitation	EMM Consulting	BEnvSc (Natural Resource Sciences)(Hons)	2
Sean Cassidy	Freshwater Ecology	EMM Consulting	BSc (Environmental Earth Science)(Hons)	6
Chris Kuzcera	Freshwater Ecology	EMM Consulting	BEng (Hons)	12
Robson Hevalao	Freshwater Ecology	Ministry of Fisheries and Marine Resources, Solomon Islands	BSc (Marine Science and Environmental Studies)	6
Evan Watterson		Royal HaskoningDHV	BEng, BSc (Coastal Engineering and Oceanography)	12
Heiko Loehr		Royal HaskoningDHV	BAppSc (Maritime Technologies), MSc (Coastal Engineering)	5

Table S.2 Technical specialists

Team Member	Project Role	Company	Qualifications	Years of Experience
Daniel Weston	Noise	EMM Consulting	BEngTech (Audio), MDesSc (Acoustics)	10
Lucas Adamson	Noise	EMM Consulting	BEng (Environmental)(Hons), Cert III Laboratory Skills	6
Rob Morris	Ecology Lead and Ornithological Specialist	EMM Consulting	BSc (Ecology)(Hons), MSc (Environmental Assessment and Management), GAICDs	25
Dr John Schenk	Forest Ecology	EMM Consulting	BSc (Hons), PhD (Ecology)	40+
Patrick Pikacha	Amphibians and Reptiles	Ecological Solutions, Solomon Islands	BA (Biogeography and Education), Dip AppSc , Post Grad Dip Geography, MA, PhD (Ecology and Evolutionary Biology)	11
Myknee Sirikolo	Terrestrial Flora	Institute of Applied Technology	Director of the National Herbarium and Botanical Gardens, Ministry of Forestry, Solomon Islands Government	20+

Appendix A

Soil assessment

San Jorge Nickel Project

Soil Assessment

Prepared for Axiom KB Limited | 15 January 2018

San Jorge Nickel Project

Soil Assessment

Prepared for Axiom KB Limited | 15 January 2018

Suite 1, Level 4, 87 Wickham Terrace
Spring Hill QLD 4000

T +61 7 3839 1800
F +61 7 3839 1866
E info@emmconsulting.com.au

www.emmconsulting.com.au

San Jorge Nickel Project

Report

Report J17022Rp1| Prepared for Axiom KB Limited | 15 January 2018

Prepared by	**Nicholas Jamson**	Approved by	**Kylie Drapala**
Position	Environmental Scientist	Position	Senior Environmental Scientist
Signature		Signature	
Date	3 November 2017	Date	3 November 2017

This report has been prepared in accordance with the brief provided by the client and has relied upon the information collected at the time and under the conditions specified in the report. All findings, conclusions or recommendations contained in the report are based on the aforementioned circumstances. The report is for the use of the client and no responsibility will be taken for its use by other parties. The client may, at its discretion, use the report to inform regulators and the public.

Document Control

Version	Date	Prepared by	Reviewed by
1	3/11/2017	N Jamson	K Drapala
1A	15/1/2018	E Thackray	K Drapala

EMM

T +61 (0)7 3839 1800 | F +61 (0)7 3839 1866

Suite 1 | Level 4 | 87 Wickham Terrace | Spring Hill | Queensland | 4000 | Australia

www.emmconsulting.com.au

Table of contents

Chapter 1 Introduction 1
1.1 Background 1
1.2 Location 1
1.3 Disturbance activities 3
1.4 Overview of rehabilitation 3
1.4.1 Other industry disturbance and alternative rehabilitation options 4
1.5 Purpose of this report 4

Chapter 2 Desktop review 5
2.1 Climate 5
2.2 Topography 5
2.3 Surface water 5
2.4 Marine environment 5
2.5 Groundwater 5
2.6 Fauna and flora 6
2.7 Land use 6
2.8 Soils and geology 6
2.8.1 Soil 6
2.8.2 Limonitic zone 6
2.8.3 Saprolitic layer 7

Chapter 3 Fieldwork 9
3.1 Method 9
3.1.1 Sample locations 9
3.1.2 Sampling method 12
3.1.3 Field assessment 12
3.2 Results 13
3.2.1 Site description 13
3.2.2 Soil description 15
3.2.3 Soil chemistry 16
3.2.4 Erosion potential 18

Chapter 4 Impact assessment and soil resource management 25
4.1 Potential impacts 25
4.1.1 Loss of soil stability 25
4.1.2 Loss of soil function 25
4.2 Soil and waste rock management 27
4.3 Management of soil stockpiles 29
4.4 Rehabilitation 29

Table of contents *(Cont'd)*

4.5 Erosion and sediment control 30

Chapter 5 Conclusion 33

References 35

Appendices

A Assessing soil texture

B Detailed laboratory results

Tables

3.1 List of check sample sites with coordinates 9

3.2 List of detailed sample sites with coordinates 10

3.3 Acidic Dystrophic Red Ferrosol typical soil profile summary 16

3.4 Acidic Dystrophic Red Ferrosol soil chemistry results median (lowest-highest concentration) 17

4.1 Potential project impacts on soil 26

4.2 Soil stripping and rehabilitation suitability criteria 27

Figures

1.1 Location of site 2

3.1 Location of sample sites 11

3.2 Primary forest (10) 14

3.3 Bracken and ferns vegetation (28) 14

3.4 Fire disturbed vegetation (1) 15

3.5 Topsoil Emerson Class Number 20

3.6 Subsoil Emerson Class Number 21

3.7 Topsoil organic carbon 22

3.8 Subsoil organic carbon 23

4.1 Recommended soil stripping depths 28

1 Introduction

1.1 Background

Axiom KB Limited (Axiom KB), a subsidiary of Axiom Mining Limited (Axiom), proposes to develop mineral deposits on San Jorge Island in the Isabel Province of the Solomon Islands (the project). The project will comprise extraction of nickel laterite deposits over a period of approximately five to ten years. The ore will be partially dried, then transferred by barge and loaded on to ships moored in Thousand Ships Bay, and then transported to regional processing hubs.

1.2 Location

The tenement area referred to in this EIS measures 9 km by 4 km, and comprises the area bound by the Ghobu Creek catchment in the north-west to the Unk and Hughu Creek catchments in the south. The eastern extent of the project area comprises the marine waters adjacent to the coastline, including Albatross Bay to the north, Astrolabe Bay to the east and Tanatola Bay to the south; beyond these bays, is the deep water mooring in Thousand Ships Bay.

San Jorge Island is very sparsely populated, with only one major settlement on the island at Talise on the central part of its east coast (Figure 1.1).

\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps_SIA\SIA001_Regional_20171027_01.mxd 27/10/2017

Source: EMM (2017); Axiom Mining Limited (2017)

Site location

Axiom Mining Limited
San Jorge Nickel Project
Soil assessment

Figure 1.1

1.3 Disturbance activities

Approximately 1348.4 hectares (ha) of land will be disturbed throughout the life of the mine. Disturbance of the deposits to extract the ore will largely be from the construction of infrastructure, including:

- open-cut pits;
- out-of-pit waste rock dumps;
- roads for haul trucks and light vehicles; and
- run-of-mine (ROM) pads for ore stockpiling.

The mine will also include ancillary infrastructure including surface water controls, administration facilities, accommodation, lay down areas, site services, and the ore loading facility within the predicted total disturbance area. There are some existing facilities and infrastructure from logging activities and previous exploration including haul roads, jetty facilities and lay down areas that Axiom KB will upgrade, replace and maintain for use by the project.

Once operational, ore will be mined from the deposits using a 'top-down approach' of contoured strips fanning out from an access road along the ridgeline. The ore will then be transported to ROM pads and progressive rehabilitation will be completed as the ore is depleted. The mining method will allow rapid and progressive rehabilitation thus minimising impacts to soil (topsoil and subsoil) resources ie soil stockpiling times will be minimised

Mining may impact on soil resources through the following:

- stripping of soil to prior to constructing infrastructure;
- compaction of soil by machine traffic and infrastructure construction;
- storage of soil in stockpiles;
- potentials loss of soil through erosion;
- potential increased sediment contribution to waterways; and
- potential contamination of soil resulting from spills, storage of fuel and chemicals and refuelling activities.

1.4 Overview of rehabilitation

At the end of mining, infrastructure will also be decommissioned as soon as possible. Rehabilitation of the mine will be undertaken progressively:

- hardstands, roads building pads and other compacted areas will be ripped to remove compaction and seeded;
- potentially contaminated soil will be excavated and appropriately managed;
- any eroded areas will be rehabilitated by re-contouring and seeding to stabilise the area against further erosion; and

- open-cut pits will be rehabilitated by replacing the ore with overburden or low grade ore, as appropriate, and soil as soon as feasible followed by seeding to stabilise the final landform.

The primary aim of rehabilitation will be to minimise and prevent soil erosion and sedimentation and their subsequent environmental impacts. Erosion and sediment control practices will be implemented to achieve this. Trees that can be used by the project or community will be marked and temporarily placed separate to other cleared vegetation. Bracken or branches can be used as laydown for erosion control. Other cleared vegetation may be wood chipped, composted and stockpiled for use in rehabilitation. Grubbing will not occur at temporary laydown areas so that soil continues to be stabilised by the existing vegetation's root system. Ultimately rehabilitation will stabilise areas disturbed by mining.

Some infrastructure ie roads, buildings or parts of the ore loading facility may remain after mining provided suitable future uses can be identified in consultation with landowners.

1.4.1 Other industry disturbance and alternative rehabilitation options

The current surrounding land uses include logging of native timbers. Exposed areas are vulnerable to soil erosion, nutrient loss and sedimentation of waterways. Cropping areas are vulnerable to soil compaction from machinery use and contamination from chemicals. Local waterways can also be polluted from nutrient and pesticide leaching.

There is currently no intention of rehabilitating the mine to include commercial cropping uses; however, alternative rehabilitation options may be examined in the future.

1.5 Purpose of this report

Soils will inevitably be impacted by mining ie clearing vegetation, stockpiling soil and the construction of infrastructure. Possible impacts include soil loss from erosion, sedimentation from the uncontrolled movement of soil, contamination from spills. The result of soil disturbance if not managed properly will be the loss of desirable soil properties eg loss of soil organic matter, fertility or physically stability which may put at risk the successful rehabilitation of the mine. In order to adequately plan for rehabilitation and any potential impacts, soil resources need to be identified, characterised (physical and chemical traits) and management practices developed and implemented based on soil type and characterisation.

A desktop and field survey of the soil in the San Jorge Tenement was conducted by EMM in September 2017 to identify soil types and collect samples to be submitted to a laboratory for characterisation.

This report has four primary purposes:

- describe the soil types and their location;
- describe the characteristics of the different soil types;
- describe potential management practices to preserve soil based on soil type and characterisation; and
- assess the suitability of the different soil types for rehabilitation.

2 Desktop review

2.1 Climate

The climate at the mine is consistent with other tropical locations. There is an average annual rainfall of 3,000-5,000 millimetres (mm). High temperatures, humidity and rainfall remain relatively constant throughout the year. A weather station installed on the south of neighbouring Santa Isabel Island (IWS01) (SMM 2012) indicates there are no defined wet and dry seasons on Santa Isabel due to inputs from the south-east trade winds and the north-west monsoon. Over four years maximum temperatures ranged from 31.5-35.9°C. Minimum temperatures ranged from 20.4-23.4°C. Monthly humidity minimums ranged from 64-72% and monthly humidity maximums ranged from 97-99%. Winds are also relatively constant throughout the year; with an average yearly wind speed of between 1.33 kilometres per hour (km/h) and 2.41 km/h.

2.2 Topography

San Jorge Island is approximately 110 km northeast of Honiara and approximately 26 km long by 14 km wide. The prospecting licence area (PL 01/15) is located on the south-eastern part of San Jorge Island, where the elevations range from sea level to 365 m above sea level and is characterised by rolling hills and steeply incised drainages. The tenement measures approximately 9 km west to east and 4 km north to south, and approximately 30% of the tenement is sea. The proposed main access road will go from the proposed port location to Camp Bungusule in the centre of the tenement at an elevation of approximately 180 m AMSL.

2.3 Surface water

The mine is situated within a network of streams that run from the higher terrain generally east to Thousand Ships Bay. Abundant rainfall and steep topography results in high rates of runoff. Lower elevation riverine areas are generally occupied with mangrove (ie Ghobu Creek, Hughu Creek, Saranavua Creek, Kogarutu Creek) and are connected with, well vegetated floodplains and overbank inundation areas. Steeper river areas include Davu Creek, Suima Creek and Vavula Creek which are more rugged and in upper catchment reaches that act as sources for runoff.

2.4 Marine environment

Thousand Ships Bay between San Jorge and Santa Isabel islands is characterised by mangroves along the shorelines, fringing coral reefs and small islands. Shorelines are either rocky or sandy. These habitats support a high diversity of flora and fauna including hard corals, numerous and mangrove seagrass species, marine reptiles (including turtles, marine snakes and saltwater crocodiles) and marine mammals (including dugongs, dolphins and whales). Previous surveys in surrounding marine areas showed that ecosystem health was generally good with some human impacts such as mangrove logging and increased sediment loads to coral reefs from logging tracks (SMM 2012). Local residents report that the bay becomes turbid after heavy rainfall, impacting fishing at this time.

2.5 Groundwater

The topography of the landscape defines the groundwater resources on San Jorge Island. The ridges and streams have influenced the formation of discontinuous aquifers and fast groundwater flows and deep groundwater lenses may also be present due to the steep terrain.

2.6 Fauna and flora

Regionally the Solomon Islands have immense species richness with an estimated 5,000 plant and 389 terrestrial fauna species that inhabit the islands. The Solomon Islands have one of the highest rates of endemism in the world with 39 species listed on the International Union of Conservation of Nature (IUCN) Red List of Threatened Species. Threatened taxa comprise two amphibian species, two reptile species, 17 bird species and 18 mammal species. Rainforests are widespread in gullies and north-facing slopes while dense groups of smaller trees occupy elsewhere.

2.7 Land use

No settlements occur in the tenement area. The closest village is approximately 2 km to the north of the tenement area. The village is composed of several grass huts located on the shoreline. Access to the marine environment sustains subsistence lifestyle of the settlements. A key part of this lifestyle is fishing and hunting around the numerous stream systems. Some commercial logging has become increasingly common resulting in the clearing of native forest.

2.8 Soils and geology

The Solomon Islands is an Archipelago, forming part of the Greater Melanesian arc system. San Jorge Island overlays Late Cretaceous ultramafics with the majority of this being hazburgite. These ultramafic rocks are serpentinised and cut by pyroxenite veins. The nickel laterite deposits on the island have formed via the weathering (largely rainfall) and decomposition of these ultramafic rocks. This then leads to the residual and supergene enrichment of Ni, cobalt (Co) and iron (Fe) in the laterite profile. Many nutrients in turn have been leached by this weathering (particularly in flat areas). Where the topography is ridged, soils are immature due to erosion rates exceeding soil formation rates. The profile above the ultramafic rocks can be broken down to four main layers, the soil, limonitic zone, transition zone and saprolitic zone.

2.8.1 Soil

The soil is highly weathered with high iron grades. The majority of the nutrients in the profile are contained in this thin layer. The upper section of the layer is dominated by organic matter (mainly roots) and varies in depth depending on the landform such as ridges and slopes. The depth varies from 0.1-0.3 m below ground surface (m bgs).

2.8.2 Limonitic zone

The topsoil is underlain by the limonitic zone. This zone extends from the topsoil down to a depth of 8-10 m bgs. Magnesium (Mg) and silicate minerals have been largely leached from this layer with iron oxides being the dominant component. Pore space and moisture is relatively high. Bedrock textures are not easily identifiable but sporadic bedrock boulders can occur. This zone has been observed to have a reddish brown or dark brown colour at the top before transitioning to brown and then yellow to yellowish brown. The texture also changes down this layer from a silty to clayey to a silty soil-like weathered rock. Residually enriched, lower-grade nickel ore is present in the lower area of limonite. Co and manganese (Mn) are also enriched in this area whereas Fe, Cr and Al are enriched higher up in the layer.

Under the limonitic zone there is a transition zone which shares characters from the limonitic zone above and the saprolite below. The layer has yellow to yellow brown sandy or clayey soils with heavily weathered serpentinite rocks. Garnierite streaks are also present.

2.8.3 Saprolitic layer

The final layer in geology is the saprolitic layer which extends down to a depth of 12-15 m bgs. The saprolite consists of sandy or clayey soils with decomposed serpentinite fragments. Bedrock textures are easily identifiable. Fragmented ultramafics are also found lower down in the saprolite. Higher grades of nickel occur in the upper part of this layer through supergene processes. It is the saprolite layer that is the focus of mining operations.

3 Fieldwork

3.1 Method

A soil survey (the survey) was completed to examine the soil types and landform of the San Jorge tenement, focusing only on the deposits. Samples were also taken for laboratory analysis. All field and desktop assessment methodology for the survey has been conducted with due regard for the following guidelines:

- *Soil Data Entry Handbook* (DLWC 2001);
- *Australian Soil And Land Survey Book* (NCST 2009); and
- *The Australian Soil Classification* (Isbell 2002).

3.1.1 Sample locations

The sampling rationale of the survey is defined in the *Australian Soil and Land Survey Field Handbook* (NCST 2009). 12 detailed sites and 25 check sites (the sites) across the deposits and some roads were studied and sampled.

There were two types of sites in the survey, either check sites or detailed sites

i Check sites

Check sites underwent a field assessment to describe the soil type only, no samples were taken and there was no laboratory analysis (Table 3.1 and Figure 3.1).

Table 3.1 List of check sample sites with coordinates

Site Number	Easting	Northing
1	573353	9059364
2	573098	9059706
3	572826	9059883
4	573459	9059651
5	572895	9059585
6	573078	9060142
7	571538	9058990
8	570762	9058486
9	570414	9057815
12	570818	9057847
13	570958	9057608
15	570365	9057539
25	571289	9060511
26	573002	9059187
28	573220	9059002
29	572533	9060729

Table 3.1 List of check sample sites with coordinates

Site Number	Easting	Northing
31	572585	9060303
32	572100	9060520
33	572030	9059942
34	575695	9059156
36	575060	9058184
37	572544	9059291
40	571584	9058850
41	573987	9059180
42	573726	9058807

Notes: 1. X coordinates = easting, Y coordinates = northing (UTM 57 L).

ii Detailed sites

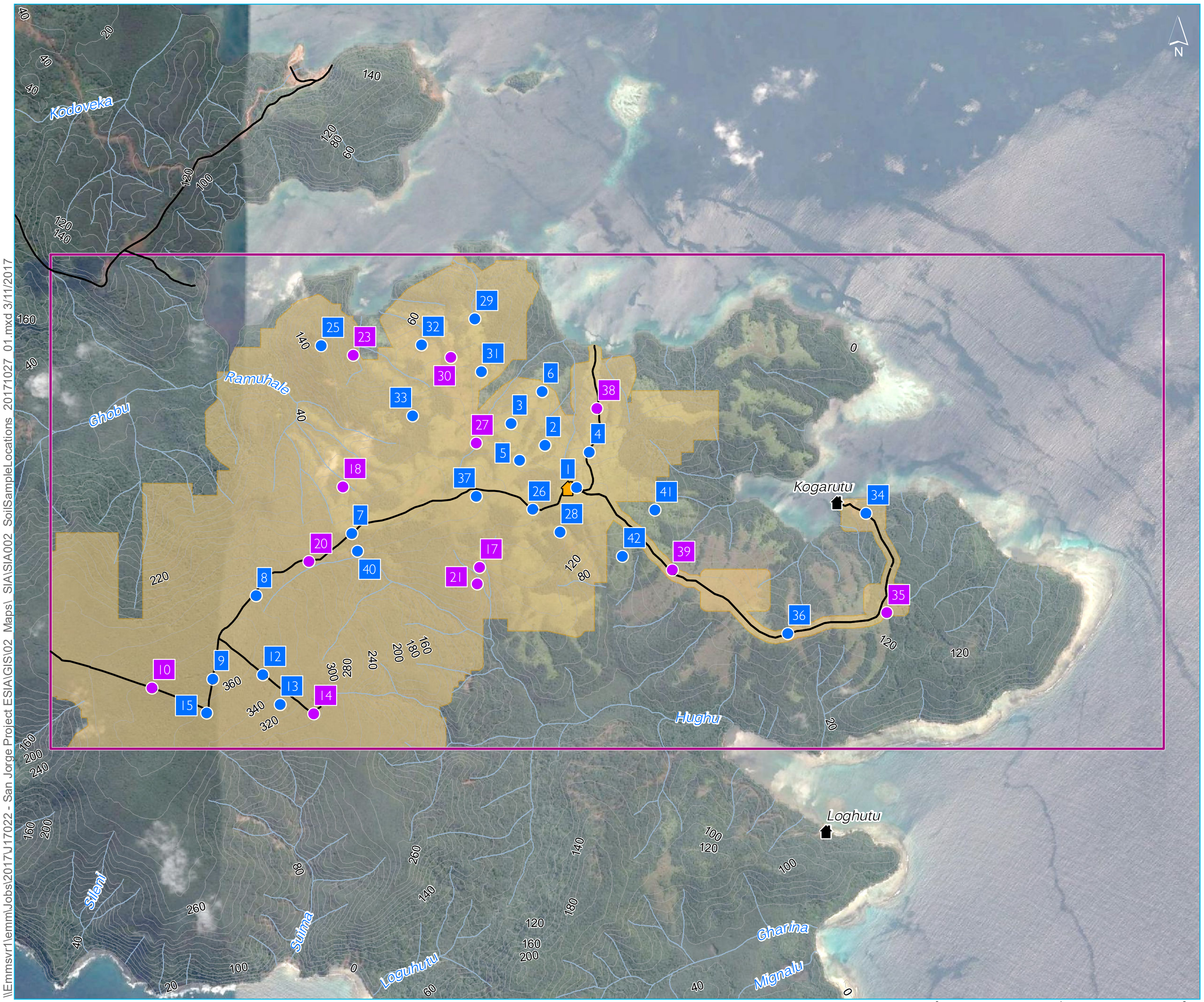
Detailed sites included a detailed description of the soil type, compared to a check site, including soil texture, structure, colour, pH and EC; further, samples of the soil profile were taken for laboratory assessment.

Detailed sites were selected to give a representative sample of soil overlaying the deposits and the surrounding land (Figure 3.1 and Table 3.2).

Table 3.2 List of detailed sample sites with coordinates

Site Number	Easting	Northing
10	569923	9057740
14	571229	9057533
17	572570	9058718
18	571466	9059369
20	571192	9058764
21	572549	9058582
23	571547	9060435
27	572543	9059721
30	572337	9060416
35	575863	9058349
38	573520	9060003
39	574128	9058696

Notes: 1. X coordinates = easting, Y coordinates = northing (UTM 57 L).



\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps_SIA\SIA002_SoilSampleLocations_20171027_01.mxd 3/11/2017

Source: EMM (2017); Axiom Mining Limited (2017); Google Earth Pro (2015)

Location of sample sites

Axiom Mining Limited
San Jorge Nickel Project
Soil Assessment
Figure 3.1

3.1.2 Sampling method

Samples were collected by EMM during September 2017. Photos were taken of the soil surface and surrounding area at each site. A hand auger was used to extract a disturbed soil profile to a depth of 1 m bgs. A description of the soil type for each profile was completed before collecting samples at detailed sites only.

At every detailed site, 400 grams (g) of soil was taken from representative depths within the soil profile. Sampled soil was placed in heavy-duty, sealable plastic bags and labelled. Holes were backfilled with soil not collected for laboratory analysis. The samples were sent from site to a National Association of Testing Authorities (NATA) accredited laboratory (ALS Global) located in Brisbane, Australia.

3.1.3 Field assessment

i Texture

Soil texture was determined using the ribboning method. This involved wetting soil in the palm of the hand and kneading for 2-10 minutes into a ball. The soil was then made into a ribbon by pushing the ball between the thumb and index finger. The length at which the ribbon broke is then used to determine field texture by referring to the table in Appendix A (DPI 2015).

ii Field electrical conductivity and pH

EC and pH were recorded using a portable pH/EC meter (Aqua-CP/A model) in a 1:5 soil:deionised water suspension.

iii Soil description

Soil profiles were logged and classified having due regard for the *Australian Soil Classification* system. The field descriptions included:

- elevation and GPS coordinates;
- permeability and drainage;
- site and slope morphology;
- boundaries (shape and size of the changes between horizons);
- colour (hue and chroma using the Munsell colour chart);
- pedality (including ped shape and size);
- fabric (spatial arrangement and nature of solid particles and associated pores);
- structure (arrangement of soil particles);
- consistence (resistance to deformation or rupture of soil material);
- presence of cracks or macropores;
- soil water status;

- coarse fragments (visual assessment of shape, size and distribution);
- hydrology (profile drainage and permeability);
- site condition (landform, groundcover and vegetation); and
- soil surface condition (crusting, cracking, self-mulching).

iv Laboratory analysis

Samples were analysed by ALS laboratories for the following components:

- moisture content;
- $pH_{1:5}$;
- $EC_{1:5}$;
- total metals (As, Cd, Cr, Cu, Ni, Pb, Zn);
- total sulfur (S);
- total organic carbon;
- exchangeable cations and cation exchange capacity (CEC);
- soluble sulfate and chloride (Cl);
- Total Kjeldahl Nitrogen (TKN), total nitrogen and nitrite and nitrate (NO_2 ,NO_3) (topsoil only);
- bicarbonate extractable phosphorous (P) (topsoil only);
- exchangeable sodium (Na) percentage; and
- Emerson aggregate stability.

Samples were couriered from Honiara to ALS laboratories via courier (Appendix B).

3.2 Results

3.2.1 Site description

Slopes ranged from gently inclined (3%) on the ridges (where the ore is located) to steep (30%) in valleys. The vegetation across the tenement varied. There were areas of dense, primary forest with a shrub understory. A thick layer of decaying organic matter (~10-35 cm) was present above the soil surface. The majority of roots observed were present in this layer. There were also areas of dense bracken (suspected *Dicranopteris linearis*) and fern species. Adjacent to the camp were areas of fire disturbed vegetation. These areas had a thick layer of burnt organic matter with patchy shrub and tree regrowth.

Highest disturbance occurred close to roads usually on fill batter or cleared areas with little or no groundcover. The soil profiles were generally shallower on steep slopes with parent material being present in some profiles. Figure 3.2, Figure 3.3 and Figure 3.4 demonstrate the three main vegetation communities observed ie bracken and ferns, primary forest and fire disturbed land.

Figure 3.2 Primary forest (10)

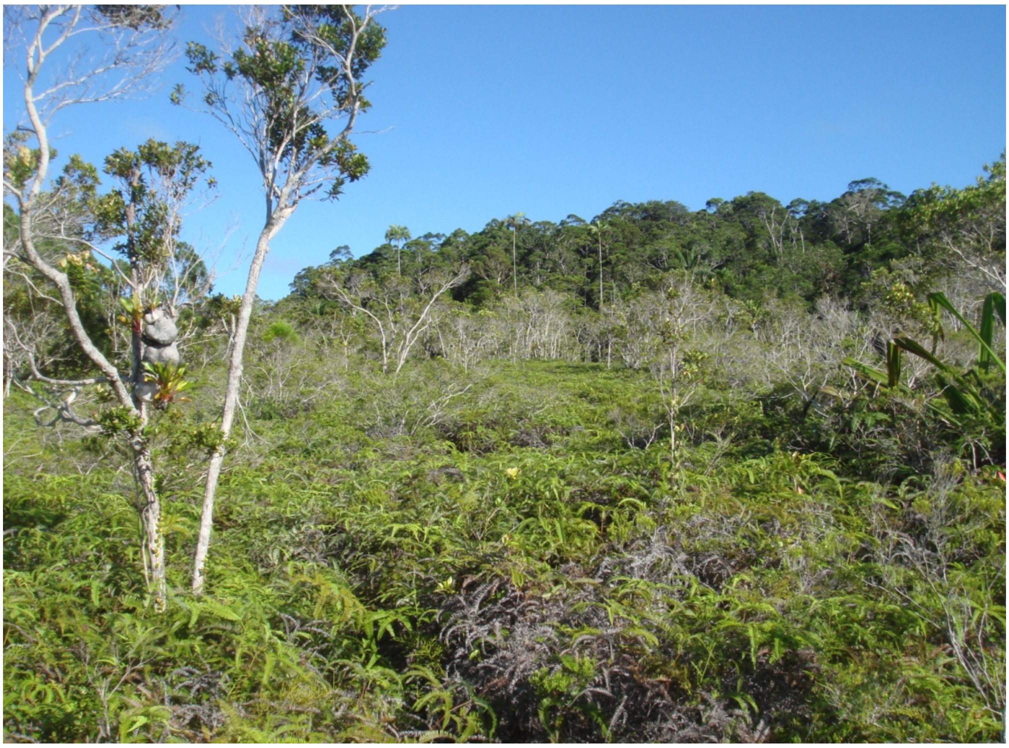


Figure 3.3 Bracken and ferns vegetation (28)

Figure 3.4 Fire disturbed vegetation (1)

3.2.2 Soil description

Acidic Dystrophic Red Ferrosols were the dominant soil type identified characterised by a B2 horizon that contained a free iron oxide content of greater than 5% and a pH of <5.5, a base status of less than 5 (milliequivalents per 100 g (meq/100g) and lacked a strong texture contrast or a B2 horizon with notable vertic properties (less than 0.3 m of the profile) (Table 3.3).

Soil texture was similar throughout the profile with clay loams transitioning to light to medium clays at depth. Very few iron-manganese oxide segregations were present at five sites (black spots in reddish brown soil). All other sites had no segregations. Mottling was absent throughout the profiles. The soil was generally strongly acidic and non-saline. Soil acidity generally slightly increased with depth.

The A horizon was dark reddish brown, moderately moist and varied in depth from 0.1-0.4 m. Very few coarse fragments were observed (ironstone) with a weak, granular (2-5 mm) structure. Roots were observed to perforate through the soil aggregates. There was also a smaller amount of sub-angular blocky peds. It was slightly plastic and moderately sticky.

The B horizon had very few coarse fragments (ironstone) and a strong, sub-angular blocky (20-50 mm) structure parting to polyhedral. Roots were observed to perforate through the soil aggregates. The horizon was moist, moderately plastic and sticky with a dark reddish brown colour.

When observed in an augered profile, the ironstone appeared dispersed. It is however likely that the distribution is stratified in the profile due to the presence of a ferric rust zone (iron cap). Soils were considered to be moderately well-drained and permeable due to the fine-medium texture of the soils and the lack of surface ponding, mottling and water logging. Moisture generally increased with depth down the profile.

Sampling location sites 23, 21 and 38 varied slightly to the Acidic Dystrophic Red Ferrosols observed across the majority of the site. The B horizon pH was >5.5 (6-6.4, medium acid to slightly acid). Due to pH-dependent CEC being dominant, this resulted in greater soil fertility (ie higher CEC). These soils were therefore classified as Haplic Mesotrophic Red Ferrosol.

Table 3.3 Acidic Dystrophic Red Ferrosol typical soil profile summary

ASC	Horizon name and depth (m bgs)	Colour, mottles and bleach	Moisture, field pH and drainage	Texture and structure	Coarse fragments, segregations and roots
	A1 0.0-0.2	Dark reddish brown, 2.5 YR 2.5/4 and no mottles.	Dry, field pH of 4.11-5.47 and moderately well-drained.	Clay loam and weak, granular (2-5 mm). Sub-dominant sub-angular blocky 10-20 mm).	Very few coarse fragments (ironstone, 2-6mm, sub-angular) and many small roots.
	B2 0.2-1.2	Dark reddish brown, 5 YR 3/4 and no mottles.	Moderately moist, field pH of 4.01-5.01 and moderately well-drained.	Light to medium clay and strong, sub-angular blocky (20-50 mm) parting to 2-5 mm, polyhedral.	Very few coarse fragments (ironstone, 2-6mm, sub-angular) and few small roots.

Notes: 1. Sources: Terminology in accordance with NCST 2009.

3.2.3 Soil chemistry

Soils were found to be very strongly acidic throughout the profile, with a slight increase in acidity down the profile. A1 and B2 horizons ranged from pH 4.4 to 6.4 and 4.6 to 6.7 respectively. The majority of soils were outside the tolerance range of all but acid tolerant plants. EC is very low in both the A1 (0.063 to 0.288 decisiemens per metre (dS/m)) and B1 (0.045 to 0.234 dS/m) horizons and would not limit plant growth or damage infrastructure or buildings. Chloride levels were low throughout the profile with both horizons ranging from <10 to 30mg/kg. This is well below the sufficiency value of <800 mg/kg. Plant available phosphorus in the A1 horizon was below detection limits (<5 mg/kg) across all sites. Total nitrogen (1190 to 3180 mg/kg) was above the plant sufficiency range in the A1 horizon for all but one site (17). Nitrates and nitrate (<0.1 to 10.9 mg/kg) were deficient. These nutrient deficiencies could potentially restrict plant growth. It is worth noting however, that the dense organic layer above the A horizon contained the majority of the plant roots. This indicates that this is where the majority of plant nutrients are contained and is crucial to plant growth and survival.

Cation exchange capacity (CEC) is very low ranging from 0.1 to 7 meq/100 grams of soil (meq/100 g) and 0 to 7.1 meq/100g for the A1 and B2 horizons respectively. All but two sites had elevated levels of exchangeable aluminium and acidity in the A1 horizon. The B2 horizon had low exchangeable aluminium but elevated exchangeable acidity at some sites. Exchangeable Ca, Mg and K were also all very low. This indicates potential fertility issues in both horizons. Organic carbon ranged from moderate to high in the A1 horizon (1.51 to 4.36%) while being low to moderate in the B1 horizon (0.87 to 1.98%). This indicates good structural condition and stability. The median, lowest and highest constituent values (provided in brackets) for the 12 detailed sites are shown in Table 3.3.

Table 3.4 Acidic Dystrophic Red Ferrosol soil chemistry results median (lowest-highest concentration)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.2 m bgs	B2 1 0.2-1.2 m bgs	Comments on results (in increasing depth)
pH	pH units	6.0-7.5	5.1 (4.4-6.4)	4.9 (4.6-6.7)	Strongly acidic to very strongly acidic with some medium and slightly acid soils.
ECse	dS/m	<1.9	0.108 (0.063-0.288)	0.081 (0.045-0.225)	Very low soil salinity.
Organic Carbon (TOC)	%	>1.2	3 (1.51-4.36)	0.98 (0.52-1.98)	Moderate to low.
Cl-	mg/kg	<800	10 (<10-30)	<10 (<10-30)	Not restrictive.
Macronutrients					
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	1.9 (<0.1-10.9)	0.4 (<0.1-4.5)	Deficient.
Total Kjeldahl N	mg/kg		2000 (1190-3180)	770 (370-1260)	
Total N	mg/kg	>1500	820 (1190-3180)	770 (370-1260)	Deficient.
P (Colwell)	mg/kg	>10	<5 (<5)	<5 (<5)	Deficient.
Total P	mg/kg		64 (47-121)	47 (31-89)	
Total metals					
As	mg/kg		<5 (<5-10)	<5 (<5-11)	
Cd	mg/kg		3 (1-4)	3 (<1-5)	
Cr	mg/kg		4470 (3940-5640)	5070 (2910-7160)	
Cu	mg/kg		63 (41-101)	78 (27-130)	
Pb	mg/kg		<5 (<5-6)	<5 (<5-7)	
Ni	mg/kg		3690 (1090-8690)	4910 (401-11200)	

Table 3.4 Acidic Dystrophic Red Ferrosol soil chemistry results median (lowest-highest concentration)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.2 m bgs	B2 1 0.2-1.2 m bgs	Comments on results (in increasing depth)
Zn	mg/kg		116 (60-180))	145 (25-228)	
Cation Exchange Capacity	meq/100g	12-25	0.95 (0.1-7)	<0.1 (<0.1-7.1)	Very low.
Ca	meq/100g	>5	0.2 (<0.1-1.1)	<0.1 (<0.1-1.6)	Very low.
Mg	meq/100g	>1	0.2 (<0.1-5.8)	<0.1 (<0.1-7.1)	Very low.
Na	meq/100g		<0.1 (<0.1-0.1)	<0.1 (<0.1)	Very low.
K	meq/100g	>0.3	<0.1 (<0.1)	<0.1 (<0.1)	Very low.
Al	%	<1	38 (<1-71.42)	<1 (<1)	Very high in the A horizon. Below detection limits in the B horizon.
Acidity	meq/100g	-	0.5 (<0.1-1.3)	<0.1 (<0.1-0.4)	Very high in the A horizon. Very high in some B horizons.
Exchangeable sodium percentage (ESP)	%	<6	11.65 (1.7-23.4)	33.7 (0.3-81.3)	Non-sodic with the exception of two sodic topsoils and two strongly sodic subsoils.
Ca/Mg ratio	-	>2	1 (0.025-3)	1 (0.007-1)	Very low ratios.
Sulfate as SO_4^{2-}	mg/kg	-	TBC	TBC	
Total Sulfur (S)	%		TBC	TBC	
Emerson Class Number	-	-	7 (7)	7 (4-7)	

Notes: 1.Sources: Baker and Eldershaw 1993, DERM 2011 and Peverill, Sparrow and Reuter, 1999. Values not provided for all parameters shown.

2. Values in brackets are the ranges measured.

3.2.4 Erosion potential

Soil erosion is the loss of soil from the landscape through water and wind leading to a reduction in land productivity and ecosystem services. Chemistry results (Appendix B) and the *Australian Soil Classification* indicate that the soils have a low erosion potential. The erosion potential of the soil, among other physical and chemical attributes, will influence the suitability of management practices and whether the soils are appropriate for use in rehabilitation.

i Emerson Aggregate Test

The Emerson Aggregate Test was carried out in order to give an indication of soil erodibility. The Emerson Aggregate Test (Table 3.3) showed soils are relatively stable with erosion stability decreasing with depth. The A horizon and B horizon generally recorded a class 7 (no dispersion or slaking) and 4 (slaking but no dispersion) respectively. Class 7 indicates that the soil is very stable and is unlikely to erode. The soil will not readily slake (breakdown of large aggregates into smaller ones) or disperse (breakdown of aggregates into single particles) but can swell (increase in volume). Class 4 indicates that the soil is stable but has a slightly higher erosion potential. The soil will generally not disperse but may slake. Calcium carbonate or gypsum is present in class 4 soils which are natural soil flocculants. This data is spatially represented in Figure 3.5 and Figure 3.6.

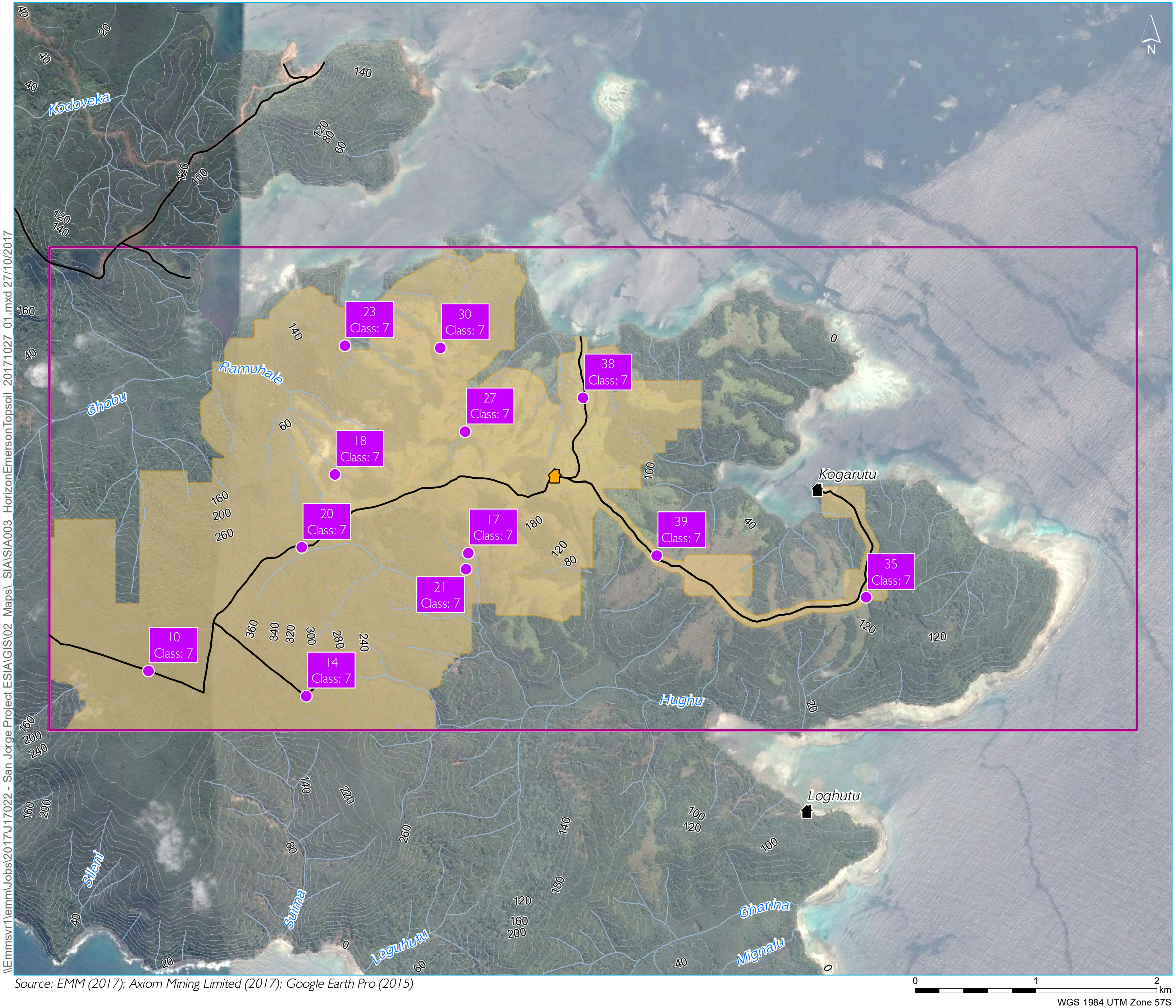
ii Exchangeable sodium percentage

When a soil has an ESP of >6% (known as sodic), structural issues can occur which make a soil more prone to erosion. All sites were sodic with the exception of 38, 23 and the A horizon of 21. These results are likely misleading. When the CEC is less than 3 meq/100 g and/or exchangeable sodium is less than 0.3 meq/100 g, sodicity calculations can be inaccurate due to the sensitivity of the analytical procedures used. Therefore, sodicity is not an appropriate indicator of erosion potential at the site.

iii Organic carbon

Soil organic carbon is known to help maintain soil structure by binding particles together into aggregates which ultimately increases infiltration and reduces runoff. Hence when soil organic carbon levels are low, soils may be more prone to erosion.

Organic carbon ranged from moderate in the A horizon (3%) to low in the B horizon (0.98%) (Table 3.3). This indicates good structural condition and stability. This is consistent with the Emerson Aggregate test which demonstrated class 7 A horizons (very stable) and a mixture of class 4 and 7 B horizons (very stable). The data is represented in (Figure 3.7 and Figure 3.8).



KEY

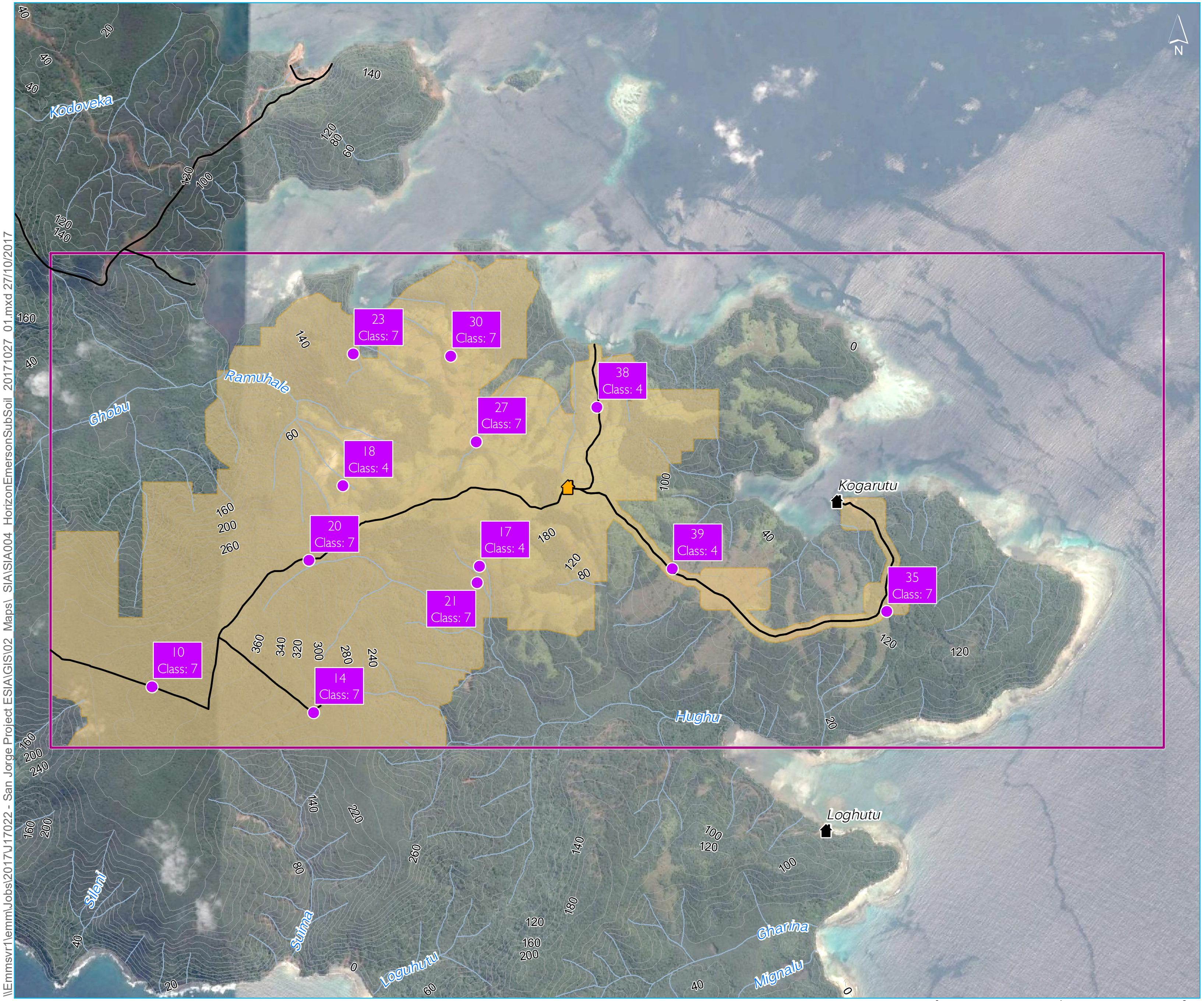
- Village
- Prospecting licence boundary
- Camp Bungusule
- Access road
- Watercourse / drainage line
- Contour (20 m)
- Detailed soil survey location

Source: *EMM (2017); Axiom Mining Limited (2017); Google Earth Pro (2015)*

\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps_SIA\SIA003_HorizonEmersonTopsoil_20171027_01.mxd 27/10/2017

A horizon Emerson Class Number

Axiom Mining Limited
San Jorge Nickel Project
Soil Assessment
Figure 3.5



KEY

- Village
- Prospecting licence boundary
- Camp Bungusule
- Access road
- Watercourse / drainage line
- Contour (20 m)
- Detailed soil survey location

B horizon Emerson Class Number

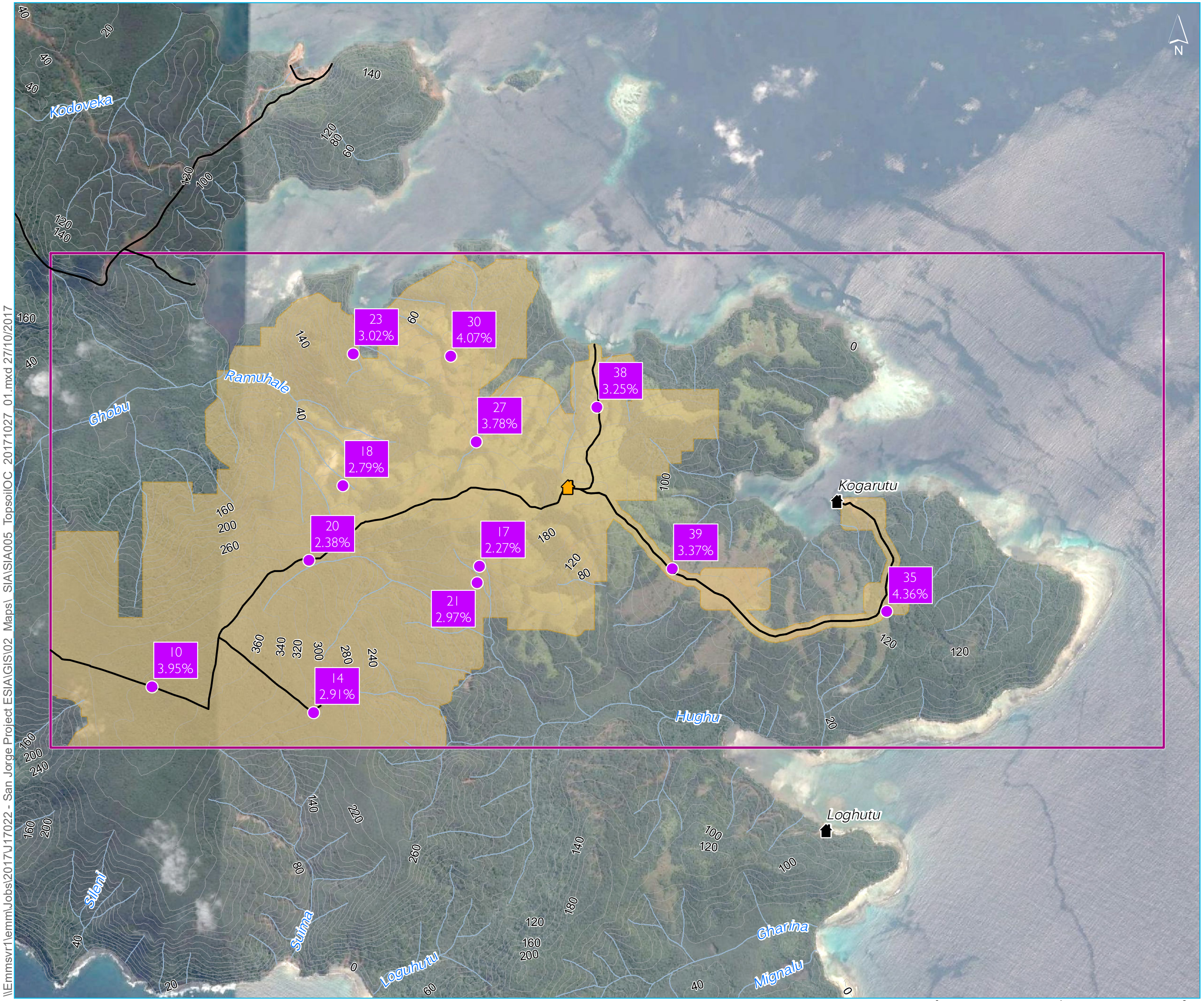
Axiom Mining Limited
San Jorge Nickel Project
Soil Assessment
Figure 3.6

EMM

Source: EMM (2017); Axiom Mining Limited (2017); Google Earth Pro (2015)

0 1 2 km
WGS 1984 UTM Zone 57S

\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps_SIA\SIA004_HorizonEmersonSubSoil_20171027_01.mxd 27/10/2017



KEY
- Village
- Prospecting licence boundary
- Camp Bungusule
- Access road
- Watercourse / drainage line
- Contour (20 m)
- Detailed soil survey location

\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps_SIA\SIA005_TopsoilOC_20171027_01.mxd 27/10/2017

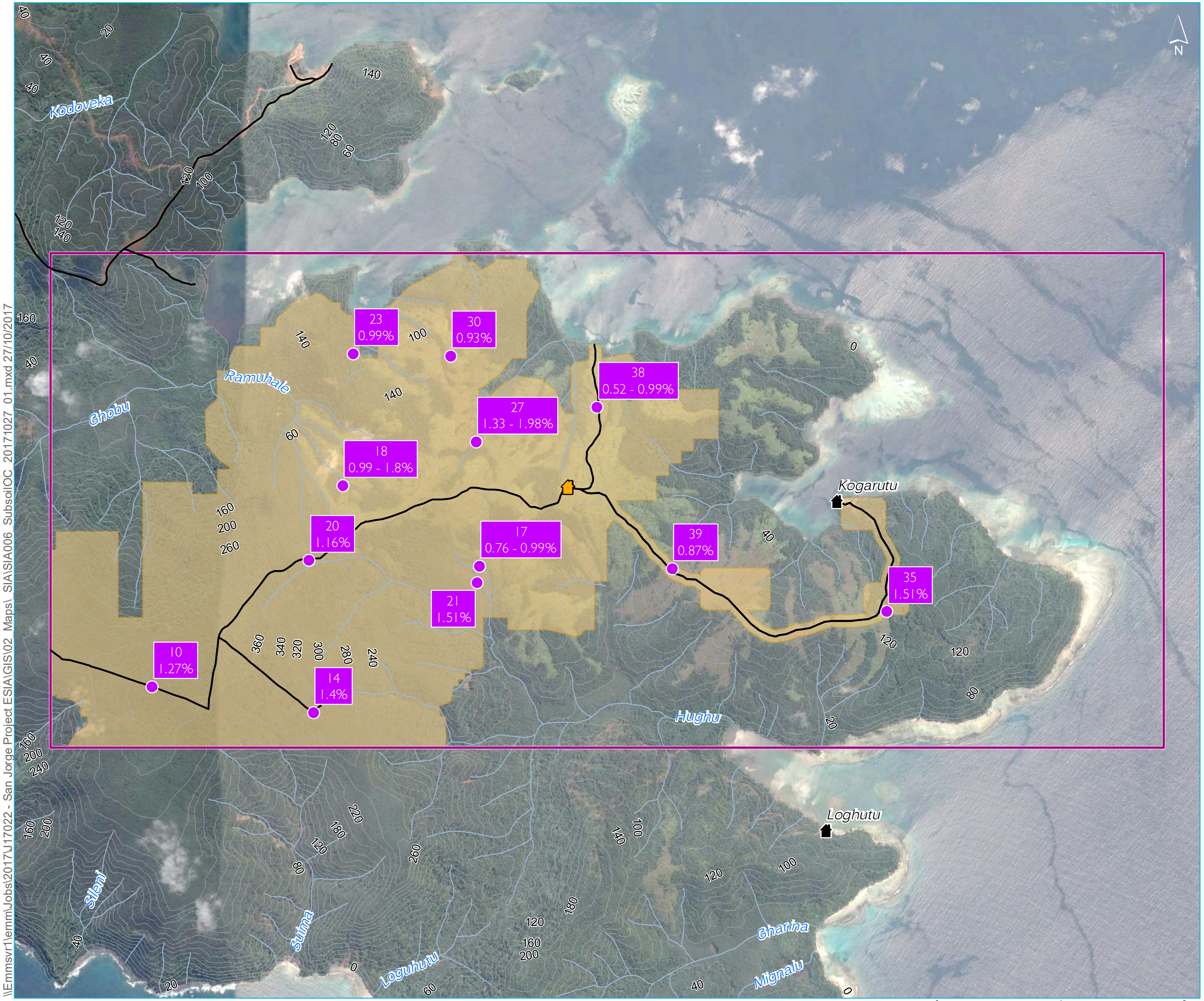
A horizon organic carbon

Axiom Mining Limited
San Jorge Nickel Project
Soil Assessment
Figure 3.7

EMM

Source: EMM (2017); Axiom Mining Limited (2017); Google Earth Pro (2015)

0 1 2 km
WGS 1984 UTM Zone 57S



KEY
- Village
- Prospecting licence boundary
- Camp Bungusule
- Access road
- Watercourse / drainage line
- Contour (20 m)
- Detailed soil survey location

Source: EMM (2017); Axiom Mining Limited (2017); Google Earth Pro (2015)

0 1 2 km

WGS 1984 UTM Zone 57S

B horizon organic carbon

Axiom Mining Limited
San Jorge Nickel Project
Soil Assessment
Figure 3.8

EMM

4 Impact assessment and soil resource management

4.1 Potential impacts

Approximately 1348.4 hectares (ha) of land will be disturbed throughout the life of the mine. Disturbance of the deposits to extract the ore will largely be from the construction of infrastructure, including open-cut pits, out-of-pit waste rock dumps, roads for haul trucks and light vehicles, and run-of-mine (ROM) pads for ore stockpiling. Without effective mitigation measures, the project has the potential to impact on soils and land in the study area in a number of ways. These include:

- loss of soil stability; and
- loss of soil function (fertility).

Table 4.1 summarises the potential impacts and their severity.

4.1.1 Loss of soil stability

While soil erodibility was shown to be low, it is important to note that this is only one component of the overall erosion hazard. The climate in the area has a high erosive force due to the high quantity and intensity of rainfall. The slopes that connect to the ridges are also much more prone to erosion than the ridges themselves due to an increase in runoff speed. Once vegetation is removed the erosion hazard will increase greatly due to increased runoff velocity which increases the potential for rill and gully erosion. Due to the high rainfall and the nature of the mining activities, there is the potential to create unstable surfaces that could be prone to collapse or landslip; however much of this risk can be mitigated prior to construction with mine design.

The potential impact of the project on soil stability without any mitigation measures will be high.

4.1.2 Loss of soil function

The soils on the tenement have moderate to low fertility, with strong acidity and nutrient deficiencies with could restrict plant growth; however, the soils in their current state support the existing ecosystem. The nature of the mining activity (ie removal of vegetation and strip mining) will significantly impact soil function, and its ability to support ecosystems or potential agriculture during construction and operation. The soils on the tenement have strong acidity, but there is the potential to expose acid sulphate soils through the process of excavation and exposure, which would increase the acidity of the soil. There is a significant potential for contamination of soils to take place from spills and leaks of chemicals and hydrocarbons from plant and equipment during construction, operation and rehabilitation of the site. In addition, litter and waste associated with the project could impact soil function if not appropriately managed.

Rehabilitation will aim to restore the soil function, but until this takes place, the potential impact on soil function will be high.

Table 4.1 Potential project impacts on soil

Impact	Duration	Magnitude of impact	Sensitivity of value	Significance
Erosion	During construction, operation and possibly beyond during rain events	High	Moderate soil erodibility and slope steepness, therefore soil stability is moderately sensitive.	High
Landslip	During construction, operation and possibly beyond during rain events	High	Moderate soil stability and slope steepness, therefore soil stability is moderately sensitive.	High
Loss of fertility	During construction, operation and beyond	Moderate	Soils in this area are nutrient poor, but supports an ecosystem therefore soil function is moderately sensitive.	Moderate
Acid sulphate soils	During construction, operation and beyond	Moderate	Soils in this area are already somewhat acidic, but support an ecosystem therefore soil function is moderately sensitive.	Moderate
Hazardous spills and leaks	During construction and operation	Moderate	Soils in this area are nutrient poor, but supports an ecosystem therefore soil function is moderately sensitive.	Moderate
Waste	During construction and operation	Moderate	Soils in this area are nutrient poor, but supports an ecosystem therefore soil function is moderately sensitive.	Moderate

4.2 Soil and waste rock management

General suitability of soil for use in rehabilitation was determined based on criteria established by Elliot & Reynolds (2007). These criteria are detailed in Table 4.2.

Table 4.2 Soil stripping and rehabilitation suitability criteria

Parameter	Criteria
structure grade	>30% peds
coherence	coherent (wet and dry)
mottling	absent
macrostructure	>10 cm
force to disrupt peds	≤3 force
gravel and sand content	<60 %
pH	4.5 to 8.4
salt content	<1.5 dS/m

i A horizon

It is recommended that all A horizon soil be stockpiled for use in future rehabilitation. The depth of the A horizon ranges from 0.1-0.4 m bgs. The A horizon at 14 is the exception to this which has a pH of 4.4 and is therefore not suitable for stripping and reuse in rehabilitation. The low pH makes it unsuitable to plant growth.

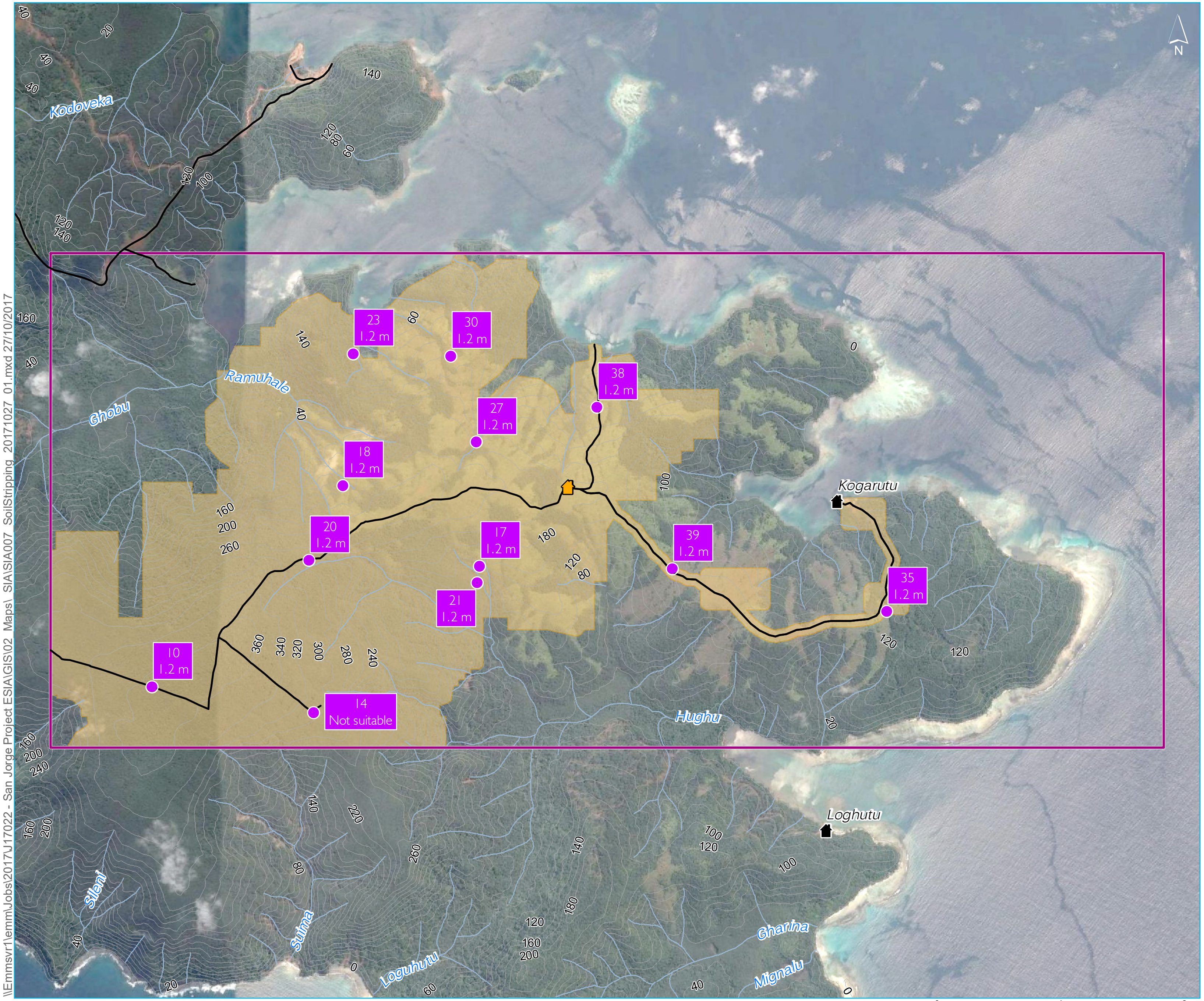
Stripping should occur when the A horizon is slightly damp and not during wet or dry conditions in order to limit structural damage and reduce dust. Vegetation should be removed prior to stripping and stockpiled separately. Too much vegetation in the stockpile could also promote biological and chemical breakdown of the seed bank which will be utilised in future rehabilitation.

ii B horizon

It is recommended that the all B horizon soil be stripped down to 1.2 m bgs and stockpiled separately to the A horizon for use in future rehabilitation. Maximum recommended stripping depths are shown in Figure 4.1 ie Figure 4.1 shows the combined maximum depth of stripping for the A and B horizon.

iii Waste rock

The overburden or low-grade ore can be used for filling the open-cut pits or as road base as required. The soil and waste rock should be stored in separate stockpiles so that their physical and chemical properties are preserved.



KEY
- Village
- Prospecting licence boundary
- Camp Bungusule
- Access road
- Watercourse / drainage line
- Contour (20 m)
- Detailed soil survey location

Source: EMM (2017); Axiom Mining Limited (2017); Google Earth Pro (2015)

\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps_SIA\SIA007_SoilStripping_20171027_01.mxd 27/10/2017

Recommended soil stripping depths

Axiom Mining Limited
San Jorge Nickel Project
Soil Assessment
Figure 4.1

4.3 Management of soil stockpiles

Soil stockpiles should be managed in the following way:

- place stockpiles in previously cleared areas as far from operations as feasible to minimise disturbance;
- place stockpiles appropriately to avoid any drainage lines or depressions;
- limit stockpiles to a height of 1.5 m or no more than 2 m to encourage infiltration and limit the potential for anaerobic conditions to develop;
- shelter stockpiles from prevailing winds and leave in a coarse condition so that infiltration is promoted and wind and water erosion are minimised;
- ensure a suitable embankment slope of the stockpile (less than 2:1) and divert drainage from higher areas around stockpiles to help prevent erosion;
- if required, sediment controls can be installed to collect runoff;
- ameliorate topsoil to maintain chemical and physical integrity, in particular phosphorous may be necessary due the low fertility of the soil;
- establish a vegetative cover of native, fast growing species via seeding in order to stabilise the stockpile; and
- protect stockpile from weeds, rubbish and chemicals as required.

4.4 Rehabilitation

Rehabilitation will be carried out progressively and will aim to:

- prevent the loss of soil from disturbed areas;
- minimise sedimentation of the downstream environment and associated environmental impacts;
- ensure that the disturbed areas are stable; and
- rehabilitate disturbed areas to a functional and appropriate state that is satisfactory for stakeholders.

Areas subject to rehabilitation include open-cut pits and slopes, mine infrastructure and building areas, haul roads, stockpiles and laydown areas.

In all areas requiring revegetation, B horizon stockpiled soil should first be spread to a depth of ≤0.5 m or to a thickness consistent with the proposed post mining land use. Prior to planting for rehabilitation, A horizon soil should be spread to a depth of ≥0.2 m or to a thickness consistent with post mining land use.

The surface should be cross ripped as needed to assist infiltration and slow runoff. A temporary cover of a fast growing, high density, native cover species should be sown so that erosion and soil loss is limited. A combination of tubestock and direct sowing of chosen species should be implemented following this to achieve effective plant establishment. Erosion controls and stabilisation methods will be used as required. Maintaining diversion channels will be essential to maintaining the stability of final landforms.

A monitoring program will need to be implemented to confirm that the rehabilitation is effective. Elements to be monitored should include soil condition, vegetation and resilience to disturbance.

Maintenance activities may need to be conducted if plant establishment is limited. These include plant replacement and protection, watering and weeding. Rehabilitation is discussed in detail in the report *San Jorge Nickel Project – Mine Rehabilitation Plan* (EMM 2017).

4.5 Erosion and sediment control

While soil erodibility was shown to be low, it is important to note that this is only one component of the overall erosion hazard. The climate in the area has a high erosive force due to the high quantity and intensity of rainfall. The slopes that connect to the ridges are also much more prone to erosion than the ridges themselves due to an increase in runoff speed. Once vegetation is removed the erosion hazard will increase greatly due to increased runoff velocity which increases the potential for rill and gully erosion.

There are a range of erosion and sediment control practices that can be used. These measures primarily aim to separate clean and mine impacted runoff (high sediment load), reduce soil erosion and improve runoff quality. This will be particularly important where A horizon soils are stripped exposing class 4, B horizon soils.

Minimising land disturbance from clearance and ensuring disturbance occurs as close in time as possible to construction works will help reduce erosion potential. This can be done by clearing only vegetation of the areas that will be actively worked and progressively rehabilitating. Limiting the construction of roads and trails will also reduce erosion and sedimentation.

The following erosion and sediment controls should be installed prior to land disturbance or as early as feasible to allow for maximum protection:

- divert runoff from undisturbed areas by installing diversion banks upslope of operations which redirects flow around the mine and into either a retention dam (to control velocity) or nearby watercourses;
- stabilise diversion banks using appropriate vegetation (grasses or riparian species);
- install mulch mounds across disturbed and newly rehabilitated areas to slow runoff and encourage sediment deposition;
- install diversion banks in disturbed and newly rehabilitated areas to channel mine impacted runoff to sediment dams or natural water ways (if water is of adequate quality);
- channels that direct to natural waterways may need to be stabilised by lining with rocks or erosion matting;
- sediment dams will store mine impacted runoff and allow sediment to collect on the bottom before being reused or discharged into natural waterways;

- a chemical flocculant may be added to detention dams to assist in settling finer clay particles;
- temporary controls such as sediment fences (made out of geotextile fabric) or traps and rock check dams can be used either in conjunction with or during the construction of the controls above; and
- ensure sediment fences have as small a catchment as feasible as they are prone to failure during high rainfall events.

i Road design

Roads will need surface drains to stop erosion at the base of slopes parallel to the road surface, especially for crowned and infall road designs. The following should be implemented:

- the road surface should be shaped to allow effective drainage and have a rock and gravel surface;
- grade the road surface to an appropriate angle and camber;
- a table drain that runs parallel to the road surface, overland flow and cut batters;
- a cut-off drain or mitre drain will relieve the flow of water from table drains and direct it to a sediment dam for treatment. The drain may need stabilising with rock or jute mesh if erosion occurs.
- road cuttings should be stabilised with the log and peg method which involves establishing log terracing along slope contours at routine intervals. Erosion covers can be incorporated into this design for maximum protection; and
- where drains cross paths with roads, culverts or a bridge embankment should be installed.

For detailed design specifics please see *Road Infrastructure and Drill Pads Rehabilitation Plan* (EMM 2015).

5 Conclusion

Landscape and soil characteristics were very similar across the San Jorge Tenement with no discernible patterns evident. Previous soil surveys on Santa Isabel Island found similar soils to the Acidic Dystrophic Red Ferrosols (SMM 2012, EMM 2016). Soils had moderate to low levels of organic carbon, low salinity and low fertility. Soil sample locations 23, 28 and 38 had a slightly higher fertility and were less acidic. These were classified as Haplic Mesotrophic Red Ferrosols.

A horizon soils generally had low soil erodibility and are unlikely to disperse or slake (Emerson class 7). B horizon soils also had a very low erosion potential and are unlikely to disperse (Emerson class 7). Some B horizon soils may slake (Emerson class 4). Organic carbon was moderate in the A horizon and low in the B horizon soil which supports the idea of low soil erodibility.

It is recommended that all A horizon soil sample locations except for sample site 14 (due to acidity) is stripped (0.1-0.4 m bgs) and stockpiled to a height of 1.5 m or no more than 2 m. It is also recommended that B horizon soil is stripped down to a depth of 1.2 m bgs.

The installation of erosion controls is recommended, especially for areas of exposed subsoil horizon soil at risk of slaking. The subsoil horizon and B horizon soils and waste rock should be stockpiled separately. Amelioration of the soil may be important to maintaining physical and chemical properties.

High rainfall, steep slopes and removal of vegetation will all increase the erosion hazard, and control methods have been suggested to counter this. These include minimising vegetation clearing and the construction of roads and trails, diverting runoff from undisturbed areas, installing mulch mounds and diverting mine impacted runoff to sediment dams.

Rehabilitation should be carried out progressively and should focus on minimising soil loss and sedimentation with the aim of achieving a stable, functionally appropriate landscape.

References

Baker DE & Eldershaw VJ 1993, *Interpreting soil analyses*, Department of Primary Industries, Queensland
Department of Environment and Resource Management (DERM) 2011, *Guidelines for applying the proposed strategic cropping land criteria*, accessed 29 October 2015, http://www.nrm.qld.gov.au/land/planning/pdf/strategic-cropping/scl-guidelines.pdf

Department of Primary Industries (DPI) 2015, *Quick reference guide: assessing soil texture*, accessed 27 January 2016, http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/soilhealth_texture_pdf/$FILE/QRG_Texture.pdf

Department of Land and Water Conservation (DLWC) 2001, 3rd Edition, *Soil data entry handbook*.

EMM Consulting Pty Limited (EMM) 2017 San Jorge Nickel Project – Mine Rehabilitation Plan. Report prepared for Axiom KB Limited.

EMM Consulting Pty Limited (EMM) 2016 Kolosori Nickel Project – Soil Assessment. Report prepared for Axiom KB Limited.

EMM Consulting Pty Limited (EMM) 2015 Road Infrastructure and Drill Pads Rehabilitation Plan. Report prepared for Axiom KB Limited.

Isbell RF 2002, *The Australian soil classification, CSIRO Publishing, Melbourne.*

National Committee on Soil and Terrain (NCST) 2009, 3rd edition, *Australian soil and land survey handbook*, *CSIRO Publishing, Melbourne*

Peverill KI, Sparrow LA, Reuter DJ (eds) 1999, *Soil analysis: interpretation manual*, CSIRO Publishing, Collingwood.

SMM Solomon Limited 2012, *Environmental impact statement Santa Isabel Island: Chapter 4 environmental values and management of impacts*. Report prepared by Hatch, AECOM, frc environmental & N&S Consulting.

Appendix A

Assessing soil texture

Texture	Behaviour of moist bolus	Approx clay %
SAND	Coherence nil to very slight; cannot be moulded; single sand grains adhere to fingers.	less than 5 %
LOAMY SAND	Slight coherence; can be sheared between thumb and forefinger to give minimal ribbon of about 5mm.	about 5 %
CLAYEY SAND	Slight coherence; sticky when wet; many sand grains stick to fingers; will form minimal ribbon of 5 - 15 mm. Discolours fingers with clay stain.	5-10 %
SANDY LOAM	Bolus just coherent but very sandy to touch; will form ribbon 15-25 mm; dominant sand grains are medium size and readily visible.	10-20 %
FINE SANDY LOAM	Bolus coherent; fine sand can be felt and heard when manipulated; will form ribbon of 15-25 mm; sand grains are clearly evident under a hand lens.	10-20 %
LIGHT SANDY CLAY LOAM	Bolus strongly coherent but sandy to touch; sand grains dominantly medium size and easily visible; will form ribbon of 20-25 mm.	15-20 %
LOAM	Bolus coherent and rather spongy; smooth feel when manipulated but with no obvious sandiness or 'silkiness'; may be somewhat greasy to the touch if much organic matter present; will form ribbon about 25 mm	about 25 %
LOAM, FINE SANDY	Bolus coherent and slightly spongy; fine sand can be felt and heard when manipulated; will form ribbon about 25 mm.	about 25 %
SILTY LOAM	Coherent bolus, very smooth and silky; will form ribbon about 25 mm	about 25 % & silt >25 %
SANDY CLAY LOAM	Strongly coherent bolus sandy to touch; medium size sand grains visible in a finer matrix; will form ribbon of 25-40 mm.	20-30 %
CLAY LOAM	Coherent plastic bolus; will form ribbon of 40-50 mm.	30-35 %
CLAY LOAM, SANDY	Coherent plastic bolus; medium size sand grains visible in finer matrix; will form ribbon of 40-50 mm.	30-35 %
SILTY CLAY LOAM	Coherent smooth bolus; plastic and often silky to the touch; will form ribbon of 40-50 mm.	30-35 % & silt >25 %
FINE SANDY CLAY LOAM	Coherent bolus; fine sand can be felt and heard when manipulated; will form ribbon of 40-50 mm.	30-35 %
SANDY CLAY	Plastic bolus; fine to medium sand can be seen, felt or heard in clayey matrix; will form ribbon of 50-75 mm.	35-40 %
SILTY CLAY	Plastic bolus; smooth and silky to manipulate; ribbon 50-75 mm	35-40 % & silt >25 %
LIGHT CLAY	Plastic bolus; smooth to touch; slight resistance to ribbon shearing between thumb and forefinger; will form ribbon of 50-75 mm	35-40 %
LIGHT MEDIUM CLAY	Plastic bolus; smooth to touch; slight to moderate resistance to ribboning shear (greater than for light clay); will form ribbon of about 75 mm.	40-45 %
MEDIUM CLAY	Smooth plastic bolus; handles like plasticine; can be moulded into rods without fracture; has moderate resistance to ribboning shear; will form ribbon of 75 mm or more.	45-55 %
MEDIUM HEAVY CLAY	Smooth plastic bolus; handles like plasticine; can be moulded into rods without fracture; has moderate to firm resistance to ribboning shear; will form ribbon of 75 mm or more.	>50 %
HEAVY CLAY	Smooth plastic bolus; handles like stiff plasticine; can be moulded into rods without fracture; has firm resistance to ribboning shear; will form ribbon of 75 mm or more.	>50 %

(DPI 2015)

Appendix B

Detailed laboratory results

CERTIFICATE OF ANALYSIS

Work Order	: **EB1720334**	Page	: 1 of 14
Amendment	: **(Preliminary Report)**		
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MS KYLIE DRAPALA	Contact	: Customer Services EB
Address	: 1/4 87 WICKHAM TERRACE SPRING HILL QLD 4000	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 3839 1800	Telephone	: +61-7-3243 7222
Project	: San Jorge	Date Samples Received	: 03-Oct-2017 14:00
Order number	: ----	Date Analysis Commenced	: 04-Oct-2017
C-O-C number	: ----	Issue Date	: 11-Oct-2017 15:24
Sampler	: NICHOLAS JAMSON		
Site	: ----		
Quote number	: BN/530/15		
No. of samples received	: 28		
No. of samples analysed	: 28		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Satishkumar Trivedi	Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG005T (Total Metals by ICP-AES): Samples EB1720334-002 (27, 20-70cm, B) and EB1720334-022 (17, 70-100cm, B22) shows poor spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- EA058 Emerson: V. = Very, D. = Dark, L. = Light, VD. = Very Dark
- ED007 and ED008: When Exchangeable Al is reported from these methods, it should be noted that Rayment & Lyons (2011) suggests Exchange Acidity by 1M KCl - Method 15G1 (ED005) is a more suitable method for the determination of exchange acidity (H+ + Al3+).

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	27, 0-20cm, A	27, 20-70cm, B	27, 70-100cm, B	20, 0-15cm, A	20, 35-65cm, B
Client sampling date / time				[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]
				EB1720334-001	EB1720334-002	EB1720334-003	EB1720334-004	EB1720334-005
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.1	5.0	5.0	4.8	4.7
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	14	14	9	13	12
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	39.3	31.6	35.4	30.8	33.1
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Dark Reddish Brown	Dark Reddish Brown	Dark Reddish Brown	Dark Reddish Brown	Dark Brown
Texture	----	-	-	Silty Loam	Silty Loam	Silty Loam	Silty Loam	Silty Clay Loam
Emerson Class Number	EC/TC	-	-	7	7	7	7	7
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	0.5	<0.1	0.3	0.2	<0.1
Exchangeable Aluminium	----	0.1	meq/100g	0.3	<0.1	<0.1	0.2	<0.1
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	0.2	<0.1	<0.1	<0.1	<0.1
Exchangeable Magnesium	----	0.1	meq/100g	0.2	0.1	0.2	0.1	<0.1
Exchangeable Potassium	----	0.1	meq/100g	<0.1	<0.1	<0.1	<0.1	<0.1
Exchangeable Sodium	----	0.1	meq/100g	0.1	<0.1	<0.1	<0.1	<0.1
Cation Exchange Capacity	----	0.1	meq/100g	1.0	0.1	0.5	0.3	<0.1
Exchangeable Sodium Percent	----	0.1	%	17.0	27.2	17.6	23.4	51.5
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	30	30	20	10	10
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg	2	3	3	3	4
Chromium	7440-47-3	2	mg/kg	5060	5110	5070	4420	5500
Copper	7440-50-8	5	mg/kg	61	78	111	63	106
Lead	7439-92-1	5	mg/kg	5	<5	7	<5	5
Nickel	7440-02-0	2	mg/kg	4470	4910	5740	3690	5110
Zinc	7440-66-6	5	mg/kg	127	129	133	113	162
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	<0.1	0.4	0.6	2.3	0.4
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	3180	1260	990	1870	640

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

			Client sample ID	27, 0-20cm, A	27, 20-70cm, B	27, 70-100cm, B	20, 0-15cm, A	20, 35-65cm, B
			Client sampling date / time	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]
Compound	CAS Number	LOR	Unit	EB1720334-001	EB1720334-002	EB1720334-003	EB1720334-004	EB1720334-005
				Result	Result	Result	Result	Result
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**3180**	**1260**	**990**	**1870**	**640**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**81**	**54**	**58**	**49**	**31**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	**6.5**	**3.4**	**2.3**	**4.1**	**2.0**

(Preliminary Report)

Work Order : EB1720334
Client : EMM CONSULTING PTY LTD
Project : San Jorge

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	39, 0-25cm, A	39, 45-75cm, B	38, 0-20cm, A	38, 30-60cm, B21	38, 70-100cm, B22
				Client sampling date / time	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]
Compound	CAS Number	LOR	Unit		EB1720334-006	EB1720334-007	EB1720334-008	EB1720334-009	EB1720334-010
					Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		4.7	4.8	4.9	5.6	6.5
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		12	6	15	9	25
EA055: Moisture Content (Dried @ 105-110°C)									
Moisture Content	----	1.0	%		31.4	31.6	32.8	34.0	42.3
EA058: Emerson Aggregate Test									
Color (Munsell)	----	-	-		Dark Reddish Brown	Dark Reddish Brown	Dark Reddish Brown	Dark Brown	Dark Brown
Texture	----	-	-		Silty Loam	Silty Clay Loam	Silty Loam	Silty Clay Loam	Silty Clay Loam
Emerson Class Number	EC/TC	-	-		7	4	7	4	4
ED005: Exchange Acidity									
Exchange Acidity	----	0.1	meq/100g		0.5	<0.1	<0.1	<0.1	----
Exchangeable Aluminium	----	0.1	meq/100g		0.3	<0.1	<0.1	<0.1	----
ED007: Exchangeable Cations									
Exchangeable Calcium	----	0.1	meq/100g		<0.1	<0.1	0.6	<0.1	<0.1
Exchangeable Magnesium	----	0.1	meq/100g		<0.1	<0.1	0.3	0.6	7.1
Exchangeable Potassium	----	0.1	meq/100g		<0.1	<0.1	<0.1	<0.1	<0.1
Exchangeable Sodium	----	0.1	meq/100g		<0.1	<0.1	<0.1	<0.1	<0.1
Cation Exchange Capacity	----	0.1	meq/100g		0.5	<0.1	0.9	0.6	7.1
Exchangeable Aluminium	----	0.1	meq/100g		----	----	----	----	<0.1
Exchangeable Potassium Percent	----	0.1	%		----	----	----	----	0.1
Exchangeable Sodium Percent	----	0.1	%		15.9	63.1	2.9	2.3	0.3
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg		10	<10	<10	<10	<10
EG005T: Total Metals by ICP-AES									
Arsenic	7440-38-2	5	mg/kg		<5	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg		2	3	4	4	2
Chromium	7440-47-3	2	mg/kg		4470	7160	5640	5520	3740
Copper	7440-50-8	5	mg/kg		41	56	97	130	77
Lead	7439-92-1	5	mg/kg		5	<5	6	<5	<5
Nickel	7440-02-0	2	mg/kg		1640	3610	6020	9030	10800
Zinc	7440-66-6	5	mg/kg		90	158	176	228	182
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		3.9	0.4	6.3	1.8	1.1
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									

(Preliminary Report)

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

			Client sample ID	39, 0-25cm, A	39, 45-75cm, B	38, 0-20cm, A	38, 30-60cm, B21	38, 70-100cm, B22
			Client sampling date / time	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]
Compound	CAS Number	LOR	Unit	EB1720334-006	EB1720334-007	EB1720334-008	EB1720334-009	EB1720334-010
				Result	Result	Result	Result	Result
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser - Continued								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**2000**	**570**	**2020**	**640**	**440**
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**2000**	**570**	**2030**	**640**	**440**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**92**	**49**	**121**	**56**	**44**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	**5.8**	**1.5**	**5.6**	**1.7**	**0.9**

(Preliminary Report)

Work Order : EB1720334
Client : EMM CONSULTING PTY LTD
Project : San Jorge

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Compound	CAS Number	LOR	Unit	18, 0-23cm, A	18, 23-65cm, B21	18, 65-100cm, B22	35, 0-13cm, A	35, 45-75cm, B
Client sampling date / time				[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]
				EB1720334-011	EB1720334-012	EB1720334-013	EB1720334-014	EB1720334-015
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.1	5.0	4.9	5.2	4.9
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	8	5	8	11	6
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	31.6	29.8	33.2	32.5	28.8
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Dark Reddish Brown	Dark Reddish Brown	Dark Reddish Brown	Dark Reddish Brown	Dark Brown
Texture	----	-	-	Silty Clay Loam	Silty Clay Loam	Silty Clay Loam	Silty Clay Loam	Silty Clay Loam
Emerson Class Number	EC/TC	-	-	7	4	4	7	7
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	0.7	<0.1	0.4	1.3	0.2
Exchangeable Aluminium	----	0.1	meq/100g	0.5	<0.1	<0.1	1.0	<0.1
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	<0.1	<0.1	<0.1	0.3	<0.1
Exchangeable Magnesium	----	0.1	meq/100g	<0.1	<0.1	<0.1	0.3	<0.1
Exchangeable Potassium	----	0.1	meq/100g	<0.1	<0.1	<0.1	<0.1	<0.1
Exchangeable Sodium	----	0.1	meq/100g	<0.1	<0.1	<0.1	<0.1	<0.1
Cation Exchange Capacity	----	0.1	meq/100g	0.7	0	0.4	1.9	0.2
Exchangeable Sodium Percent	----	0.1	%	17.5	36.2	81.3	10.0	33.7
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	10	<10	10	20	<10
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg	3	2	3	1	1
Chromium	7440-47-3	2	mg/kg	4910	4380	4710	3940	3420
Copper	7440-50-8	5	mg/kg	53	54	90	52	60
Lead	7439-92-1	5	mg/kg	<5	5	6	5	<5
Nickel	7440-02-0	2	mg/kg	3090	2540	4720	1660	1710
Zinc	7440-66-6	5	mg/kg	103	96	145	86	84
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	<0.1	<0.1	<0.1	0.2	0.5
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	1830	1180	640	2000	830

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	18, 0-23cm, A	18, 23-65cm, B21	18, 65-100cm, B22	35, 0-13cm, A	35, 45-75cm, B
			Client sampling date / time	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]
Compound	CAS Number	LOR	Unit	EB1720334-011	EB1720334-012	EB1720334-013	EB1720334-014	EB1720334-015
				Result	Result	Result	Result	Result
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	1830	1180	640	2000	830
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	64	48	44	116	82
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	4.8	3.1	1.7	7.5	2.6

(Preliminary Report)

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	10, 0-20cm, A	10, 55-85cm, B	14, 0-18cm, A	14, 45-75cm, B	17, 0-17cm, A
			Client sampling date / time	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]
Compound	CAS Number	LOR	Unit	EB1720334-016	EB1720334-017	EB1720334-018	EB1720334-019	EB1720334-020
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	5.1	4.9	4.4	4.6	5.0
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	18	11	26	17	9
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	34.8	27.3	36.6	32.5	27.3
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Dark Brown	Dark Brown	Reddish Brown	Dark Brown	Dark Reddish Brown
Texture	----	-	-	Silty Loam	Silty Clay Loam	Silty Loam	Silty Loam	Silty Loam
Emerson Class Number	EC/TC	-	-	7	7	7	7	7
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	1.2	<0.1	0.9	<0.1	0.1
Exchangeable Aluminium	----	0.1	meq/100g	0.9	<0.1	0.6	<0.1	<0.1
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	0.2	<0.1	0.3	<0.1	<0.1
Exchangeable Magnesium	----	0.1	meq/100g	0.2	<0.1	0.1	<0.1	<0.1
Exchangeable Potassium	----	0.1	meq/100g	<0.1	<0.1	<0.1	<0.1	<0.1
Exchangeable Sodium	----	0.1	meq/100g	<0.1	<0.1	<0.1	<0.1	<0.1
Cation Exchange Capacity	----	0.1	meq/100g	1.6	0	1.3	0	0.1
Exchangeable Sodium Percent	----	0.1	%	13.2	67.0	9.9	23.3	19.9
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	10	20	10	<10
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg	<1	<1	3	3	4
Chromium	7440-47-3	2	mg/kg	4500	2910	4130	3650	3990
Copper	7440-50-8	5	mg/kg	44	27	67	76	62
Lead	7439-92-1	5	mg/kg	<5	<5	<5	<5	<5
Nickel	7440-02-0	2	mg/kg	1090	401	2820	3800	4430
Zinc	7440-66-6	5	mg/kg	60	25	113	123	136
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	4.8	0.7	10.9	4.5	<0.1
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	2080	770	2040	860	1190

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	10, 0-20cm, A	10, 55-85cm, B	14, 0-18cm, A	14, 45-75cm, B	17, 0-17cm, A
			Client sampling date / time	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]
Compound	CAS Number	LOR	Unit	EB1720334-016	EB1720334-017	EB1720334-018	EB1720334-019	EB1720334-020
				Result	Result	Result	Result	Result
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**2080**	**770**	**2050**	**860**	**1190**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**61**	**47**	**60**	**44**	**47**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	**6.8**	**2.2**	**5.0**	**2.4**	**3.9**

(Preliminary Report)

Work Order : EB1720334
Client : EMM CONSULTING PTY LTD
Project : San Jorge

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	17, 25-55cm, B21	17, 70-100cm, B22	21, 0-13cm, A1	21, 15-45cm, A11/B	30, 0-25cm, A
			Client sampling date / time	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]
Compound	CAS Number	LOR	Unit	EB1720334-021	EB1720334-022	EB1720334-023	EB1720334-024	EB1720334-025
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	4.9	4.9	5.2	6.0	5.1
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	8	9	12	11	7
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	30.2	34.0	34.6	32.4	29.6
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Dark Reddish Brown	Dark Reddish Brown	Dark Reddish Brown	Dark Reddish Brown	Dark Reddish Brown
Texture	----	-	-	Silty Clay Loam	Silty Clay Loam	Silty Loam	Silty Loam	Silty Clay Loam
Emerson Class Number	EC/TC	-	-	4	4	7	7	7
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	<0.1	<0.1	<0.1	----	0.2
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	<0.1	<0.1	----	0.1
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	<0.1	<0.1	<0.1	----	0.2
Exchangeable Magnesium	----	0.1	meq/100g	<0.1	<0.1	2.0	----	0.1
Exchangeable Potassium	----	0.1	meq/100g	<0.1	<0.1	<0.1	----	<0.1
Exchangeable Sodium	----	0.1	meq/100g	<0.1	<0.1	<0.1	----	<0.1
Cation Exchange Capacity	----	0.1	meq/100g	<0.1	<0.1	2.0	----	0.5
Exchangeable Sodium Percent	----	0.1	%	63.2	75.6	2.8	----	10.1
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	10	<10	<10
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg	4	5	3	3	3
Chromium	7440-47-3	2	mg/kg	4520	5450	3970	4220	4860
Copper	7440-50-8	5	mg/kg	84	110	101	95	66
Lead	7439-92-1	5	mg/kg	<5	<5	<5	<5	5
Nickel	7440-02-0	2	mg/kg	5750	11200	6950	8690	3250
Zinc	7440-66-6	5	mg/kg	168	196	167	180	116
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	<0.1	<0.1	5.0	1.9	<0.1
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	1000	370	1760	1220	1690

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	17, 25-55cm, B21	17, 70-100cm, B22	21, 0-13cm, A1	21, 15-45cm, A11/B	30, 0-25cm, A
			Client sampling date / time	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]
Compound	CAS Number	LOR	Unit	EB1720334-021	EB1720334-022	EB1720334-023	EB1720334-024	EB1720334-025
				Result	Result	Result	Result	Result
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**1000**	**370**	**1760**	**1220**	**1690**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**44**	**32**	**48**	**49**	**105**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	<5	<5
EP004: Organic Matter								
Organic Matter	----	0.5	%	**1.7**	**1.3**	**5.1**	**2.6**	**7.0**

(Preliminary Report)

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	30, 50-80cm, B	23, 0-10cm, A	23, 40-70cm, B	----	----
			Client sampling date / time	[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	----	----
Compound	CAS Number	LOR	Unit	EB1720334-026	EB1720334-027	EB1720334-028	--------	--------
				Result	Result	Result	----	----
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	**5.0**	**6.4**	**6.7**	----	----
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	**5**	**32**	**20**	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**29.9**	**28.6**	**35.2**	----	----
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	**Dark Reddish Brown**	**Dark Reddish Brown**	**Dark Reddish Brown**	----	----
Texture	----	-	-	**Silty Clay Loam**	**Silty Clay Loam**	**Silty Clay Loam**	----	----
Emerson Class Number	EC/TC	-	-	**7**	**7**	**7**	----	----
ED005: Exchange Acidity								
Exchange Acidity	----	0.1	meq/100g	<0.1	----	----	----	----
Exchangeable Aluminium	----	0.1	meq/100g	<0.1	----	----	----	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	<0.1	**1.1**	**1.6**	----	----
Exchangeable Magnesium	----	0.1	meq/100g	<0.1	**5.8**	**3.9**	----	----
Exchangeable Potassium	----	0.1	meq/100g	<0.1	<0.1	<0.1	----	----
Exchangeable Sodium	----	0.1	meq/100g	<0.1	**0.1**	<0.1	----	----
Cation Exchange Capacity	----	0.1	meq/100g	**0**	**7.0**	**5.5**	----	----
Exchangeable Aluminium	----	0.1	meq/100g	----	<0.1	<0.1	----	----
Exchangeable Potassium Percent	----	0.1	%	----	**1.0**	**0.2**	----	----
Exchangeable Sodium Percent	----	0.1	%	**19.8**	**1.7**	**1.0**	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	<10	----	----
EG005T: Total Metals by ICP-AES								
Arsenic	7440-38-2	5	mg/kg	**7**	**10**	**11**	----	----
Cadmium	7440-43-9	1	mg/kg	**3**	**3**	**4**	----	----
Chromium	7440-47-3	2	mg/kg	**5320**	**4500**	**5980**	----	----
Copper	7440-50-8	5	mg/kg	**77**	**85**	**101**	----	----
Lead	7439-92-1	5	mg/kg	<5	<5	<5	----	----
Nickel	7440-02-0	2	mg/kg	**3560**	**7150**	**10200**	----	----
Zinc	7440-66-6	5	mg/kg	**117**	**178**	**154**	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**0.2**	**1.1**	**0.7**	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Client sample ID				30, 50-80cm, B	23, 0-10cm, A	23, 40-70cm, B	----	----
Client sampling date / time				[03-Oct-2017]	[03-Oct-2017]	[03-Oct-2017]	----	----
Compound	CAS Number	LOR	Unit	EB1720334-026	EB1720334-027	EB1720334-028	--------	--------
				Result	Result	Result	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser - Continued								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	850	2520	600	----	----
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	850	2520	600	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	89	72	45	----	----
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	<5	<5	<5	----	----
EP004: Organic Matter								
Organic Matter	----	0.5	%	1.6	5.2	1.7	----	----

SYDNEY
Ground floor, Suite 01, 20 Chandos Street
St Leonards, New South Wales, 2065
T 02 9493 9500   F 02 9493 9599

NEWCASTLE
Level 1, Suite 6, 146 Hunter Street
Newcastle, New South Wales, 2300
T 02 4907 4800   F 02 4907 4899

BRISBANE
Level 4, Suite 01, 87 Wickham Terrace
Spring Hill, Queensland, 4000
T 07 3839 1800   F 07 3839 1866

Appendix B

Rehabilitation plan

San Jorge Nickel Project

Mine Rehabilitation Plan

Prepared for Axiom KB Limited | 18 January 2018

San Jorge Nickel Project

Mine Rehabilitation Plan

Prepared for Axiom KB Limited | 18 January 2018

Suite 1, Level 4, 87 Wickham Terrace
Spring Hill QLD 4000

T +61 7 3839 1800
F +61 7 3839 1866
E info@emmconsulting.com.au

www.emmconsulting.com.au

San Jorge Nickel project

Report

Report J17022RP1 | Prepared for Axiom KB Limited | 3 November 2017

Prepared by	**Nicholas Jamson**	Approved by	**Kylie Drapala**
Position	Environmental Scientist	Position	Senior Environment Scientist
Signature	NJamson	Signature	KDrapala
Date	18 January 2018	Date	18 January 2018

This report has been prepared in accordance with the brief provided by the client and has relied upon the information collected at the time and under the conditions specified in the report. All findings, conclusions or recommendations contained in the report are based on the aforementioned circumstances. The report is for the use of the client and no responsibility will be taken for its use by other parties. The client may, at its discretion, use the report to inform regulators and the public.

Document Control

Version	Date	Prepared by	Reviewed by
A	9 October 2017	N Jamson	K Drapala
A1	3 November 2017	N Jamson	K Drapala
A2	18 January 2018	E Thackray	K Drapala

EMM

T +61 (0)7 3839 1800 | F +61 (0)7 3839 1866

Suite 1 | Level 4 | 87 Wickham Terrace | Spring Hill | Queensland | 4000 | Australia

www.emmconsulting.com.au

Table of contents

Chapter 1 Introduction 1
1.1 Background 1
1.2 Location 1
1.3 Disturbance activities 3
1.4 Overview of rehabilitation 5
1.4.1 Other industry disturbance and alternative rehabilitation options 5
1.5 Purpose and scope 6
1.5.1 Purpose 6
1.5.2 Scope 6

Chapter 2 Preferred rehabilitation strategy 7
2.1 Final land uses 7
2.2 Rehabilitation objectives 7
2.3 Conceptual final land form 7
2.3.1 Open-cut pits 7
2.3.2 Out-of-pit waste rock dumps 9
2.3.3 Roads 11
2.3.4 Run-of-mine pads 11
2.3.5 Ancillary infrastructure 11

Chapter 3 Rehabilitation activities 13
3.1 Scheduling of works 13
3.2 Financial assurance 13
3.3 Soil management 14
3.4 Erosion and sediment control 15
3.5 Revegetation 15
3.5.1 Temporary revegetation 15
3.5.2 Permanent revegetation 15
3.6 Open-cut pits water management after rehabilitation 16
3.6.1 Control of surface inflow 16
3.7 Rehabilitation maintenance 17
3.7.1 Weed management 17
3.7.2 Watering 17
3.7.3 Fencing and access 17

Chapter 4 Performance monitoring and rehabilitation monitoring 19
4.1 Performance criteria 19
4.2 As built survey 20
4.3 Surface water 20

Table of contents *(Cont'd)*

4.4 Groundwater 20
4.5 Contaminated land 20
4.6 Erosion 20
4.6.1 Set-up and sampling 20
4.6.2 Procedure 21
4.7 Soil sampling 22
4.7.1 Sample density 22
4.7.2 Analysis of physical properties 22
4.7.3 Analysis of chemical properties 22
4.8 Vegetation 23
4.8.1 Set-up and sampling 23
4.9 Quality assurance 25
4.9.1 Corrective action 26

Chapter 5 Delegations and review 27
5.1 Roles and responsibilities 27
5.2 Review 27

References 29

Tables

1.1 Plan scope 6
3.1 FA calculations 13
4.1 Proposed rehabilitation restoration success criteria and monitoring program 19
4.2 Chemical analysis of topsoil and spoil 23
4.3 Vegetation measuring and sampling procedure 24

Figures

1.1	Location of mine	2
1.2	Mining areas	4
2.1	Proposed final landform scenarios for open-cut pits	8
2.2	Proposed final landform for out-of-pit waste rock dumps	10
4.1	Erosion monitoring transect	21
4.2	Monitoring plot set-up	24

1 Introduction

1.1 Background

Axiom KB Limited (Axiom KB), a subsidiary of Axiom Mining Limited (Axiom), proposes to develop mineral deposits on San Jorge Island in the Isabel Province of the Solomon Islands (the project). The project will comprise extraction of nickel laterite deposits over a period of approximately five to ten years. The ore will be partially dried, then transferred by barge and loaded on to ships moored in Thousand Ships Bay, and then transported to regional processing hubs.

1.2 Location

The project area is located on San Jorge island. The tenement area measures 9 km by 4 km, and comprises the area bound by the Ghobu Creek catchment in the north-west to the Unk and Hughu Creek catchments in the south. The eastern extent of the project area comprises the marine waters adjacent to the coastline, including Albatross Bay to the north, Astrolabe Bay to the east and Tanatola Bay to the south; beyond these bays, is the deep water mooring in Thousand Ships Bay.

San Jorge Island is very sparsely populated, with only one major settlement on the island at Talise on the central part of its east coast (Figure 1.1).

KEY
- Camp Bungusule
- Prospecting licence boundary
- San Jorge Island coastline

Source: EMM (2017); Axiom Mining Limited (2017)

\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps_MRP\MRP001_Regional_20171103_02.mxd 3/11/2017

Site location

Axiom Mining Limited
San Jorge Nickel Project
Rehabilitation plan
Figure 1.1

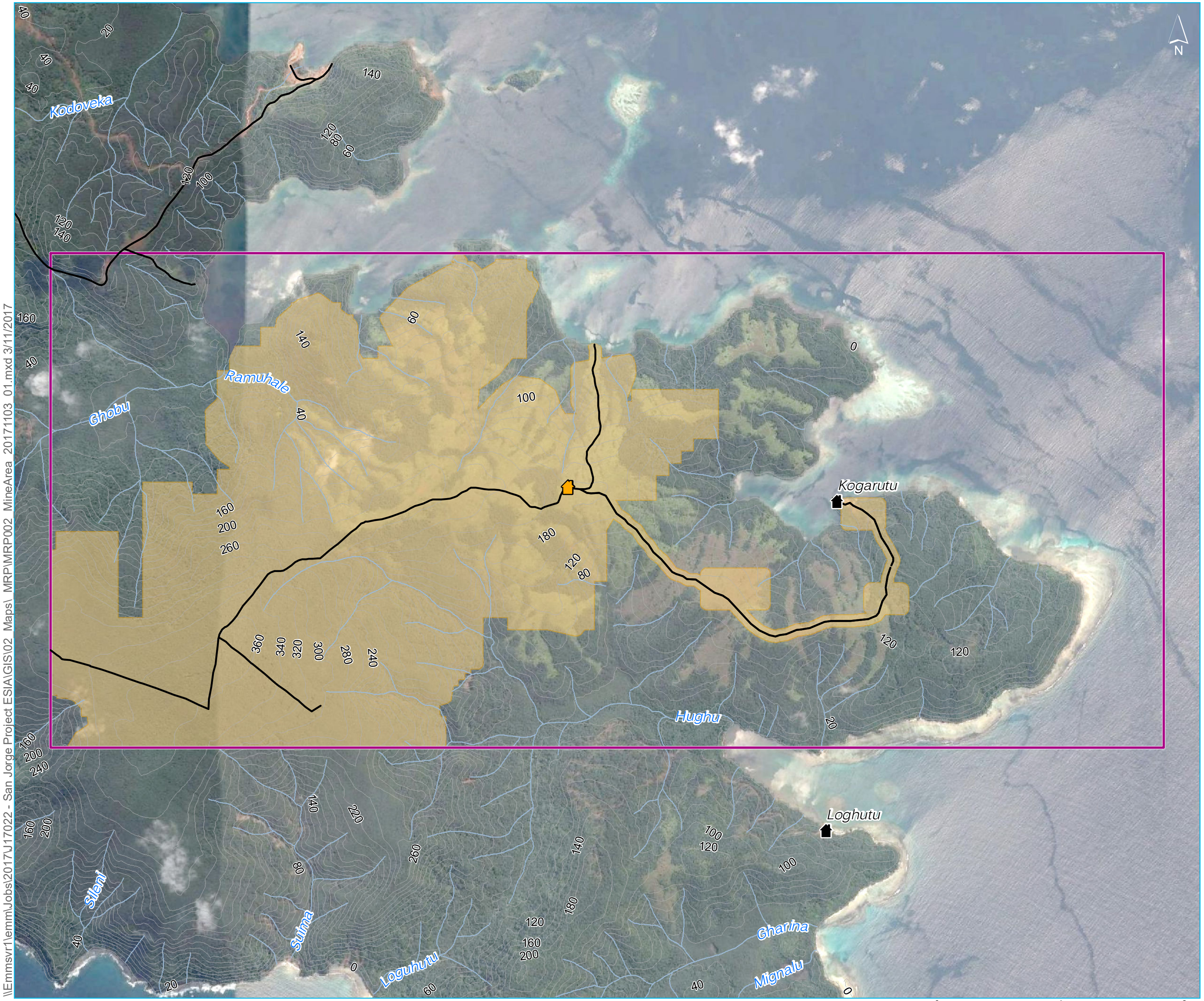
EMM

1.3 Disturbance activities

Approximately 1348.4 hectares (ha) of land will be disturbed throughout the life of the mine. Land disturbance to extract the ore will largely be from extraction activities and the construction of infrastructure, including:

- open-cut pits;
- out-of-pit emplacement areas;
- roads for haul trucks and light vehicles; and
- run-of-mine (ROM) pads for ore stockpiling.

The mine will also include ancillary infrastructure including surface water controls, administration facilities, accommodation, lay down areas, site services, and the ore loading facility within the predicted total disturbance area. The area of disturbance is provided in Figure 1.2.



KEY
- Village
- Prospecting licence boundary
- Potential area of disturbance
- Camp Bungusule
- Access road
- Watercourse / drainage line
- Contour (20 m)

Source: EMM (2017); Axiom Mining Limited (2017); Google Earth Pro (2015)

0 1 2 km
WGS 1984 UTM Zone 57S

\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps_MRP\MRP002_MineArea_20171103_01.mxd 3/11/2017

Mine area

Axiom Mining Limited
San Jorge Nickel Project
Rehabilitation plan
Figure 1.2

EMM

Once operational, ore will be mined from the deposits using a 'top-down approach' of contoured strips fanning out from an access road along the ridgeline. The ore will then be transported to ROM pads and progressive rehabilitation will be completed as the ore is depleted. The mining method will allow rapid and progressive rehabilitation thus minimising impacts to soil (topsoil and subsoil) resources ie soil stockpiling times will be minimised.

Mining may impact on soil resources through the following:

- stripping of soil to prior to constructing infrastructure;
- compaction of soil by machine traffic and infrastructure construction;
- storage of soil in stockpiles;
- potentials loss of soil through erosion;
- potential increased sediment contribution to waterways; and
- potential contamination of soil resulting from spills, storage of fuel and chemicals and refuelling activities.

1.4 Overview of rehabilitation

At the end of mining infrastructure will be decommissioned as soon as possible. Rehabilitation of the mine will be undertaken progressively:

- hardstands, roads building pads and other compacted areas will be ripped to remove compaction and seeded;
- contaminated soil will be excavated and appropriately managed;
- any eroded areas will be rehabilitated by re-contouring and seeding to stabilise the area against further erosion; and
- open-cut pits will be rehabilitated by replacing the ore with overburden or low grade ore, as appropriate, and soil as soon as feasible followed by seeding to stabilise the final landform.

The primary aim of rehabilitation will be to stabilise the final landform by minimising and preventing soil erosion and sedimentation and their subsequent environmental impacts. Erosion and sediment control practices will be implemented to achieve this.

Some infrastructure ie roads, buildings or parts of the ore loading facility may remain after mining provided suitable future uses can be identified in consultation with landowners.

1.4.1 Other industry disturbance and alternative rehabilitation options

Land use surrounding the project area is mostly natural habitat, with some logging and very small-scale cropping (eg coconut, pineapple, and banana) associated with settlements on the island. Exposed areas are vulnerable to soil erosion, nutrient loss and sedimentation of waterways. Cropping areas are vulnerable to soil compaction from machinery use and contamination from chemicals. Local waterways can also be polluted from nutrient and pesticide leaching.

There is currently no intention of rehabilitating the mine to facilitate commercial cropping uses; however, alternative rehabilitation options may be examined in the future.

1.5 Purpose and scope

Land resources at the mine will inevitably be impacted by the proposed activities. The primary aim of this plan is to describe environmental controls that will minimise and prevent soil erosion and sedimentation and their subsequent environmental impacts and describe how the land will be stabilised after mining has finished.

1.5.1 Purpose

The purpose of the plan is to identify environmental control measures for the rehabilitation of disturbed areas. The details apply predominantly to the rehabilitation of the following:

- open-cut pits;
- external pit emplacement areas;
- roads for;
- ROM pads; and
- ancillary infrastructure including surface water controls, administration facilities and accommodation, lay down areas, site services, and the ore loading facility.

1.5.2 Scope

Table 1.1 presents the plan scope.

Table 1.1 Plan scope

Chapter	Description
1	Background information and general description of the mine.
2	Rehabilitation strategy and objectives for rehabilitation of the mine.
3	Rehabilitation activities including final void management.
4	Rehabilitation monitoring.
5	Delegation of authority.

2 Preferred rehabilitation strategy

2.1 Final land uses

The current surrounding land uses include natural habitat, logging and very small-scale cropping (eg coconut, pineapple, and banana) associated with settlements. The proposed final land use will aim to return the area to a stable final landform. There may be potential for forestry as a final land use. The open-cut pits are not expected to have groundwater ingress.

2.2 Rehabilitation objectives

The rehabilitation objectives at the mine are to:

- ensure that soil and waste rock are stored and used in an appropriate manner;
- prevent the loss of soil from disturbed areas;
- minimise sediment-laden runoff travelling to the receiving environment and the associated impacts on marine and freshwater ecosystems;
- ensure that roads, lay down areas, open-cut pits, external pit emplacement areas and associated disturbed areas are stable; and
- rehabilitate disturbed areas to a stable final landform.

2.3 Conceptual final land form

2.3.1 Open-cut pits

Rehabilitation of mining areas will occur progressively, with mined out pits backfilled with overburden from the next area to be mined. Waste rock or overburden will be used first, followed by B horizon soils and A horizon soils for revegetation. The aim will be to produce a final landform shape which is consistent with the surrounding landscape and is stable. The final landform of each open-cut pit may include:

- contaminated soil assessments. Contaminated soils will preferentially be treated at the mine;
- installation of effective bunding or fencing around the perimeter and danger signs as a safety feature to limit the potential for injury;
- surface water redirection away from the open-cut pits using diversion banks located upslope;
- re-profiling the surface to an angle of ≥18° (1(V):3(H)) – scenario 1 or ≤18° - scenario 2;
- strip mining panels will be progressively backfilled with low grade pre or overburden, followed by B horizon then A horizon soils; and erosion control measures (section 3.3) will be implemented as required.

Figure 2.1 demonstrates two potential scenarios for recontoured pit slopes required to achieve geotechnical stability for the open-cut pits.

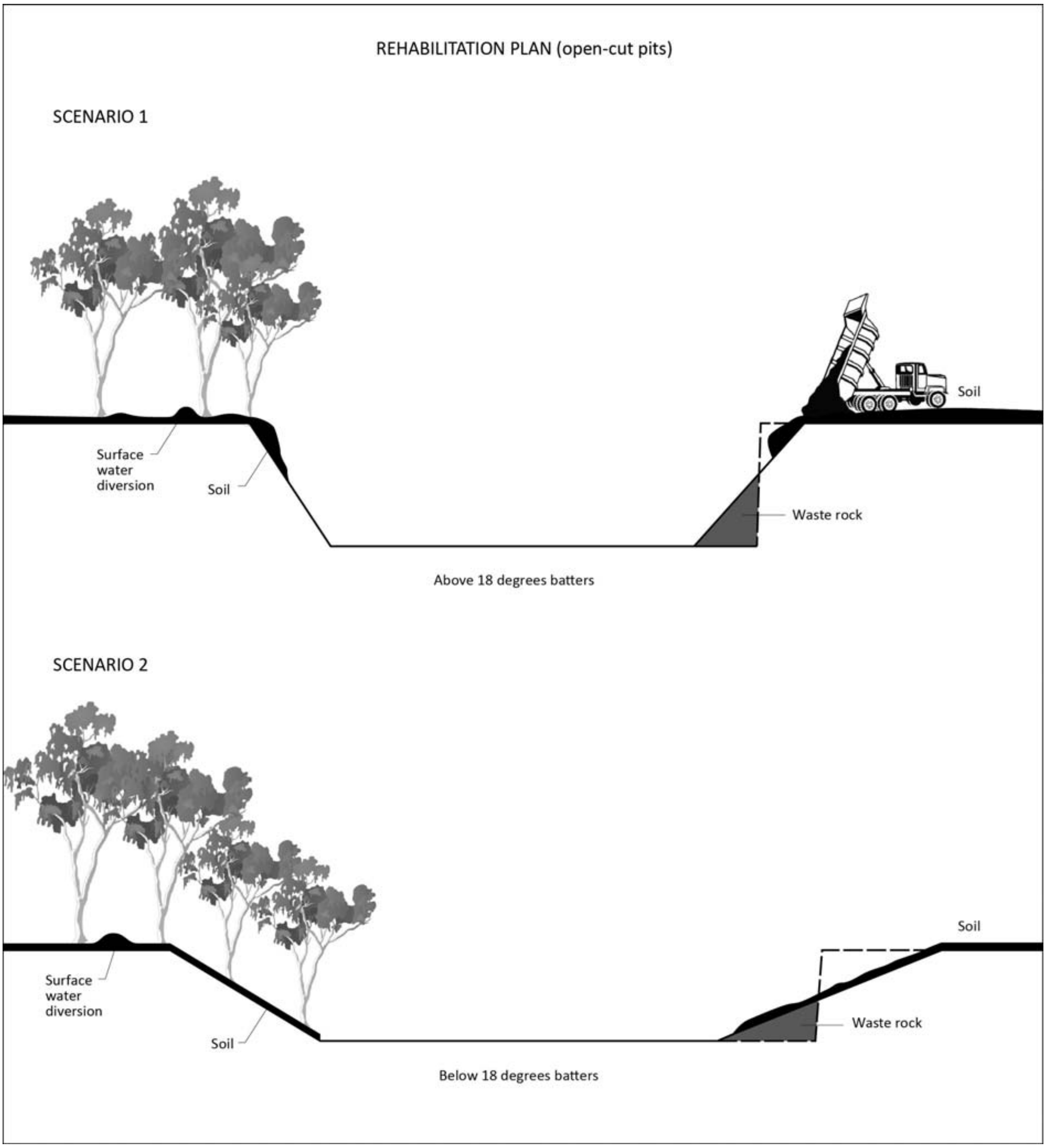


Figure 2.1 Proposed final landform scenarios for open-cut pits

2.3.2 External pit emplacement areas

The final external pit emplacement area landforms will tie into natural landscapes where possible. Selective management and handling of waste rock will ensure external pit emplacement areas will not affect surface water because any rock with adverse chemical or physical characteristics will be encapsulated away from the outer slopes.

If required drainage structures will be constructed to capture runoff and seepage from the external pit emplacement areas; further, surface water redirection away from the flat top surface of the out-of-pit waste rock dumps will be constructed where there is potential for interconnection to adjacent catchments.

External pit emplacement areas will be designed to be safe and stable based on geotechnical assessments and where recontouring is required for stability and will not exceed 18° slope angle on outer surface slopes.

The external pit emplacement slopes will have:

- At least 0.2 m of soil respread on the surface; and
- grass and tree species supported by soil conditions and consistent with the final land use. Rock armouring will be used to limit the potential for erosion if required.

Figure 2.2 demonstrates the proposed out-of-pit waste rock dump final landform where recontouring is required, including drainage structures which may or may not be required.

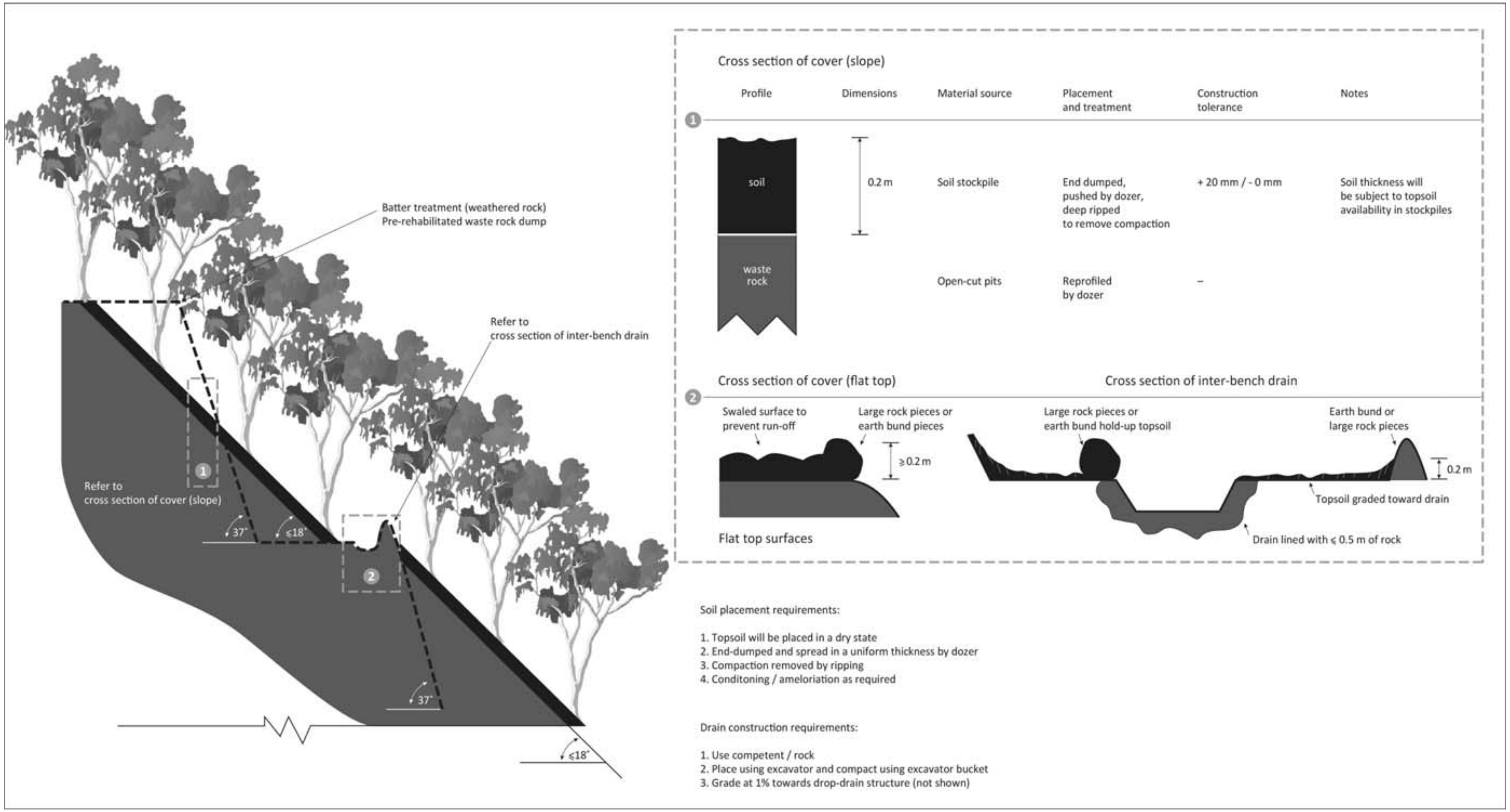


Figure 2.2 **Proposed final landform for out-of-pit waste rock dumps**

2.3.3 Roads

The roads will have a rock and gravel surface and connect the deposits and infrastructure. Any constructed roads not required after rehabilitation of the mine will be decommissioned. The roadbed material will be assessed for potential contamination as required. Contaminated soil, rock and gravel will preferentially be treated at the mine and will be used to partially fill the open-cut pits as required.

Earthworks and landform shaping of decommissioned roads will be performed to match the surrounding landscape where feasible.

Compacted surfaces will be ripped and soil will be spread up to 0.2 m deep. Soils will be seeded as required (section 3.5). Selected grass and tree species will be supported by soil conditions and consistent with the final land use.

Any natural drainage lines intersected by the roads will be re-established where appropriate after decommissioning and erosion and sediment controls will be implemented as needed (section 3.4).

2.3.4 Run-of-mine pads

After completion of mining and removal of all ore from the ROM pads the flat top surface will be deep ripped to remove traffic compaction and seeded. Selected grass and tree species will be supported by soil conditions and consistent with the final land use.

Erosion and sediment controls will be implemented as needed (section 3.4).

2.3.5 Ancillary infrastructure

i Surface water controls

The mine design includes sediment dams to store and treat contaminated runoff from diversion banks. There may also be retention dams which act to slow the velocity of clean runoff from the catchment above the retention dam before discharging into the receiving environment. Water quality and sediment will be sampled and tested for potential contamination prior to rehabilitation. Any potential contamination will be cleaned-up by either removing or treating water and/or sediment.

Surface water controls will either be retained for use in rehabilitation or removed. The decommissioning approach for surface water controls will consist of the following:

- if required contaminated water will be treated before being discharged into the receiving environment;
- if required contaminated sediments will be preferentially treated at the mine and used to partially backfill the open-cut pits;
- water control structures will be breached so that they are incapable of storing water; and
- the breached structure will be graded and land formed in order to restore free draining conditions and reduce the potential for ponding.

Compacted surfaces will be ripped and soil will be spread up to 0.2 m deep, as required. Soils will be seeded as required (section 3.5). Selected grass and tree species will be supported by soil conditions and consistent with the final land use. Erosion and sediment controls will be implemented as needed (section 3.3).

ii Administration facilities and accommodation

Prior to the decommissioning of administration facilities and accommodation, alternative uses, resale and recycling options will be considered.

Building materials may be tested for asbestos and other contaminants where appropriate.

iii Lay down areas

Lay down areas will be scrapped to remove any potential contamination which will preferentially be treated at the mine. Scrapped soil and rock will be used to partially back fill the open-cut pits. The flat top surface will be deep ripped to remove traffic compaction and seeded. Selected grass and tree species will be supported by soil conditions and consistent with the final land use. Erosion and sediment controls will be implemented as needed (section 3.4).

iv Site services

All site services will be treated and isolated (eg oil drained and depressurised) in an environmentally responsible way. All material that is able to be recovered will be removed from the mine for resale or recycling. Recyclables likely to be found on the mine include metals and electrical products. Below ground services will be left in place provided they do not present any issues to future land uses. Any services or infrastructure left underground will have their location recorded. If site services do pose a threat, they will be disconnected and excavated to a suitable depth.

Above ground site services which are not intended for future use (eg power lines), will be taken apart with their materials recycled, resold or disposed of appropriately.

Contaminated soil assessments will be conducted as required. Contaminated soils will preferentially be treated at the mine.

Compacted surfaces will be ripped and soil will be respread (section 3.2). Some areas may need grading and landform shaping in order to restore drainage and reduce ponding. Soils will be seeded (section 3.4) as required. Erosion and sediment controls will be implemented as needed (section 3.3).

v Ore loading facility

Prior to the decommissioning of the ore loading facility, alternative uses, resale and recycling options will be considered.

Any facilities not to remain after decommissioning (in agreement with landowners) will be dismantled for reuse, resale or disposal in on-site landfill (non-hazardous materials only). Any hazardous materials will be removed from site for reuse or disposal at an approved facility.

After dismantling of facilities any remaining concrete pads will be covered with a minimum 0.5 m depth of clean fill and seeded. Soils in the area will be assessed for contamination and if contamination is found the affected soils will be treated (in-situ or ex-situ) appropriately.

3 Rehabilitation activities

3.1 Scheduling of works

Rehabilitation of the mine will be progressively staged as soon as possible after mining is finished. Staging of rehabilitation activities will require identification of timelines for decommissioning of the infrastructure described in section 2. A more detailed schedule of works will be developed as part of the final rehabilitation plan 12 to 24 months prior to the confirmed closure.

3.2 Financial assurance

A preliminary financial assurance (FA) calculation was completed for the identified deposits to be mined, the current known resource extent and the total potential area of disturbance. The FA calculation has been prepared using the standard rates table presented in the Queensland Government FA Calculation tool. The following assumptions were made:

- the identified deposit area is 361.35 ha;
- the current known resource extent is 791.49 ha;
- the potential area of disturbance is 1348.4 ha;
- 0.2 m of topsoil will be applied to disturbed areas;
- 1 m of subsoil will be applied to disturbed areas;
- it will cost approximately $3.26 AUD to haul 1 m^3 of topsoil or subsoil from a stockpile to the disturbed area (<1 km haul distance);
- it will cost approximately $2,500 AUD/ha for direct seeding of topsoiled areas; and
- maintenance will cost approximately $2,000 AUD/ha.

The FA for each of the three scenarios is listed below in Table 3.1. These figures are based off of current mine infrastructure plans and are likely to change when detailed mine planning occurs.

Table 3.1 FA calculations

Scenario	Identified deposits	Current known resource extent	Total potential area of disturbance
Source, cart and spread topsoil/subsoil	$14,136,012.00	$30,963,088.80	$52,745,416.00
Direct seeding (native tree/shrub/grass species)	$903,375.00	$1,978,725.00	$3,370,744.00
Maintenance	$722,700.00	$1,582,980.00	$2,696,595.00
Total	**$15,762,087.00**	**$34,524,793.80**	**$58,812,757.00**

3.3 Soil management

A soil assessment carried out by EMM (2017) found that the soils on the mine are Acidic Dystrophic Red Ferrosols. The soil has low soil erodibility however after high intensity rainfall; the steep slopes on the mine combined with future vegetation removal may result in an erosion hazard that is much higher.

Stripping of soil will occur prior to construction of mine domains and will follow guidelines from the report San Jorge *Nickel Project – Soil Assessment* (EMM 2017):

> ...It is recommended that all A horizon soil except for that surrounding site 14 (due to acidity) is stripped (0.1-0.4m bgs) and stockpiled to a height of 1.5 m or no more than 2 m. It is also recommended that B horizon soil is tripped down to a depth of 1.2 m bgs and stockpiled.

Before the soil can be spread all landform shaping for each domain to be rehabilitated needs to be completed. Following this the soil can be spread and managed using the following strategy:

- soil will be replaced in reverse sequence to its removal with B horizon soil placed first and covered with A horizon soil;
- the B horizon soil surface may be levelled, but will not be smoothed prior to A horizon soil application:
    - B horizon soil will be respread first at a depth consistent with the post mining land use. The depth of B horizon soil will depend on whether any is needed for covering areas where A horizon soil is unavailable for rehabilitation.
- A horizon soil will be spread on the contour to minimise erosion potential and improve moisture infiltration:
    - A horizon soil will be up to 0.2 m thick or a thickness consistent with the post mining land use.
- the final surface may be levelled, but will not be compacted or smoothed in order to minimise runoff velocity and aid infiltration;
    - the final surface may be racked or scarified using the teeth of a grader as needed so that big clods are broken down, the surface is even and the soil is easy to traverse during seeding.
- rehabilitated areas will include sediment and erosion control; and
- barricades (eg large rocks or tree trunks) and appropriate signage will be setup to limit vehicular disturbance to the newly rehabilitated areas.

The volume of soil available (determined by A horizon and B horizon soil volumes) will be reconciled with the estimated area for rehabilitation prior to commencing earthworks. The mine will place the thickest available soil cover over the infrastructure areas during rehabilitation.

3.4 Erosion and sediment control

Erosion and sediment control measures for the operations phase of the mine are described in detail in the report *San Jorge Nickel Project – Soil Assessment* (EMM 2017). In addition to these measures, the following will be implemented as required to assist in erosion and sediment control:

- maintain and monitor sediment traps and dams in order to ensure they remain effective;
- rehabilitate exposed areas as soon as feasibly possible;
- place rip-rap in drainage lines to reduce runoff velocity;
- maintain sediment structures around newly rehabilitated areas until they are deemed stable;
- freshly laid soil will be immediately seeded and could also be sprayed with a tack coat if necessary to ensure stability;
- stockpiled vegetation will be spread along the contour in rehabilitated areas to slow runoff velocity; and
- high risk areas for erosion (eg steep slopes) will be closely monitored and corrective actions taken as required.

3.5 Revegetation

3.5.1 Temporary revegetation

Once landform shaping is complete, the surface will need to be revegetated as quickly as possible. This is an important step in completing successful rehabilitation. The reshaped landform may be sown with a fast growing, high density, native cover species to reduce erosion and soil loss. The species will form an extensive root network and benefit the mine by slowing runoff, binding and stabilising the landform surface and increasing soil organic carbon. This will ultimately make soil conditions more favourable for the establishment of native species.

3.5.2 Permanent revegetation

The aim of permanent revegetation will be to provide a long term stable final landform. Once the temporary cover is established, the infrastructure areas will be seeded with a mix of native species, or established using propagated cuttings. Using a mix of seeds is important as the initial seed mix will likely strongly reflect the final vegetation composition of the rehabilitated infrastructure area.

Several trees and plants have been suggested for the rehabilitation work during and after any mining operation on San Jorge Island. These species have been selected based on recent field observations and assessments carried out as part of rehabilitation studies on Choiseul and Isabel ultramafic forest locations. The plants can survive in harsh environmental conditions, on poor soils with minimal soil treatments during the establishment period. They regenerate well through seeds in cleared areas of previous disturbance

The suggested species includes pioneer species and other secondary re-growth species observed during rehabilitation at cleared sites. These will also be complemented with selected timber trees, fruit and nut trees and other milti-purpose agro-forestr crops which can be integrated into the rehabilitation plan.

The suggested species are presented in Table 3.2.

Table 3.2 Potential species for use during revegetation

Scientific Name:	Common Name:	Plant Type:
1. Macaranga dioica	Macaranga	Pioneer tree
2. Macaranga similis	Macaranga	Pioneer tree
3. Trichospermum psilocladum	Trichospermum	Pioneer/ secondary tree
4. Commersonia bartramia	Commersonia	Pioneer/ secondary tree
5. Melochia umbellata	Melochia	Pioneer tree
6. Timonius timon	Timonius	Secondary tree
7. Colona velutina	Colona	Pioneer/ secondary tree
8. Dicranopteris linearis	Gleichenia fern	Secondary regrowth
9. Gymnostoma papuana	Casuarina/ Gymnostoma	Primary species regeneration
10. Casuarina equisetifolia	Casuarina, Naru, Aru	Primary species regeneration
11. Dillenia crenata	Dillenia	Primary species regeneration
12. Lycopodium cernuum	Lycopodium	Secondary regrowth
13. Dacrydium elatum	Dacrydium, Gymnosperm	Primary species regeneration
14. Euodia solomonensis	Euodia	Secondary regrowth
15. Syzygium nemorale	Syzygium	Primary species regeneration
16. Cryptocary whitmorei	Cryptocarya	Secondary regrowth
17. Xanthostemon melanoxylon	Ebony, Ironwood, Tubi, Rie	Primary species regeneration
18. Dysoxylum excelsum	Dysox	Secondary regrowth
19. Canarium liguliferum	Canarium	Primary species regeneration
20. Calophyllum obscurum	Calophyllum	Primary species regeneration
21. Gliricidia sepium	Gliricidia	Introduced Nitrogen-fixing tree
22. Fagraea obtusifolia	Fagraea	Primary species regeneration

Local stakeholders will be consulted from the early stages of operations with regards to final land uses and vegetative species composition. If the final land uses and vegetation species proposed are feasible, Axiom KB will incorporate this into their revegetation trials. Possible limitations for including stakeholder suggestions include the suitability of rehabilitated soils and landforms and the availability and viability of seeds.

The response of the chosen native species to fertiliser will need to be considered before seeding. The seed mix may also need to be adjusted based on the landscape (eg adding more shade tolerant species on slopes that receive minimal sunlight). Any conditions that these native plants require to germinate also need to be factored in (eg some seeds require specific amounts of light to germinate). A small amount of stoloniferous grass may need to be included in seed mix to ensure adequate groundcover is maintained during native vegetation establishment.

Seeding will require the following actions:

- photograph infrastructure area to be rehabilitated prior to any sowing or planting so that progress can be tracked;
- inspect the infrastructure area and inform the operator regarding the presence of wildlife, erosion prone areas or safety concerns;
- completed a contaminated land assessment, if required, and treat any potential contaminates at the mine prior to using it to partially backfill the open-cut pits;
- complete earthworks to achieve final landform shape (section 2.3) and prepare soil for seeding (section 3.2);
- implement any required sediment and erosion controls (section 3.3);
- seed the appropriate cover crop species to stabilise the infrastructure area. Aerial seeding may be required with no safe access; and
- photograph the infrastructure area following completion of work. Ongoing photography will be used as part of the monitoring program to assess rehabilitation.

3.6 Open-cut pits water management after rehabilitation

During operation of the mine there is not expected to be any groundwater ingress into the open-cut pits; however, rainfall may accumulate in the pit during heavy rainfall. In this case the water will be captured in a sump at the base of the open-cut pit and pumped to a storage dam before being used for dust suppression or released from the mine to the receiving environment.

After rehabilitation the open-cut pits will be backfilled and designed to be free-draining with diversion and other water control structures as needed.

3.6.1 Control of surface inflow

As per the *San Jorge Nickel Project – Soil Assessment* (EMM 2017) report, diversion channels will be installed prior to the start of operations. The water is then redirected to either a retention dam or sediment dam to slow velocity before release into the receiving environment. Maintaining these channels will be essential in reducing inputs to the backfilled mining areas as well as preventing failure of rehabilitation.

3.7 Rehabilitation maintenance

In order to establish a stable final landform, maintenance of rehabilitation areas is essential. Stability of the final landform will be assessed against performance criteria (section 4). Where performance criteria have not been met, maintenance works, and continued monitoring may need to be continued until such time that the performance criteria have been met.

It is expected that maintenance inputs required will decrease as the vegetation becomes established. The monitoring program (section 4) will identify rehabilitated infrastructure areas that need further maintenance efforts. Maintenance activities may include:

- re-seeding and, where necessary, application of more soil and/or the application of specialised treatments in areas where vegetation death has occurred or where inadequate cover has not developed;
- use of soil amendments such as fertiliser and composted mulch in areas with poor vegetation establishment;
- constructing temporary fencing suitable for the exclusion of over abundant grazers should faunal impacts be excessive; and
- monitoring and maintaining erosion and sediment controls if deemed inadequate or compromised until the final landform is stable. Sediment control structures will need to be carefully examined after high rainfall events so that silt can be removed and any failures can be repaired.

3.7.1 Weed management

Weed species have the potential to significantly impact rehabilitation success of the final landform. They can also reduce the biodiversity value of the rehabilitated infrastructure areas and reduce habitat and food resources. During the establishment period, rehabilitation areas are most prone to weed invasions. Some weeds that are significant in the Solomon Islands include navua sedge (*Cyperus aromaticus*), *Mimosa pudica*, *Mimosa invisa* and *Sida acuta* (FAO 2009). Weeds may be managed through the following mitigation measures:

- herbicide spraying or scalping weeds from soil stockpiles prior to re-spreading;
- regular inspections of rehabilitated infrastructure areas for weed infestations; and
- identifying and spraying existing weed populations together with regular spraying during mine operations.

3.7.2 Watering

Seeding of final landforms will coincide with seasonal rainfall to reduce the requirement for watering; however, the final landforms may require watering after seeding to aid germination and vegetation growth. If required water will be sourced from the open-cut pits and water storage areas provided it is of adequate quality.

3.7.3 Access

Fencing or a similar barrier to access will be maintained during the rehabilitation maintenance phase.

4 Performance monitoring and rehabilitation monitoring

4.1 Performance criteria

The proposed performance criteria and monitoring program for the mine is described in detail in Table 4.1. Monitoring will be conducted by suitably skilled personnel at sites representative of the variation within the rehabilitated infrastructure areas. Regular reviews of collected data will be undertaken to assess rehabilitation performance and monitoring program suitability.

The rehabilitation elements and monitoring indicators are factors which are used to determine whether rehabilitation is successfully occurring. The monitoring criteria itself is a measurable property used to verify these factors. The monitoring plan will be further developed and refined based on initial results after the first 2 years of rehabilitation monitoring.

Analogue sites will be chosen and monitored to allow for rehabilitation success to be measured against a control site. The analogue sites will be undisturbed which is considered to be examples of stable landforms.

Table 4.1 Proposed rehabilitation restoration success criteria and monitoring program

Rehabilitation element	Monitoring indicator	Monitoring criteria	Monitoring frequency
Decommissioning	Timeline	Plan and implement rehabilitation in a timely and resource efficient manner.	Prior to decommissioning.
	Buildings, equipment and foundations	All buildings and equipment removed and foundations covered.	During decommissioning.
	Water storage facilities	All water storage areas not to be used in rehabilitation are removed.	During decommissioning.
	Contaminated soils and sediments	Soils and sediments that were deemed contaminated have been treated.	During decommissioning.
Landform stability	Slope gradient	To be determined.	Prior to high walls being rehabilitated or covered by overburden then half-yearly.
		Slopes of the final landform are safe and stable.	As overburden is shaped and prior to soil coverage.
		There are no signs of mass movement within the open-cut pits.	Half-yearly.
	Erosion control	Erosion and sediment control measures have been implemented.	Half-yearly.
		Erosion and sediment control measures have been maintained.	Half-yearly.
	Surface water drainage	Surface water diversions above the open-cut voids have been maintained.	Quarterly and event based.
		There is no evidence of surface water entering the final open-cut pits.	Quarterly and event based.
	Dust	Dust levels are below determined thresholds.	As necessary.

Table 4.1 Proposed rehabilitation restoration success criteria and monitoring program

Rehabilitation element	Monitoring indicator	Monitoring criteria	Monitoring frequency
Topdressing	Topsoil and subsoil	Soil and waste rock are layered in the correct order.	During soil coverage and prior to revegetation.
		Soil depth is adequate.	Half-yearly.

4.2 As built survey

An as built survey of final landforms will be completed by site survey staff. The survey will be completed with sufficient accuracy to allow the development of a one meter digital elevation model.

4.3 Surface water

The surface water monitoring and management program will be reviewed and revised annually during the life of the mine and will be in accordance with the environmental management plan. The surface water monitoring and management program will be adapted over time to suit the requirements of monitoring for the performance criteria.

4.4 Groundwater

The groundwater monitoring and management program will be reviewed and revised as described for surface water in section 4.3.

4.5 Contaminated land

The operational site will maintain a contaminated land register. The register will include the location of recorded spills, type of contaminant and the estimated volume of contaminant spilled. The register will be reviewed prior to decommissioning of the infrastructure areas. Contamination clean-up will be included in the decommissioning plan if required based on confirmation testing.

4.6 Erosion

4.6.1 Set-up and sampling

Erosion monitoring will be completed on all rehabilitated final landforms. This is to be performed along existing sloped transects on rehabilitated waste rock dumps and open-cut pits or analogue sites, at the same time as the vegetation assessment.

The procedure is to be performed across slope. That is along the contour not orientated towards the crest and toe of the slope.

The method involves laying a 150 m tape measure along the ground starting from the first peg of the transect. The tape must be secured at the beginning and pulled firm to ensure that it lies as close as possible to the horizontal. The transect design is illustrated in Figure 4.1.

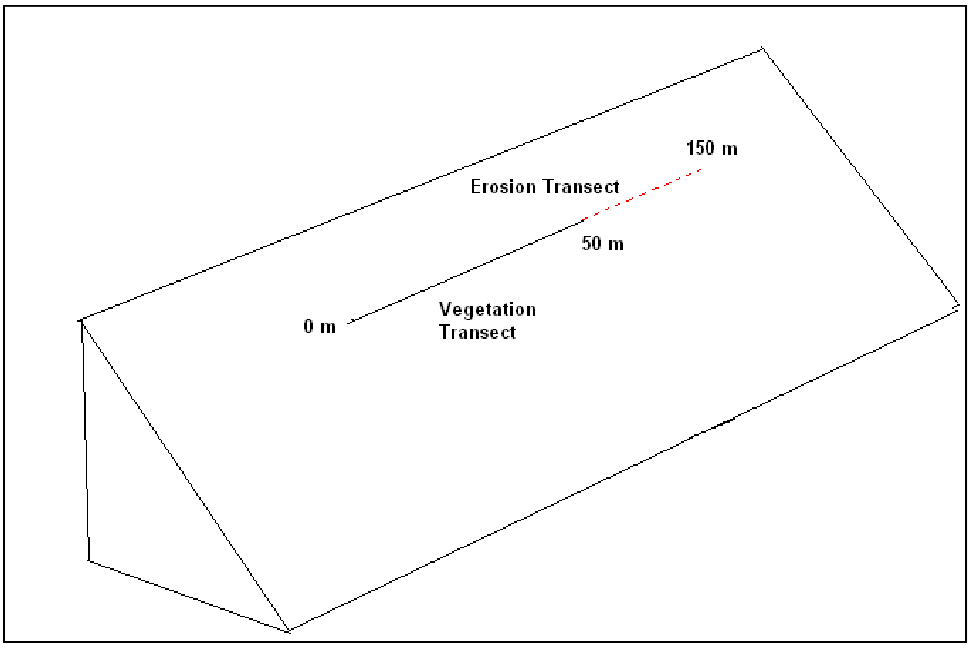


Figure 4.1 Erosion monitoring transect

The density of sampling has not yet been determined but will include a combination of upper slope areas, mid-slope areas and toe slope areas. The density of sampling will be determined by the mine in collaboration with the local government authority.

4.6.2 Procedure

The monitoring procedure is:

- walk along the transect and identify any gullies (ie rills that are more than 30 cm deep);
- for each gully, measure the deepest point at which the tape crosses the gully (depth) and the distance from the "0" peg at which it occurs;
- measure the total width of the gully (again, where tape crosses the gully); and
- take a photo from the nearest previous peg of the whole gully and record the details in the data sheet.

Where the transect does not cross any gullies, but there are significant gullies elsewhere on the slope, then the following procedure should be followed:

- select a number of gullies. The gully transect should not aim to go through the deepest part of the gully but should be randomly selected;
- five metres prior to the start of a gully and 5 m past the end of a gully (around the slope) a star picket should be inserted. These positions should be logged using GPS;
- for the identified gully, measure the deepest point (depth) and the distance from the starting star picket at which it occurs;

- measure the total width of the gully; and
- take a photo from the star picket of the whole gully and record the details on the erosion data sheet.

4.7 Soil sampling

4.7.1 Sample density

The sample collection density for soil is:

- one sample location per 15 ha. If the area is less than 15 ha than the minimum number of sample locations is one;
- sample locations should extend to 0.5 m bgs or to the maximum depth of soil. Whichever is deepest; and
- samples should be taken at 0.1 m increments below ground level for the full soil thickness.

4.7.2 Analysis of physical properties

The assessment should include the following analysis:

- electrical conductivity (EC);
- chloride content;
- calcium to magnesium (Ca:Mg) ratio;
- cation exchange capacity (CEC);
- exchangeable sodium percentage (ESP); and
- Emerson aggregate stability.

Samples will be sent to a NATA accredited laboratory for analysis.

4.7.3 Analysis of chemical properties

Analysis will be as described in Table 4.2. The table also provides justification for why each analysis is required.

Table 4.2 Chemical analysis of topsoil and spoil

Test	Reason for inclusion
pH	Measurement of pH is probably the most commonly made test. It is regarded as a useful indicator of other soil properties (e.g. values >8.5 usually indicate high exchangeable sodium levels and the presence of carbonates) and of the need for amendment with lime. Some plants tolerate a wide range of pH, while some are sensitive to acidity and some to alkalinity. The availability of some nutrients would be affected by soil pH.
Carbonate Content	Carbonate may exist in soil as predominately either calcite or dolomite. Its presence, which may vary from trace amounts to high percentages of the soil, is of significance because of its effect on the general physical condition, especially on consistence. When present in large amounts as fine-earth carbonate it can modify soil texture. It can constitute a potential source of calcium for the replacement of exchangeable sodium, thus improve stability.
Soluble Ca, Mg, Na, K, CO_3, HCO_3, SO_4	Knowledge of soluble cations and anions and their relative proportions is valuable in assessing saline and alkaline soils and their response to various treatments. Chloride is usually the principal anion in extracts of soil and it is specifically toxic to some plants. Other anions may also be toxic to plants. Bicarbonate is a normal constituent of saline and sodic soil extracts. Both CO_3 and HCO_3 have a tendency to precipitate the divalent cations Ca and Mg, resulting in an increase in the ratio of Na to Ca-Mg in the soil solution. This favours the absorption of Na by the exchange complex and the development of unfavourable sodic-soil conditions.
Bicarbonate Phosphorous (Caldwell method)	If the amount of phosphorous in soil is too small then yield is jeopardised, but increasing reserves to very high levels is an unnecessary expense. Thus the concept of a critical level in soil is necessary.
Nitrogen	As above
Potassium	As above
Organic Matter	Organic matter is important in maintaining soil structure, in slightly increasing the soil's water holding capacity and holding a small store of N, P, S and trace elements in organic forms. These cannot be taken up directly by plant roots but have first to be converted by soil microbes to inorganic (ionic) forms identical to those supplied in fertilisers.
Total digest for molybdenum, manganese, iron, copper, zinc, boron, chloride, sodium, cobalt and selenium	Although only required in small amounts, trace elements (or micronutrients) are essential for plant growth. These nutrients often act as catalysts in chemical reactions. It is possible to have toxicities of trace elements, as well as deficiencies. A deficiency may reduce plant growth. An excess of a trace element, although not common, may be toxic to the plant and may cause an imbalance, reduced yield, impaired quality or increased susceptibility to disease.

4.8 Vegetation

4.8.1 Set-up and sampling

To ensure consistency and repeatability of the monitoring programme, permanent sites need to be established within the rehabilitation area. Star pickets are a cost effective and durable material to use for this purpose.

The site design is illustrated in Figure 4.2 and the sampling procedure is described in Table 4.3

At each site a central star picket is located and four additional star pickets are located at the four compass points (ie north, east, south and west) five metres from the central star picket. The star pickets should be pushed into the ground up to a permanently visible and unchangeable point (ie a painted line or engraving) so that ground level is at the marked point.

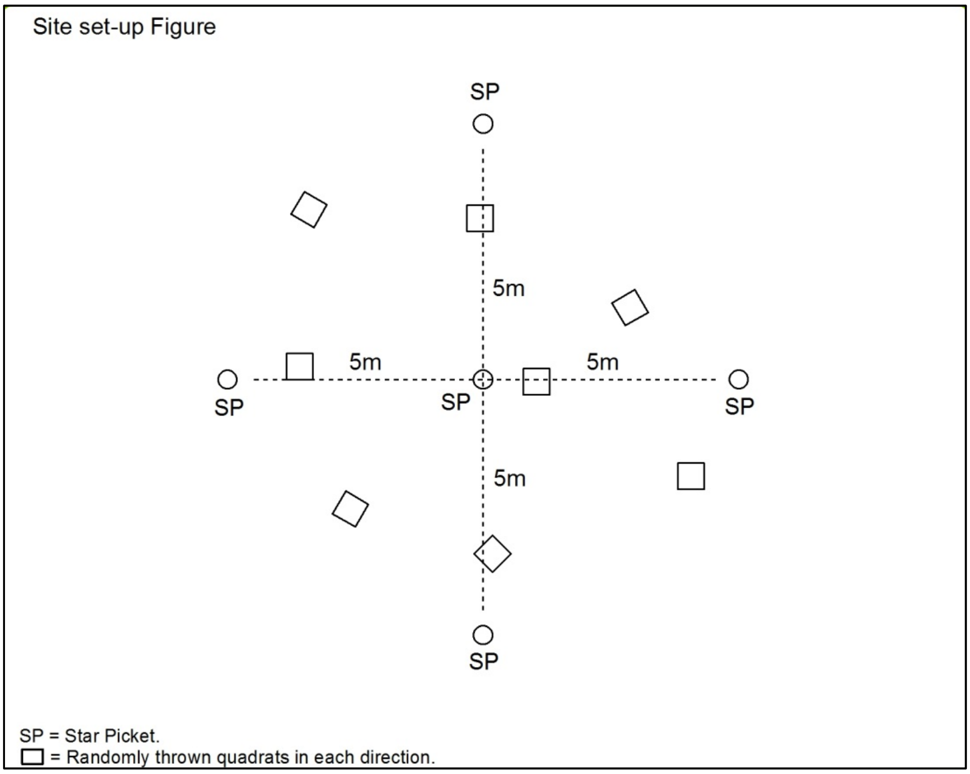


Figure 4.2 Monitoring plot set-up

Eight one square metre quadrats are assessed at each site and the procedure for determining their location is described in Table 4.3. Only one quadrat is required for the process, not eight.

Table 4.3 Vegetation measuring and sampling procedure

Step	Equipment required	Procedure
Step 1 – photographing the site	Camera	Stand at the central star picket Take four photos at each compass point (ie facing N, E, S, W) Record photo numbers on field sheet Each star picket can also be numbered with the site number and the first photograph can be taken of the star picket number for ease of referencing photos
Step 2 – general site notes	None	Record estimate of overall ground cover Note if any evidence of soil erosion Note if any evidence of use by fauna (ie. sightings of fauna, scats, hair, grazed vegetation) Record any woody vegetation growing in the monitoring plot or in the vicinity of the monitoring plot
Step 3 – measure soil loss	Tape measure	At each of the four compass point star pickets, measure the distance from the ground to the previously determined mark (ie hole). For the first time

Table 4.3 Vegetation measuring and sampling procedure

Step	Equipment required	Procedure
		this is carried out the distances will all be zero and is not necessary to be completed.
Step 4 – measuring ground cover and species	1m quadrat Camera	Measure ground cover and species at eight quadrat locations: Stand at the centre star picket, facing north Randomly throw the quadrat towards north (aim to be within the external star pickets) Take a photo of the quadrat and record photo number on data sheet Within the quadrat measure: estimate total ground cover percentages (vegetation, bare earth, rock, woody debris); species present and their relative percentage (of the vegetation cover, not the total quadrat); and repeat at all eight compass points – N, NE, E, SE, S, SW, W, NW.
Step 5 (in conjunction with Step 4) – measuring biomass	Scissors/secateurs Bag Oven	Choose a quadrat from Step 4 which is representative of the percentage of groundcover across that site Collect all vegetation within the quadrat back in office/laboratory – dry the vegetation at 105 degrees Celsius for 48 hours Weigh dry vegetation to determine kg/ha dry vegetation mass

Vegetation monitoring will be completed on all rehabilitated final landforms. As for erosion monitoring, the density of sampling has not yet been determined but will include a combination of upper slope areas, mid slope areas and toe slope areas.

4.9 Quality assurance

Monitoring, data assessment and reporting will be done by a suitably qualified person. This could be mine staff (eg environment officer) or external consultant(s).

All monitoring data files will be stored at the mine.

The mine will be responsible for reviewing monitoring data, analysis, reports and managing consultants.

Aspects to consider when reviewing the data, analysis and reports include quality assurance/quality control of data, fluctuating trends in data from previous years, accuracy of figures and graphs and general conclusions made about rehabilitation progress.

4.9.1 Corrective action

The following corrective actions are to be employed by the mine where required:

- revision of construction, operation and rehabilitation activities as required;
- an incident report will be filled out if any non-conformances with this plan are found;
- in the event of an environmental incident, appropriate response measures will be implemented to ensure environmental harm from the event is minimised;
- all non-conformances will be corrected as soon as possible and strategies identified, evaluated and implemented to reduce the likelihood of the non-conformance re-occurring; and
- all non-conformances and corrective actions will be closed out as soon as practicable.

5 Delegations and review

5.1 Roles and responsibilities

The site manager is responsible for administering the plan. This includes:

- allocating tasks and duties stated in the plan;
- providing and making adequate resources available;
- ensuring employees and contractors are trained and upskilled to be able to complete their allocated tasks; and
- implementing any supplementary plans.

Employees and employees have their own responsibilities which include:

- adhering to all requirements as set out in the plan; and
- completing any tasks allocated by the site manager.

The on-site environmental manager or representative will be required to:

- audit against the plan requirements and standards and ensure compliance; and
- organise updates where necessary.

5.2 Review

The plan detailed in this report is expected to be reviewed and modified throughout the life of the mine. As operations begin and operational plans become established the rehabilitation plan will need to be updated to reflect this. Closer to the closure date, a final version of the rehabilitation plan will be developed in order to ensure the rehabilitated final landscape is managed appropriately.

References

Australian and New Zealand Environment and Conservation Council (ANZECC) 2000, *Australian and New Zealand guidelines for fresh and marine water quality*, Canberra, Australia.

EMM Consulting Pty Limited (EMM) 2017 San Jorge Nickel Project – Soil Assessment. Report prepared for Axiom KB Limited.

Food and Agriculture Organization of the United Nations (FAO) 2009, Country Pasture/Forage Resource Profiles – Solomon Islands, viewed 14 January 2016, http://www.fao.org/ag/agp/agpc/doc/Counprof/southpacific/Solomon.htm#6.4

SYDNEY
Ground floor, Suite 01, 20 Chandos Street
St Leonards, New South Wales, 2065
T 02 9493 9500 F 02 9493 9599

NEWCASTLE
Level 1, Suite 6, 146 Hunter Street
Newcastle, New South Wales, 2300
T 02 4907 4800 F 02 4907 4899

BRISBANE
Level 4, Suite 01, 87 Wickham Terrace
Spring Hill, Queensland, 4000
T 07 3839 1800 F 07 3839 1866

www.emmconsulting.com.au

Appendix C

Freshwater assessment

San Jorge Nickel Project

Environmental Impact Statement | Preliminary Surface Water Assessment

Prepared for Axiom Mining Limited | 16 January 2018

Ground Floor, Suite 01, 20 Chandos Street
St Leonards, NSW, 2065

T +61 2 9493 9500
F +61 2 9493 9599
E info@emmconsulting.com.au

www.emmconsulting.com.au

San Jorge Nickel Project

Final

Report J17022RP1 | Prepared for Axiom Mining Limited | 16 January 2018

Prepared by	**Sean Cassidy / Chris Kuczera**	Approved by	**Rob Morris**
Position	Senior Hydrogeologist / Associate Water Resource Engineer	Position	Associate Director
Signature		Signature	
Date		Date	

Document Control

Version	Date	Prepared by	Reviewed by
1	7.1132017	Sean Cassidy / Chris Kuczera	Rob Morris / James Duggleby
2	16.01.2018	Chris Kuczera	Rob Morris

T +61 (0)2 9493 9500 | F +61 (0)2 9493 9599

Ground Floor | Suite 01 | 20 Chandos Street | St Leonards | New South Wales | 2065 | Australia

www.emmconsulting.com.au

Table of contents

Chapter 1	Introduction	1
1.1	Overview and project description	1
1.2	Disturbance activities	1
1.3	Purpose of this report	2
Chapter 2	Existing Environment	3
2.1	Topography	3
2.2	Climate	4
	2.2.1 Rainfall	4
2.3	Vegetation	4
2.4	Local soil conditions	4
	2.4.1 Soil Erodibility	5
2.5	Geological setting	5
2.6	Existing Watercourses	6
2.7	Logging Disturbance	8
2.8	Geomorphological setting	9
	2.8.1 Stream order	9
	2.8.2 Long profile analysis	10
	2.8.3 Channel planform	11
	2.8.4 Sediment characteristics and transport	12
2.9	Hydrogeology	18
Chapter 3	Impact Assessment and Surface Water Management Strategy	23
3.1	Definitions	23
3.2	Potential Impacts	23
3.3	Mining Area Water Management Strategy	25
	3.3.1 Overview of Mining Methods	25
	3.3.2 Mining Area Water Management Strategy	25
	3.3.3 Sedimentation Basin Design Principles	27
3.4	Access Road Water Management	28
	3.4.1 Overview of Access Roads	28
	3.4.2 Access Road Design Principles	29
3.5	Ore Handling Facility Water Management	29
3.6	Water Supply	30
3.7	Waste Water Management	30
3.8	Water Management Plan Development	30
3.9	Residual Impacts	31

Table of contents *(Cont'd)*

Chapter 4 Monitoring and Mitigation Plan 33
4.1 Surface Water Monitoring and Inspection Plan 33
4.2 Mitigation Plan 34

Chapter 5 Sediment Load Estimates 35
5.1 Review of available data 35
5.1.1 Site Specific Data 35
5.1.2 Relevant data from the SINP EIS 35
5.2 Suspended Sediment Concentration Estimates 36

Chapter 6 Summary 39
6.1 Summary of Potential Impacts 39
6.2 Summary of Management Measures 39
6.3 Residual Impacts 40
6.4 Summary of Additional Investigations 40
6.5 Additional Information 40

References 41

Appendices

A Surface Water Quality

Tables

Table 2.1 San Jorge Island stratigraphic soil horizon/profile 5
Table 2.2 Southern San Jorge geological stratigraphic sequence 6
Table 2.4 Surface Water Quality Results Summary Table 14
Table 2.3 Sinuosity estimates for study reaches 17
Table 2.5 Sediment quality 20
Table 3.1 Potential Impacts and Management Measures 24
Table 3.2 Mining Area Water Management Objectives and Measures 26
Table 3.3 Indicative basin Volumes 28
Table 4.1 Monitoring and Inspection Program 33
Table 4.2 Proposed Analytes 34
Table 4.3 Potential Mitigation Measures 34
Table 5.1 Assumed Suspended Sediment Concentrations 36
Table 5.2 Worse Case Sediment Loads for the Extreme Rainfall Scenario 38

Figures

Figure 1	Geological setting	7
Figure 2	San Jorge (south) surface water catchments	10
Figure 3	San Jorge – South (southern catchments)	16
Figure 4	San Jorge – South (eastern catchments)	16
Figure 5	San Jorge – South (northern catchments)	17
Figure 6	Particle size distributions	19
Figure 7	Surface water and sediment quality monitoring locations	21
Figure 8	Example Water Management Plan for Mining Areas	27

Photographs

1	View from San Jorge Nickel Project, facing northwest, toward Astrolabe Bay	3
2.2	Typical higher reach watercourse (Sumia Creek)	8
2.3	Typical lower reach watercourse	9
2.4	Shows Davu Creek with logging disturbance in the background	11
2.5	Confluence of two watercourses clearly showing the impacts of logging.	12

1 Introduction

1.1 Overview and project description

Axiom KB Limited (Axiom KB), a subsidiary of Axiom Mining Limited (Axiom), proposes to develop a nickel laterite mineral deposit in the San Jorge Mining Tenement as part of the San Jorge Nickel Project, San Jorge Island, Solomon Islands (the project).

The project will comprise extraction of approximately 2 million tonnes per annum (Mtpa) of nickel laterite ore over a period of approximately 5 years. Ore will be mined from the deposits using a 'top-down approach' of contoured strips fanning out from an access road along a ridgeline. The ore will then be transported to run-of-mine (ROM) pads and progressive rehabilitation of mining areas will be undertaken as the ore is depleted. This mining method will allow rapid and progressive rehabilitation which will minimise the disturbance area and associated impacts. The ore will be loaded onto barges in for transfer to ships moored in Thousand Ships Bay, and then transported to regional processing hubs. Approximately 1321.3 hectares (ha) of land will be disturbed throughout the life of the mine.

Axiom KB has secured a Prospecting Licence (PL01/15) over the San Jorge Tenement (36 km^2).

Mining is a "prescribed" development under the *Environment Act (1988) (Environment Act)* and requires the production of an Environment Impact Statement (EIS) compliant with the *Environment Regulations (2008) (Environment Regulations)*.

Axiom KB engaged EMM Consulting Pty Limited (EMM) to prepare an environmental and social impact statement (EIS), which describes the construction, mining and rehabilitation activities proposed by Axiom KB and associated impacts and mitigation measures. This report documents a Surface Water Assessment, which forms part of the EIS.

1.2 Purpose of this report

Local receiving waters will inevitably be impacted by the mining activities. Potential impacts include:

- increased sedimentation in receiving waters;
- impacts to aquatic ecology due to increased turbidity and sedimentation;
- potential for localised impacts to aquatic ecology if concentrations of metals and other pollutants increase above existing levels or known toxicity thresholds;
- changes to the existing hydrologic regimes due to changes to catchment areas; and
- erosion of drainage lines due to direct disturbance of watercourses and changes to hydrologic regimes.

This surface water assessment describes a water management strategy for the project that has been developed to mitigate potential impacts and is structured as follows:

- Section 2 describes the existing surface water environment.
- Section 3 discusses potential impacts and a water management strategy.

- Section 4 describes a monitoring and mitigation plan.
- Section 5 describes sediment load calculations that have been undertaken to inform a marine impact assessment that has been prepared by Royal HaskoningDHV (Royal HaskoningDHV 2017).

2 Existing Environment

2.1 Topography

The Solomon Islands are an archipelago of islands and coral atolls located in the Pacific Ocean. The islands form a double chain, which are separated by the New Georgia Sound, and are aligned northwest to southeast, stretching approximately 1,400 km from Bougainville to the Santa Cruz Islands.

The islands are mountainous with an estimated total land area of 28,446 square kilometres (km^2), comprising six major islands and 992 small islands, atolls and reefs. The major islands are Choiseul, New Georgia, Santa Isabel, Guadalcanal, Malaita, Makira and Santa Cruz. The capital of the Solomon Islands, Honiara, is on Guadalcanal.

San Jorge Island is approximately 110 km northeast of Honiara and is approximately 26 km long by 14 km wide. The project area lies within the southern extent of San Jorge Island. This area of the island is characterised by rolling hills and steeply incised watercourses (Photograph 2.1). Within this area, highland regions reach a maximum elevation of approximately 365 m above mean sea level.

Photograph 2.1 View from San Jorge Nickel Project, facing northwest, toward Astrolabe Bay

2.2 Climate

The Solomon Islands have a climate that is typical of most tropical bioregions, with warm to hot temperatures, high humidity and abundant rainfall in most months.

Weather data used to inform this assessment has been derived from climate information presented in SMM Solomon Limited's (SMM), Solomon Islands Project Environment and Community Baseline Study (SMM 2011). This assessment applies to SMM's Solomon Islands Nickel Project, located approximately 5 km northeast of the project.

2.2.1 Rainfall

Solomon Islands average annual rainfall has historically ranged between 3,000–5,000 millimetres per year (mm/year). Monthly variations in rainfall, prompted by the northwest tropical monsoon and the equatorial trough, respectively coincides with increased monthly rainfall totals between January and March, and drier months between June and September.

There are no known weather stations on the San Jorge Island. The closest station is the Santa Isabel (IWS01) weather station that is located approximately 20km to the north of the project area on the Santa Isabel Island. Reported monthly rainfall totals at this weather station ranged between 106 mm (April 2010) and 643.5 mm (January 2010) (SMM, 2011). The reported five-year historic data record (2008-2012) displays no defined wet and dry seasonal weather pattern, atypical of the Solomon Islands southeast climate.

The Solomon Islands lies at the northern limit for cyclone prevalence, however typically experiences between one and two tropical cyclones per year. Cyclone prevalence and strength is strongly influenced by the northwest tropical monsoon. Given the northern location of San Jorge Island and the distinct lack of wet and dry climate seasonality, it is reasonable to assume cyclone intensity will be low.

2.3 Vegetation

The project area contains three major vegetation communities:

1. Ironwood Forest: forest over ultramafic/ultrabasic rocks;
2. Lowland rainforest; and
3. Mangroves.

Vegetation remains relatively intact with over 50% of the project area covered with old growth forest. Some portions of the project area have been cleared for commercial forestry.

2.4 Local soil conditions

The soil profile for the project area is subdivided into three divisions:

1. laterite (or limonitic zone);
2. saprolite; and
3. basement.

The shallower limonitic zone is further subdivided into three limonite types classified according to colour, texture, and grainsize. The underlying saprolitic zone comprises a transition zone and a deeper decomposed serpentinite unit. The basal basement unit has two distinct subdivisions; a weathered transitioning unit and the distinct fresh rock. Typical stratigraphic soil horizon/profile descriptions and associated mineralogical leaching has been detailed in Table 2.1.

Table 2.1 San Jorge Island stratigraphic soil horizon/profile

Division	Subdivision	Typical Thickness (mbgl)[1]	Description	Mineralogy
Laterite	Topsoil	0-0.1	Detritus – plant litter, roots, organic material	
	Limonite 1	0.1-4	Reddish brown to dark brown silty-clayey heterogenous limonitic laterite	Iron, Chromium, Aluminium enriched. Magnesium, Silica leachability
	Limonite 2	1-5	Brown, silty limonitic laterite	
	Limonite 3	2-8	Yellow to brown heterogenous silty limonitic laterite	Nickel, Copper, Manganese enriched. Magnesium, Silica leachability
Saprolite	Transition zone		Yellow to brown, sandy to clayey soil with highly weathered serpentinite fragments and intense garnierite stains	Nickel enriched
	Weathered serpentinite		Sandy to Clayey soils with serpentinite fragments and weathered ultramafics	
Basement	Weathered		Weathered gabbro, ultramafics. Presence of garnierite veining	
	Fresh rock		Fresh basement rock (gabbro, ultramafics, serpentinite)	

Notes: 1.mbgl=metres below ground level.

2.4.1 Soil Erodibility

A Soil Assessment prepared as part of the EIS (EMM 2017) made the following conclusions regarding soil erodibility:

- *A horizon* soils generally had low soil erodibility and are unlikely to disperse or slake (Emerson class 7).
- *B horizon* soils also had a very low erosion potential and are unlikely to disperse (Emerson class 7). Some *B horizon* soils may slake (Emerson class 4).
- Organic carbon was moderate in the *A horizon* and low in the *B horizon* soil which supports the idea of low soil erodibility.

2.5 Geological setting

The Solomon Islands is an archipelago composed of six major islands forming a northwest-southeast trending double chain of islands. Most of the islands and their corresponding geology are derived from volcanic activities and continental/oceanic crustal uplift due to the presence of active subduction and collision zones between the Indo-Australian and Pacific Tectonic Plates (Petterson *et al*. 1997).

San Jorge is located within the Central Province, a geological region structurally separated from the Pacific Province to the east by the northwest trending Kia-Kapito-Korighole-Fault System (KKKS), and to the west (Volcanic Province) by active volcanism.

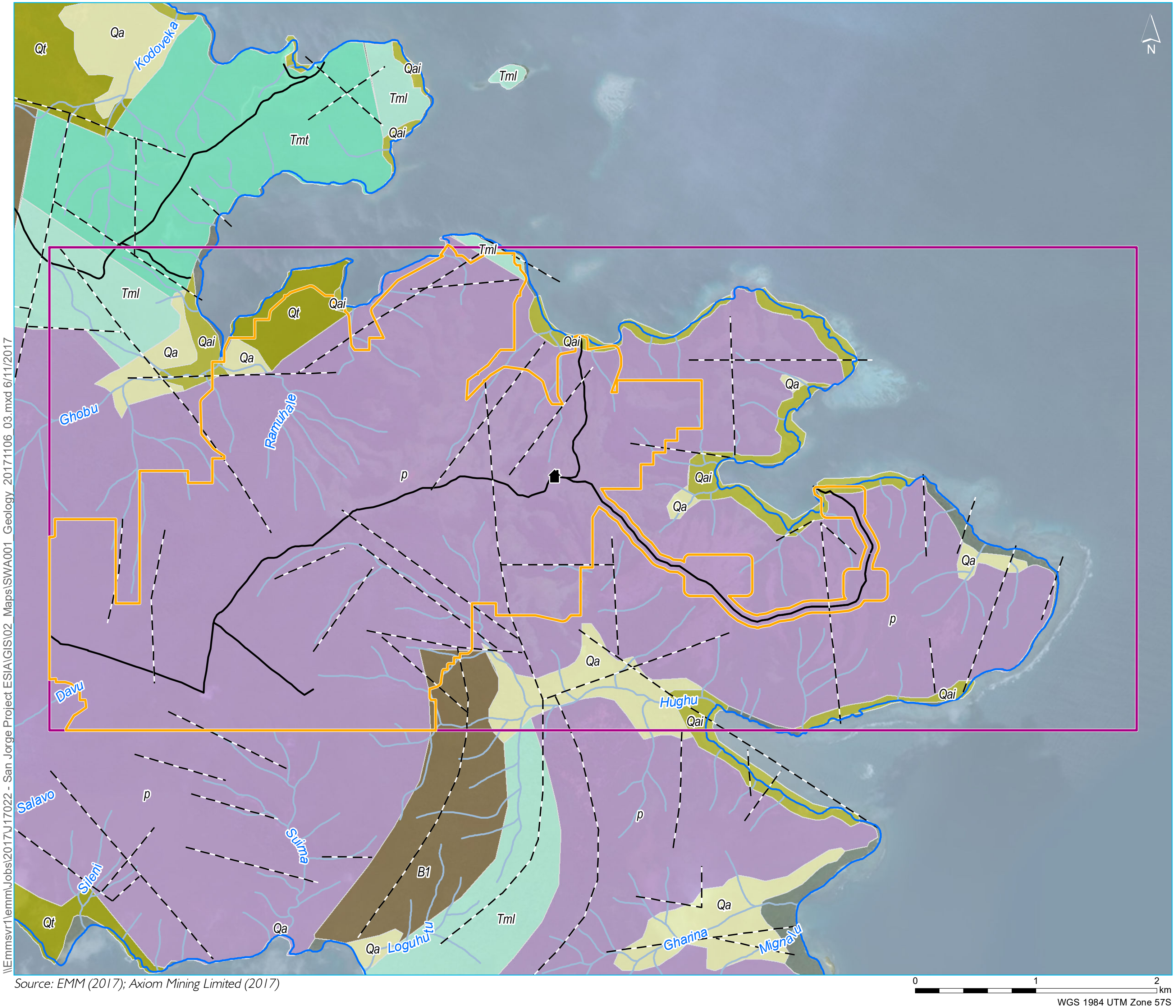
The Central Province consists of pillowed and massive flows of basaltic to andesitic lavas (San Jorge Volcanics), with associated plutonic equivalent micro-medium grained gabbros. These units are present across the southern extent of San Jorge and are thought to be fragments of ocean floor uplift, associated with tectonic subduction processes (Petterson *et al* 1999). Late Cretaceous fault-bound peridotite rocks, associated with the KKKS are also deposited across San Jorge, and termed the Kolomola Ultramafics.

Elsewhere, and typically along riparian and coastal estuarine fringes, calcareous, siliceous sands and gravels have accumulated, supporting the distinct riparian and coastal fringe vegetation on southern San Jorge Island.

The southern San Jorge Island geological stratigraphic sequence is provided in Table 2.2. The island geology is shown on Figure 1.

Table 2.2 Southern San Jorge geological stratigraphic sequence

Unit	Age	Formation description
Alluvium	Pleistocence – Quaternary	Sand, gravel, silt and clay
Mangrove swamp deposits	Pleistocence – Quaternary	Silt, sand and gravel
Coralline beach deposits	Pleistocence – Quaternary	Calcareous, sand and gravel
Loguhutu Formation	Miocence – Tertiary	Siltstones, banded, calcareous, soft, bioturbated beds, minor sandstone and mudstone
Kolomola Ultramafics	Oligiocene - Tertiary	Intrusive serptentinized ultramafic rock
San Jorge Volcanics	Lower Miocence - Cretaceous	Basalts amygdaloidal and vesicular



\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps\SWA001_Geology_20171106_03.mxd 6/11/2017

Source: EMM (2017); Axiom Mining Limited (2017)

KEY

- Prospecting licence boundary
- Potential area of disturbance
- Camp Bungusule
- San Jorge Island coastline
- Access road
- Watercourse / drainage line
- Fault

Geology

- B1 - San Jorge Volcanics
- Qa - Alluvium
- Qai - Mangrove swamp deposits
- Qt - Mt Tohebakala Conglomerate
- Tml - Loguhutu Formation
- Tmt - Albatross Bay Limestone Member
- p - Kolomola Ultramafic - Serpentinized

Geological setting

Axiom Mining Limited
San Jorge Nickel Project
Preliminary surface water assessment
Figure 1

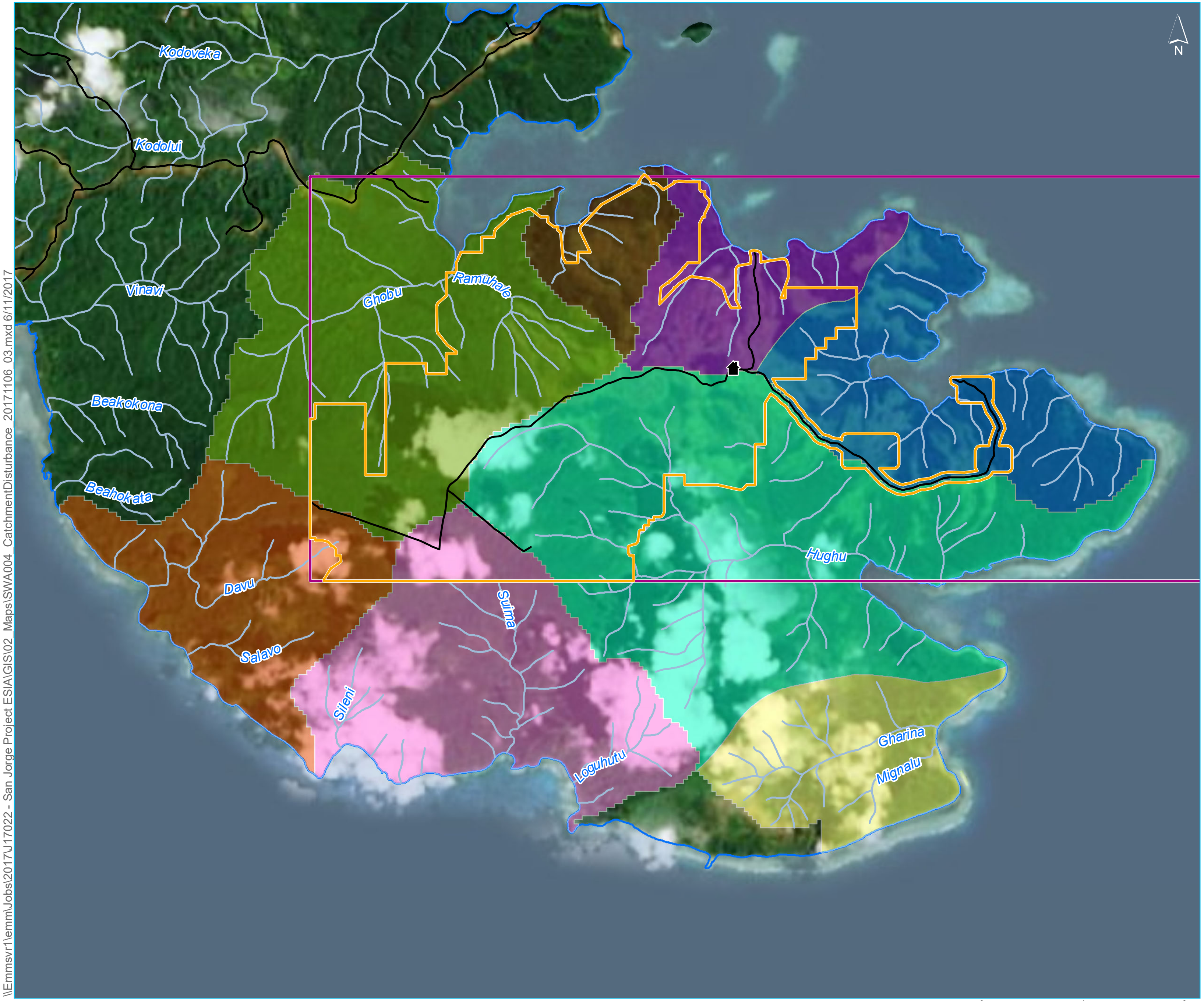
2.6 Watercourses

The project area is located within the southern extent of San Jorge Island. This area of the island is characterised by rolling hills and steeply incised watercourses. The project area drains into eight separate catchments, which have areas ranging from 148 to 1234 ha. Typically watercourses in the upper reaches of the catchments are characterised by steep incised drainage lines in well defined gullies (Photograph 2.2). The upper reaches transition into larger watercourses that typically have flatter channel gradients and densely vegetated floodplains (Photograph 2.3). The lower reaches have tidal influences and are populated with mangroves.

Catchment areas and watercourses alignments are shown in Figure 2.

Photograph 2.2 Typical higher reach watercourse (Suima Creek)

Photograph 2.3 Typical lower reach watercourse (Hughu Creek)



KEY

- Prospecting licence boundary
- Potential area of disturbance
- Camp Bungusule
- San Jorge Island coastline
- Access road
- Watercourse / drainage line

Surface water catchment

- Davu
- Gharina - Mignalu
- Ghobu - Ramuhale
- Hughu
- Kogarutu
- Saranavua - Vuvula
- Suima
- Unnamed

0 1 2 km

WGS 1984 UTM Zone 57S

Existing Catchments and Watercourses

Axiom Mining Limited

San Jorge Nickel Project

Preliminary surface water assessment

Figure 2

EMM

Source: Axiom Mining Limited (2017)

\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps\SWA004_CatchmentDisturbance_20171106_03.mxd 6/11/2017

2.7 Logging Disturbance

Some portions of the project area are currently disturbed by logging. Photograph 2.4 was taken from Davu Creek and shows a logging area in the background. Sediment laden water was observed in watercourses downstream of logging areas or logging roads. Photograph 2.5 shows the confluence of a watercourse with logging disturbance in the catchment and a watercourse with no disturbance in the catchment. The photograph clearly shows the impact of logging on water quality.

Photograph 2.4 Shows Davu Creek with logging disturbance in the background

Photograph 2.5 Confluence of two watercourses clearly showing the impacts of logging.

2.8 Water Quality Characteristics

Freshwater quality samples were collected from watercourses across the study area with the objective of establishing baseline conditions. Water quality samples were collected from 21 monitoring locations over a period of 10 months between October 2016 and August 2017. Sampling was typically undertaken during base flow conditions. Sampling sites were located on the following creeks:

- Davu Creek (two sites);
- Suima Creek (one site);
- Hughu Creek (five sites);
- Saravanua Creek (five sites);
- Kogarutu Creek (four sites);
- Vuvula Creek (one site);
- Unnamed Creek (one site);
- Ramuhale Creek (one site); and
- Ghobu Creek (one site).

Monitoring locations are shown on Figure 2.

Water samples were analysed for a comprehensive suite of physical and chemical parameters, broadly including physicochemical properties, major ions, alkalinity, heavy metals and nutrients. A statistical summary of key results is provided in Table 2.3. All results are tabulated in Appendix A.

Key water quality characteristics are described below:

- pH ranged between 6.8 and 8.1 which is consistent with typical values for an undisturbed watercourse.

- Electrical Conductivity varied between 102 - 713 µS/cm and Total Dissolved Solids varied between 66 – 463 mg/L, reflecting fresh water conditions.

- Dissolved metal concentrations were compared to ANZECC (2000) trigger values for 95% level of species protection. The following metals were elevated relative to the guideline values:

  - Total Chromium results ranged between 0.01 to 0.033 mg/l compared to a guideline value of 0.001 mg/l (note the guideline value refers to Chromium IV, which is one form of Chromium). Hence, comparison of Total Chromium concentrations to the guideline value is conservative.

  - Dissolved Zinc concentrations ranged from 0.0025 to 0.021 mg/l compared to a guideline value of 0.016 mg/l.

- Nitrogen and phosphorus results were consistent with typical values for an undisturbed watercourse.

Table 2.3 Surface Water Quality Results Summary Table

Analyte grouping/Analyte	Units	Guideline Value[1]	Number of Samples	20th Percentile	Average	80th Percentile	Minimum	Maximum
Physicochemical								
pH Value		-	41	7.48	7.63	7.91	6.80	8.10
Electrical Conductivity @ 25°C	µS/cm	-	41	115	174	158	102	713
Total Dissolved Solids (Calc.)	mg/l	-	41	75	113	103	66	463
Suspended Solids (SS)	mg/l	-	41	2.5	3.2	2.5	2.5	24.0
Nutrients								
Ammonia as N	mg/l	-	9	0.04	0.07	0.08	0.02	0.20
Nitrite	mg/l	-	9	0.01	0.01	0.01	0.01	0.01
Nitrate	mg/l	-	9	0.19	0.28	0.38	0.13	0.41
TKN	mg/l	-	9	0.05	0.07	0.05	0.05	0.20
Total Phosphorus	mg/l	-	9	0.01	0.13	0.26	0.01	0.37
Dissolved Metals								
Arsenic	mg/l	0.0013	29	0.0005	0.0005	0.0005	0.0005	0.0005
Beryllium	mg/l	-	29	0.0005	0.0005	0.0005	0.0005	0.0005
Barium	mg/l	-	29	0.0005	0.0034	0.0080	0.0005	0.0110
Cadmium	mg/l	0.0004	29	0.0001	0.0001	0.0001	0.0001	0.0001
Total Chromium	mg/l	0.001	29	0.0156	0.0202	0.0230	0.0100	0.0330
Cobalt	mg/l	-	29	0.0005	0.0005	0.0005	0.0005	0.0005
Copper	mg/l	0.0028	29	0.0005	0.0005	0.0005	0.0005	0.0005
Lead	mg/l	0.0094	29	0.0005	0.0005	0.0005	0.0005	0.0005
Manganese	mg/l	1.9	29	0.0005	0.0017	0.0030	0.0005	0.0090
Nickel	mg/l	0.022	29	0.0110	0.0151	0.0190	0.0060	0.0220
Selenium	mg/l	0.011	29	0.0050	0.0050	0.0050	0.0050	0.0050
Vanadium	mg/l	-	29	0.0050	0.0050	0.0050	0.0050	0.0050
Zinc	mg/l	0.016	29	0.0025	0.0046	0.0055	0.0025	0.0210
Boron	mg/l	0.370	29	0.0250	0.0250	0.0250	0.0250	0.0250

Notes: 1: Guideline Value refers to the ANZECC (2000) trigger value for 95% level of species protection. Hardness adjustments were made to some values using the methods recommended in ANZECC.

2.9 Geomorphological setting

The drainage lines that either intersect or are located directly down-gradient of the proposed mining areas generally have two distinct riverine morphologies. The typical lower elevation riverine reaches, occupied with mangrove (i.e. Ghobu Creek, Hughu Creek, Saranavua Creek, Kogarutu Creek) where channel gradients are flatter, have predominantly finer grained sediments and are connected with, in most cases, well vegetated floodplains and overbank inundation areas. These riverine types have also developed complex tidal interactions, prompting a transitional vegetation class. A second group (i.e. Davu Creek, Suima Creek, Vavula Creek) transition with varying degrees (depending on the river system) to steeper river gradients and more rugged and steep terrain in upper catchment reaches that act as sources for runoff and predominantly coarser grained sediments.

A combination of existing historic baseline data and site data collected as part of this study was collated to characterise existing geomorphological conditions, which are described in the following sections.

2.9.1 Stream order

The Strahler stream classification system is a method of classifying waterways according to the number of tributaries associated with each waterway (Strahler 1957). Numbering begins at the top of a catchment where the headwaters of the system start. As the stream order increases the contributing catchment area and channel size also increase. Small tributaries at the top of the catchment are assigned as a first order watercourse. Where two first order watercourses join, the waterway downstream of the junction is referred to as a second order watercourse. Higher order watercourses are found in the lower parts of the catchment.

All watercourses within the immediate area surrounding the proposed mine resource are classified as first order streams, with the exception of Hughu Creek (Tributary A and Tributary B) which are both regarded as second order streams.

2.9.2 Long profile analysis

Gradients have been assessed to assist in the characterisation of major watercourses.

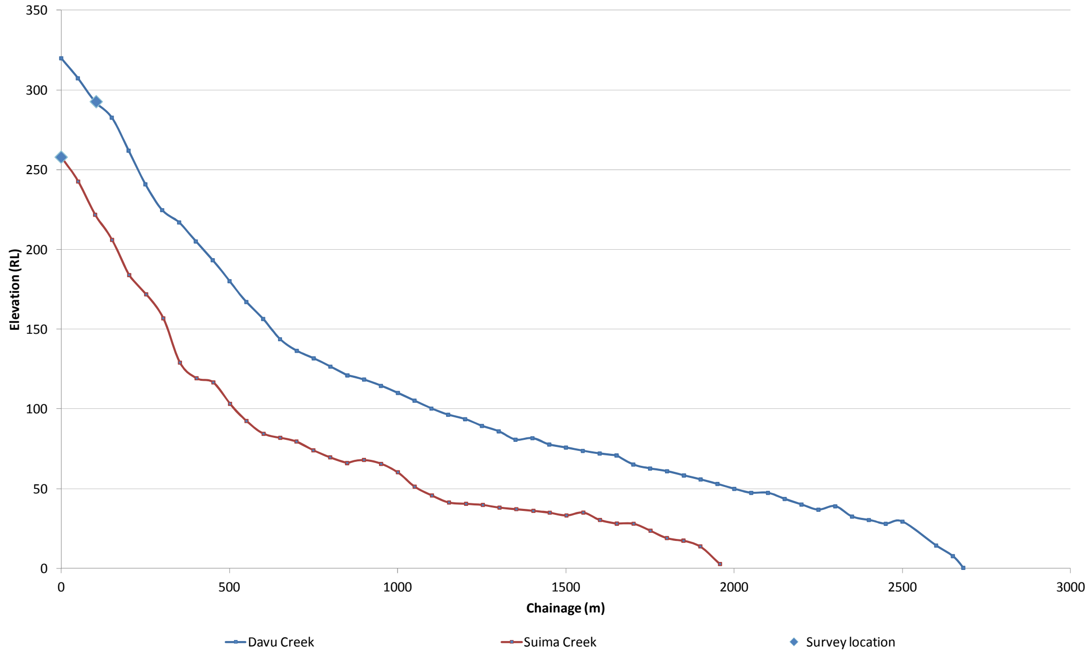


Figure 3 San Jorge – South (southern catchments)

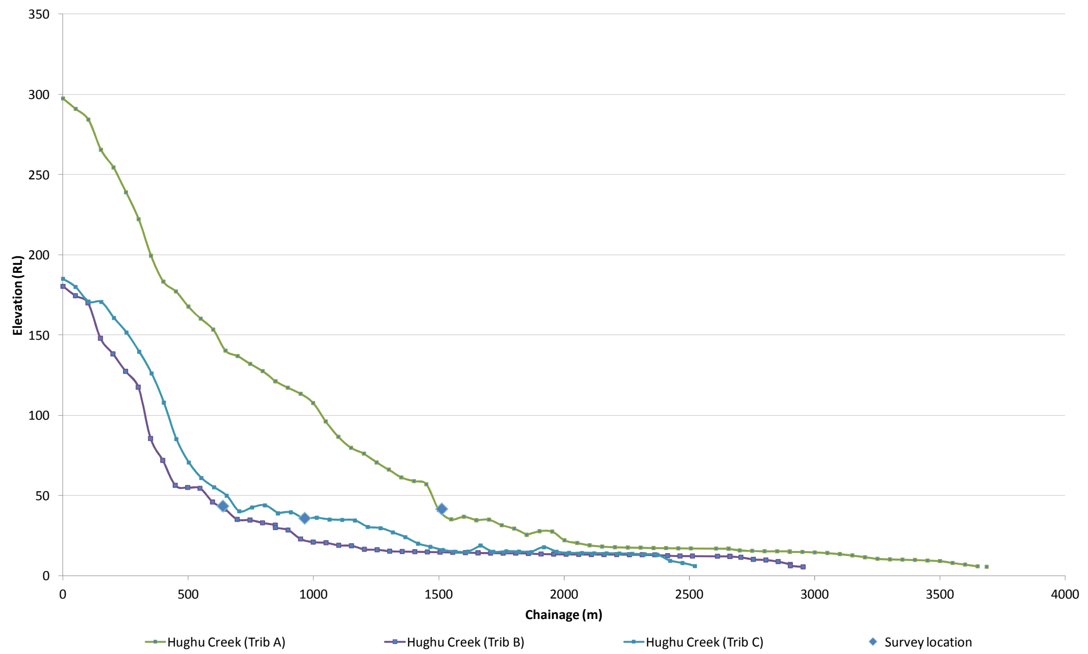


Figure 4 San Jorge – South (eastern catchments)

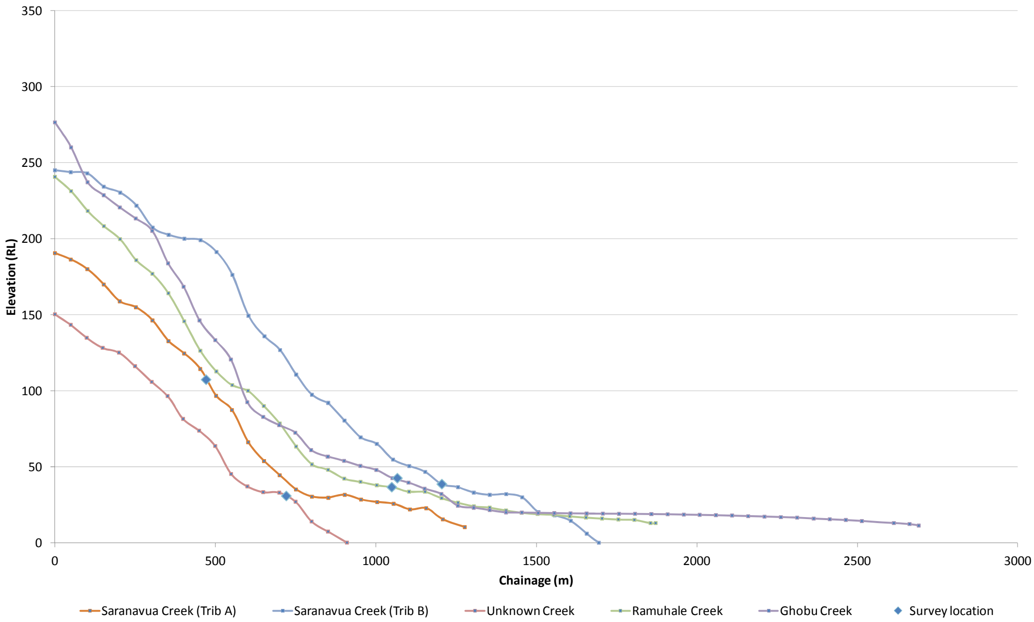


Figure 5 San Jorge – South (northern catchments)

Typically erosion zones are likely to occur on steep/vertical down gradient sections and deposition zones will occur on flat reaches with little to no downfall. Pronounced steep, vertical gradients are apparent within the headwaters of southern (Figure 3) and eastern (Figure 4) catchments of San Jorge (south). The northern catchments (Figure 5), associated with Saranavua, Vuvula, Ramuhale and Ghobu Creek catchments have a more gradual gradient, transitioning into a low-lying floodplain, occupied with mangroves.

2.9.3 Channel planform

Sinuosity has been assessed to assist in the characterisation of major watercourses. Sinuosity provides an additional measure of channel morphology, indicating the erosive/depositional characteristics of the environment. The sinuosity derivations have been provided in Table 2.4.

Table 2.4 Sinuosity estimates for study reaches

Study reach	Mapped channel length (m)[1]	Downvalley length (m)	Sinuosity (SI)	Description
Davu Creek	2681.0	1922.3	1.39	Meandering
Suima Creek	1957.9	1693.3	1.16	Low
Hughu Creek (Trib A)	3686.3	3301.1	1.12	Low
Hughu Creek (Trib B)	2953.6	2608.0	1.13	Low
Hughu Creek (Trib C)	2600.4	2171.4	1.20	Low
Saravanua Creek (Trib A)	1277.0	1199.9	1.06	Low
Saravanua Creek (Trib B)	1694.5	1607.0	1.05	Low
Unnamed Creek	909.7	794.2	1.15	Low
Ramuhale Creek	1871.5	1488.7	1.26	Low
Ghobu Creek	2691.4	2095.7	1.28	Low

Notes: 1.m=metres.

Sinuosity is considered low if the degree of calculated sinuosity is between 1.06 and 1.30 and meandering between 1.31 and 3.0 (Brierly and Fryirs 2005). All sites, with the exception of Davu Creek have a low calculated sinuosity. This is typical of an erosional environment with steeply incised valleys and defined channels.

As the majority of the study reaches are located at the headwaters of the surface water catchments, with low sinuosity, characterisation of meander bed characteristics (ie wavelength, amplitude, bend radius) was not considered applicable to this assessment.

2.9.4 Sediment characteristics and transport

i Physical characteristics

Streambed sediment samples were collected at the seven locations in indicated in Figure 7. Particle size distribution plots for the seven sampling sites are shown on Figure 6. Notable trends in particle size distributions were:

- RAMU1 (Ramuhale Creek) and TB6 (Hughu Creek (Trib A)) had the largest proportion large particle sized gravels, representative of higher energy environments, suggestive of high flow velocities;
- KOKOLO1 (unnamed drainage) and SC1 (Saranavua Creek (Trib A)) had the largest proportion of small particle sized very fine sand. Both samples were obtained in flood out zones within typically low energy depositional environments. KOKOLO1 was also sampled immediately adjacent to the Main Access Road, constructed by a neighbouring landholder;
- samples were absent of coarse gravels and cobbles;
- median particle size for KOKOLO1 and SC1 was in the <0.075 mm Coarse Silt to Clay range;
- median particle size for RAMU1, TB6 and SC2 was between 1.18-6.7 mm (Fine to Medium Gravel); and
- median particle size for GHOBU1 and DAVU2 was between 0.425-1.18 mm (Medium to Coarse Sand).

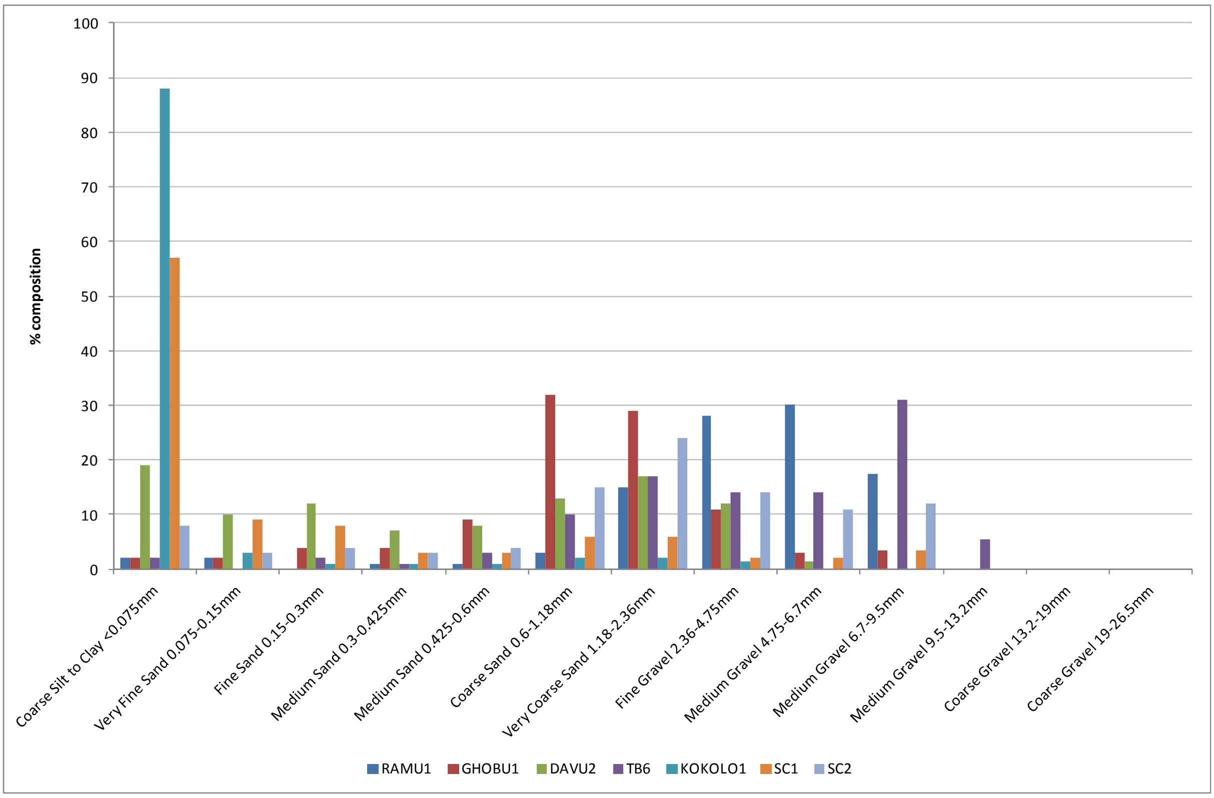


Figure 6 Particle size distributions

ii Chemical characteristics

Sediment samples were collected in August 2017 from creek beds in each of the major surface water catchments expected to be impacted by the project. In total, 9 samples were collected across the project area. Sampling locations are shown on Figure 7.

Samples were analysed for major ions and total metals. Table 2.5 presents all results and compares the results to the Interim Sediment Quality Guidelines (ISQG) that are documented in Table 3.5.1 of ANZECC (2000).

Key sediment quality characteristics are described below:

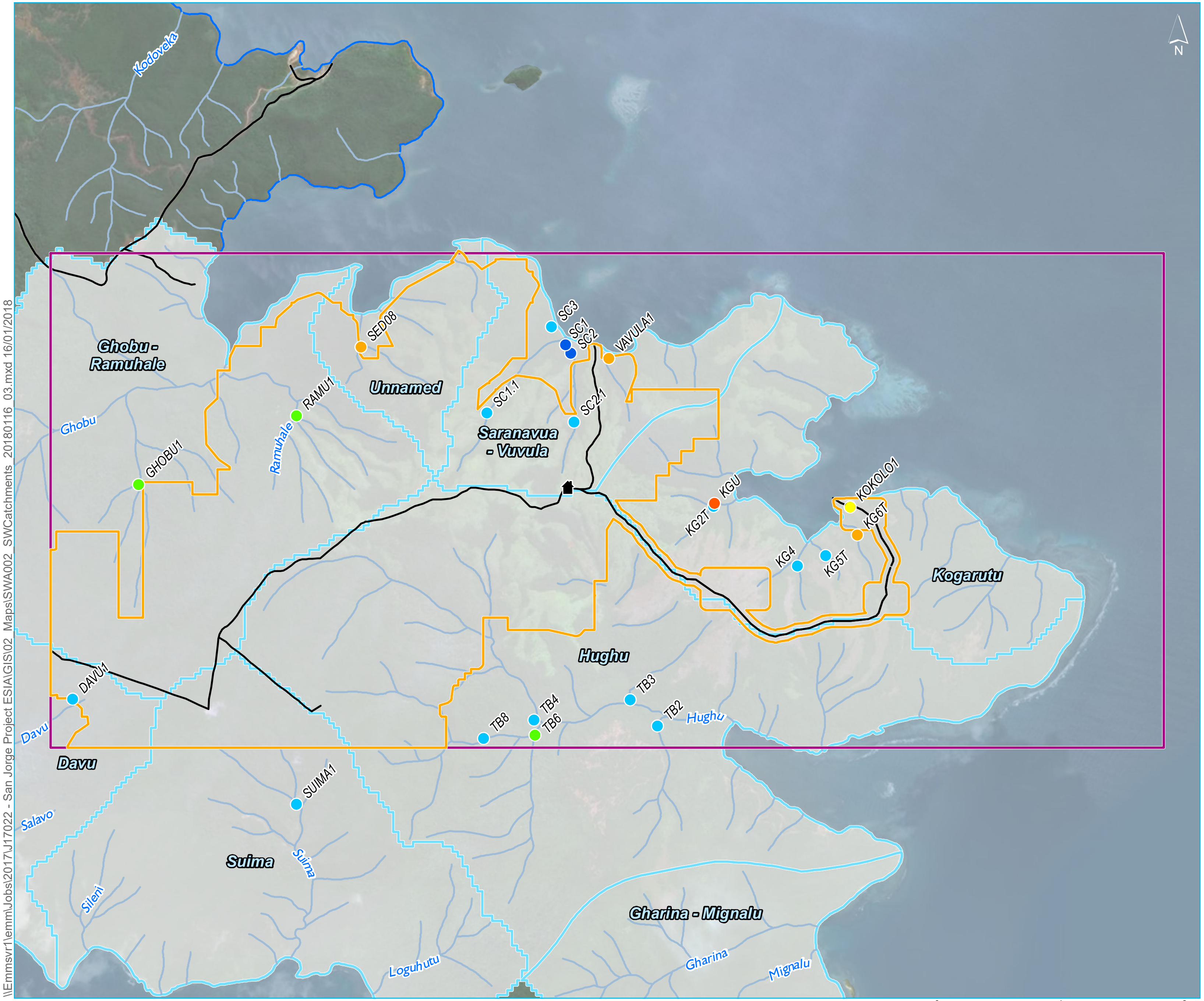
- Chromium and Nickel were significantly elevated relative to the ISQG-High guideline values, indicating that the soils in the contributing catchment areas are naturally elevated in these metals.
- Some samples of Cadmium and Copper exceeded the ISQG–Low guideline values but were below the ISQG-High values.
- Heavy metal results were consistently higher at location ID KOKOLO, located immediately down-gradient of an established access road which is substantially eroded and has little to no sediment and erosion controls.
- Chloride and Sodium concentrations at location ID KOKOLO were substantially elevated relative to other sampling locations.

Table 2.5 Sediment quality

Analyte grouping/Analyte	Unit	LOR	Guideline Value		RAM1	SED08	GHOBU1	DAVU2	VUVULA1	TB6	KOKOLO	KG6t	KGU
Major ions			**ISQG - Low**	**ISQG-High**									
Sulfate as SO_4^{2-}	mg/kg[1]	10	-	-	5	5	5	5	780	5	570	240	50
Chloride	mg/kg	10	-	-	5	5	5	10	1,410	5	830	330	40
Calcium	mg/kg	10	-	-	5	5	5	5	10	5	280	5	5
Magnesium	mg/kg	10	-	-	20	30	30	50	60	30	50	5	5
Sodium	mg/kg	10	-	-	5	5	5	5	1,060	5	400	420	100
Potassium	mg/kg	10	-	-	5	5	5	5	70	5	10	20	5
Total metals													
Aluminium	mg/kg	50	-	-	3,750	10,100	8,530	4,550	27,300	4,560	30,100	21,200	15,100
Arsenic	mg/kg	5	-	-	2.5	2.5	2.5	2.5	2.5	2.5	2.5	15	2.5
Cadmium	mg/kg	1	1.5	10	1	2	0.5	0.5	4	0.5	4	3	2
Chromium	mg/kg	2	80	370	1,400	2,390	1,100	966	3,550	1,300	3,060	4,000	3,800
Cobalt	mg/kg	2	-	-	96	241	53	102	452	79	636	266	103
Copper	mg/kg	5	65	270	17	35	22	18	61	18	82	55	36
Iron	mg/kg	50	-	-	56,000	120,000	39,200	55,100	225,000	51,400	268,000	219,000	130,000
Lead	mg/kg	5	50	220	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Manganese	mg/kg	5	-	-	850	1,950	460	851	2,780	734	4,160	1,000	259
Nickel	mg/kg	2	21	52	3,490	5,950	1,520	2,470	5,340	2,170	3,660	5,240	2,670
Zinc	mg/kg	5	200	410	29	78	19	24	105	28	114	112	83

Notes: 1.mg/kg = milligrams per kilogram.

2. Guideline Value refers to the recommended sediment quality guidelines that are documented in Table 3.5.1 of ANZECC (2000). ISQG refers to Interim Sediment Quality Guideline.



KEY

- Camp Bungusule
- San Jorge Island coastline
- Prospecting licence boundary
- Potential area of disturbance
- Catchment boundary
- Access road
- Local road
- Watercourse / drainage line

Surface water and sediment quality monitoring location

- Sediment
- Sediment, water
- Sediment, particle size distribution
- Sediment, water, particle size distribution
- Water
- Water, particle size distribution

Surface water and sediment quality monitoring locations

Axiom Mining Limited
San Jorge Nickel Project
Preliminary surface water assessment
Figure 7

Source: EMM (2017); Axiom Mining Limited (2017)

\\Emmsvr1\emm\Jobs\2017\J17022 - San Jorge Project ESIA\GIS\02_Maps\SWA002_SWCatchments_20180116_03.mxd 16/01/2018

2.10 Hydrogeology

San Jorge Island was formed at the collision boundary between the Ontong Java Plateau of the Pacific Province and the Old Solomon Arc of the Central Province. Collisions at the plate boundary resulted in tectonic uplift and obduction of seafloor sediments along with volcaniclastic sediments and limestone which form the present day basement complex across southern San Jorge.

Plate boundary environments experience high tectonic stress, resulting in the propagation of faulting and fracturing of the basement complex. The structural geologic alterations typically enhance the secondary permeability of the rock matrix, allowing for greater potential for groundwater movement both horizontally and vertically.

Groundwater has been observed locally across the project area in both auger holes and as groundwater springs. Springs typically occur at the headwaters immediately down-gradient of the San Jorge south ridgeline. Typical spring flows were estimated to vary between <0.01 L/s and 2 L/s. Spring flows and groundwater seepage into the drainage lines are expected to be the primary source of stream flows during base flow conditions.

Groundwater presence is expected in the relatively permeable shallow quaternary alluvium and beach and swamp deposits, and within the tertiary sedimentary formations. Where ultramafics and volcanic sequences are present secondary permeability (with groundwater flowing through fractures) is expected to be predominant. Locally, groundwater is expected to display a muted reflection of the local topography, typically flowing from ridgelines towards local drainage lines or coastal discharge areas.

3 Impact Assessment and Surface Water Management Strategy

This section describes potential impacts and the proposed surface water management strategy and is structured as follows:

- Section 3.1 introduces terminology used in this section.
- Section 3.2 discusses potential impacts and provides a summary of key management measures.
- Sections 3.3 to 3.7 discuss the proposed water management strategies for mining areas, access roads, the stockpile, handling facility, and waste water.
- Section 3.8 discusses additional investigations that will be required to progress the strategy to a water management plan.
- Section 3.9 discusses residual impacts.

3.1 Definitions

Water within the project area has been differentiated into the following categories based on expected water quality:

- **Clean Water** – refers to runoff from areas that will be undisturbed or areas that have been fully rehabilitated. Clean water is unlikely to have poor water quality and does not require management.
- **Sediment Laden Water** – refers to runoff from disturbed areas such as haul roads, mining and recently rehabilitated areas. Sediment laden water is likely to contain elevated suspended sediment concentrations. Elevated concentrations of metals and other pollutants may also occur as a result of disturbance.
- **Wastewater** – refers to wastewater generated from amenities such as toilets and showers. Wastewater contains human waste and associated pathogens.

3.2 Potential Impacts

Table 3.1 provides a summary of potential changes to the surface water environment due to the project and associated impacts and management measures.

Table 3.1 Potential Impacts and Management Measures

Potential Change due to Project	Duration of Change	Potential Receiving Water Impacts	Proposed Management Measures
Increased sediment laden runoff from mining areas, access roads and stockpile areas.	During disturbance and early stages of rehabilitation.	• Increased sedimentation in receiving waters. • Impacts to aquatic ecology due to increased turbidity and sedimentation.	• Progressively rehabilitate mining areas to minimise disturbance area and duration. • Provide sediment and erosion controls to manage runoff from disturbance areas.
Increased concentrations of metals and other pollutants in runoff from disturbed areas.	During disturbance and early stages of rehabilitation.	• Potential for localised impacts to aquatic ecology if concentrations of metals and other pollutants increase above existing levels or known toxicity thresholds.	• A water quality monitoring program will be implemented that will include ongoing monitoring of water within the sedimentation dams and receiving waters. Monitoring results will be interpreted to identify any impacts. • Water treatment solutions can be implemented to address any identified impacts.
Changes to catchment areas and drainage lines due to mining and haul road construction.	During disturbance and early stages of rehabilitation.	• Changes to hydrologic regimes due to changes to catchment areas. • Erosion of drainage lines due to direct disturbance of watercourses and changes to hydrologic regimes.	• Disturbance areas will be rehabilitated to form stable free draining landforms. Where possible the rehabilitated landform will mimic existing catchment boundaries. • Vegetated riparian zones will be maintained around select drainage lines. The extent and widths of specific zones will be established at the mine planning stage. • Transverse drainage (i.e. road culverts or bridges) will be designed and constructed to minimise erosions risks.

3.3 Mining Area Water Management Strategy

This section describes the key water management principles that will be applied to manage surface water within mining areas. It is proposed to further develop this strategy into a detailed Water Management Plan for each mining area as part of the mine plan development process. This is discussed further in Section 3.8.

3.3.1 Overview of Mining Methods

Mining of nickel laterites in sloping terrain is typically undertaken using a 'top-down approach' of contoured strips fanning out from an access road along a ridgeline. Mining will include sequential clearing of vegetation, pre-stripping of overburden and relocation of waste rock and topsoil to a previous mining block for progressive backfilling of the mine-out pits.

The top-down method commences at the highest point on a bench with mining progressing downhill in benches to provide for continued stability of the slope. More than one panel may be mined at a time, but, preparation (clearing of vegetation and topsoil, and overburden removal) of the next bench below will only start once all panels of the previous bench have been prepared.

The main benefits of this method are that disturbance is minimised as clearing and removal of overburden only occurs immediately prior to mining and the mined area is rehabilitated as soon as practicable after mining. This approach maximises progressive rehabilitation so that erosion and sedimentation impacts are reduced during the operations phase and the rehabilitation burden at the conclusion of the project is minimised.

Once the panel is cleared, limonite will be mined through the formation of narrow benches that will allow grade control. The saprolite will then be mined in high grade areas. The ore will be trucked to a lay-down area at the ore loading facility for drying prior to blending and shipping.

3.3.2 Mining Area Water Management Strategy

Table 3.2 describes the water management objectives and associated management measures that are proposed for mining areas. Figure 8 shows an example Water Management Plan that has been prepared to spatially demonstrate the proposed strategy. As noted above, it is proposed to develop detailed Water Management Plans for each mining area as part of the mine plan development process. This is discussed further in Section 3.8.

Table 3.2 Mining Area Water Management Objectives and Measures

Water Management Objective	Management Measures
1. Minimise the mining disturbance areas to reduce the volume of runoff that requires management.	Mined out areas will be progressively rehabilitated throughout the life of the project to minimise the disturbance area that requires management.
2. Establish Riparian Protection Zones around major watercourses to: a. avoid direct disturbance of watercourses. b. reduce the need to reconstruct watercourses; and c. provide conduits for clean water drainage through mining areas.	Riparian Protection Zones will be maintained around select watercourses. By way of example, a number of Riparian Protection Zones are indicated in Figure 8. The extent and widths of specific zones will be established at the mine planning stage.
3. Where possible, divert clean water around mining areas to reduce the volume of runoff from mining areas that requires management.	Where possible, clean water diversion drains will be constructed up-gradient of mining areas. The drains will divert clean water runoff around mining areas into existing watercourses. By way of example, a number of clean water diversion drains are shown in Figure 8.
4. Construct sedimentation basins to treat runoff from mining areas.	Sedimentation basins will be constructed down-gradient of all mining areas. The sedimentation basins will be sized to effectively treat runoff from the contributing catchment in accordance with the methods recommended in best practice erosion and sediment control guidelines. Section 3.3.3 provides further information on proposed sedimentation basin design principles. Water captured within the basins will be preferentially used for dust suppression. There is also potential to dewater the basins to a water treatment plant if further treatment is required.
5. Progressively monitor water quality and implement further water treatment if poor water quality is identified.	A water quality monitoring program will be implemented that will include ongoing monitoring of water within the sedimentation dams and receiving waters. Monitoring results will be interpreted to identify any impacts. A surface water monitoring and mitigation plan is outlined in Section 4.

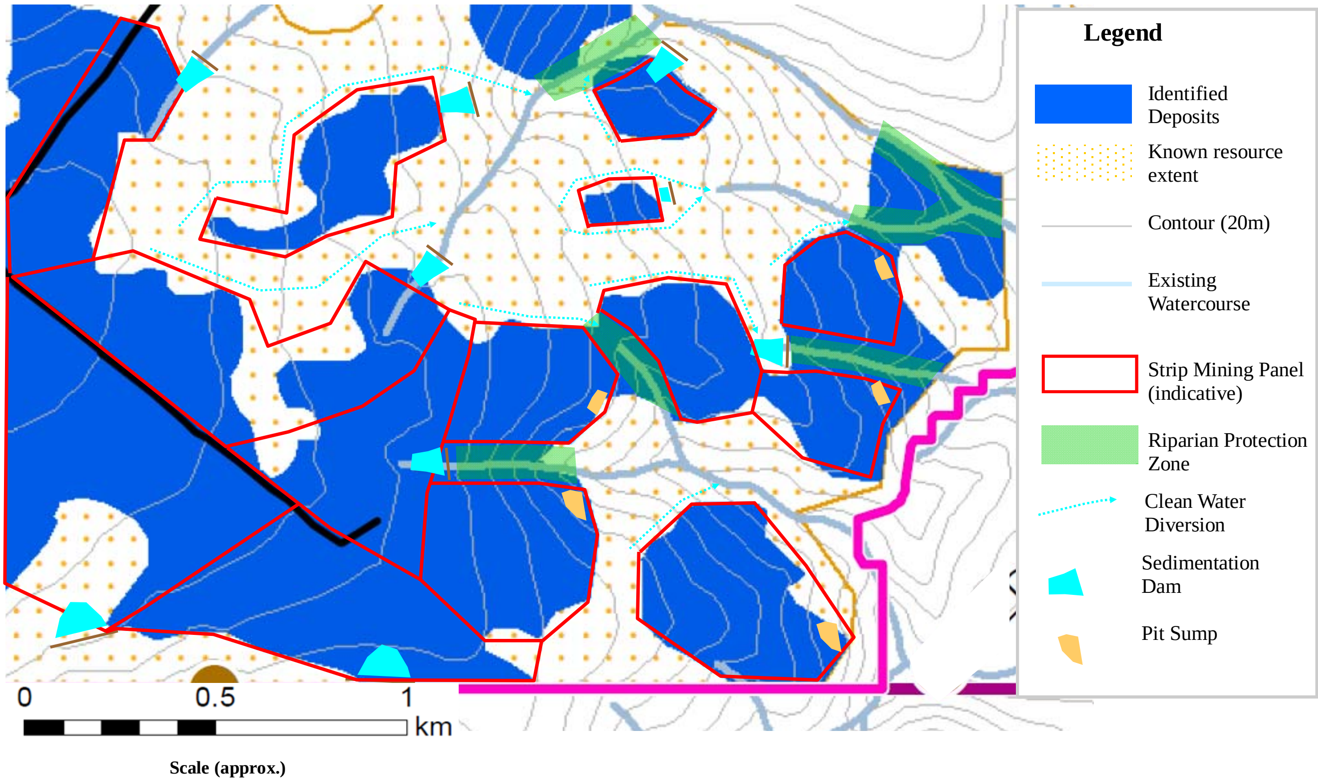


Figure 8 Example Water Management Plan for Mining Areas

3.3.3 Sedimentation Basin Design Principles

Sedimentation basins will be established down gradient of each mining panel. The basins will be in the form of either:

- A traditional dam formed behind an earthen fill embankment where topography is favourable for dam construction; or
- An excavated pit sump in areas where topography is not favourable for dam construction.

Figure 8 shows the potential distribution and location of sedimentation dams and pit sumps. The most appropriate basin design for each mining panel will be established at the mine planning stage.

Section 2.4.1 established that the A and B horizon soils are likely to have low erodibility and are unlikely to have significant dispersive materials. Accordingly, soils within the project area are considered to be Type F (fine soils).

The basins will be designed and constructed to achieve the design principles recommended in the Best Practices Erosion and Sediment Control Guideline (IECA 2008). Key recommendations from this guideline include:

- For catchments that contain fine (Type F) or dispersive (Type D) soils, sedimentation treatment volumes should be sized to capture runoff from an 85th Percentile 5 day storm event. The Erosion and Sediment Control Strategy (Golder Associates 2014c) that was prepared for the Solomon Islands Nickel Project (SINP) calculated a 5 day 85th Percentile rainfall depth of 81.6 mm from the

Santa Isabel IWS01 gauge record. This rainfall depth is considered to be appropriate for use in the project area.

- A sediment storage volume should be provided in the lower portion of basin. This storage volume should be equivalent to 50% of the sedimentation treatment volume.

- Where basins are constructed with fill embankments, the basins should incorporate an adequately sized spillway and freeboard to the embankment crest.

Table 3.3 reproduces the unit area basin volumes that were recommended in the SINP Erosion and Sediment Control Strategy (Golder Associates 2014c). These basin volumes are considered to be appropriate for the project.

Table 3.3 Indicative basin Volumes

Basin Zone	Volume
Sedimentation Treatment Zone	$571\ m^3/ha^1$
Sediment Storage Zone	$286\ m^3/ha^1$
Spillway Freeboard	Required for fill embankments to accommodate spillway flow depths and freeboard to the embankment crest.
Total Basin Volume	$857\ m^3/ha^1$ + freeboard volume

Notes: 1.Sourced from Table 5 of the SINP Erosion and Sediment Control Strategy (Golder 2014c)

3.4 Access Road Water Management

This section describes the key design and erosion and sediment control principles that will be applied to manage surface water runoff from access roads.

3.4.1 Overview of Access Roads

Where access to mining blocks is not available on an existing road, additional roads will be constructed. New roads or extensions of existing roads will only be constructed as far as the next bench to be mined to reduce the level of disturbance open at any one time. Roads will be surveyed, mapped and staked to mark the limits of disturbance. The following main road types will be required:

a. Primary haul roads

There are existing haul roads (old logging roads and exploration roads) within the project area that are being used for Axiom's exploration and drilling program. These will be upgraded prior to mining. The primary haul roads will be designed to an appropriate width (including 2 m wide berms or drains either side) to enable two way passage of haul trucks. The roads will be sheeted to an appropriate depth.

b. Mine access roads

The mine access roads will enable access for vehicles and equipment from the primary haul roads to the mining areas. The internal road within the mining area will run from the highest to lowest benches and the external road will run from the primary haul road to the top of the first bench. The roads will be constructed progressively as the benches progress down-slope.

The mine access roads will be up to 8 m wide, including 1 m wide berms or drains either side, and will be sheeted to an appropriate depth. These roads are intended for short-term use and will be rehabilitated once the final bench in a mining block is rehabilitated.

c. Bench access roads

The bench access road will enable access to individual benches from the mine access road and will be up to 6 m wide, including drains, with a slight gradient for drainage. The roads will be at the base of each bench and will be sheeted to an appropriate depth. These roads are also intended for short-term use only and will be rehabilitated as part of progressive pit rehabilitation.

3.4.2 Access Road Design Principles

All access roads will be designed to respond to the local topography, service life and other identified constraints. The following design principles will be applied to minimise erosion risks and other impacts:

- Where possible, roads will be constructed along ridge lines to minimise cut and fill batter footprints and the need for watercourse crossings.
- Cut and fill batters will be stabilised by vegetation and / or rock armouring. Where required, clean water diversions will also be established along the top of the cut batter (up-gradient of the road) to divert runoff from up-gradient areas into designated transverse drainage systems.
- Transverse drainage (or cross drainage) systems will be appropriately designed to convey clean water under the haul roads. Scour protection will be applied at inlet and outlets as required.
- Longitudinal road drainage will be suitably configured and sized for the contributing catchment area, local topography and road design (i.e. single or double cross fall roads). The length of longitudinal drainage will be minimised to prevent excessive flows. Scour protection such as rock armouring will be incorporated into the design as required.
- Small sedimentation basins (commonly referred to as pocket ponds) will be established at longitudinal drainage outlets to provide sedimentation treatment.
- Roads will be sheeted with appropriate material.

Design of Primary Haul Roads will be undertaken at the mine planning stage of the project. This is discussed further in Section 3.8.

3.5 Ore Handling Facility Water Management

The ore handling facility will be located adjacent to the port, and will be used for personnel and material movements, as well as ore handling. The ore will be delivered to separate windrows for limonite and saprolite by the long haul fleet, for drying. These windrows will measure approximately 4 to 5 m high and 30 m long, and will be covered with large tarpaulins during rain. The windrows will be managed and turned continuously to reduce moisture to the correct level. Once the ore has dried sufficiently (<30% moisture by weight) it will be loaded onto barges by tip truck or loader for transfer to ocean going vessels moored in Thousand Ships Bay.

Runoff from the ore handling area has potential to contain elevated concentrations of suspended sediments, metals and other pollutants.

The following water management principles will be applied to the design and operation of the ore handling facility:

- The ore handling facility will be graded to drain inland so that all surface water drains away from the marine environment. Water will be directed into sedimentation basins for treatment. Water captured in the basins will be used for haul road dust suppression. There is also potential to dewater the basins to a water treatment plant if further treatment is required.

- Stockpiles will be covered during periods of rainfall. This will prevent rainfall seeping through stockpiles and mobilising fine particles.

- All fuel storage areas will be bunded and refuelling areas will be covered and bunded to minimise the risk of hydrocarbons entering the drainage system.

3.6 Water Supply

Potable water supply will be required for all mining camps and site amenities. It is expected that water will be sourced from clean water springs or local watercourses and will be treated as required to meet potable water quality specifications.

Operational water will be required for dust suppression and vehicle wash down. Given the high rainfall, it is expected that all operational water can be harvested from sedimentation basins and no extraction of water from local watercourses or groundwater systems will be required.

3.7 Waste Water Management

Appropriately designed onsite waste water management systems will be established to manage wastewater (i.e. sewage) from all mining camps and site amenities.

3.8 Water Management Plan Development

Water Management Plans will be developed in conjunction with mining plans. The Water Management Plans will apply the water management principles discussed in this section and will provide detailed information on:

- Catchment areas and drainage lines.

- Proposed mining and disturbance areas.

- The extent and nature of Riparian Protection Zones.

- The alignment and geometries of all drainage.

- The location and size of all sedimentation dams.

- Drainage lines that require scour protection.

The Water Management Plans will be informed by the following engineering designs:

- Engineering designs of Primary Haul Roads will be prepared. The designs will consider all transverse and longitudinal drainage.

- Engineering designs will be prepared for all sedimentation dams that have earthen fill embankments. The designs will include appropriately designed spillways and consider geotechnical risks.

3.9 Residual Impacts

The proposed water management measures will reduce the potential magnitude of the surface water impacts described in Section 3.2. However, given the scale of disturbance, residual impacts are expected to occur during operation and construction. Impacts are most likely to occur during significant rainfall events when the design capacity of the erosion and sediment controls is exceeded.

Potential impacts to the receiving marine environment are assessed separately in the Marine Assessment (RHDHV 2017).

4 Monitoring and Mitigation Plan

4.1 Surface Water Monitoring and Inspection Plan

Axiom KB will implement a Surface Water Monitoring and Inspection Plan over the life of the project. The plan will include:

- Establishment of an on-site weather station to record rainfall and other climatic conditions.
- Quarterly monitoring of water quality in select sedimentation dams and receiving water locations.
- Quarterly inspection of water management controls.

A preliminary monitoring plan is described in the following tables:

- Table 4.1 outlines a monitoring and inspection program.
- Table 4.2 provide proposed monitoring parameters.

Table 4.1 Monitoring and Inspection Program

Aspect	Objective	Monitoring Locations	Monitoring Description
Rainfall Monitoring	To accurately record site rainfall.	Central to the project area	Install a weather station that is capable of recording rainfall at < 10 minute increments.
Water Quality Monitoring	To collect data to enable the effectiveness of the water management system to be assessed and identify impacts.	• Up to four sedimentation dams in active mining areas. • All sedimentation dams that receive runoff from the handling and stockpile facility. • 6 receiving water locations downstream of active or recently rehabilitated mining areas. • 3 undisturbed reference locations.	Quarterly monitoring will be undertaken during wet weather conditions using hand held water quality meters and grab samples that will be sent to a certified laboratory for analysis. Table 4.2 provides proposed monitoring parameters. Laboratory analyses will be assessed to determine temporal changes in water quality and identify potential impacts.
Inspection of water management controls	To identify underperforming or high risk components of the water management system.	All drainage lines and water management dams will be inspected by a suitably qualified expert.	An inspection report will be prepared that notes the condition of all infrastructure and makes improvement recommendations

Table 4.2 Proposed Analytes

Category	Proposed Sampling Analytes
General Analytes	pH, Electrical Conductivity (EC), Turbidity, Suspended Solids, Total Dissolved Solids, Temperature, Oil and Grease and Total Hardness.
Nutrients	Total Nitrogen, Ammonia, Nitrate, Nitrite and Total Kjeldahl Nitrogen Total Phosphorus and Reactive Phosphorous
Metals (dissolved)	Al, As, Ag, B, Ba, Cr, Co, Cd, Cu, Fe, Hg, Ni, Pb, Se and Zn

4.2 Mitigation Plan

Table 4.3 lists a number of mitigation measures that could be implemented to improve the performance of the water management system if required. The trigger /timing and expected outcomes are also noted.

Table 4.3 Potential Mitigation Measures

Mitigation Measures	Trigger / Timing	Outcomes
Add chemical flocculants and/or coagulants to sedimentation dams to improve suspended sediment removal.	If monitoring and inspections identify that the sedimentation dams are underperforming.	Improved sedimentation rates in basins will improve the effectiveness of the sedimentation basins and reduce the potential for sediment laden water to enter receiving waters.
Dewater select sedimentation basins to a water treatment plant for further treatment prior to discharge.	If monitoring indicates that overflows from a particular or numerous sedimentation basins contain elevated metals or other pollutants that are adversely impacting the receiving water environment.	The additional treatment will reduce concentrations of pollutants of concern and associated receiving water risks.
Improvements to any indentified underperforming or high risk component of the water management system.	If the quarterly inspection identifies underperforming or high risk components of the water management system.	Improved functionality of the water management system.

5 Sediment Load Estimates

Estimates of sediment loads in runoff from catchments that will be disturbed by the project were undertaken to inform a Marine Assessment that has been prepared by Royal HaskoningDHV (RHDHV 2017). The Marine Assessment applies linked hydrodynamic and sediment transport models to assess marine water quality impacts associated with a potential increases in sediment loads from disturbance areas. The impact assessment assessed the following two rainfall scenarios:

- **Typical Rainfall Conditions** – comprising a 85th Percentile 5 day rainfall event. It is expected that the erosion and sedimentation controls will provide effective treatment of runoff from disturbed areas during these conditions.

- **Extreme Rainfall Conditions** - comprising a 99th Percentile 5 day rainfall event. It is expected that the erosion and sedimentation controls will provide some treatment of runoff from disturbed areas. However, suspended sediment concentrations from disturbed areas are likely to be higher than concentrations from undisturbed areas.

5.1 Review of available data

5.1.1 Site Specific Data

As discussed in Section 2.9.4, water quality monitoring has been undertaken from 21 locations within proximity to the project area. All results are tabulated in **Appendix A**. A total of 41 suspended sediment samples were collected. Recorded suspended sediment concentrations ranged from 2.5 – 24 mg/l. The average concentration was 3.2 mg/l. These samples were collected during baseflow conditions and therefore have limited relevance to higher flow conditions.

5.1.2 Relevant data from the SINP EIS

Golder Associates (2014b) prepared a Water and Sediment Transport Assessment for the SINP. This assessment was informed by data from a comprehensive monitoring program that included stream gauging and water quality sampling from major rivers in 11 separate catchment areas which ranged in area from 512 to 7,665 ha. The catchments were generally undisturbed and have similar topography to the catchments located within the San Jorge Project disturbance area.

The monitoring data was used to calibrate catchment scale sediment and water balance models that were applied to assess sediment load characteristics under a range of stream flow conditions. In the absence of any relevant site specific data, the information documented in this report is considered to provide the most reliable estimates of suspended sediment concentrations during elevated stream flow conditions.

Key relevant information from the Golder Associates (2014b) report includes:

- Water quality monitoring recorded suspended sediment concentrations ranging from <10 to 1,000 mg/l. This data suggests that undisturbed catchments have low (<20 mg/l) suspended sediment concentrations during base flow conditions, with higher concentrations occurring during runoff events.

- Reported results from the calibrated water and sediment transport model include:

- Average simulated daily suspended sediment concentrations from the eleven catchments assessed ranged from 115 to 202 mg/l. 120 mg/l was selected as a typical value.

- 95th Percentile simulated suspended sediment concentrations from the eleven catchments ranged from 716 to 1,702 mg/l. 850 mg/l was selected as a typical value.

The report doesn't include any information or assessment of sediment loads during mining, citing the model does not allow for the representation of sediment and erosion controls.

5.2 Suspended Sediment Concentration Estimates

Table 5.1 provides estimates of suspended sediment concentrations in runoff from undisturbed, disturbed areas (with erosion and sediment controls), recently rehabilitated, and established rehabilitation areas. Separate values are provided for the typical and extreme runoff scenarios. The following assumptions were applied when calculating these values:

- The information sourced from the Water and Sediment Transport Assessment (Golder Associates 2014b) that is described in Section 5.1.2 was adopted for the undisturbed land-use values.

- For the typical runoff event scenario, it was assumed that the erosion and sediment controls would provide effective treatment. Accordingly, it was assumed that treated runoff from disturbed and rehabilitated areas would have similar suspended sediment concentrations to runoff from undisturbed areas.

- For the extreme runoff event scenario, suspended sediment concentrations from disturbed and recently rehabilitated areas were assumed to be materially higher than concentrations from undisturbed areas. The adopted values for disturbed and recently rehabilitated areas are estimates only and are not informed by data.

Table 5.1 Assumed Suspended Sediment Concentrations

	Average Suspended Sediment Concentration (mg/l)	
	Typical Runoff Event	**Extreme Runoff Event**
Undisturbed Areas	120 mg/l[1]	850 mg/l[1]
Disturbed Areas (with erosion and sediment controls)	120 mg/l	5,000 mg/l
Recently Rehabilitated Areas (< 2 years since rehabilitation commenced)	120 mg/l	2,500 mg/l
Established Rehabilitation (>2 years since rehabilitation commenced)	120 mg/l	850 mg/l

Notes: 1. Suspended Sediment concentrations for undisturbed land uses were sourced from information presented in Tale 21 of the Water Balance and Sediment Transport Report (Golder Associates, 2014b). Refer to Section 5.1.2 for further information.

Suspended sediment concentrations were calculated for the extreme rainfall scenario as a function of the values provided in Table 5.1 and the estimated worst case land-use ratios in each of the eight catchments that are partially located in the potential disturbance area. The worst-case land-use ratio assumes peak mining disturbance in the given catchment. Accordingly, worse case conditions will not occur in all catchments simultaneously. Catchment areas are indicated in Figure 2 (provided in Section 2).

Table 5.2 provides the following information for each of the eight catchments:

- total catchment area;
- potential disturbance area within the catchment;
- assumed actual disturbance area within the catchment;
- assumed worst case mining area within the catchment;
- assumed recently rehabilitated area within the catchment;
- assumed established rehabilitated area or undisturbed area with the catchment; and
- calculated suspended sediment concentration.

Refer to the table notes for key assumptions.

The calculated suspended sediment concentrations for each of the eight catchments were provided to Royal HaskoningDHV to inform their hydrodynamic and sediment transport models that were applied to assess marine impacts (RHDHV 2017).

Table 5.2 Worse Case Sediment Loads for the Extreme Rainfall Scenario

Catchment Name	Catchment Area	Potential Disturbance Area	Assumed Actual Disturbance Area[2]	Worst Case Disturbance[1]: Per Catchment Basis			
				Mining Disturbance Area[3]	Recently Rehabilitated Area[4]	Undisturbed or Established Rehabilitated Area	Calculated Suspended Sediment Concentration
	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(mg/l)
Unnamed	148	128	90	90	0	58	3364
Davu	460	41	29	29	0	431	1111
Suima	658	76	53	53	0	604	1187
Hughu	1234	415	290	162	129	944	1565
Kogarutu	480	92	64	64	0	416	1404
Ghobu - Ramuhale	917	419	294	133	161	623	1740
Gharina - Mignalu	322	0	0	0	0	322	850
Saranavua - Vuvula	262	177	124	124	0	138	2813

Notes:

1. Worst Case Disturbance assumes peak mining disturbance in the given catchment. Accordingly, worse case conditions will not occur in all catchments simultaneously.

2. Actual disturbance is assumed to be 70% of the potential disturbance. This accounts for Vegetated Riparian Zones that will be maintained and areas of the potential disturbance area that will not be mined due to lack of resource or topographic or environmental constraints.

3. The maximum mining disturbance area at any point in time is assumed to be 90 ha.

4. Recently rehabilitated areas were calculated as the actual disturbance area less the mining disturbance area.

6 Summary

Axiom KB proposes to develop a nickel laterite mineral deposit in the San Jorge Mining Tenement as part of the San Jorge Nickel Project. The project will comprise extraction of approximately 2 Mtpa of nickel laterite ore over a period of approximately 5 years. Ore will be mined from the deposits using a 'top-down approach' of contoured strips fanning out from an access road along a ridgeline. The ore will then be transported to ROM pads and progressive rehabilitation of mining areas will be undertaken as the ore is depleted. This mining method will allow rapid and progressive rehabilitation which will minimise the disturbance area and associated impacts. The ore will be loaded onto barges for transfer to ships moored in Thousand Ships Bay, and then transported to regional processing hubs.

This report documents a Surface Water Assessment, which forms part of the Environmental Impact Statement for the project.

6.1 Summary of Potential Impacts

The project will disturb up to 1348.4 ha of land over the life of the project. Local receiving waters will inevitably be impacted by the mining and construction activities. Potential impacts include:

- Increased sedimentation in receiving waters.
- Impacts to aquatic ecology due to increased turbidity and sedimentation.
- Potential for localised impacts to aquatic ecology if concentrations of metals and other pollutants increase above existing levels or known toxicity thresholds.
- Changes to the existing hydrologic regimes due to changes to catchment areas.
- Erosion of drainage lines due to direct disturbance of watercourses and changes to hydrologic regimes.

6.2 Summary of Management Measures

This surface water assessment describes a water management strategy for the project that has been developed to mitigate potential impacts. Key management measures are summarised as follows:

- Section 3.3 describes the proposed water management strategy for mining areas. The strategy includes commitments to establish Riparian Protection Zones around key watercourses and to construct and operate best practices erosion and sediment controls, which include sedimentation basins sized to capture runoff from an 85th Percentile 5 day rainfall event.
- Section 3.4 describes key design principles that will be applied to the design and construction of access roads to manage sediment and erosion risks.
- Section 3.5 describes a proposed water management strategy for the ore handling and stockpile facility. The proposed strategy includes covering of ore during rainfall to prevent mobilisation of fine particles and drainage to direct surface water runoff into sedimentation basins for treatment.
- Section 4 describes a Monitoring and Mitigation Plan. Implementation of this plan will enable the project's surface water impacts to be progressively assessed and underperforming or high risk components of the water management system to be identified and improved. The mitigation plan

identifies a number of measures (including water treatment) that could be implemented to improve the performance of the water management system if required.

6.3 Residual Impacts

The proposed water management measures will reduce the potential magnitude of any surface water impacts. However, given the scale of disturbance, residual impacts are expected to occur during operation and construction. Impacts are most likely to occur during significant rainfall events when the design capacity of the erosion and sediment controls is exceeded.

Potential impacts to the receiving marine environment are assessed separately in the Marine Assessment (RHDHV 2017).

6.4 Summary of Additional Investigations

Water Management Plans will be developed in conjunction with mining plans. The Water Management Plans will apply the water management principles described in this report and will provide detailed information on:

- catchment areas and drainage lines;
- proposed mining and disturbance areas;
- the extent and nature of Riparian Protection Zones;
- the alignment and geometries of all drainage;
- the location and size of all sedimentation dams; and
- drainage lines that require scour protection.

The Water Management Plans will be informed by the following engineering designs:

- Engineering designs of Primary Haul Roads will be prepared. The designs will consider all transverse and longitudinal drainage.
- Engineering designs will be prepared for all sedimentation dams that have earthen fill embankments. The designs will include appropriately designed spillways and consider geotechnical risks.

6.5 Additional Information

Section 5 describes sediment load calculations that have been undertaken to inform a Marine Assessment that has been prepared by Royal HaskoningDHV (RHDHV 2017).

References

ANZECC - Australian and New Zealand Environment and Conservation Council (2000): Australian and New Zealand Guidelines for Fresh and Marine Water Quality

Brierley, G.J. and Fryirs, K.A. 2005. Geomorphology and River Management: Applications of the River Styles Framework. Blackwell Publications, Oxford, UK.

EMM Consulting Pty Ltd (2017): San Jorge Nickel Project: Soils Assessment

Golder Associates (2014a) Solomon Islands Nickel Project: Climate Baseline Report. Report prepared for SMM Solomon Ltd.

Golder Associates (2014b) Solomon Islands Nickel Project: Water Balance and Sediment Transport Model. Report prepared for SMM Solomon Ltd.

Golder Associates (2014c) Solomon Islands Nickel Project: Erosion and Sediment Control Strategy. Report prepared for SMM Solomon Ltd.

IECA (International Erosion Control Association) (2008): Best Practice Erosion & Sediment Control.

Petterson M. G., Babbs T., Neal C. R., Mahoney J. J., Saunders A. D., Duncan R. A., Tolia D., Magu R., Qopoto C., Mahoa H., Natogga D.. Geological–tectonic framework of Solomon Islands, SW Pacific: crustal accretion and growth within an intra-oceanic setting, Tectonophysics, 1999, vol. 301 (pg. 35-60)

Petterson, M. G. et al. (1997). Structure and deformation of north and central Malaita, Solomon Islands: Tectonic implications for the Ontong Java Plateau-Solomon arc collision, and for the fate of oceanic plateaus. Tectonophys. 283:1-33.

RoyalHaskoningDHV (2017): Marine Assessment, San Jorge Island: EIS Appendix D

SMM Solomon Limited (2011): Solomon Islands Project Environment and Community Baseline Study.

Appendix A

Surface Water Quality

Analyte grouping/Analyte	Unit	LOR	Guideline	SC1			SC2			SC3				SC1.1				SC2.1				KG2T		
				02/12/2016	06/12/2016	21/08/2017	02/12/2016	06/12/2016	21/08/2017	14/10/2016	03/12/2016	06/12/2016	21/08/2017	14/10/2016	03/12/2016	06/12/2016	19/08/2017	14/10/2016	03/12/2016	06/12/2016	19/08/2017	03/12/2016	06/12/2016	21/08/2017
Physicochemical																								
pH Value	pH Unit	0.01		7.95	7.58	7.94	7.54	7.39	7.9	7.65	7.53	7.41	7.91	7.55	7.49	7.27	8	7.53	7.32	7.48	7.89	7.54	7.55	7.99
Electrical Conductivity @ 25°C	µS/cm	1		144	132	144	152	125	686	223	108	120	120	118	105	108	109	118	124	171	102	122	135	240
Total Dissolved Solids (Calc.)	mg/L	1		94	86	94	99	81	446	145	70	78	78	77	68	70	71	77	81	111	66	79	88	156
Suspended Solids (SS)	mg/L	5		2.5	2.5	2.5	2.5	2.5	5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	6
Alkalinity																								
Total Hardness as CaCO3	mg/L	1		62	62	56	62	62	96	68	49	58	54	58	49	54	49	66	58	74	49	58	66	75
Hydroxide Alkalinity as CaCO3	mg/L	1		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Carbonate Alkalinity as CaCO3	mg/L	1		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Bicarbonate Alkalinity as CaCO3	mg/L	1		66	63	69	69	68	66	62	58	61	62	63	56	56	63	73	68	72	57	60	74	75
Total Alkalinity as CaCO3	mg/L	1		66	63	69	69	68	66	62	58	61	62	63	56	56	63	73	68	72	57	60	74	75
Major ions																								
Sulfate	mg/L	1		2	3	2	1	0.5	24	4	0.5	0.5	1	0.5	0.5	0.5	1	0.5	0.5	5	0.5	0.5	0.5	4
Chloride	mg/L	1		10	7	10	9	3	173	26	3	4	6	2	8	2	2	2	3	14	3	4	3	30
Calcium	mg/L	1		0.05	0.05	1	0.5	0.5	4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2
Magnesium	mg/L	1		15	15	13	15	15	21	16	12	14	13	14	12	13	12	16	14	18	12	14	16	17
Sodium	mg/L	1		5	6	8	10	2	104	17	5	3	2	1	4	2	1	2	4	12	1	4	3	20
Potassium	mg/L	1		0.5	0.5	0.5	0.5	0.5	5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Fluoride	mg/L	0.1		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Dissolved metals																								
Arsenic	mg/L	0.001		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Beryllium	mg/L	0.001		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Barium	mg/L	0.001		0.008	0.001	0.0005	0.004	0.0005	0.0005		0.0005	0.0005	0.0005		0.001	0.009	0.0005		0.0005	0.004	0.001	0.001	0.01	0.004
Cadmium	mg/L	0.0001		0.00005	0.00005	0.00005	0.00005	0.00005	0.00005		0.00005	0.00005	0.00005		0.00005	0.00005	0.00005		0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Chromium	mg/L	0.001		0.017	0.023	0.015	0.021	0.02	0.024		0.02	0.03	0.033		0.022	0.018	0.021		0.021	0.016	0.023	0.023	0.011	0.014
Cobalt	mg/L	0.001		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Copper	mg/L	0.001		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Lead	mg/L	0.001		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Manganese	mg/L	0.001		0.0005	0.0005	0.003	0.0005	0.0005	0.002		0.0005	0.0005	0.003		0.0005	0.0005	0.001		0.0005	0.0005	0.002	0.0005	0.0005	0.005
Nickel	mg/L	0.001		0.011	0.011	0.017	0.018	0.011	0.01		0.016	0.018	0.018		0.017	0.013	0.019		0.01	0.019	0.021	0.012	0.019	0.02
Selenium	mg/L	0.01		0.005	0.005	0.005	0.005	0.005	0.005		0.005	0.005	0.005		0.005	0.005	0.005		0.005	0.005	0.005	0.005	0.005	0.005
Vanadium	mg/L	0.01		0.005	0.005	0.005	0.005	0.005	0.005		0.005	0.005	0.005		0.005	0.005	0.005		0.005	0.005	0.005	0.005	0.005	0.005
Zinc	mg/L	0.005		0.0025	0.012	0.0025	0.0025	0.0025	0.0025		0.0025	0.0025	0.0025		0.0025	0.0025	0.0025		0.0025	0.01	0.01	0.014	0.0025	0.0025
Boron	mg/L	0.05		0.025	0.025	0.025	0.025	0.025	0.025		0.025	0.025	0.025		0.025	0.025	0.025		0.025	0.025	0.025	0.025	0.025	0.025
Total metals																								
Aluminium	mg/L	0.01																						
Arsenic	mg/L	0.001		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Beryllium	mg/L	0.001		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Barium	mg/L	0.001		0.009	0.002	0.001	0.004	0.0005	0.001		0.0005	0.0005	0.0005		0.004	0.01	0.003		<0.001	0.004	0.001	0.001	0.012	0.004
Cadmium	mg/L	0.0001		0.00005	0.00005	0.00005	0.00005	0.00005	0.00005		0.00005	0.00005	0.00005		0.00005	0.00005	0.00005		0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Chromium	mg/L	0.001		0.019	0.025	0.018	0.022	0.022	0.023		0.022	0.033	0.034		0.025	0.02	0.022		0.024	0.017	0.024	0.026	0.016	0.015
Cobalt	mg/L	0.001		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Copper	mg/L	0.001		0.0005	0.0005	0.0005	0.0005	0.0005	0.001		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Lead	mg/L	0.001		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Manganese	mg/L	0.001		0.0005	0.0005	0.006	0.0005	0.0005	0.005		0.0005	0.0005	0.005		0.0005	0.0005	0.002		0.0005	0.002	0.005	0.0005	0.004	0.007
Nickel	mg/L	0.001		0.012	0.013	0.017	0.021	0.013	0.012		0.022	0.021	0.02		0.02	0.016	0.021		0.013	0.021	0.02	0.014	0.028	0.021
Selenium	mg/L	0.01		0.005	0.005	0.005	0.005	0.005	0.005		0.005	0.005	0.005		0.005	0.005	0.005		0.005	0.005	0.005	0.005	0.005	0.005
Vanadium	mg/L	0.01		0.005	0.005	0.005	0.005	0.005	0.005		0.005	0.005	0.005		0.005	0.005	0.005		0.005	0.005	0.005	0.005	0.005	0.005
Zinc	mg/L	0.005		0.0025	0.0025	0.0025	0.007	0.0025	0.0025		0.0025	0.0025	0.0025		0.098	0.0025	0.0025		0.0025	0.0025	0.0025	0.0025	0.014	0.014
Iron	mg/L	0.05																						
Boron	mg/L	0.05		0.025	0.025	0.025	0.025	0.025	0.025		0.025	0.025	0.025		0.025	0.025	0.025		0.025	0.025	0.025	0.025	0.025	0.025
Mercury	mg/L	0.0001		0.00005	0.00005	0.00005	0.00005	0.00005	0.00005		0.00005	0.00005	0.00005		0.00005	0.00005	0.00005		0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Nutrients																								
Ammonia as N	mg/L	0.01																						
Nitrite	mg/L	0.01																						
Nitrate	mg/L	0.01																						
TKN	mg/L	0.1																						
Total Phosphorus	mg/L	0.01																						
Ionic composition																								
Total Anions	meq/L	0.01		1.64	1.52	1.7	1.65	1.44	6.7	2.06	1.24	1.33	1.43	1.32	1.36	1.18	1.34	1.51	1.44	1.94	1.22	1.31	1.56	2.43
Total Cations	meq/L	0.01		1.45	1.5	1.03	1.67	1.32	6.58	2.11	1.2	1.28	1.16	1.2	1.16	1.16	1.03	1.4	1.33	2	1.03	1.33	1.45	2.37

Analyte grouping/Analyte	Unit	LOR	KG4			KG5T			KG6		TB2	TB3	TB4	RAMU1	SED08	GHOBU1	DAVU2	DAVU1	VAVULA1	TB6	SUIMA1	TB8
			03/12/2016	06/12/2016	21/08/2017	05/12/2016	07/12/2016	21/08/2016	05/12/2016	06/12/2016	21/08/2017	21/08/2017	21/08/2017	3/09/2017	3/09/2017	2/09/2017	1/09/2017	31/08/2017	1/09/2017	31/08/2017	2/09/2017	31/08/2017
Physicochemical																						
pH Value	pH Unit	0.01	7.55	7.47	7.97	7.57	7.42	7.89	7.51	7.54	8.1	7.91	7.98	7.78	7.51	7.56	8.02	6.8	7.2	7.5	7.63	7.6
Electrical Conductivity @ 25°C	µS/cm	1	126	112	142	136	104	126	109	198	713	555	136	120.2	115.3	157.5	228.3	120.8	137.8	143.1	123.7	123.7
Total Dissolved Solids (Calc.)	mg/L	1	82	73	92	88	68	82	71	129	463	361	88	78	75.4	102.7	148.2	78.65	89.7	92.5	80.6	87.2
Suspended Solids (SS)	mg/L	5	2.5	2.5	5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	24
Alkalinity																						
Total Hardness as CaCO3	mg/L	1	58	54	66	66	49	49	54	62	131	94	63									
Hydroxide Alkalinity as CaCO3	mg/L	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Carbonate Alkalinity as CaCO3	mg/L	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Bicarbonate Alkalinity as CaCO3	mg/L	1	64	60	75	72	55	71	57	61	88	63	71	62	63	79	114	62	69	72	64	74
Total Alkalinity as CaCO3	mg/L	1	64	60	75	72	55	71	57	61	88	63	71	62	63	79	114	62	69	72	64	74
Major ions																						
Sulfate	mg/L	1	0.5	0.5	1	0.5	0.5	2	0.5	3	22	18	1	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5
Chloride	mg/L	1	4	3	5	3	2	8	2	26	173	134	6	3	2	5	8	3	3	6	3	6
Calcium	mg/L	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	8	3	2	0.5	0.5	2	4	0.5	0.5	2	0.5	3
Magnesium	mg/L	1	14	13	16	16	12	12	13	15	27	21	14	15	14	19	26	15	17	18	16	17
Sodium	mg/L	1	4	2	2	3	2	2	2	14	97	75	3	2	2	4	4	2	2	4	2	4
Potassium	mg/L	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	4	3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Fluoride	mg/L	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Dissolved metals																						
Arsenic	mg/L	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005									
Beryllium	mg/L	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005									
Barium	mg/L	0.001	0.0005	0.0005	0.011	0.01	0.001	0.008	0.009	0.008	0.002	0.002	0.001									
Cadmium	mg/L	0.0001	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005									
Chromium	mg/L	0.001	0.031	0.02	0.01	0.011	0.022	0.02	0.018	0.015	0.018	0.018	0.03									
Cobalt	mg/L	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005									
Copper	mg/L	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005									
Lead	mg/L	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005									
Manganese	mg/L	0.001	0.0005	0.0005	0.003	0.0005	0.0005	0.003	0.0005	0.0005	0.009	0.007	0.003									
Nickel	mg/L	0.001	0.017	0.017	0.022	0.019	0.018	0.015	0.013	0.01	0.006	0.014	0.006									
Selenium	mg/L	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005									
Vanadium	mg/L	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005									
Zinc	mg/L	0.005	0.0025	0.0025	0.0025	0.01	0.0025	0.0025	0.021	0.0025	0.0025	0.0025	0.0025									
Boron	mg/L	0.05	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025									
Total metals																						
Aluminium	mg/L	0.01												0.01	0.14	0.01	0.03	0.005	0.01	0.02	0.005	0.58
Arsenic	mg/L	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Beryllium	mg/L	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005									
Barium	mg/L	0.001	0.0005	0.002	0.013	0.011	0.002	0.01	0.01	0.009	0.002	0.002	0.002									
Cadmium	mg/L	0.0001	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Chromium	mg/L	0.001	0.035	0.022	0.01	0.012	0.024	0.02	0.021	0.016	0.021	0.02	0.031	0.029	0.049	0.038	0.021	0.037	0.026	0.028	0.046	0.032
Cobalt	mg/L	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Copper	mg/L	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Lead	mg/L	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Manganese	mg/L	0.001	0.0005	0.003	0.005	0.0005	0.0005	0.005	0.0005	0.0005	0.013	0.012	0.004	0.002	0.03	0.0005	0.007	0.0005	0.004	0.001	0.0005	0.036
Nickel	mg/L	0.001	0.021	0.025	0.023	0.023	0.02	0.016	0.017	0.013	0.008	0.015	0.008	0.014	0.088	0.005	0.016	0.049	0.014	0.009	0.023	0.024
Selenium	mg/L	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005									
Vanadium	mg/L	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005									
Zinc	mg/L	0.005	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Iron	mg/L	0.05												0.12	0.92	0.025	0.34	0.025	0.06	0.08	0.025	0.92
Boron	mg/L	0.05	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025									
Mercury	mg/L	0.0001	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005									
Nutrients																						
Ammonia as N	mg/L	0.01												0.02	0.03	0.05	0.07	0.08	0.07	0.06	0.08	0.2
Nitrite	mg/L	0.01												0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Nitrate	mg/L	0.01												0.2	0.13	0.27	0.37	0.29	0.18	0.41	0.26	0.4
TKN	mg/L	0.1												0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.2
Total Phosphorus	mg/L	0.01												0.005	0.005	0.09	0.37	0.24	0.29	0.15	0.02	0.005
Ionic composition																						
Total Anions	meq/L	0.01	1.39	1.28	1.66	1.52	1.16	1.68	1.2	2.01	7.1	5.41	1.61	1.32	1.32	1.72	2.52	1.32	1.46	1.61	1.36	1.65
Total Cations	meq/L	0.01	1.33	1.16	1.4	1.45	1.07	1.07	1.16	1.84	6.94	5.22	1.38	1.32	1.24	1.84	2.51	1.32	1.49	1.76	1.4	1.72

Appendix D

Physical marine assessment

REPORT

Marine Assessment, San Jorge Island

Solomon Islands

Client: EMM Consulting

Reference: M&APA1145R001F0.2

Revision: 0.2/Final

Date: 16 January 2018

HASKONING AUSTRALIA PTY LTD.

Unit 2
55-57 Township Drive
QLD 4220 Burleigh Heads
Australia
Maritime & Aviation
Trade register number: ACN153656252

+61 07 5602 8544 **T**
project.admin.australia@rhdhv.com **E**
royalhaskoningdhv.com **W**

Document title: Marine Assessment, San Jorge Island

Document short title: San Jorge Marine Assessment
Reference: M&APA1145R001F0.2
Revision: 0.2/Final
Date: 16 January 2018
Project name: San Jorge Marine Assessment
Project number: PA1145
Author(s): James Lewis, Heiko Loehr, Evan Watterson

Drafted by: Heiko Loehr, James Lewis

Checked by: Evan Watterson

Date / initials: **16/01/2018 EW**

Approved by: Evan Watterson

Date / initials: **16/01/2018 EW**

Classification
Project related

MANAGEMENT SYSTEM CERTIFICATION DNV·GL ISO 9001 = ISO 14001 OHSAS 18001

Royal HaskoningDHV

Table of Contents

1	**Introduction**	**5**
1.1	General	5
1.2	Project Background	5
1.3	Previous Physical Marine Monitoring	6
1.4	Scope and Report Structure	6
2	**Background Information**	**8**
2.1	Study Area	8
2.2	Climate	8
2.3	Wind	9
2.4	Freshwater	9
2.5	Sediments	11
3	**Metocean Data Collation and Analysis**	**16**
3.1	Data Sources	16
3.2	Meteorology	18
3.3	Waves	20
3.4	Currents and Water Level	22
3.5	Turbidity	26
4	**Numerical Modelling Systems**	**27**
4.1	Model Description	27
4.2	Modelling Approach	27
4.3	Model Setup	27
4.4	Model Verification	30
4.5	Modelling Limitations	31
5	**Impacts on Receiving Waters**	**33**
5.1	Surface Water Runoff Impacts	33
5.2	Marine Loading Impacts	40
6	**Discussion and Limitations**	**46**
6.1	Surface Water Runoff Impacts	46
6.2	Marine Loading Impacts	47
6.3	Limitations	48

7 References 50

Table of Tables

Table 1: Catchment areas and disturbance assumptions (source: EMM). 11

Table 2: Deployment Summary for monitoring sites at San Jorge Island. 17

Table 3: Deployment Averaged (54 days) Wave Statistics recorded at the Tanatola Bay AWAC location; 30th Jan – 24th Mar 2016. 20

Table 4: Depth-averaged and near bed, mid-water column and surface current magnitude statistics recorded at the Tanatola Bay AWAC location; 30th Jan – 24th Mar 2016. 23

Table 5: Fluvial and sediment load source terms for the surface water runoff simulations. 35

Table 6: Ore composition based on Golder hydrometer PSD results from Isabel sediment samples. 42

Table of Figures

Figure 1: Axiom's proposed development at San Jorge Island. 6

Figure 2: Local topography of Santa Isabel and San Jorge Islands. 8

Figure 3: San Jorge topography map (AXIOM, 2015). 10

Figure 4: San Jorge surface water catchment extents (source: EMM). 11

Figure 5: Hydrometer and particle size distribution analysis of sediment samples taken at Santa Isabel tenements. (Golder, 2014) 13

Figure 6: Composition of sediment samples taken around San Jorge and Santa Isabel Islands. 14

Figure 7: Aerial photograph showing increased sediment concentrations in the receiving waters from freshwater sources (imagery date 7 July 2013). 15

Figure 8: Overview of San Jorge monitoring deployment locations. 17

Figure 9: Metocean instrument location and NOAA WWII data extraction point. 18

Figure 10: 2016 wind rose (left) at the NOAA extraction point and deployment period wind rose (right). 19

Figure 11: Summary of meteorological data measured at the San Jorge site during the wet season deployment period in 2016 (note, significant data gaps occurred during this period). 19

Figure 12: Tanatola Bay AWAC processed waves wet season deployment 2016; (top to bottom) Significant wave height, peak wave direction, peak wave period. 21

Figure 13: NOAA WWIII extracted [-8.5°, 159.5°] wind and wave data concurrent to RHDHV wet season deployment in 2016; (top to bottom) Significant Wave Height, Peak Wave Direction, Peak Wave Period, Wind Speed, Wind Direction. 22

Figure 14: Deployment averaged net residual currents at each 1m 'bin' recorded at the Tanatola Bay AWAC location; 30th Jan – 24th Mar 2016. 23

Figure 15: Tanatola Bay AWAC processed currents, wet season deployment 2016; (top to bottom) depth-averaged current speed, acoustic backscatter intensity, surface elevation, depth-averaged current direction. 24

Figure 16: Current profile during high current event at Tanatola Bay AWAC, 5th Feb, 2016. 25

Figure 17: Hughu Creek FLNTUs processed data wet season deployment 2016; (top to bottom) NTU, CHL. 26

Figure 18: Numerical model domain and interpolated bathymetry. 28

Figure 19: Close up of San Jorge model domain, unstructured mesh, interpolated bathymetry and hydrodynamic source locations. 28

Figure 20: Spatially varying hydraulic roughness (Manning's M) around the Hughu hydraulic source point. 29

Figure 21: San Jorge HD model surface elevation verification at the Tanatola Bay AWAC location. 30

Figure 22: San Jorge HD model surface elevation, depth-averaged current speed and direction verification at the Tanatola Bay AWAC location. 31

Figure 23: 2015-2016 Kolosori Ridge average daily rainfall data. The magenta window represents an 85th percentile rainfall event of 120 mm over 5 days. The cyan window represents a 99th percentile rainfall event of 2,50 mm over 5 days. 34

Figure 24: Measured stream cross-section at Hughu (left) and Ghobu (right). 34

Figure 25: Mean (top left) and 99th percentile (top right) Total Suspended Sediment (TSS) concentration, (bottom) total net accumulated deposition during the Scenario 1 simulation. 36

Figure 26: Mean (top left) and 99th percentile (top right) Total Suspended Sediment (TSS) concentration, (bottom) total net accumulated deposition during the Scenario 2 simulation. 37

Figure 27: Mean (top left) and 99th percentile (top right) Total Suspended Sediment (TSS) concentration, (bottom) total net accumulated deposition during the Scenario 3 simulation. 38

Figure 28: Difference in total net accumulated deposition between (Scenario 3 (disturbed upper catchment, extreme event) and Scenario 2 (undisturbed upper catchment, extreme event)).. 39

Figure 29: Locations of Marine Loading Facility (MLF) and assumed location of the transhipment mooring. 40

Figure 30: Mean (top left) and 99th percentile (top right) Total Suspended Sediment (TSS) concentration, (bottom) total net accumulated deposition during the Scenario 4 simulation. 43

Figure 31: Mean (top left) and 99th percentile (top right) Total Suspended Sediment (TSS) concentration, (bottom) total net accumulated deposition during the Scenario 5 simulation. 44

Figure 32: Mean (top left) and 99th percentile (top right) Total Suspended Sediment (TSS) concentration, (bottom) total net accumulated deposition during the Scenario 6 simulation. 45

Figure 33: Total accumulated sediment throughout entire model domain over each scenario run. 47

1 Introduction

1.1 General

Royal HaskoningDHV (RHDHV) was engaged by EMM Consulting (EMM) in October 2017 to undertake a high-level assessment of mining impacts from the proposed San Jorge nickel mine on the marine receiving waters. This assessment is considered to be a first pass, or feasibility assessment for the marine impact assessment for the project. The study utilises data that was available at the start of the study as well as hydrodynamic and sediment transport modelling tools. This report presents the results of this high-level marine impact assessment.

1.2 Project Background

Axiom has appointed EMM Consultants (EMM) to prepare an Environmental and Social Impact Assessment (ESIA) to support an application for approvals to develop a mine at San Jorge, Solomon Islands. It is understood that Axiom will be applying to undertake the following activities within the proposed tenement boundary (see Figure 1) that are relevant to the marine assessment:

- Site preparation works, e.g. vegetation clearance for construction, pad creation, surface water controls and water supply;
- Construction of:
  - Haul roads between the San Jorge mining areas and the ore loading facility;
  - The ore loading facility, including a Ro-Ro ramp;
- Operations:
  - Progressive vegetation clearance prior to mining;
  - Progressive haul and service road development within the mining area;
  - Ore extraction within the mine area;
  - Ore drying using windrows;
  - Ore transport to ore loading facility;
  - Ro-Ro barge loading;
  - Transfer from barges to ocean-going vessels moored in Thousand Ships Bay (less than 1km from the onshore ore loading facility);
  - Progressive rehabilitation and closure.

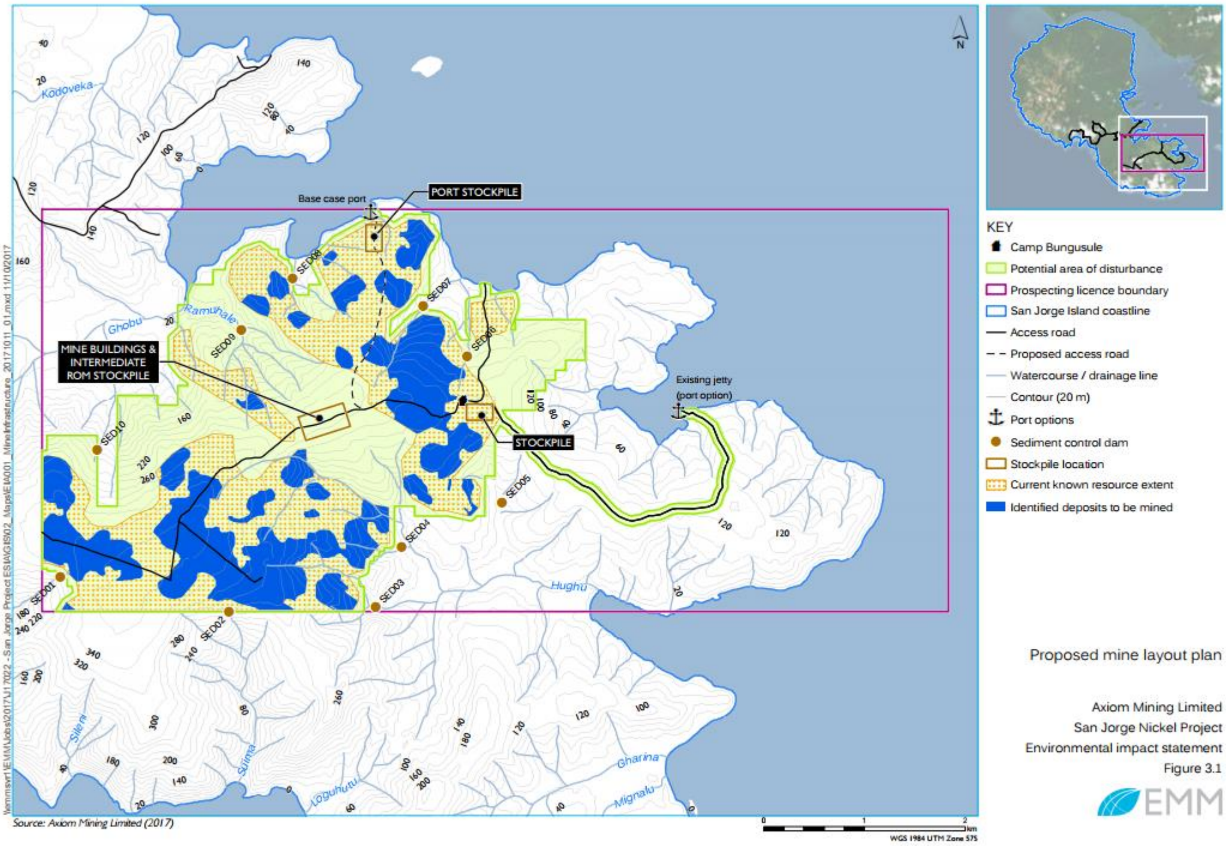


Figure 1: Axiom's proposed development at San Jorge Island.

1.3 Previous Physical Marine Monitoring

This work follows on from previous work on this and nearby proposed mining developments completed by RHDHV on behalf of EMM. In October 2015 RHDHV undertook a Physical Marine Assessment of the Kolosori tenement on Santa Isabel Island in the Solomon Islands (RHDHV, 2016). The Physical Marine Assessment formed part of EMM's ongoing work to undertake an Environmental Impact and Social Assessment (ESIA) for Axiom Mining as part of their Isabel Nickel Project.

In January 2016, following completion of the Isabel Nickel Project work, RHDHV were engaged to undertake a similar investigation on the adjacent island of San Jorge. Metocean monitoring instruments were deployed within streams and feeding waterways of the island. A weather station was also installed. The Project was stopped unexpectedly in March, 2016. Subsequently all instruments were removed from the field by local staff and the Project and subsequent data analysis was put on hold.

1.4 Scope and Report Structure

The scope of this report is to undertake a high-level marine assessment of the receiving waters of San Jorge Island to considering surface water runoff and loading spillage in the vicinity of the proposed ore loading facility and transhipment anchorage. The scope has been undertaken in there (3) distinct phases:

- Phase 1 - involved the collation and analysis of available data to determine the dominant metocean conditions in the marine receiving waters as well as derive suitable input parameters for use in the numerical modelling. This phase is presented in **Section 3**.

- Phase 2 - involved setting up and verifying of numerical modelling that were suitable to represent the hydrodynamic and sediment transport at the study site. This phase is presented in **Section 4**.

- Phase 3 - involved applying the numerical modelling to predict the dispersion of sediment released into the marine environment. This phase is presented in **Section 5**.

2 Background Information

2.1 Study Area

The Project is located on the south-eastern shore of San Jorge Island, approximately 100 km north of Honiara. The ore deposits, which are generally in hilly areas reaching a maximum height of about 350 m, extend close to the coastline as seen in Figure 2.

The marine environment in Thousand Ships Bay between San Jorge and Santa Isabel islands is characterised by a mixture of mangrove shoreline, fringing coral reef and small islands. The bay is a submerged valley with depths up to 50 m at the entrance to the Ortega Channel. South of San Jorge the ocean floor drops rapidly to depths of over 1,000 m.

Figure 2: Local topography of Santa Isabel and San Jorge Islands.

2.2 Climate

The climate of San Jorge Island can be described as an equatorial monsoon climate (Golder, 2014b), characterised by high and rather uniform temperature and humidity with high rainfall. San Jorge lies within 8.5° latitude of the equator and more than 1,500 km from the nearest continent. The study region, because of its low latitude, is less subject to the damaging effects of tropical cyclones than elsewhere in the south-west Pacific, although cyclones still pose a serious threat.

The weather and climate of the region can be explained largely by the seasonal movement and development of the equatorial trough or Intertropical Convergence Zone (ITCZ). From about January to March the ITCZ is usually found close to, or south of, the Solomon Islands. This results in seasonal westerly to north-westerly monsoonal winds. The heaviest rainfall at most places also occurs at this time, however the wettest months in the Project area occurs around November. The ITCZ moves to the northern hemisphere from May to October and the Solomon Islands then lie within the region of the south-east trade winds (the south-east trades being the stronger and more persistent winds). These winds are moisture-bearing, having had a long path over the ocean, and heavy rainfall can also occur during the south-easterly season, especially on the windward side of the Islands.

2.3 Wind

The seasonal nature of the prevailing winds in the Solomon Islands has been mentioned above. East to south-east winds are usual from May to October and, although not usually as strong as in other Pacific regions further south or east, still have a large degree of constancy. The typical speed of the winds over the sea, free from the influence of the mountainous islands of the region, would be about 30 km/hr (SIG, 2017). Stronger south-east winds occur at times, possibly blowing at more than 40 km/hr for several days, when the subtropical high pressure belt is stronger than usual in the south.

West to north-west winds from about November to April are typically lighter than the south-east trades and much less persistent.

In addition to the seasonal winds, there is also a strong diurnal wind pattern caused by the islands themselves and several effects contribute to this. Over land areas the wind speed tends to increase during the morning, reaching a maximum during the afternoon at about the time of the maximum temperature, before dying away at night to become light and variable or calm (SIG, 2017). In coastal areas, the greater heating of the land during the day drives a flow of air from the cooler sea. The strength of these sea breezes can typically reach 20‑30 km/h. Conversely, at night a land breeze can occur because of the more rapid cooling of the land. This offshore directed breeze is much weaker than the sea breeze. Finally, where there is hilly or mountainous terrain, cool and relatively dense air can flow downhill at night as a katabatic wind. If this reaches the coast, it can combine with the land breeze effect to give an offshore directed wind as strong as 20 km/h in the early morning. All of these effects are important in the Solomon’s in determining the daily wind pattern at any particular location.

These localised wind effects are particularly important when considering coastal impacts around the project site at San Jorge. The island itself has several large mountains and deep valleys terminating into the bays of which port infrastructure is proposed.

Extreme winds may be caused by the occasional tropical cyclone between November and April season, or thunderstorm squalls at any time of the year. A very intense cyclone would be rare but have winds of up to 200 km/h near its centre (SIG, 2017).

2.4 Freshwater

The Project area is located in an area of steep coastal ridges with catchments of limited size which drain into either Thousand Ships Bay or into the ocean to the west of San Jorge. An elevation map of the San Jorge tenement site and adjacent bays can be seen in Figure 3. Catchment and streams in which mining developments are proposed are likely to be directly impacted by the Project. The steep terrain and high rainfall of the region result in high rates of runoff. A survey undertaken in 2014 (PHCG, 2015) also identified steep sloping and relatively short run river and stream systems; with the larger river systems tending to terminate in mangrove estuaries.

During the wet season high runoff rates with increased turbidity and high sediment loads are reportedly frequent. Discoloured water discharges into Thousand Ship Bay and it is therefore likely that the aquatic fauna in streams and discharge zones are adapted to the variation in flows and water quality that occur naturally. The local villagers use the freshwater sources close to their villages for drinking water and food such as freshwater molluscs and eels. The freshwater resource in the Project area is used sporadically by local villagers for drinking if they are passing through (Coffey, 2011).

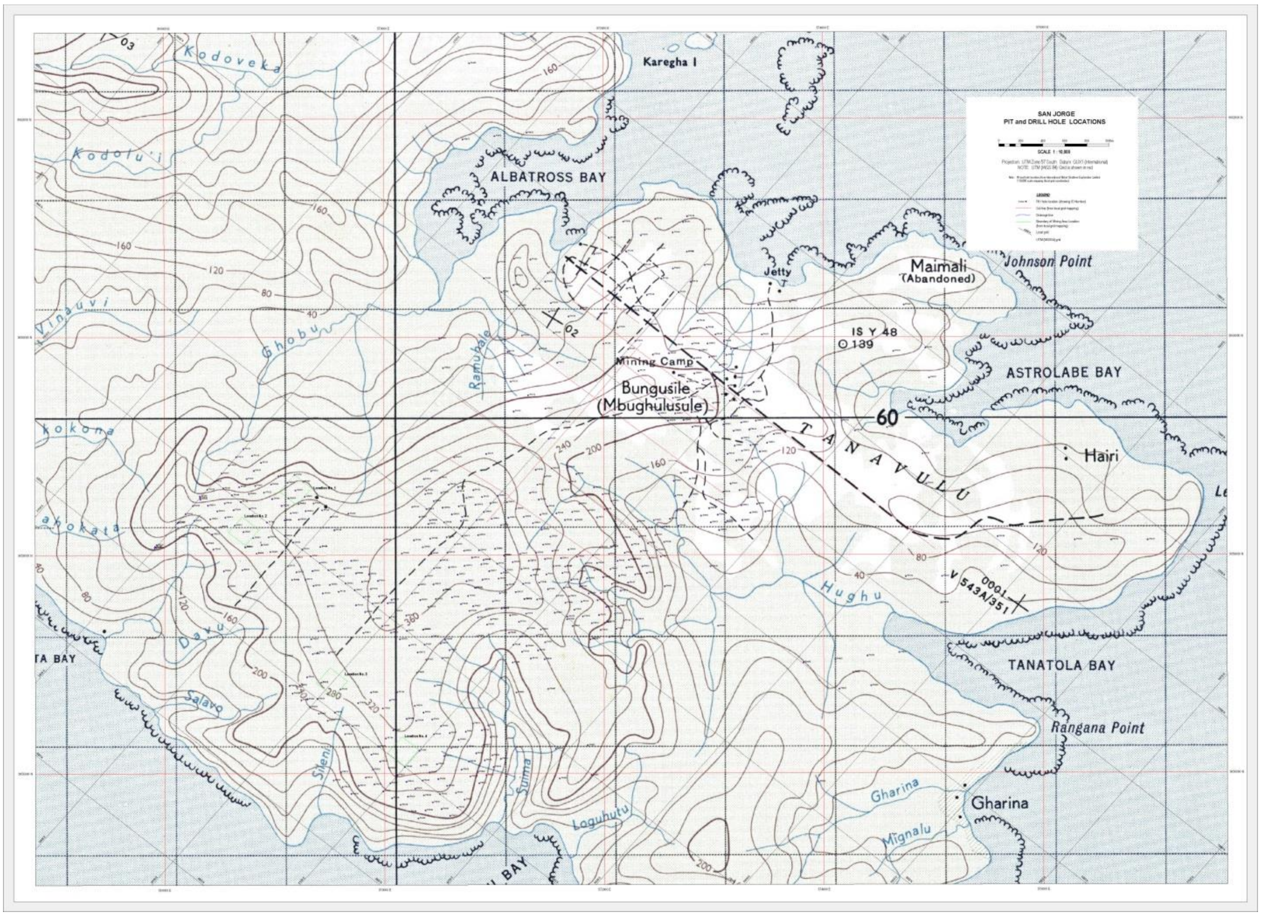


Figure 3: San Jorge topography map (AXIOM, 2015).

The average annual rainfall for the Solomon Islands is within the range 3,000 - 5,000 mm (Golder, 2014b) with the majority of monthly rainfall amounts in excess of 200 mm. Depending on the local topography, rainfall could be expected to increase with elevation with a maximum at about 600 - 1,000 m above mean sea level on windward slopes. Extreme falls seem to be confined to the transition months of December and April when the equatorial trough is migrating across the islands. Between these months, the north-west monsoon tends to give frequent rain but with lesser daily rainfall totals. Very heavy daily falls can also occur during the south-easterly season at places exposed to the prevailing wind.

An overview of the San Jorge catchments and the assumed mining disturbances has been supplied by EMM consulting and can be seen in Figure 4 and Table 1.

Royal HaskoningDHV

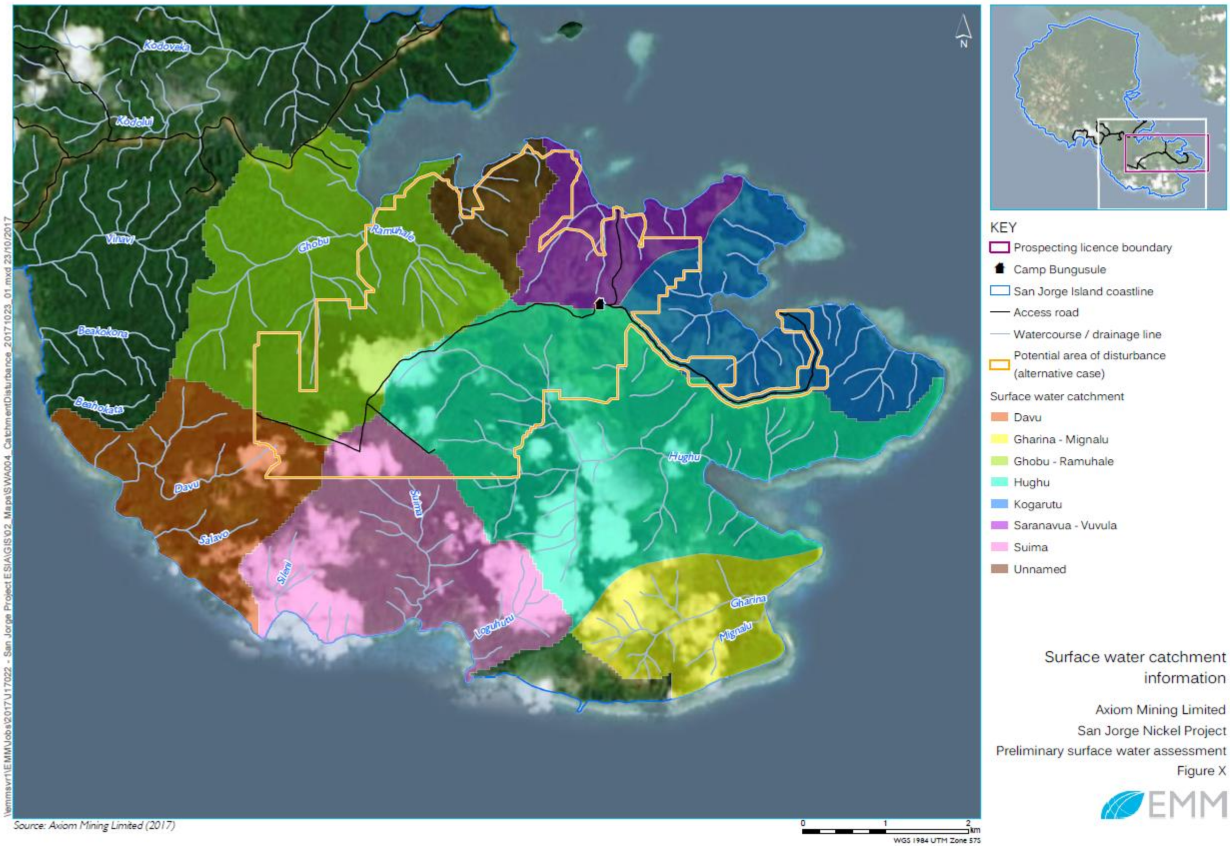


Figure 4: San Jorge surface water catchment extents (source: EMM).

Table 1: Catchment areas and disturbance assumptions (source: EMM).

Catchment Name	Catchment Area (ha)	Potential Disturbance Area (ha)	Assumed Actual Disturbance Area (ha)
Unnamed	148	128	90
Davu	460	41	29
Suima	658	76	53
Hughu	1234	415	290
Kogarutu	480	92	64
Ghobu - Ramuhale	917	419	294
Gharina - Mignalu	322	0	0
Saranavua - Vuvula	262	177	124

2.5 Sediments

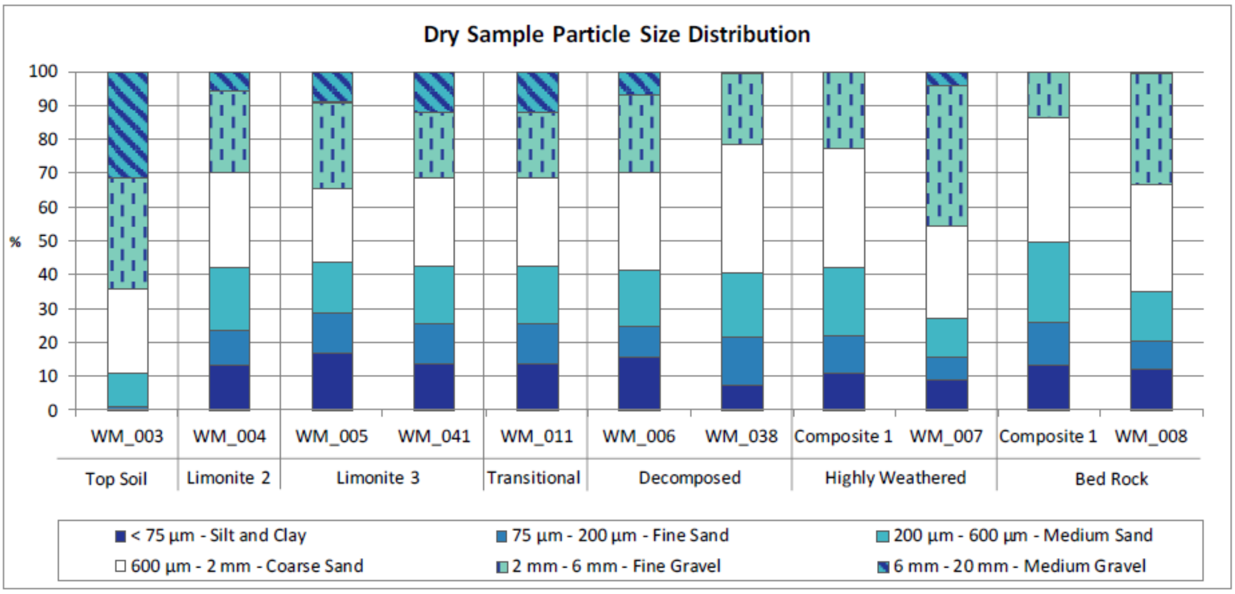
Golder (2014) undertook a detailed analysis of the geology and soil characteristics of the adjacent tenement on Santa Isabel Island. They classified the soil lithography as follows:

- Top Soil
- Limonite 2 and 3
- Transitional
- Decomposed

- Highly Weathered
- Bed Rock

Dry sample and hydrometer particle size distribution (PSD) can be seen in Figure 5. The results of the dry PSD for the top soil, Limonite 2 and Limonite 3 material do not correspond with the hydrometer PSD analysis. This may indicate that this material is readily soluble in water, producing more fine sized particles once in water. While these sediment samples were not collected in the development area of San Jorge Island they do provide additional information on the type of soils in the region. It is highly recommended that further investigations are conducted on the San Jorge sediments that are to be disturbed by the proposed mining. This information is required to more accurately assess the dispersion of soil material that is released into the marine environment.

Recently sediment samples have been collected on San Jorge and Santa Isabel islands as part of the EIA process at several locations around the study site. The results of the PSD analysis of the recent San Jorge sediment samples have been provided to RHDHV by EMM and can be seen in Figure 6.



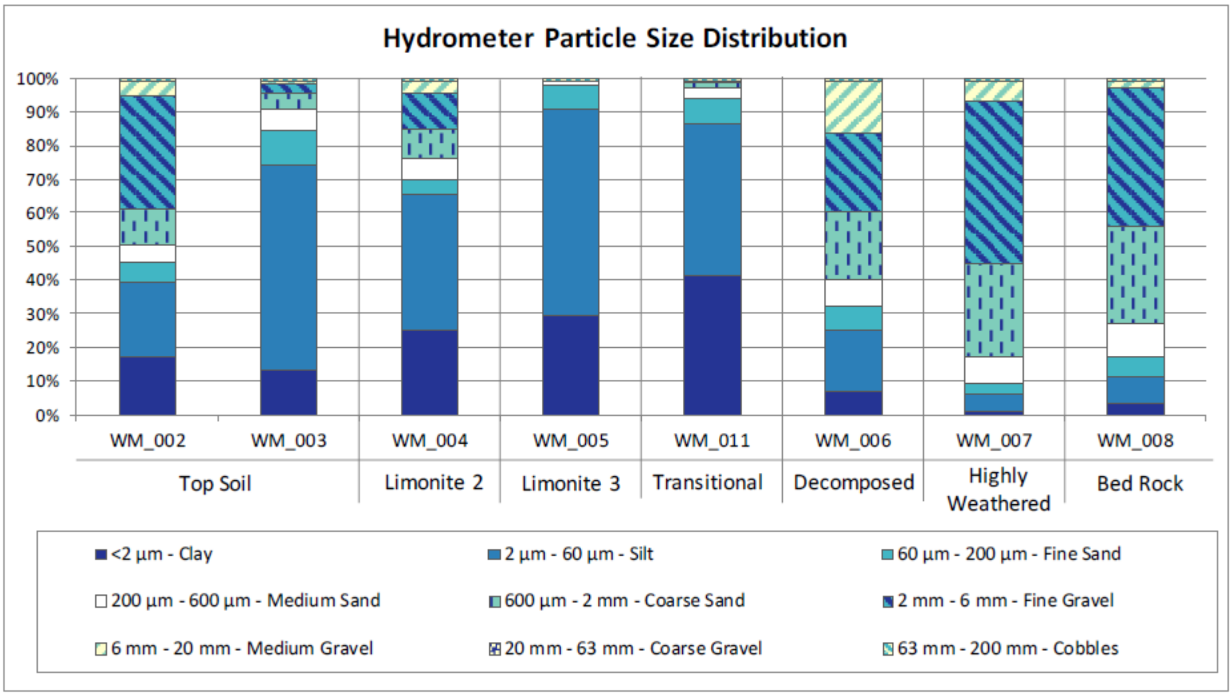
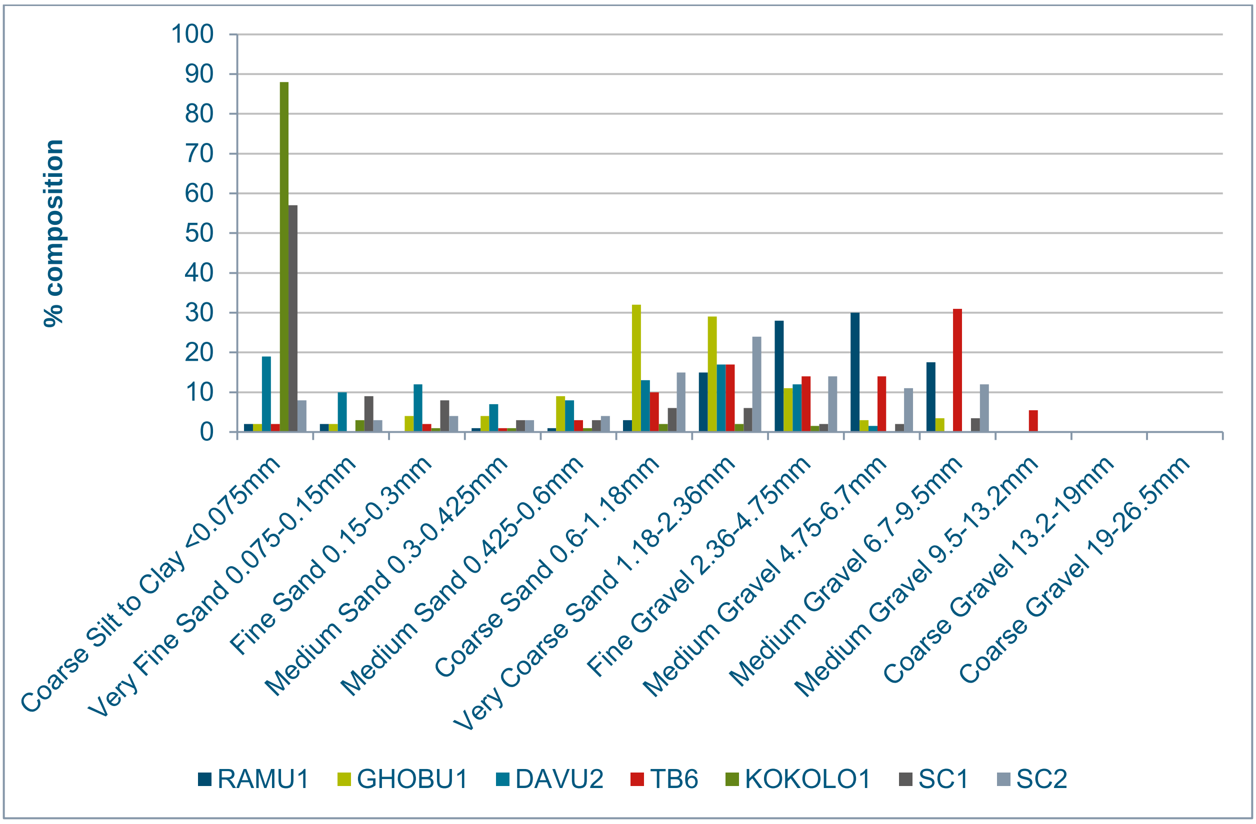


Figure 5: Hydrometer and particle size distribution analysis of sediment samples taken at Santa Isabel tenements. (Golder, 2014)



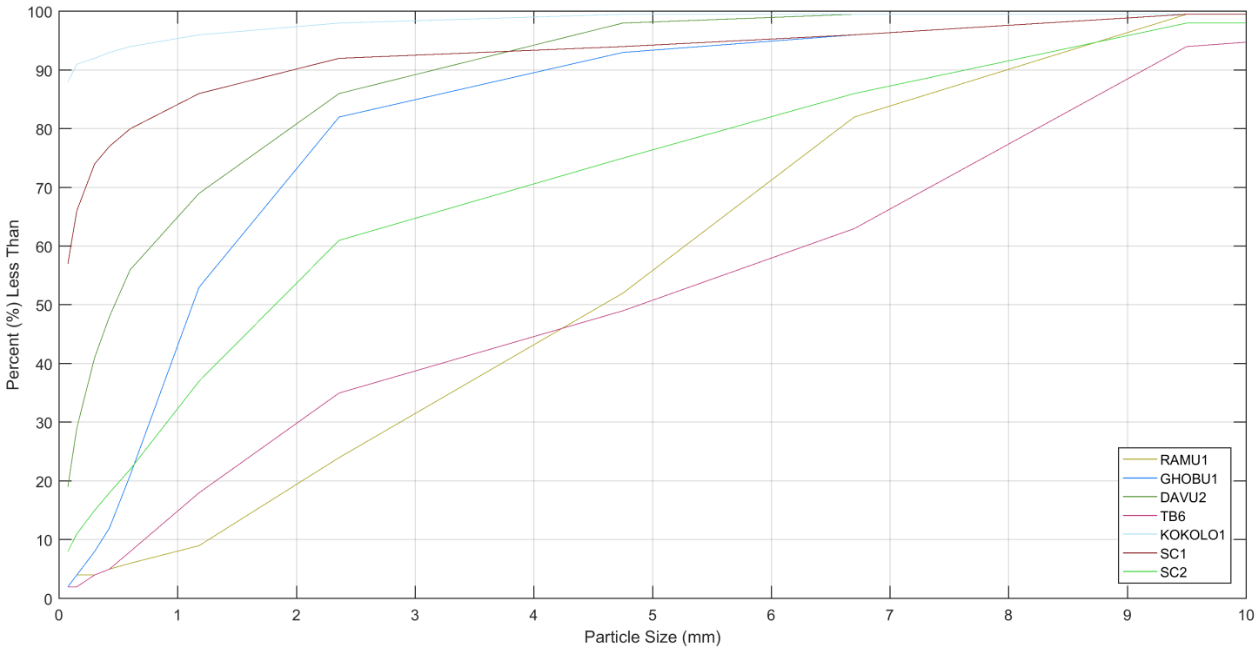


Figure 6: Composition of sediment samples taken around San Jorge and Santa Isabel islands.

Periods of high rainfall result in high surface water runoff into the receiving waters around San Jorge, typically increasing turbidity locally. It is expected during these times (and following mine operations) that the predominant contributor to the increased turbidity would be the runoff of top soil into the catchment.

An example of increased turbidity following rainfall is shown in the satellite imagery in Figure 7. During these times, it is expected that the heavier particles settle out of the water column almost immediately following their release into receiving waters (from creek catchments) and that the finer particles are transported by the prevailing currents. This is further supported by the satellite imagery as there is a large deposition zone directly at the mouth of Hughu Creek.

During future marine loading scenarios, it is envisaged that spillages of ore during the loading/transfer processes will have a higher concentration of Limonite 2 and Limonite 3.

Figure 7: Aerial photograph showing increased sediment concentrations in the receiving waters from freshwater sources (imagery date 7 July 2013).

Royal HaskoningDHV

3 Metocean Data Collation and Analysis

3.1 Data Sources

The following paragraphs describe the data sources used for the baseline marine assessment.

3.1.1 In-situ Monitoring

In January 2016, EMM and AXIOM requested an extension to RHDHV's initial Physical Marine and Freshwater Monitoring at Santa Isabel (RHDHV, 2016) to include an additional monitoring program on adjacent San Jorge Island.

Directional waves and currents were recorded at the entrance to Tanatola Bay on the southern shore of San Jorge Island using an Acoustic Doppler Current Profiler (ADCP) instrument, Figure 8. This site was named Tanatola Bay and also included a sub-surface buoy attached to a mooring equipped with an Eco Wetlabs NTUs logger to measure near-surface turbidity.

Hughu1 was located upstream in Hughu Creek feeding into Tanatola Bay. Turbidity and flow were monitored at this location using a flow and water level gauge in addition to an Eco Wetlabs NTU logger. The instrument location was selected to ensure that it was sufficiently upstream to no longer have tidal influence.

Ghobu1 is located upstream in Ghobu Creek feeding into Albatross Bay on San Jorge's eastern shore approximately 5 km north of the Hughu1 site. As with Hughu1, this site was equipped with the same instruments and the location was selected to ensure that it was sufficiently upstream to no longer have tidal influence.

A meteorological station was installed on San Jorge Island in close proximity to the proposed operations. The station was to record (at a minimum): rainfall, wind speed and direction, humidity and temperature. At first only a temporary weather station was installed which was due to be replaced with a permanent station later in the project timeline.

Figure 8: Overview of San Jorge monitoring deployment locations.

In mid-March 2016, EMM (and RHDHV) were informed to rapidly retrieve the instruments from all locations as the Project was put on hold. The instruments were not retrieved by RHDHV staff but rather by local staff and then sent back to RHDHV office in Australia. At several sites data was compromised and only minimal information was retrievable.

Table 2 summarises the dates and times the instruments were deployed and retrieved at each of the San Jorge Island sites as well as approximate data capture rates.

Table 2: Deployment Summary for monitoring sites at San Jorge Island.

Location	Deployment: Date, Time and Location	Recovery Date, Time and Location	Deployment Duration	Instruments Deployed	Data Capture
Tanatola Bay	30 January 2016, 10:15 h SBT, [8° 31.944'; 159° 41.533'E]	24 March 2016 15:15 h SBT [8° 31.944'; 159° 41.533'E]	54.2 days	Nortek AWAC ECO FLNTUs	AWAC 98.6% FLNTU 0%
Ghobu Creek	31 January 2015, 14:35h SBT, [8°30.044'S; 159°37.988'E]	18 April 2016 12:11 h SBT [8°30.044'S; 159°37.988'E]	78.04 days	Sontek IQ+ ECO FLNTUs	IQ+ 0% FLNTU 0%
Hughu Creek	31 January 2016 11:13 h SBT, [8°31.569'S; 159°40.238'E]	18 April 2016 11:01 h SBT [8°31.569'S; 159°40.238'E]	77.91 days	Sontek IQ+ ECO FLNTUs	IQ+ 0% FLNTU 95%

It can be seen that several instruments have a 0% data capture rate. This is attributed to the rapid nature at which the instruments were removed. Local staff reported that some instruments had been vandalised in the field, whilst others most likely suffered data loss due to the incorrect stoppage of the instruments and through insufficient protection during the freighting process.

The data that could be salvaged was processed and quality controlled using RHDHV's standard procedures and is shown in the following sections.

Royal HaskoningDHV

3.1.2 Global Model Data

In order to attain a longer term dataset for the metocean analysis, data was obtained from the NOAA Global WaveWatch (WWIII) hindcast 0.5° resolution model. Wind and wave data was attained at an offshore point (-8.5°, 159.5°, as seen in Figure 9).

Figure 9: Metocean instrument location and NOAA WWII data extraction point.

3.2 Meteorology

The distinct difference in wind patterns between wet and dry seasons introduced in Section 2 can be seen in the NOAA WWIII extraction point wind rose comparisons seen in Figure 10. The dominant south-east (SE) trade winds are evident in the 2016 wind rose, whereas the more pronounced westerly to north-westerly (W-NW) inclination of the winds throughout the 2016 wet season deployment can be seen on the right in Figure 10. A summary of the measured wind and rainfall data at San Jorge (and Kolosori) concurrent to this deployment period is provided in Figure 11. Maximum wind speeds of up to 25 km/h were recorded during this period.

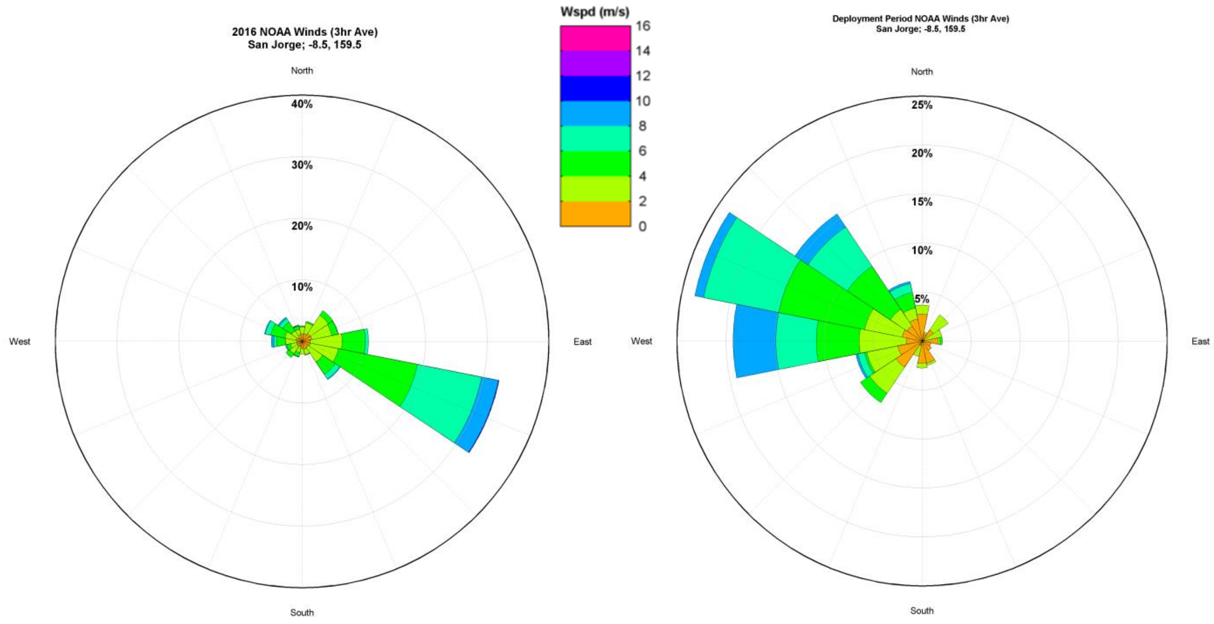


Figure 10: 2016 wind rose (left) at the NOAA extraction point and deployment period wind rose (right).

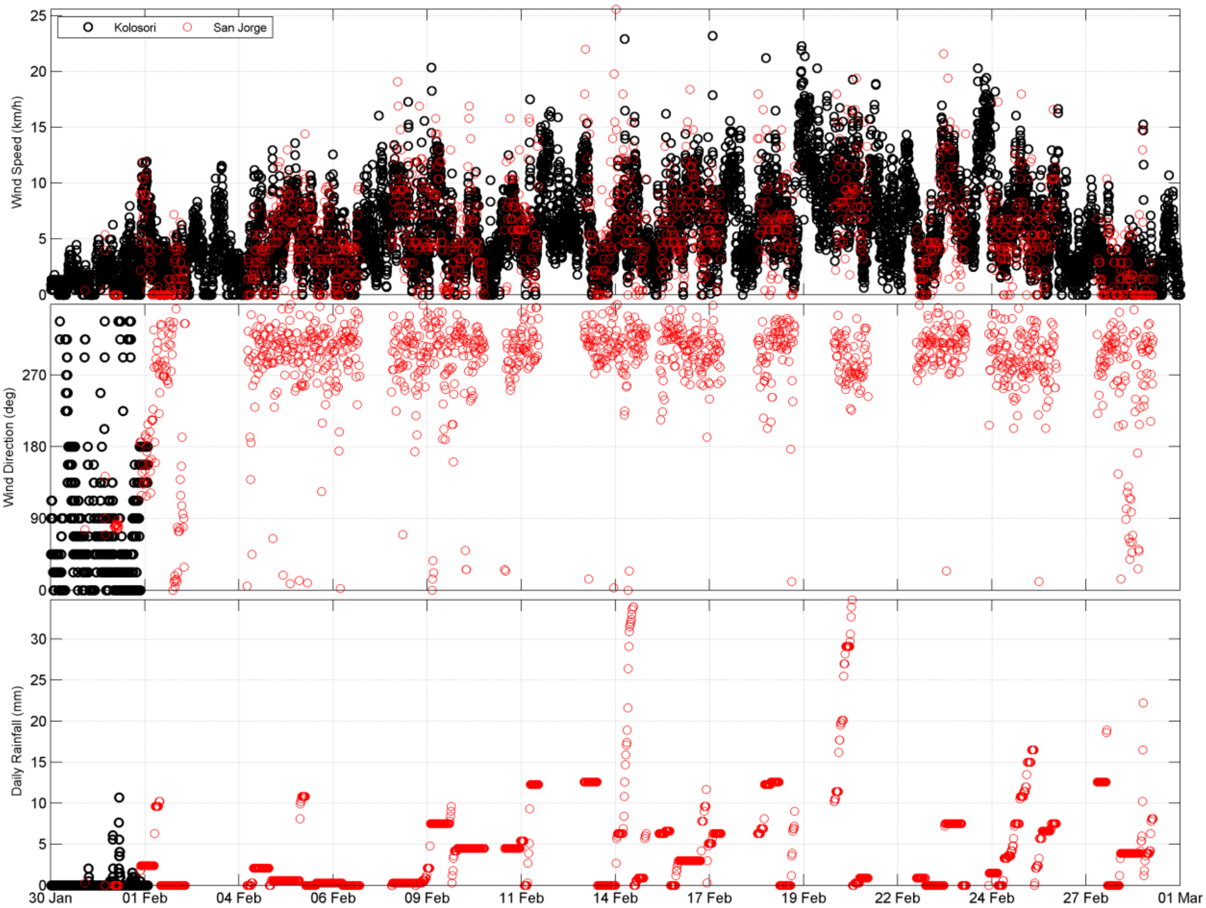


Figure 11: Summary of meteorological data measured at the San Jorge site during the wet season deployment period in 2016 (note, significant data gaps occurred during this period).

3.3 Waves

The proposed infrastructure site on San Jorge Island is relatively protected from open ocean swells due to its location on the leeward side with respect to northerly Pacific Ocean swells as well as the blocking effects of Guadalcanal and Puavuvu Islands from Coral Sea swells to the south. The persistent trade winds experienced in the region are aligned to create wind-generated waves within the vicinity of the proposed infrastructure site and may pose impacts to shipping operations as well as nearshore turbidity.

Deployment averaged statistics for the recorded waves at the Tanatola Bay site can be seen in Table 2. The deployment period is represented by a fairly benign wave climate, with average significant wave heights (Hs) being around 20 cm, dominated by a majority of wind swell events (i.e. Peak Period Tp <8 sec). Most waves enter the site from a south-south-east (SSE) direction (D_p). The largest recorded waves at the AWAC site can be seen to occur during the periods of highest wind speed; i.e. 12th and 21st February (Figure 12).

Processed NOAA WWIII wind and wave data for February to March 2016, concurrent to the metocean deployment, can be seen in Figure 13.

Table 3: Deployment Averaged (54 days) Wave Statistics recorded at the Tanatola Bay AWAC location; 30th Jan – 24th Mar 2016.

Parameter	Statistic	Deployment Average (54 days)
Hs (m)	Average	0.20
	20%ile	0.13
	90%ile	0.32
	Max	0.62
Tp (s)	Average	8.4
	% of Time Sea (Tp<8s)	53%
	% of Time Swell (Tp>8s)	47%
Weighted Dp (°N)	Weighted Average	158
	St Dev (σ)	20

Two events of increased wave heights at the AWAC site were identified which occurred during the periods of highest wind speed; 12th and 21st February (Figure 12).

The largest waves at the NOAA site are seen to occur on the 12th February (0.6 m), coinciding with a strong NW wind (approx. 9.5 m/s). Whereas the highest waves at the AWAC site are seen to occur on the 21st February, coinciding with a more westerly wind (approx. 9 m/s). The difference in height is due to the protection afforded the Tanatola Bay site by the headland to the south causing NW waves to refract (and dissipate energy) more than westerly-inclined swells. These large wave events are seen to have little effect on the magnitude of the depth-averaged currents recorded at the Tanatola Bay AWAC site (see Section 3.4).

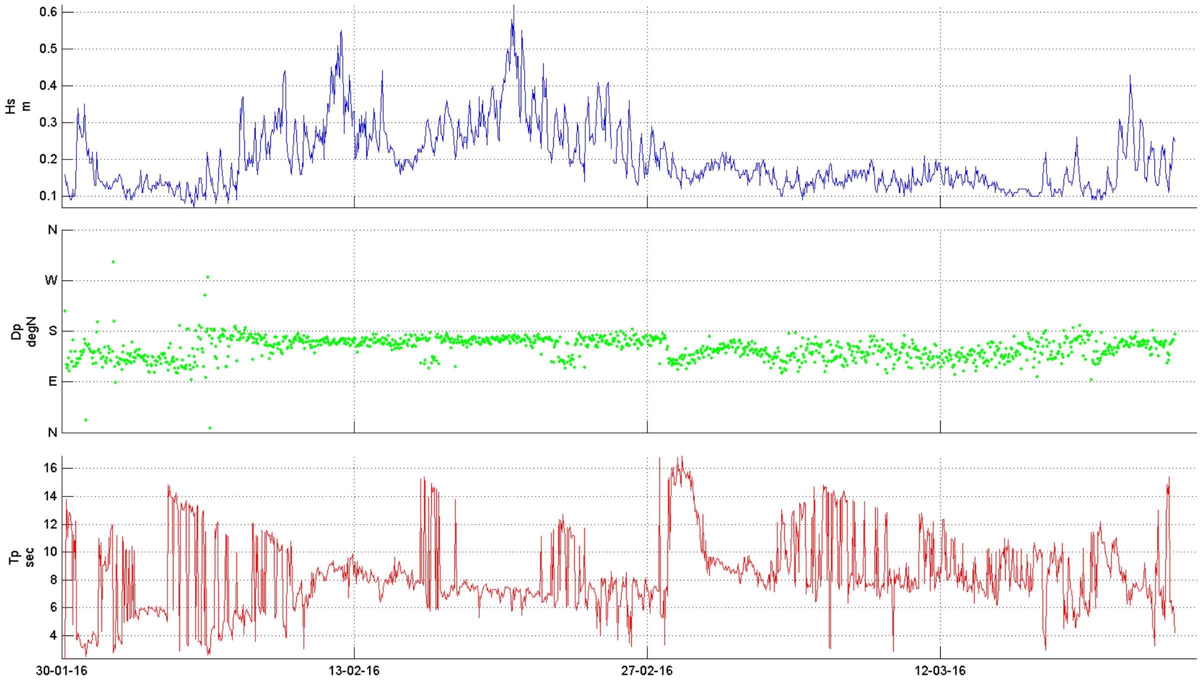


Figure 12: Tanatola Bay AWAC processed waves wet season deployment 2016; (top to bottom) Significant wave height, peak wave direction, peak wave period.

Figure 13: NOAA WWIII extracted [-8.5°, 159.5°] wind and wave data concurrent to RHDHV wet season deployment in 2016; (top to bottom) Significant Wave Height, Peak Wave Direction, Peak Wave Period, Wind Speed, Wind Direction.

3.4 Currents and Water Level

The AWAC deployed at Tanatola Bay recorded directional currents through the water column at 1 m intervals. Depth-averaged as well as near bed, mid-water column and surface current statistics for the 54-day deployment period are provided in Table 4. The profile distribution of currents were also analysed to determine if 3D flow occurred through the water column at the study site (e.g. during wind driven circulation events). Deployment averaged (54 days) currents through the water column can be seen in Figure 14.

Thousand Ship Bay is known as a micro-tidal environment with a spring tidal range of less than 1.5 m. The tidal signal is semi-diurnal meaning there is on average two high and two low tides per day.

The correlation between current magnitude and surface elevation (tide) is evident in Figure 15. It can be safely assumed that the main drivers of current during this deployment period are tide and wind, with waves having a much smaller influence at this location and depth.

Table 4: Depth-averaged and near bed, mid-water column and surface current magnitude statistics recorded at the Tanatola Bay AWAC location; 30th Jan – 24th Mar 2016.

Parameter	Statistic	Depth-averaged Deployment Average (54 days)	Bin1 (bed) Deployment Average (54 days)	Bin6 (mid) Deployment Average (54 days)	Bin 11 (surface) Deployment Average (54 days)
Current Magnitude (m/s)	Average	0.05	0.06	0.07	0.07
	20%ile	0.02	0.03	0.03	0.03
	90%ile	0.09	0.11	0.12	0.13
	Max	0.26	0.31	0.32	0.31

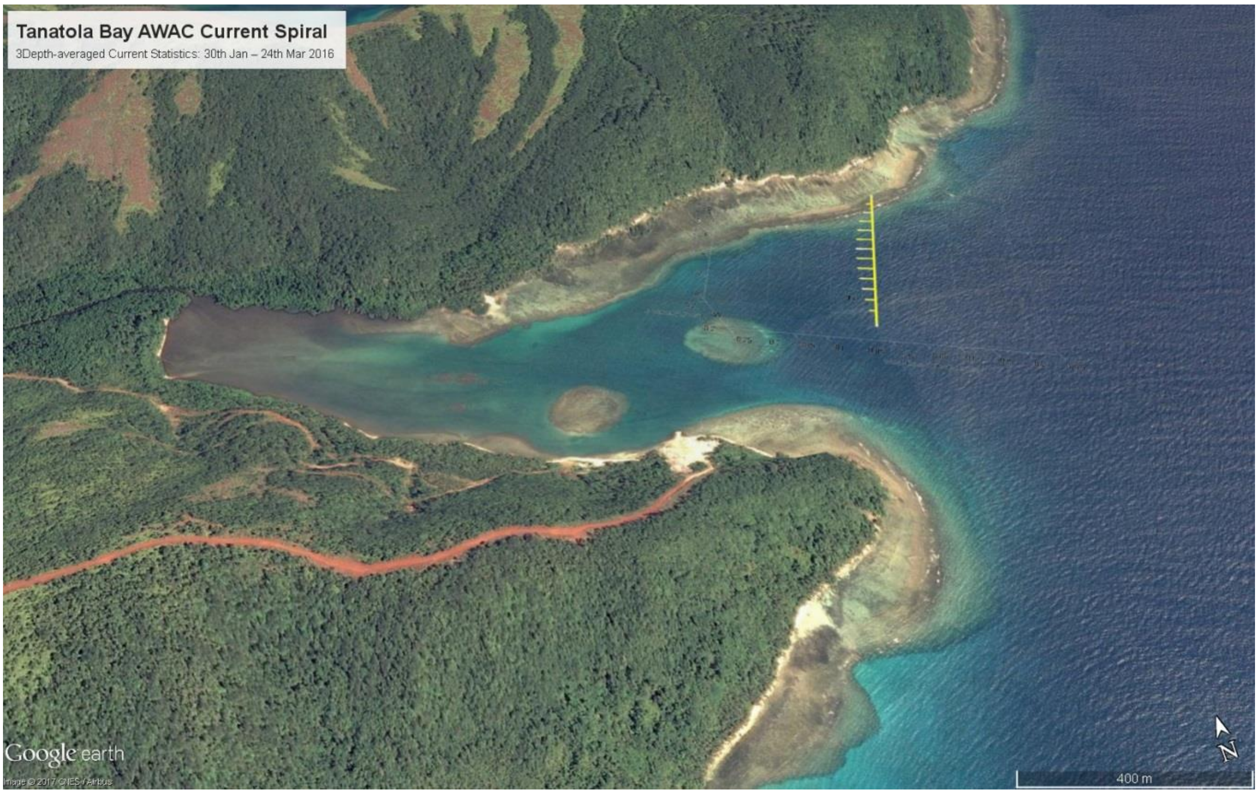


Figure 14: Deployment averaged net residual currents at each 1m 'bin' recorded at the Tanatola Bay AWAC location; 30th Jan – 24th Mar 2016.

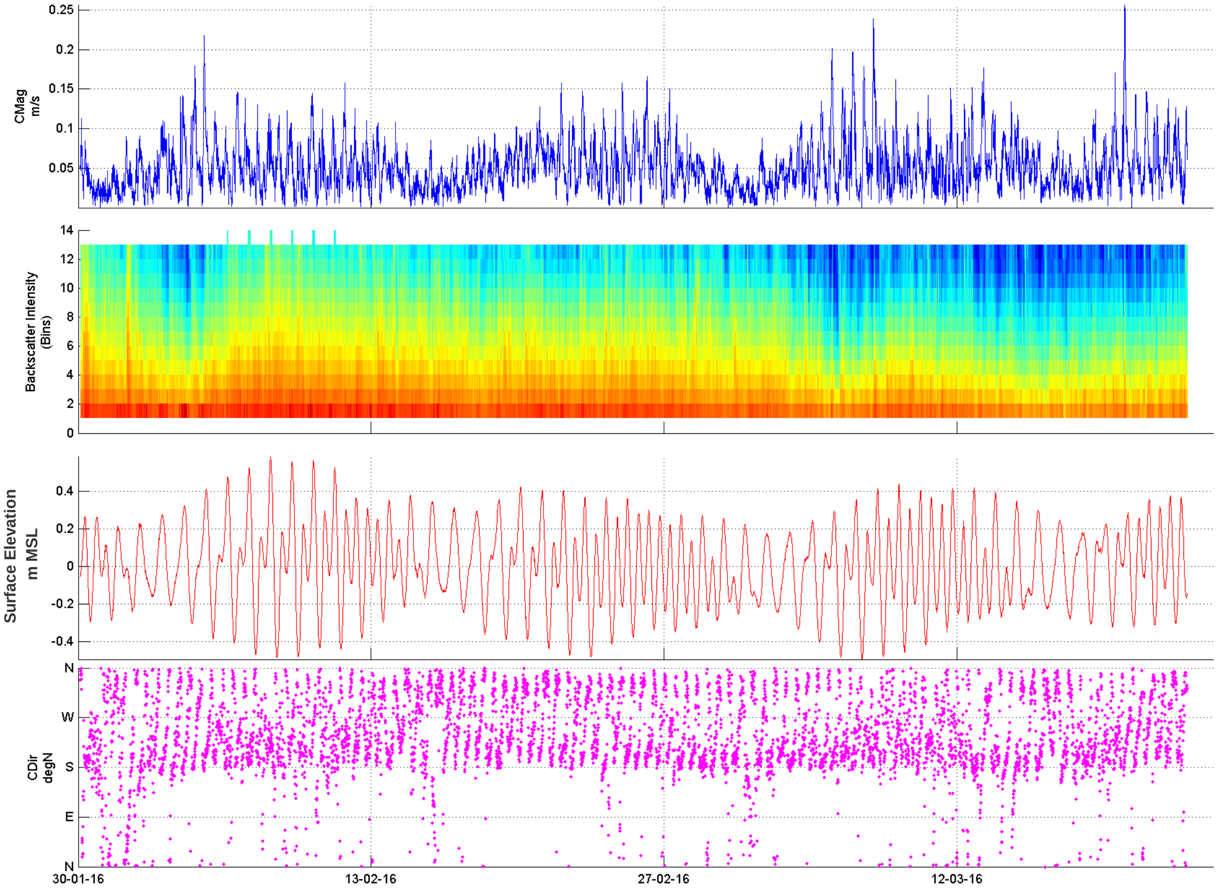


Figure 15: Tanatola Bay AWAC processed currents, wet season deployment 2016; (top to bottom) depth-averaged current speed, acoustic backscatter intensity, surface elevation, depth-averaged current direction.

One of the highest peaks in depth-averaged current speed can be seen to occur around 5th February (see Figure 15) peaking at approximately 0.22 m/s over a 3 hour duration. The 3D flow profile of this event can be seen Figure 16. The analysis of this high event as well as the longer term statistics presented above show that average current magnitudes throughout the water column are fairly small (0.06 - 0.07 m/s) and that the net flow shows a general trend flowing into Tanatola Bay (~220°). This is an important trend to understand in terms of deposition of sediment loads that may be entering the wider Thousand Ships Bay via Tanatola Bay during runoff events.

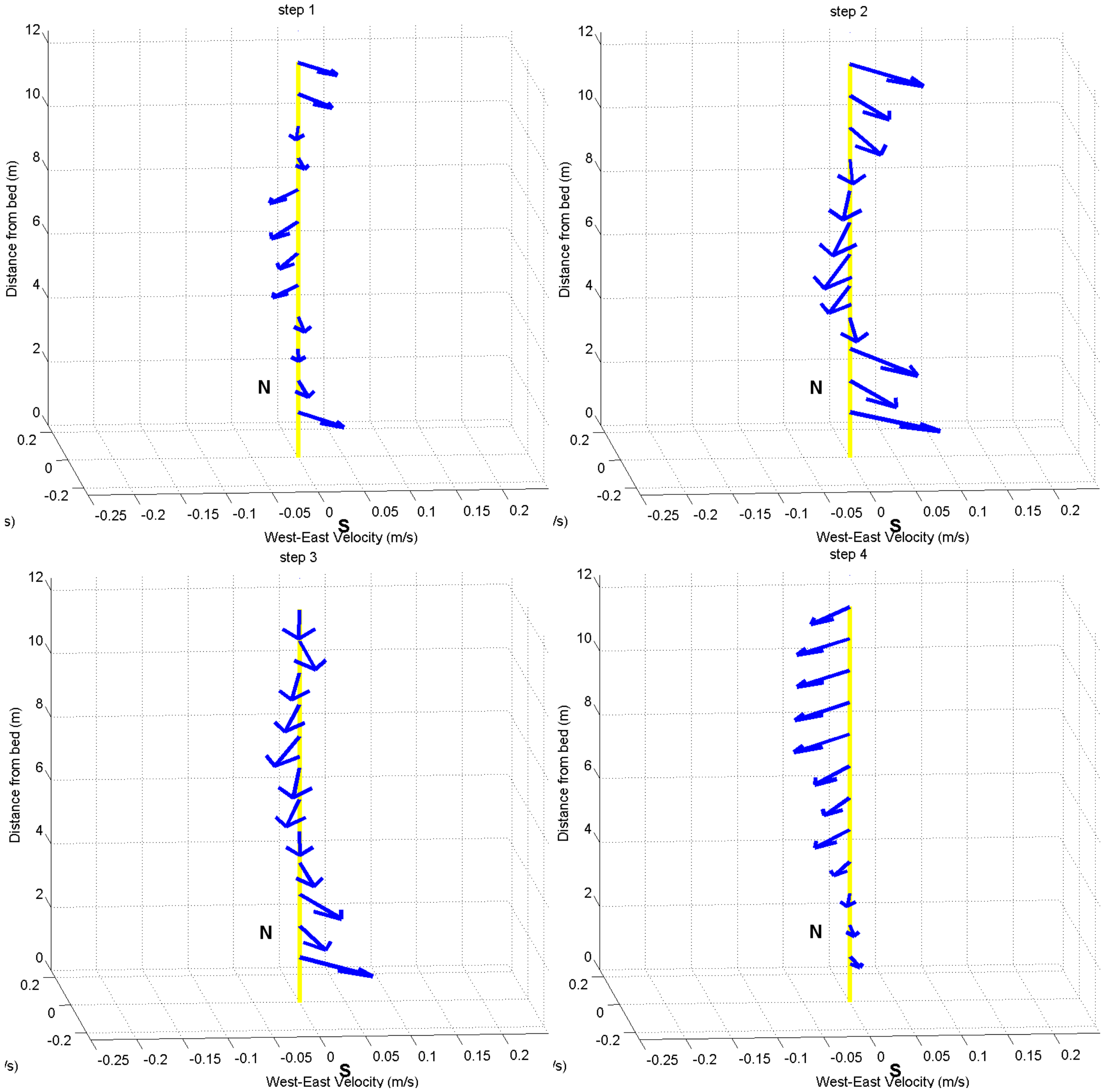


Figure 16: Current profile during high current event at Tanatola Bay AWAC, 5th Feb, 2016.

3.5 Turbidity

Turbidity data was only recovered from the Hughu1 site, this data is shown in Figure 17. It can be seen that periods of increased turbidity occur regularly and are likely linked to surface water runoff events. Increased turbidity events were short-lived and typically ranged between 50 to 170 NTU.

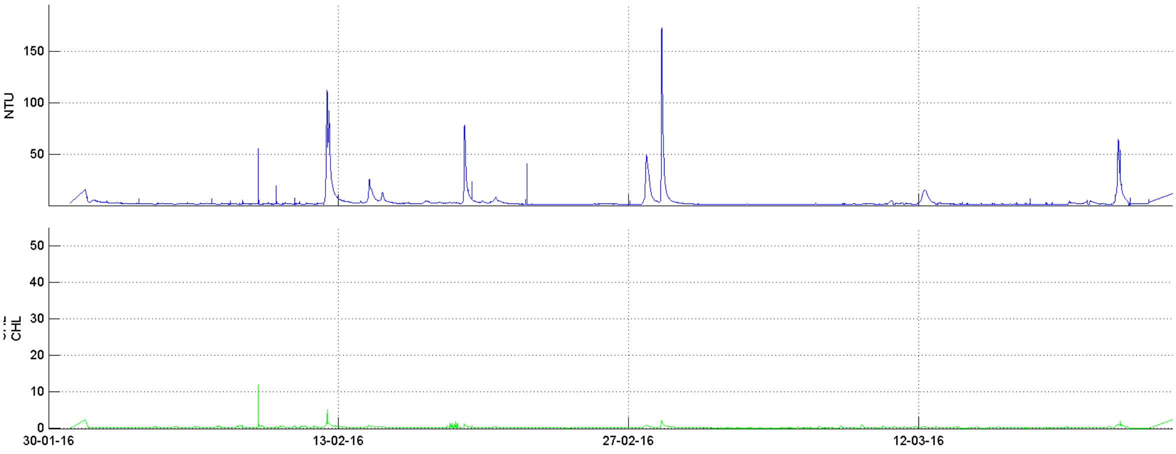


Figure 17: Hughu Creek FLNTUs processed data wet season deployment 2016; (top to bottom) NTU, CHL.

Royal HaskoningDHV

4 Numerical Modelling Systems

4.1 Model Description

The MIKE 21 software package has been adopted for use in this study. MIKE 21 is a numerical modelling suite that simulates flows, waves, sediment transport and ecology in rivers, lakes, estuaries, bays, coastal areas and seas in two dimensions. MIKE is developed by the Danish Hydraulic Institute (DHI).

The Flexible Mesh (FM) version of MIKE 21 has been adopted as it allows the spatial resolution of the computational grid to be locally increased in areas of interest, i.e. at the project site, while the resolution in other areas can be coarser to help maintain acceptable model run times. The spatial discretisation of the equations in MIKE 21 FM is performed using a cell-centred finite volume method.

The MIKE 21 FM Hydrodynamic (HD) and Mud Transport (MT) modules have been used in this study (DHI, 2017a). The HD module system is based on the numerical solution of the two-dimensional shallow water equations - the depth-integrated incompressible Reynolds averaged Navier-Stokes equations. Thus, the model consists of continuity, momentum, temperature, salinity and density equations.

4.2 Modelling Approach

In order to determine the hydrodynamics of the study areas and the wider Thousand Ship Bay, the following numerical modelling methodology has been undertaken;

- **Model establishment**: Hydrodynamic (HD) and mud transport (MT) models of San Jorge Island and receiving waters.
- **Model verification:** Verification of simulated water levels and currents using available (measured and global hindcast) data;
- **Surface water runoff impacts**: Three (3) HD/ST simulations of typical and extreme rainfall (and runoff) events including expected pre/post mining disturbance sediment loading. Both surface water runoff and direct spillage during marine loading impacts are reported in Section 5.
- **Marine loading impacts**: Three (3) HD/MT simulations used to predict impacts from marine loading operations over a 30 day period.

4.3 Model Setup

4.3.1 Bathymetry

The MIKE 21 FM HD domain, computational mesh and interpolated model bathymetry are presented in Figure 18 and Figure 19. The model extent has been determined by a number of sensitivity tests in order to create efficiency with run-time, bathymetric representation and extent. The bathymetric data was sourced from a combination of digitised nautical charts and the January 2016 single beam echo sounding (SBES) survey undertaken by RHDHV during deployment operations. It is noted that this bathymetrical description is relatively coarse.

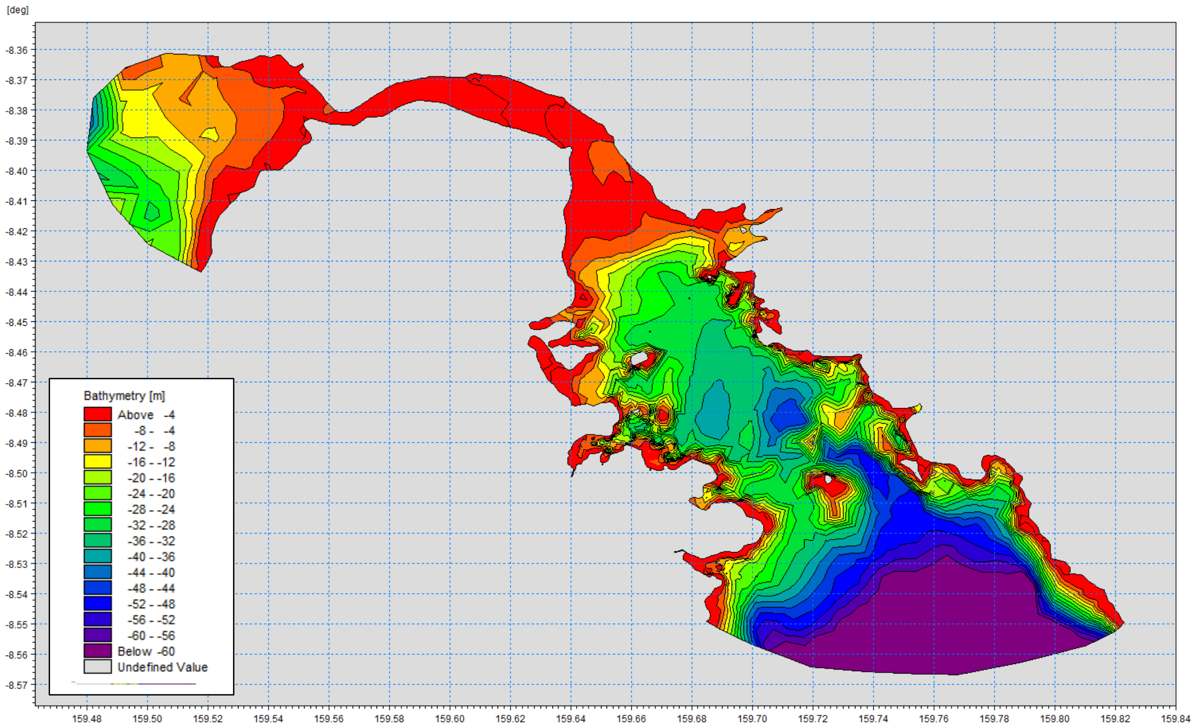


Figure 18: Numerical model domain and interpolated bathymetry.

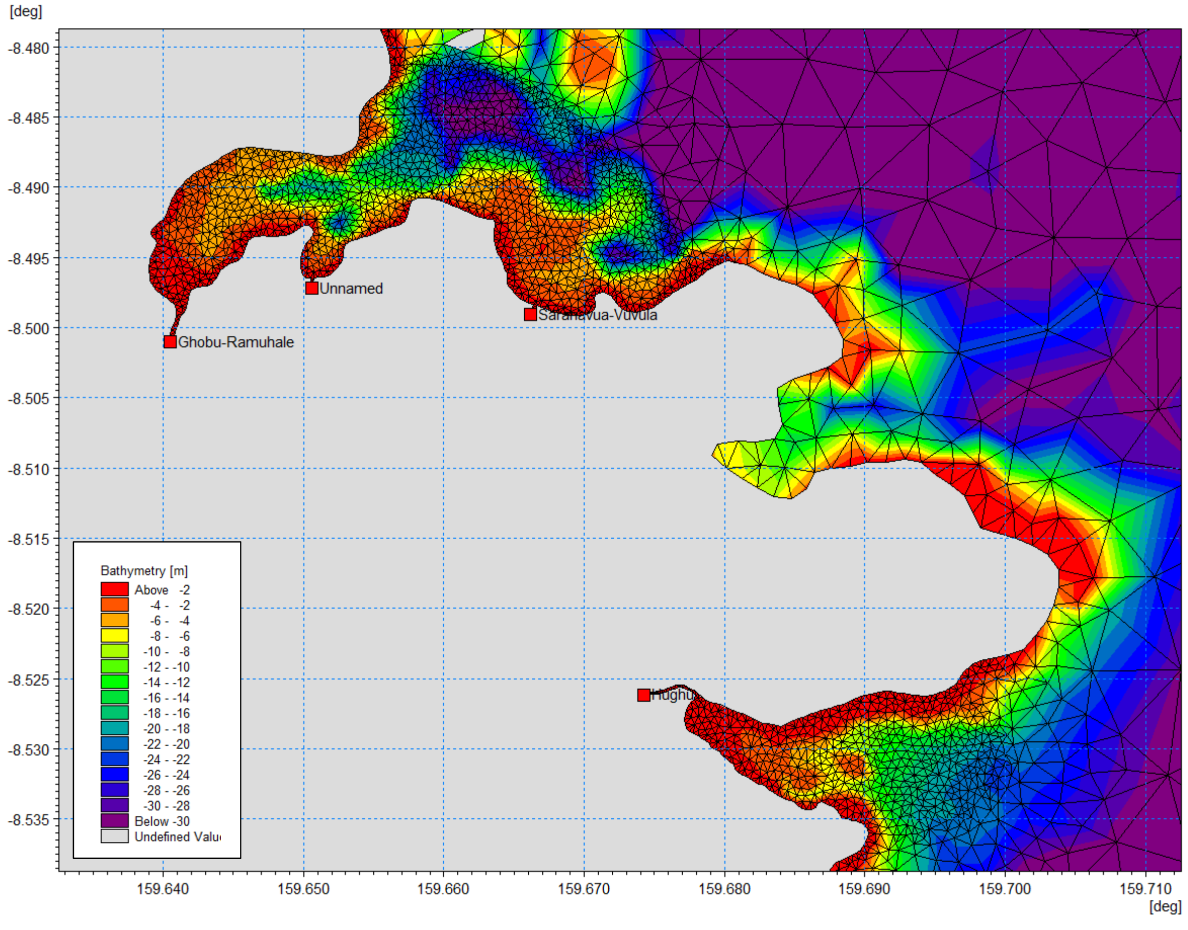


Figure 19: Close up of San Jorge model domain, unstructured mesh, interpolated bathymetry and hydrodynamic source locations.

Hydraulic roughness was varied spatially throughout the domain with depth and composition, as seen in Figure 20.

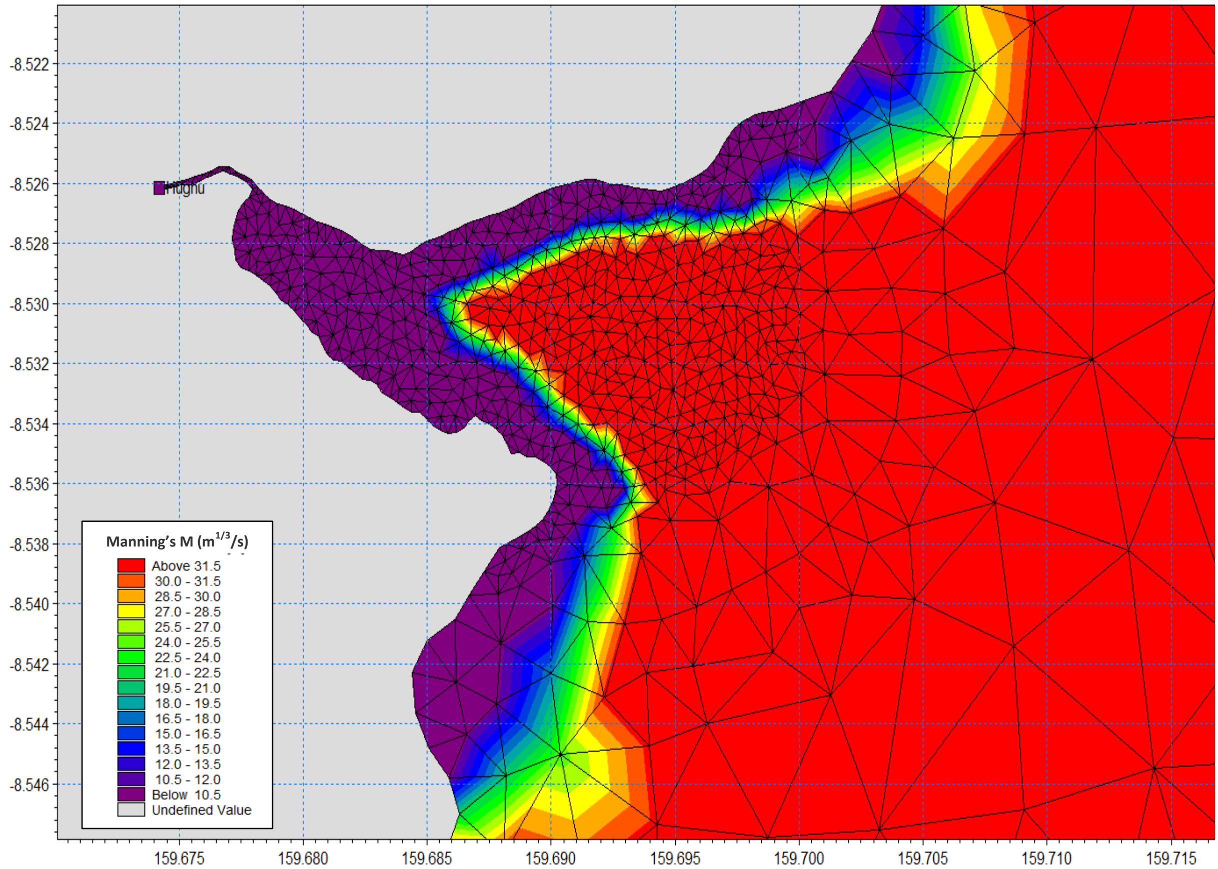


Figure 20: Spatially varying hydraulic roughness (Manning's M) around the Hughu hydraulic source point.

4.3.2 Sediment Parameters

Based on preliminary field observations it was considered that GHOBU1 had the most representative soil characteristics of the available sediment data for the marine assessment of the Project. It can be seen from Figure 6 (Section 2.5) that approximately 50% composition of the sediment collected at GHOBU1 is larger than 0.6 - 1.18 mm (Coarse Sand), this correlated well to the hydrometer tests of the top soil taken at Santa Isabel (Figure 5) which showed a 50% breakdown of particles <0.6 mm and those greater than that size.

In order to calculate approximate settling velocities for modelling purposes, appropriate D_{50} values were assumed by the breakdown of the PSD lithology for each sediment fraction used in the model.

4.3.3 Boundary Conditions

The model boundaries were placed a sufficient distance offshore from the area of interest in order to sufficiently characterise the hydrodynamics of the project area and to track the full extent of any plumes generated via the hydrodynamic source points. The two offshore boundaries are located in deep water (>50 m depth) to the north-west of the entrance to Thousand Ships Bay and along its southern opening. A varying (along boundary and in time) water level boundary condition was placed along the length of each model boundary based on predictions from DHI's Global Tide model (DHI, 2017b). The deep water

Royal HaskoningDHV

location of the tidal boundary ensured generation of the varying water level was not impacted by gradients in bathymetry.
Due to the lack of spatially varying wind data, wind was only varied in time across the domain, with no spatial variation.

Hydrodynamic sources were placed at the entrance of four major creeks of the catchments in the study area (as shown in Figure 19). The source discharge at each location was calculated based on extreme and typical rainfall events over each catchment area, using the following formula (provided by EMM):

$$\text{Discharge } (m^3/s) = \text{Catchment Area } (m^2) \times \text{Rainfall } (m/s) \times \text{Runoff coefficient } (Cv)^*$$

**Cv = 0.5 for typical rainfall event and Cv = 0.8 for extreme rainfall event*

4.4 Model Verification

Model verification was undertaken over two stages; initially water levels were calibrated at the AWAC location in Tanatola Bay to confirm the models capability of simulating the transformation of the tidal wave from the boundaries followed by a comparison of simulated and measured depth-averaged currents.

The model was seen to represent tidal variation accurately over both spring and neap tidal periods at the AWAC location, as seen in Figure 21. Any discrepancies between modelled and measured can be attributed to localised atmospheric effects and the higher recording frequency of the AWAC compared to the model time step. The agreement between modelled and measured is considered suitable for the purposes of this high-level investigation.

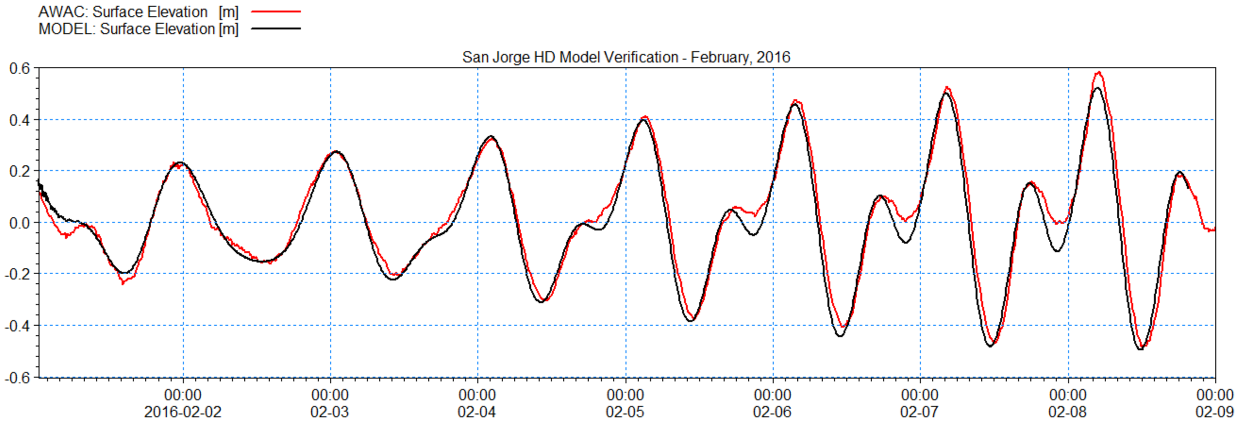


Figure 21: San Jorge HD model surface elevation verification at the Tanatola Bay AWAC location.

As described in Section 3.4, the general current patterns occurring at the deployment location are predominantly tidally-driven. Highest current speeds occurred on the highest recorded tides and as such the verification period was chosen during the highest spring tide of the deployment period, occurring on 8th February, 2016. A plot showing modelled and measured current speed and direction at the Tanatola Bay AWAC location can be seen in Figure 22. The magnitude of the current speeds simulated in the model are within acceptable limits for verification as is the general pattern of the change in current direction and phasing of these changes.

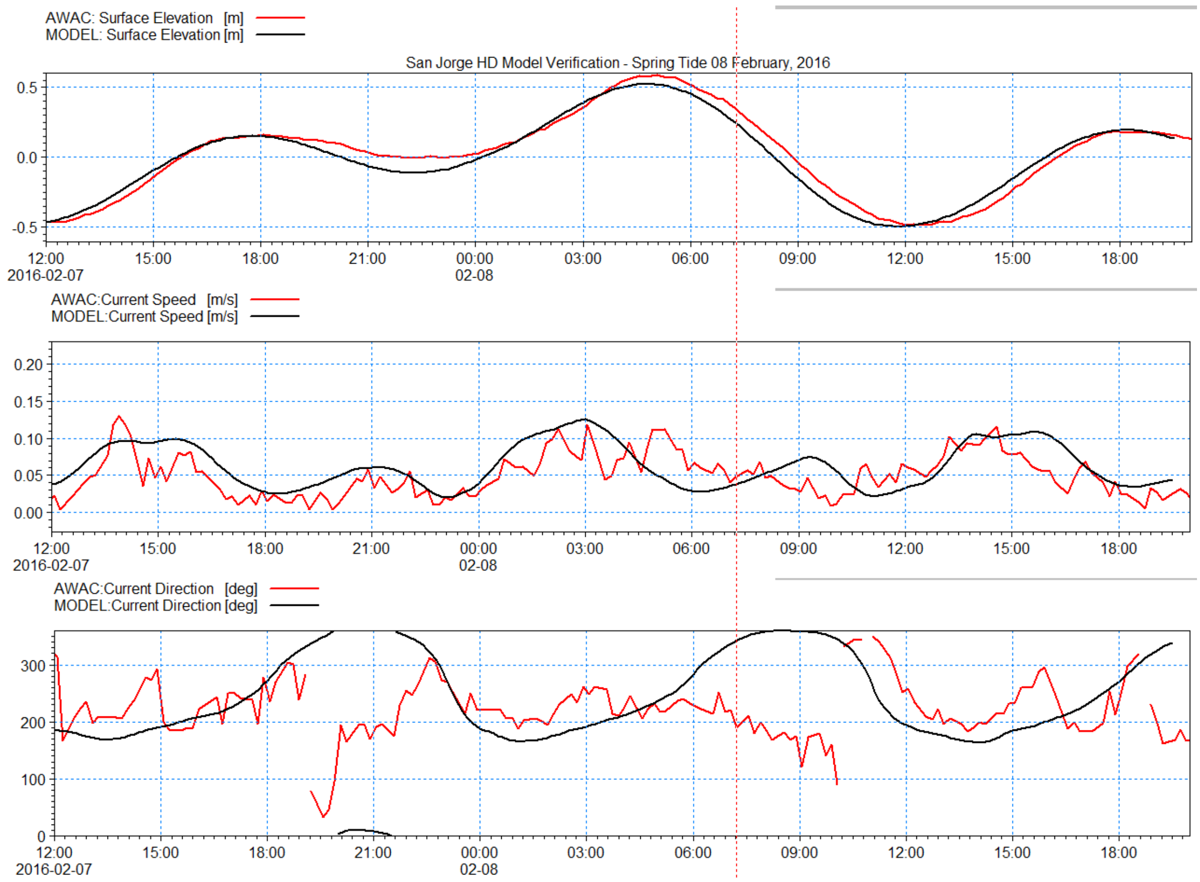


Figure 22: San Jorge HD model surface elevation, depth-averaged current speed and direction verification at the Tanatola Bay AWAC location.

4.5 Modelling Limitations

The following limitations have been identified in the modelling approach based upon insufficient data available at the time of the study. All assumptions have been made based upon empirical or similar evidence based assessments;

- Introduced in Section 3.4, micro-tidal environments tend to have low tidally-driven currents and hence a thorough understanding of current drivers is paramount to understanding net circulation. Due to the lack of spatially diverse current data, it is difficult to describe drivers throughout the model domain.

- Due to the topography of the project site, determining localised winds is essential in understanding the hydrodynamics of these bays. Long-term, concurrent, localised wind data was not available for the catchments or waterway areas of the study site; as such assumptions were made during the modelling phase about the spatial variability of the wind field from the available data.

- The bathymetry data is relatively coarse for conducing detailed hydrodynamic modelling.

- Assumptions were required to estimate the freshwater flow into the study area from the modelled creeks as no suitable measured data was available.

- No suitable data (e.g. turbidity measurements) were available to fully validate the sediment transport model in the receiving waters. As a preliminary verification, a comparison of model results to aerial imagery during periods of increased turbidity in the study area was undertaken.

Royal HaskoningDHV

5 Impacts on Receiving Waters

Mining activities are predicted to increase the sediment loads entering the marine environment due to both surface water runoff and by direct spillage of material during loading operations. To predict the potential mining impacts on the water quality of the receiving waters the numerical modelling tools described in Section 4 have been used. For each impact type the numerical models will be used to predict the advection, dispersion and deposition of sediment discharged into the marine environment.

5.1 Surface Water Runoff Impacts

In order to assess the impacts of increased sediment load due to the development of San Jorge catchments, three (3) coupled hydrodynamic and sediment transport simulations were setup to reproduce a range of typical wet season metocean conditions for pre and post mining development. Hypothesized hydraulic source terms (discharges) at each of the four selected catchments for both typical and extreme rainfall events were adopted based on information provided by EMM. The following surface water runoff scenarios have been included in the numerical modelling:

- **Scenario 1: Typical Rainfall Event, Undisturbed Catchment:**
  - 85th percentile 5 day runoff (rainfall) event: 120 mm over 5 days
  - 50th percentile wet season wind condition: 1.5 m/s from the NW
  - Spring Tide (7-days)
  - Undisturbed Total Suspended Sediment (TSS) concentration at each hydraulic discharge location.
- **Scenario 2: Extreme Rainfall Event, Undisturbed Catchment:**
  - 99th percentile 5 day runoff (rainfall) event: 250 mm over 5 days
  - 99th percentile wet season wind condition: 11 m/s from the WNW
  - Spring tide (7-days)
  - Undisturbed TSS concentration at each hydraulic discharge location.
- **Scenario 3: Extreme Rainfall Event, Disturbed Catchment:**
  - 99th percentile 5 day runoff (rainfall) event: 250 mm over 5 days
  - 99th percentile wet season wind condition: 11 m/s from the WNW
  - Spring Tide (7day event)
  - Disturbed TSS concentration at each hydraulic discharge location.

The derivation of the parameters used in each of the surface water runoff scenarios is described below.

5.1.1 Source Terms

For each simulation, hydraulic source terms were calculated by first utilising the measured rainfall data (at Kolosori Ridge) to determine an appropriate time series for both ‘Typical’ and ‘Extreme’ rainfall events. A 5-day event window was found where accumulated totals equated to 120 mm and 250 mm, as seen in Figure 23.

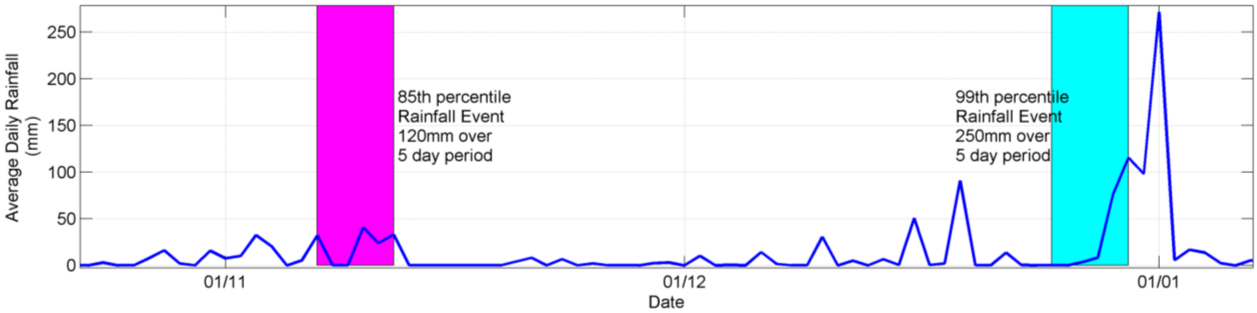


Figure 23: 2015-2016 Kolosori Ridge average daily rainfall data. The magenta window represents an 85th percentile rainfall event of 120 mm over 5 days. The cyan window represents a 99th percentile rainfall event of 250 mm over 5 days.

Following the selection of each rainfall time series, the discharge formula (detailed in Section 4.3 was used to calculate a subsequent hydraulic flow time series for each catchment source point in the model. U- and V- velocity components were also calculated for each source point based upon approximations of channel area from the field investigations, detailed in Figure 24.

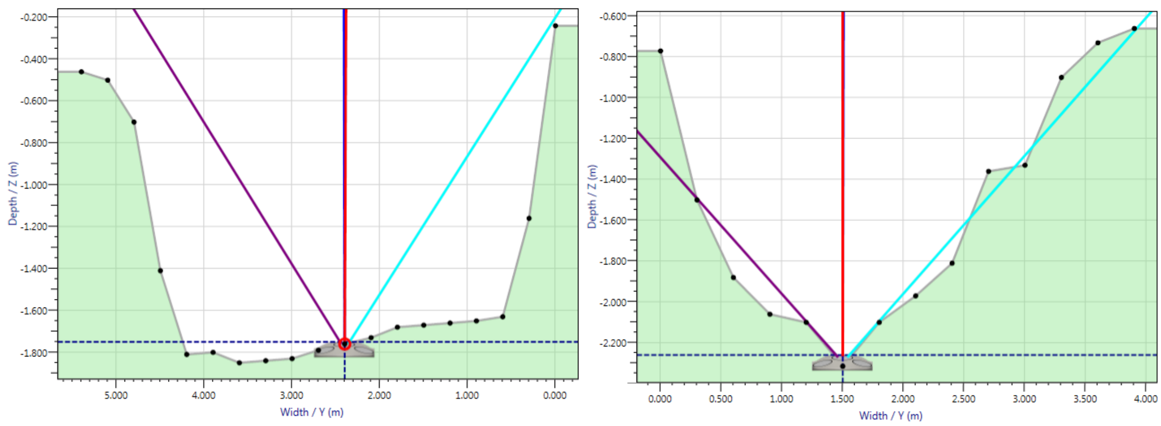


Figure 24: Measured stream cross-section at Hughu (left) and Ghobu (right).

The calculations for the hydraulic source terms were completed utilising information provided by EMM (EMM per comms., Oct. 17) relating to disturbed and undisturbed catchments and typical and extreme total suspended sediment (TSS) concentrations to be expected in each catchment. Table 5 details the fluvial and sediment source terms adopted for the surface water runoff simulations.

Table 5: Fluvial and sediment load source terms for the surface water runoff simulations.

HD/MT Source	Undisturbed Catchment Area (ha)	Disturbed Catchment Area (ha)	Scenario 1 TSS (mg/l)	Scenario 2 TSS (mg/l)	Scenario 3 TSS (mg/l)
Unnamed (SE08)	148	90	120	850	3,364
Hughu	1,234	290	120	850	1,565
Ghobu - Ramuhale	917	294	120	850	1,740
Saranavua (SE07)	262	124	120	850	2,813

As discussed in Section 2.5 and further in Section 4.3.2, the sediments within the project site appear to be quite inhomogeneous. For the purposes of this study two (2) sediment fractions were selected to represent both fine and coarse particles by varying their settling velocities (Ws). The two velocities were calculated empirically from the literature as:

- Fraction 1: Ws1 = 0.0009 m/s (for sands and larger materials)
- Fraction 2: Ws2 = 0.0001 m/s (for fine silts and clays)

Each particle has been given a 50% split in loading into the model.

5.1.2 Results

The results of each of the three scenarios tested are presented in the following figures, they are presented as maps of the mean and 99th percentile TSS statistics as well as total net deposition (accumulated over the simulation duration). These are:

- Figure 25 shows the results from Scenario 1: Typical Rainfall Event, Undisturbed Catchment
- Figure 26 shows the results from Scenario 2: Extreme Rainfall Event, Undisturbed Catchment
- Figure 27 shows the results from Scenario 3: Extreme Rainfall Event, Disturbed Catchment.

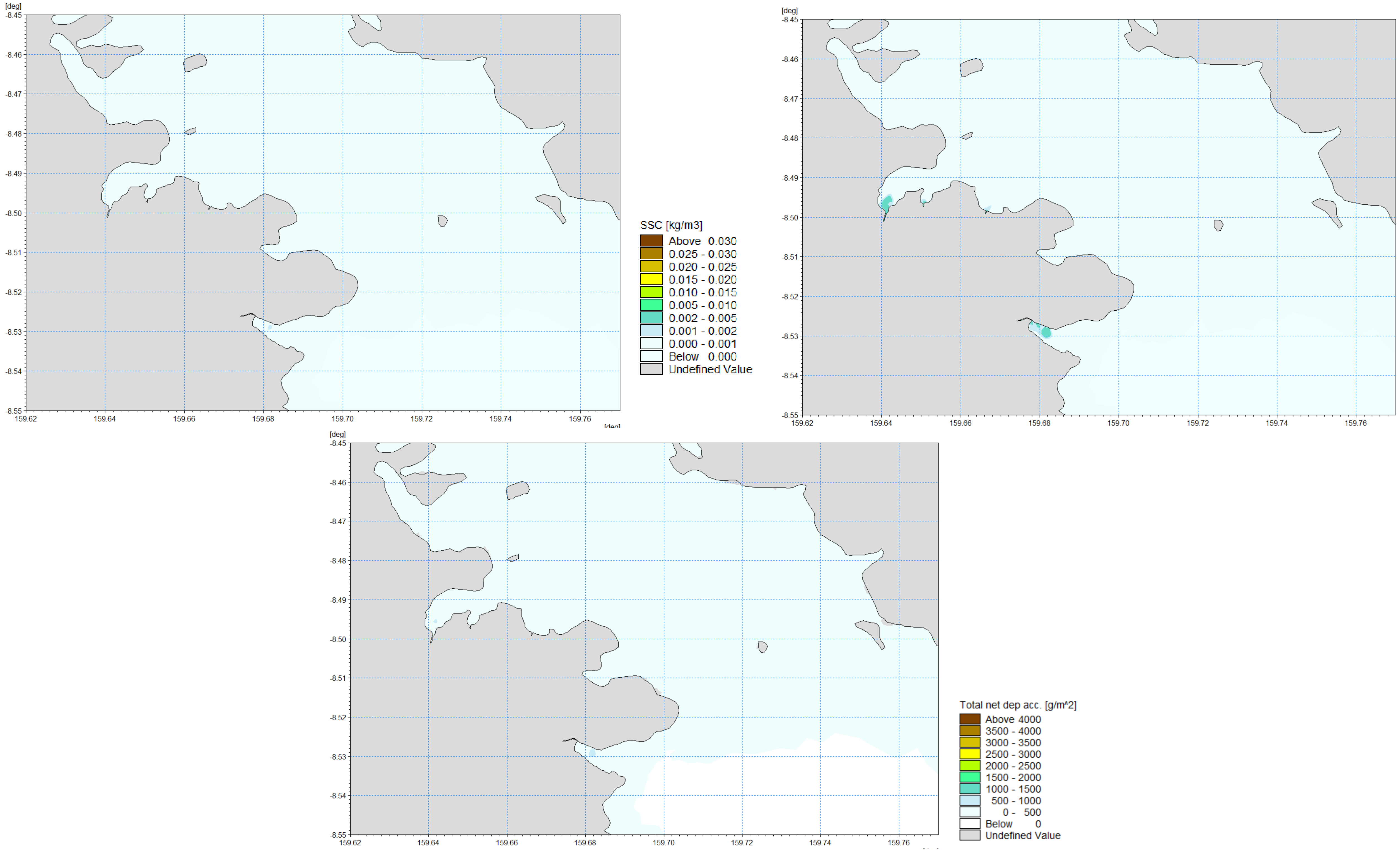


Figure 25: Mean (top left) and 99th percentile (top right) Total Suspended Sediment (TSS) concentration, (bottom) total net accumulated deposition during the Scenario 1 simulation.

Royal HaskoningDHV

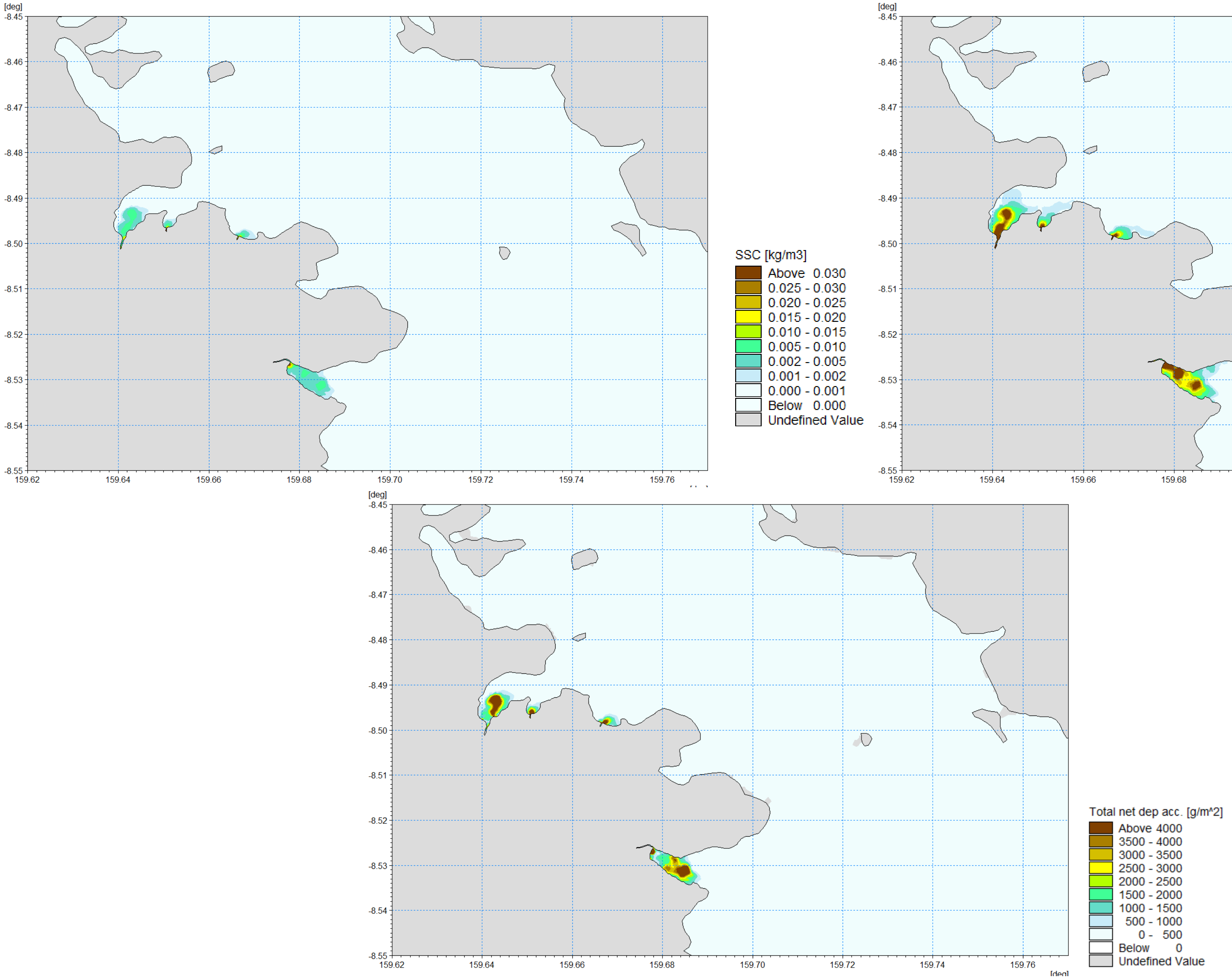


Figure 26: Mean (top left) and 99th percentile (top right) Total Suspended Sediment (TSS) concentration, (bottom) total net accumulated deposition during the Scenario 2 simulation.

Royal HaskoningDHV

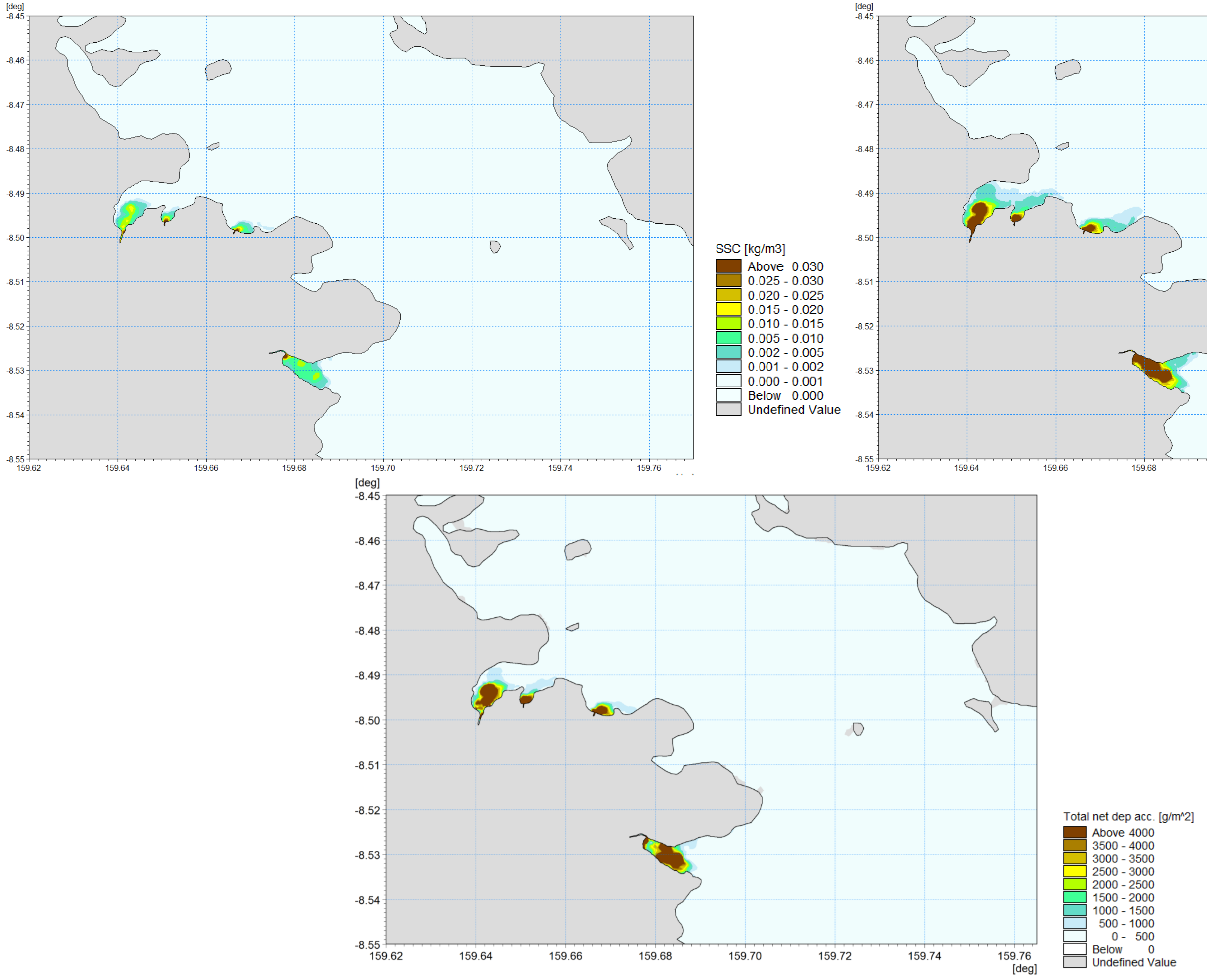


Figure 27: Mean (top left) and 99th percentile (top right) Total Suspended Sediment (TSS) concentration, (bottom) total net accumulated deposition during the Scenario 3 simulation.

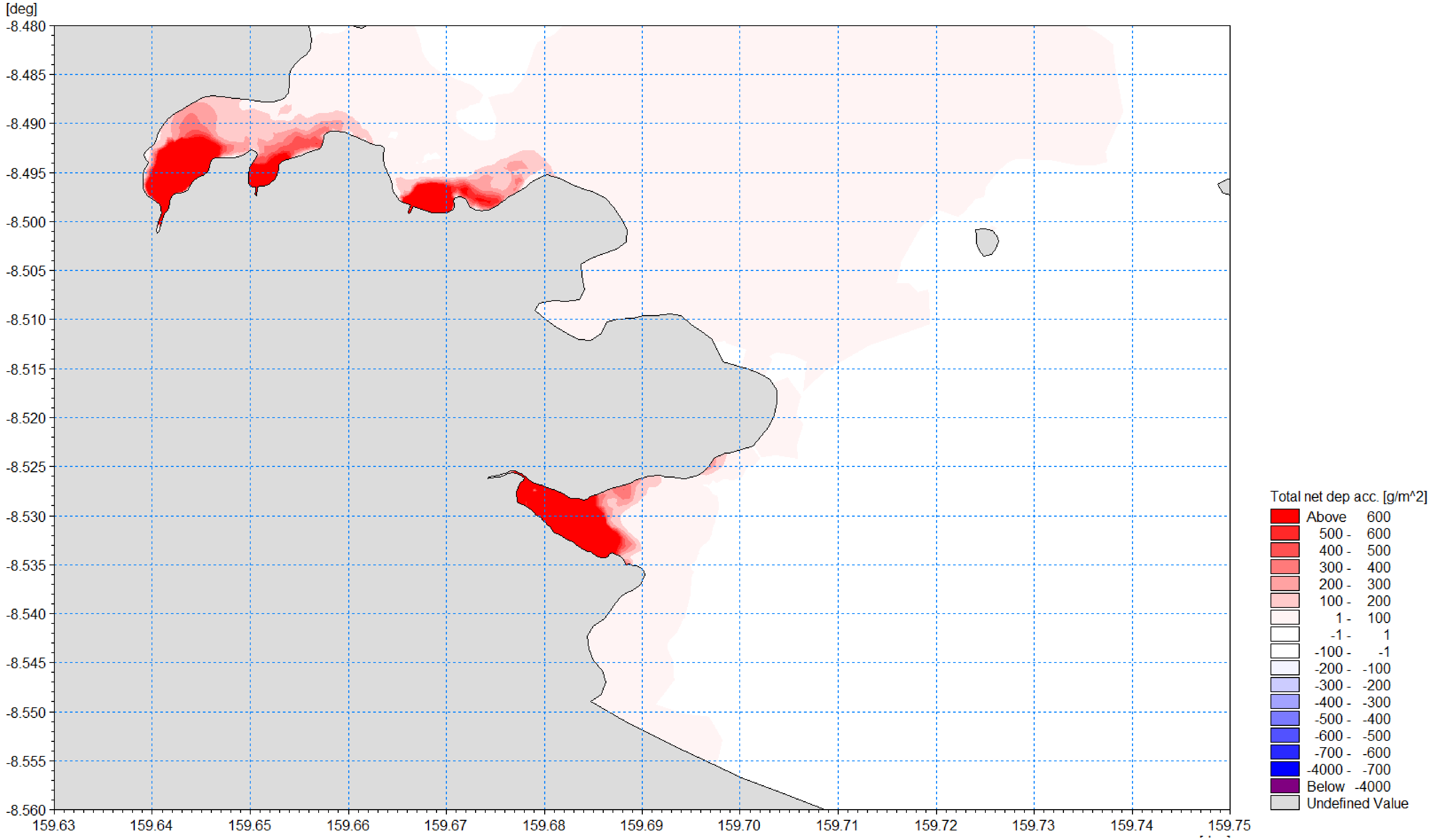


Figure 28: Difference in total net accumulated deposition between (Scenario 3 (disturbed upper catchment, extreme event) and Scenario 2 (undisturbed upper catchment, extreme event)).

5.2 Marine Loading Impacts

In order to assess the impact of direct spillage of ore on the marine receiving waters during marine loading operations, three (3) coupled hydrodynamic and sediment transport simulations were setup to reproduce the sediment dispersion for a range of typical metocean conditions.

While limited information is available on the planned marine loading operations, IMC's (2016) report provides a description of the strategy for the barging and shipping of the ore at the San Jorge mine. Based on this report and information from EMM the following describes the assumptions used in this assessment:

- Ore will be loaded on to barges at a Marine Loading Facility (MLF or 'Port') located in Albatross Bay. Ore will then be transport by the barges and loaded onto to ships which will be moored at a transhipment location in Thousand Ship Bay (see Figure 29).
- Three (3) shipments of ore will be required every month. The ships used to export the ore would be either 55,000 t or 72,000 t vessels.
- Ore will be loaded onto barges using front end loaders or trucks via a RO-RO ramp.The design of the MLF is yet to be completed. No information is provided on the method of transferring the ore from the barges onto the ships. For the purpose of this assessment it has been assumed that this would be done with a crane and grab mounted on the ship.
- IMC's base case assumes that 2 barges would be used, with each barge assumed to have a capacity of 4,000 t. IMC used barge loading cycle times to estimate that when operating 24 hours a day it will take around 4 days to load a 55,000 t ship and around 6 days to load a 72,000 t ship.

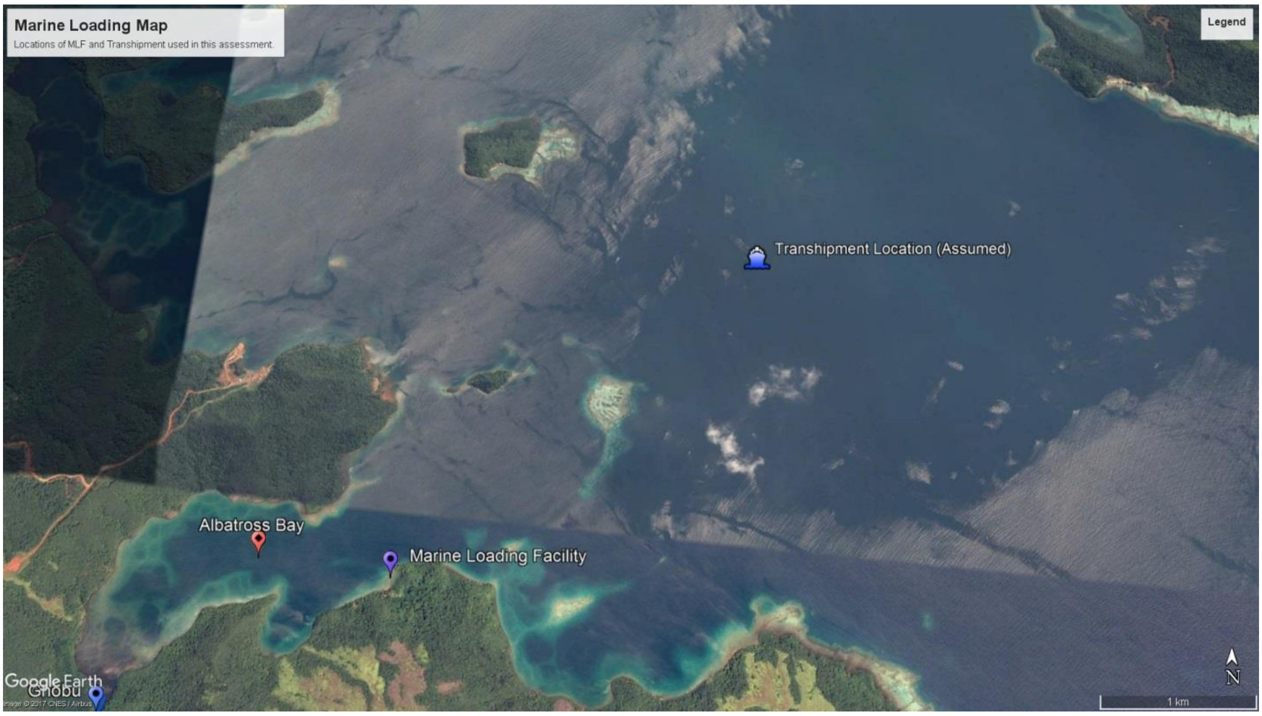


Figure 29: Locations of Marine Loading Facility (MLF) and assumed location of the transhipment mooring.

Using the description of marine loading operations provided in IMC (2016) and the sediment data presented in Section 2.5, three (3) modelling scenarios were developed to represent the typical wet and dry season metocean conditions during the mining operations. It is noted that all direct spillage modelling scenarios were run for a 29-day period that included typical tidal conditions with no surface water runoff. Surface water runoff is not expected to significantly affect circulation at the MLF site or at the transhipment location. Therefore these scenarios examine the impact of the marine loading as being independent of the surface water impacts considered in Section 5.1. The following direct spillage scenarios have been included in the numerical modelling:

- **Scenario 4:** Wet season conditions, with typical direct spillages
  - Typical wet season wind conditions (i.e. W to NW winds) were selected by using winds from the month of February 2016 (wind derived from NOAA global modelled data, see **Section 3.2**).
  - A spill rate of 1% of the loading rates for each of the two barges is assumed at both the MLF and at the transhipment site. This rate is a typical spillage based on the loading description provided by IMC and experience from previous projects.
- **Scenario 5:** Wet season conditions, with high (worst-case) direct spillage
  - Typical wet season wind conditions (as per Scenario 4 above).
  - A spill rate of 2% of the loading rates for each of the two barges is assumed at both the MLF and at the transhipment site. This rate is a conservative worst case scenario based on the loading description provided by IMC and experience from previous projects.
- **Scenario 6:** Dry season conditions, with high (worst-case) direct spillage
  - Typical dry season wind conditions (i.e. ESE trade winds) were selected by using winds from the month of July 2016 (wind forcing is derived from NOAA global modelled data, see Section 3.2).
  - A spill rate of 2% of the loading rates for each of the two barges is assumed at both the MLF and at the transhipment site. This rate is a conservative worst case scenario based on the loading description provided by IMC and experience from previous projects.

The derivation of the parameters used in each of the marine loading (or direct spillage) scenarios are described below.

5.2.1 Model Parameters

The following model parameters were common to all month-long direct spillage scenarios:

- The locations for direct spillage were the MLF (bed level of approximately 5 m below MSL) and transhipment mooring (bed level of approximately 30 m below MSL).
- All ships visiting in the simulated month are assumed to be 72,000 t.

Royal HaskoningDHV

- The composition of the ore is based on the hydrometer PSD undertaken on sediment samples Limonite 2 and Limonite 3 (Golders, 2014). These sediment parameters are provided in Table 6 below.

Table 6: Ore composition based on Golder hydrometer PSD results from Isabel sediment samples.

Parameter	Fraction 1 – Clay (<2µm)	Fraction 2 – Silt (2µm to 60 µm)	Fraction 3 – Fine Sand (60µm to 200 µm)	Fraction 4 – Coarser than find sand (>200) **[NOT MODELLED]**
% by weight of total sample	25%	35%	10%	30%
% by weight of modelled sample	36%	50%	14%	-
Fall velocity	0.5 x 10^{-5} m/s	0.0001m/s	0.0009 m/s	

5.2.2 Results

The results of each of the three Marine Loading Investigation (MLI) scenarios tested are presented in the following figures; they are presented as maps of the mean and 99th percentile TSS statistics as well as total net deposition (accumulated over the simulation duration). These are:

- Figure 25 shows the results from Scenario 4: Wet season conditions, with typical direct spillages
- Figure 26 shows the results from Scenario 5: Wet season conditions, with high (worst-case) direct spillage
- Figure 27 shows the results from Scenario 6: Dry season conditions, with high (worst-case) direct spillage

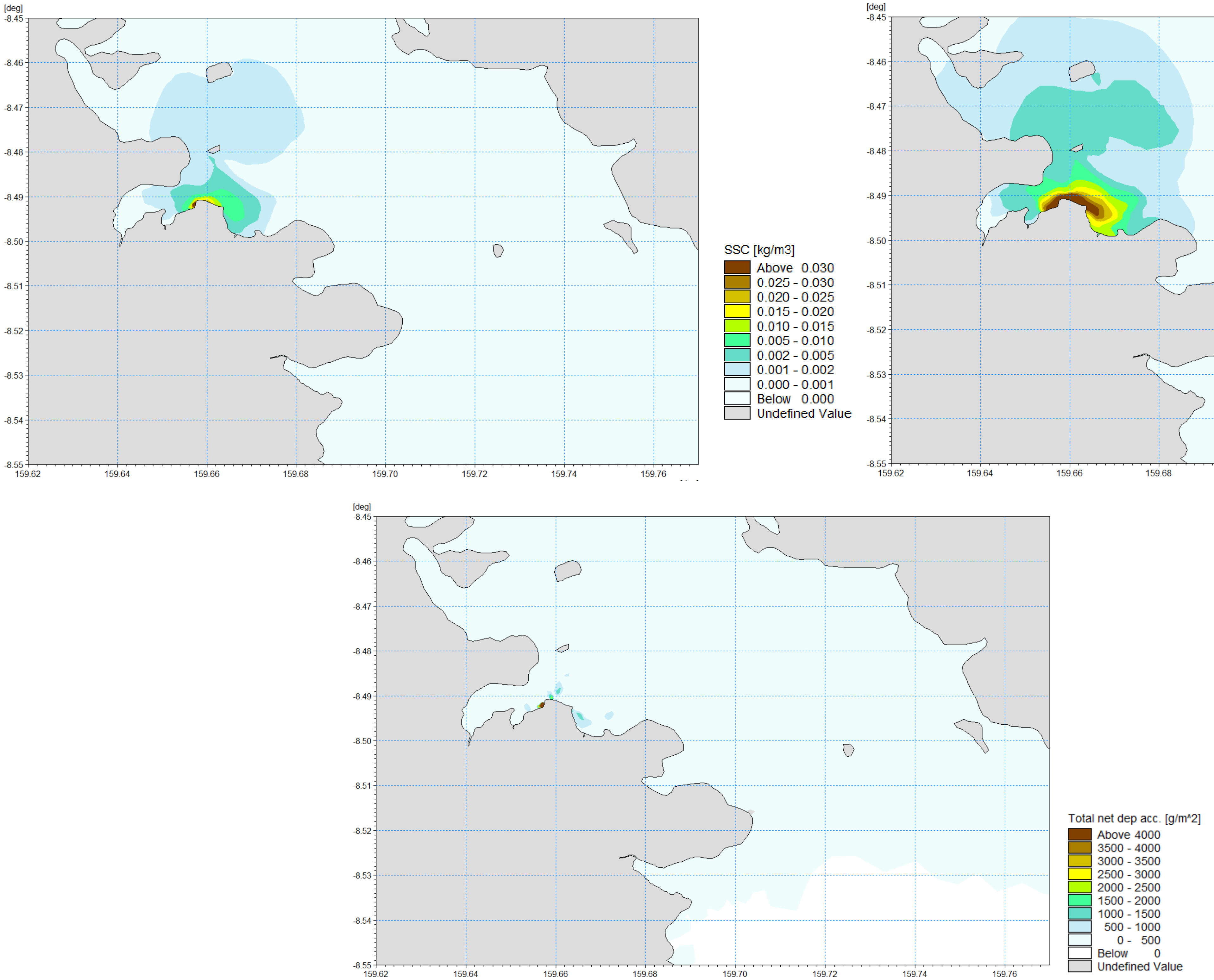


Figure 30: Mean (top left) and 99th percentile (top right) Total Suspended Sediment (TSS) concentration, (bottom) total net accumulated deposition during the Scenario 4 simulation.

Royal HaskoningDHV

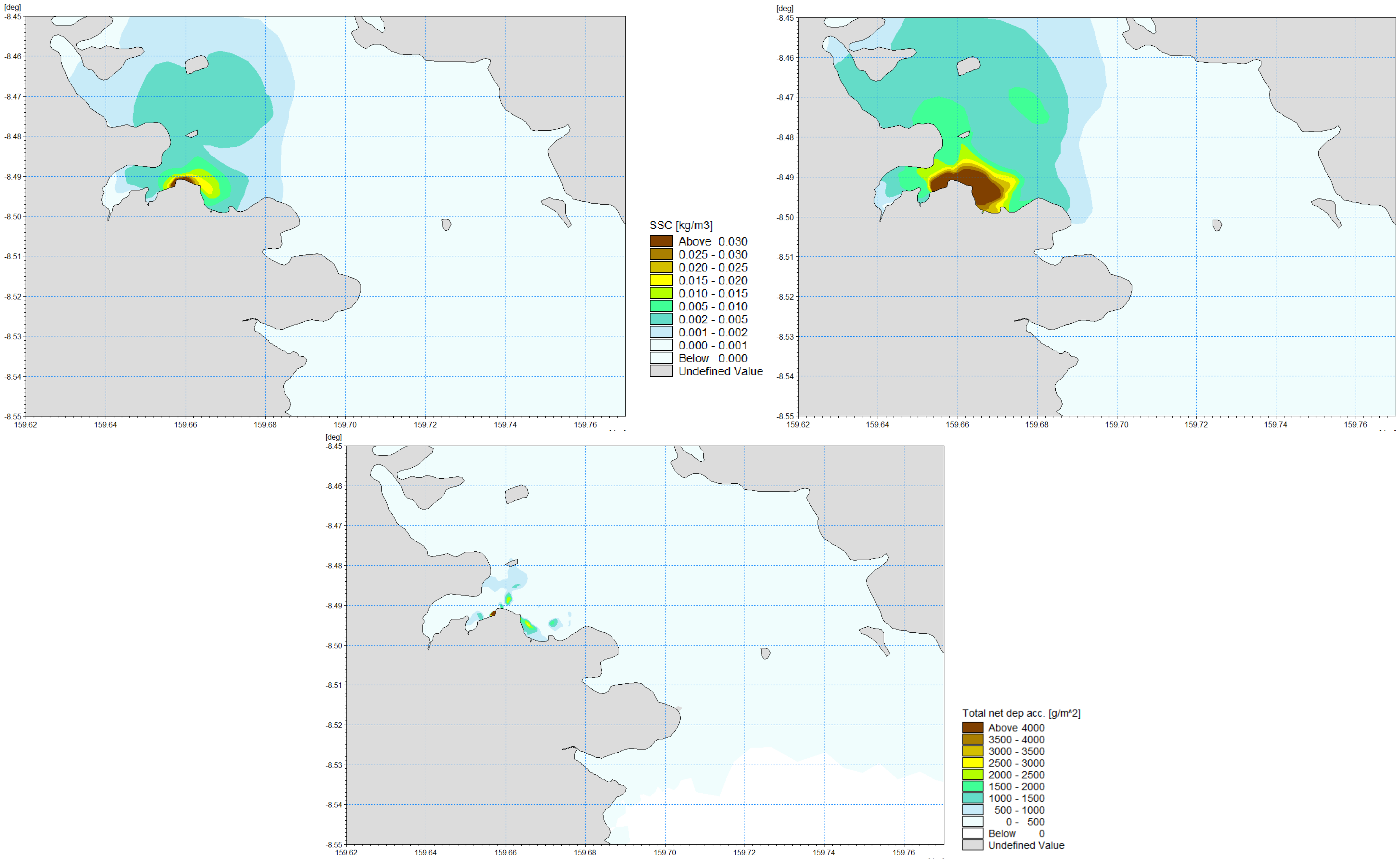


Figure 31: Mean (top left) and 99th percentile (top right) Total Suspended Sediment (TSS) concentration, (bottom) total net accumulated deposition during the Scenario 5 simulation.

Royal HaskoningDHV

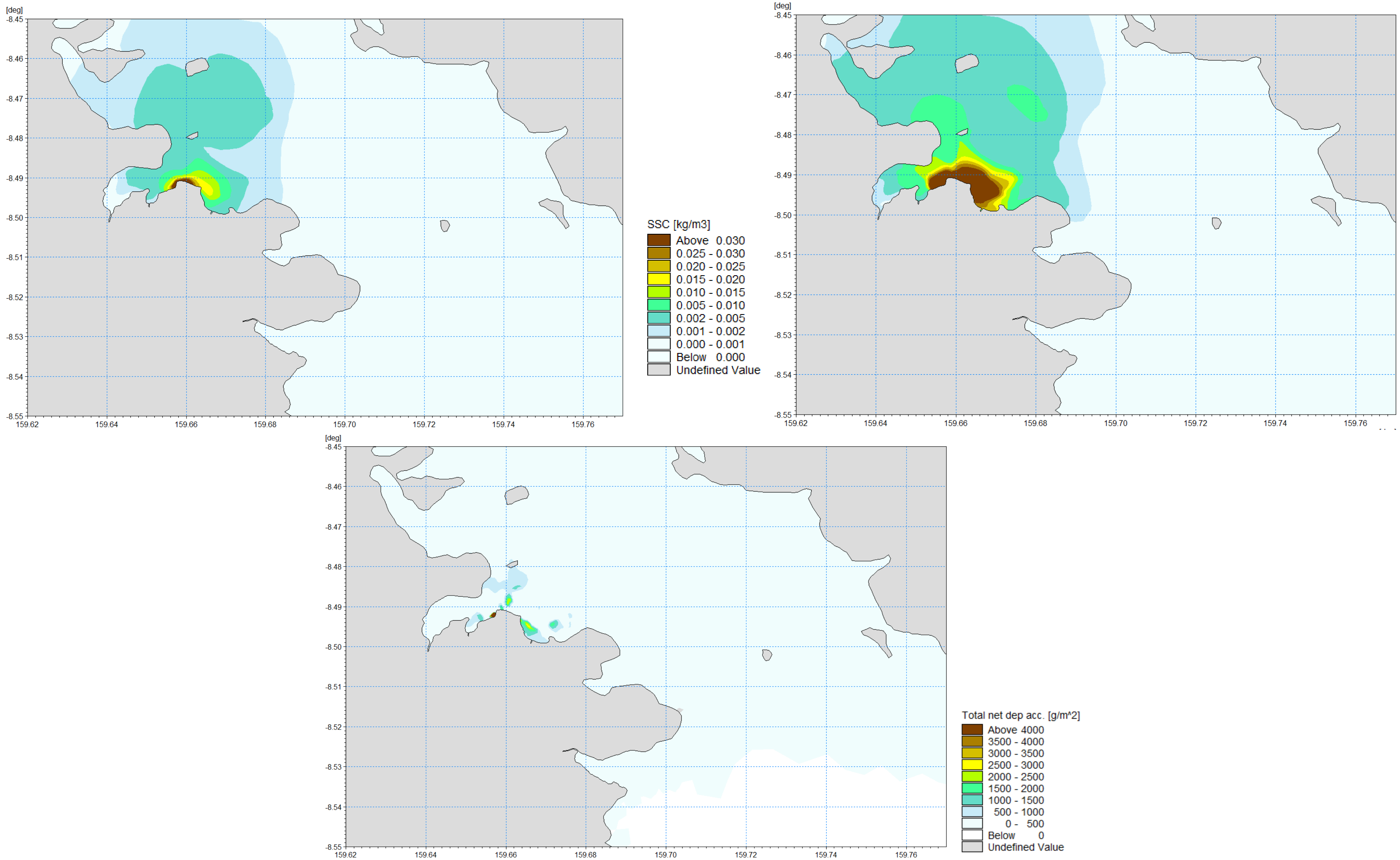


Figure 32: Mean (top left) and 99th percentile (top right) Total Suspended Sediment (TSS) concentration, (bottom) total net accumulated deposition during the Scenario 6 simulation.

6 Discussion and Limitations

6.1 Surface Water Runoff Impacts

The scales for the TSS results plots for scenarios 1 to 6 presented in Section 5 have been set with an upper limit of 30 mg/L. This has been based on the findings of Erftemeijer (2012):

> *"Some individual coral species can tolerate short-term exposure (days) to suspended sediment concentrations as high as1,000 mg/L while others show mortality after exposure (weeks) to concentrations as low as 30 mg/L".*

As the corals found along the shoreline of San Jorge are regularly exposed to high TSS levels due to natural variation in metocean and fluvial conditions, the selection of this colour scale can be considered a conservative one.

Again, following Erftemeijer (2012) the upper limit of the net deposition colour scale in the results plots in Section 5 has been set to 400 mg/cm^2 (or 4,000 g/m^2) based on:

> *"Maximum daily sedimentation rates that can be tolerated by different corals range from <10 mg/cm^2/day to > 400 mg/cm^2/day."*

The deposition plots herein have been produced from week- and month-long simulations and show total deposition rather than a daily rate.

The results of the surface water runoff scenarios (Section 5.1.2) show a general trend of localised increases in total suspended sediment (TSS) and sediment deposition which is predominantly confined to the individual bays where the various creeks discharge. This is because the circulation in these bays is relatively weak (i.e. low current speeds) and the sediment discharged via the creek entrances is able to fall out of suspension before reaching Thousand Ship Bay. This deposition pattern is reaffirmed through Figure 28, which shows the difference in net accumulated sediment deposition between Scenario 3 (disturbed upper catchment, extreme event) and Scenario 2 (undisturbed upper catchment, extreme event). Although there is a significant increase in the amount of sediment entering the marine environment, the deposition is almost entirely confined to each bay at which the discharge location is located. Sensitive environmental receptor sites (e.g. coral reefs) within the areas identified may be impacted by these predicted increases in suspended sediment and sediment deposition.

The majority of the deposition within each bay occurs in the deep areas as current speeds in the exposed and shallower areas (e.g. reef flats, etc.) are higher. The total sediment load that enters the marine receiving waters during the modelled 5-day period increases from Scenario 1 (101 kg) to Scenario 2 (859 kg) to Scenario 3 (1,907 kg). A time series of the net accumulated sediment throughout the model domain for each scenario can be seen in Figure 33.

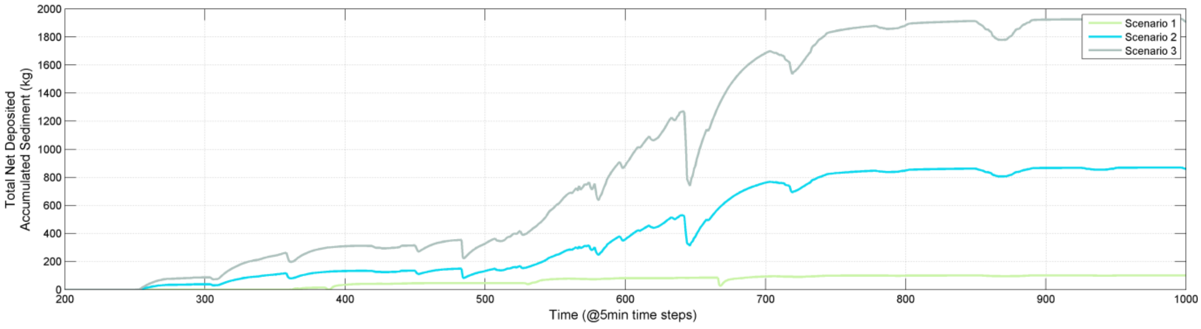


Figure 33: Total accumulated sediment throughout entire model domain over each scenario run.

The reported average rainfall for the Solomon Islands is between 3,000 to 5,000 mm per annum (Section 2.4). Utilising the discharge formula (see Section 4.3.3) and adopting the assumed sediment concentrations for each catchment (undisturbed and disturbed, Table 5), empirical calculations were undertaken for each of the rainfall scenarios (hydraulic coefficients for typical and extreme rainfall) to get an understanding as to the amount of deposition that may occur naturally within the receiving waters each year (see Table 6). The calculations show an approximate annual increase in sediment load of 117% and 149% into the receiving waters (adopting an extreme rainfall hydraulic coefficient) due to the disturbance of each of the catchments assuming a 4,000 mm and 5,000 mm annual rainfall, respectively.

Table 6: Estimates of total annual sediment load into the receiving waters of the study site, utilising the discharge formula (from Section 4.3.3) and extrapolating the assumed sediment concentrations for typical annual rainfall values (Table 5).

Annual Rainfall (mm)	Total Annual Sediment Load (t)			
	Scenario 1: Hydraulic Coef. C_v=0.5 Undisturbed Catchment Areas	**Scenario 2:** Hydraulic Coef. C_v=0.8 Undisturbed Catchment Areas (approx.)	**Scenario 3:** Hydraulic Coef. C_v=0.8 Disturbed Catchment Areas	**Scenario 3 - 2:** Approximate Increase due to mining disturbance
4,000	6,150	70,000	152,000	82,000 (117%)
5,000	7,680	87,000	190,000	130,000 (149%)

6.2 Marine Loading Impacts

Undertaking a preliminary conservative qualitative assessment of the impact of the marine loading (assuming that all ships visiting in a year are 72,000 t) the annual increase in the sediment loads due to direct spillage are:

- 52,000 t for the typical spillage scenarios (i.e. 1% spill rates); and
- 104,000 t for the high spillage scenarios (i.e. 2% spill rates).

When considering that only half of this spillage is assumed to occur at the marine loading facility (MLF) and the other half at the transhipment site, these are comparable to the increase in sediment loads from the surface water runoff due to mining disturbance in the upper catchments.

It can be seen that the mean and 99th percentile plots of TSS for the marine loading scenarios (Scenario 4 to 6) appear considerably higher than those of the surface water runoff scenarios (Scenario 1 to 3). As mentioned above, the colour scale shown in the results plots in Section 5 has been set to a conservative limit to highlight any potential impacts on sensitive receptors. The large water depth at this site also means that concentrations, when averaged over the water column are expected to be low.

In addition, the extent of this (temporary) small increase in TSS is primarily due to the finer sediments that have been modelled as part of the spillage at both the MLF and transhipment location. These finer particles have a much lower fall velocity and as such remain suspended in the water column for longer periods of time. These particles are also much more susceptible to (seasonal) wind-driven currents due to their location in the water column. The effect of the differences in the sediment composition between the ore and the surface runoff should be investigated further.

The general net deposition for the month-long marine loading investigations (Scenario 4 to 6) is seen to be considerably lower than that seen for the week-long surface water runoff scenarios (Scenario 1 to 3). As mentioned above, the large volume of (coarser) sediment deposited within the model domain for these scenarios is generally confined to the shallow entrances to each bay.

6.3 Limitations

Section 4.5 provides a list of limitations relevant to the numerical modelling undertaking in this study. As a high-level impact assessment, which has been based on limited available field data, the additional general limitations of this study should be noted. These are:

- As per the requirements of the scope this assessment is considered to be a first-pass and rapid assessment aimed at determining the feasibility of the Project in regard to environmental impacts.
- No additional field measurements have been undertaken for this first stage assessment and the following key gaps and modelling assumptions will require to be re-assessed during later stages of the assessment:
    - Sediment properties for the sediment to be disturbed by the mining activities at San Jorge. This should include sampling, analysis and investigation of sediment expected in the surface water runoff and in the ore products for shipping. Sediment dispersion properties and particle size distribution (PSD) in sea water need to be determined along with an NTU-TSS relationship.
    - Higher resolution bathymetry data;
    - Additional metocean and water quality measurements including local wind (especially considering topographic effects), stream flow, turbidity, currents and waves.
- The maximum model simulation has been for a period of 30-days. Long-term or accumulative impacts have not been assessed.
- It was assumed that the process of wave setup over the fringing reefs is not important in terms of the advection and dispersion of the sediment and has therefore been ignored. Further sensitivity testing should be undertaken.
- No assessment of impacts during construction was undertaken and additional potential operational impacts such as sediment disturbance due to propeller wash (e.g. from barges) or wind-blown sediment entering the ocean were not investigated.

- No development or assessments of potential mitigation measures to reduce impacts have been considered.

7 References

DHI, 2017a. *MIKE 21/3 Hydrodynamic modelling (HD FM) - MIKE Powered by DHI Short description.* Accessible at https://www.mikepoweredbydhi.com/.

DHI, 2017b. *DHI's Global Tidal Model* https://www.mikepoweredbydhi.com/-/media/shared%20content/mike%20by%20dhi/flyers%20and%20pdf/product-documentation/mike-21-toolbox-global-tide-model.pdf (accessed October 30, 2017)

Erftemeijer, P., Riegl, B., Hoeksema, B., Todd, P., 2012. *Environmental impacts of dredging and other sediment disturbances on corals: A review*. Marine Pollution Bulletin 64 (2012) 1737–1765

Golder, 2014. *Erosion and Sediment Control Strategy.* Jejevo/Isabel B project, Appendix H. Golder Associates, 2014.

Golder, 2014b. *Climate Baseline Report.* Jejevo/Isabel B project, Appendix F. Golder Associates, 2014.

IMC, 2016. *San Jorge Technical Study – Mining.* Report prepared for Axiom KB Limited

PHCG, 2015. *Environmental Scoping Report – Axiom Kolosori Operations*. Redraft 23 March, 2015.

RHDHV, 2016. *Kolosori Physical Marine and Freshwater Assessment – Data Acquisition and Interpretation Report*. Report prepared for EMM.

Rusli N., Majid M. R. and Din A. H. M., 2013. *Google Earth's derived digital elevation model: A comparative assessment with Aster and SRTM data*. Proceedings of the 8th International Symposium of Digital Earth (8th ISDE).

SIG, 2017. *Solomon Islands Climate in Brief.* Solomon Islands Government Meteorologicl Services Dvision. Ministry of Environment Climate Change Disaster Management and Meteorology. http://www.met.gov.sb/solomon-islands-climate-in-brief (last accessed, Oct 30, 2017)

Appendix E

Terrestrial species list

Appendix E i

Species List for Ultramafic Forest, Fernlands and Riparian Forest on the Ultrabasic soils.

A combined species list for the ultramafic forest associations, fernlands and associated riparian habitats are presented as one list due to ultrabasic soil being the present in all these vegetation types.

The trees present include;

Macaranga tanarius

Terminalia calamansanai

Xanthostemon melanoxylon

Planchonella firma

Timonius pulposus

Calophyllum obscurum

Gymnostoma papuana

Myristica fatua

Syzygium sp.

Dysoxylum excelsum

Teijsmanniodendron ahernianum

Calophyllum vitiense

Metrosideros solomonensis

Dacrydium solomonensis

Dillenia ingens

Dillenia crenata

Mapania cuspida

Euodia solomonensis

Euodia hortensis

Ficus chrysochaete

Decaspermum sp.

Polyscias guilfoylei

Polyscias sp

Ficus septic

Ficus variegata

Ficus virgata

Ficus longifolia

Ficus wassa

Ficus copiosa

Canarium liguliferum

Euodia trifolia

Garcinia solomonensis

Pandanus spiralis

Finschia waterhousiana

Finschia chloroxantha

Diospyros insularis

Palaquium sp.

Cryptocarya sp.

Vitex cafassus

Commersonia bartramia

Podocarpus sp.

Palms present in the ultramafic hill forest include only:

Hydriastele hombronii

Cyrtostachys kisu

Heterospathe minor

Heterospathe solomonensis

The shrubs are scarce in these vegetation types and only include:

Alyxia maluensis

Myrtella beccarii

Codiaeum sp.

Melastoma affine.

The vines and climbers which become more abundant in the riparian habitats are:

Medinilla sp.

Flagellaria indica

Flagellaria gigantean

Calamus hollrungii

Calamus stipitatus

Scindapsus altissimus

Rhapidophora sp.

Freycinetia solomonensis

Freycinetia decipiens

Mussaenda cylindrocarpa

Merremia peltata.

The ground layer in the fernlands and ultramafic hill forest included the following species:

Dicranopteris linearis

Lycopodium cernuum.

Scleria polycarpa

Dianella ensifolia

Spathoglottis plicata

Selaginella rechingeri

Dendrobium sp.

Bulbophyllum sp.

Appendix Eii Bird species recorded on San Jorge during field survey September 2017

SPECIES NAME	*SCIENTIFIC NAME*	CONSERVATION STATUS / ENDEMIC STATUS	STATUS ON SAN JORGE
GALLIFORMES:	*Megapodiidae*		
Melanesian Scrubfowl	*Megapodius eremita*	Widespread across the Bismarks and Solomons. Monotypic	Scarce. Heard only in forested areas.
PELECANIFORMES:	*Ardeidae*		
Rufous Night-Heron	*Nycticorax caledonicus*	Widespread across the Bismarks and Solomons, and from Philippines / Indonesia to Australia and the Pacific. Sub-species *mandibularis*.	Scarce around the coastal area.
ACCIPITRIFORMES:	*Pandionidae*		
Eastern Osprey	*Pandion cristatus*	Widespread across the Bismarks and Solomons, from Indonesia to Australia. Monotypic	Scarce around the coastal area.
CHARADRIIFORMES:	*Scolopacidae*		
Whimbrel	*Numenius phaeopus*	Migrant from the Northern hemisphere.	A single bird seen on the coast. On migration.
Common Sandpiper	*Actitis hypoleucos*	Migrant from the Northern hemisphere.	A single bird seen on the coast. On migration.
CHARADRIIFORMES:	*Laridae*		
Black Noddy	*Anous minutus*	Widespread across the Bismarks and Solomons, and across the tropical / sub-tropical Pacific and Atlantic oceans.	100s seen from the coast feeding inshore. Presumably a local breeding species.
Bridled Tern	*Onychoprion anaethetus*	Widespread across the Bismarks and Solomons, and across the tropical / sub-tropical Pacific, Indian and Atlantic oceans.	Small numbers seen from the coast feeding inshore. Presumably a local breeding species.
Roseate Tern	*Sterna dougallii*	Widespread but scarce across the Bismarks and Solomons, and across the tropical / sub-tropical and temperate Pacific, Indian and Atlantic oceans.	Small numbers seen from the coast feeding inshore. Presumably a local breeding species.
Great Crested Tern	*Thalasseus bergii*	Widespread across the Bismarks and Solomons, and across the tropical / sub-tropical and temperate Pacific and Indian oceans.	Small numbers seen from the coast feeding inshore. Presumably a local breeding species.
COLUMBIFORMES:	*Columbidae*		

SPECIES NAME	*SCIENTIFIC NAME*	CONSERVATION STATUS / ENDEMIC STATUS	STATUS ON SAN JORGE
Superb Fruit-Dove	*Ptilinopus superbus*	Widespread across Bismarks and Solomons, to Eastern Indonesia and Eastern Australia. Sub-species *superbus*	Scarce. Heard only in forested areas.
Claret-breasted Fruit-Dove	*Ptilinopus viridis*	Widespread across the Solomons to Eastern Indonesia. Sub-species *lewisii*	Scarce. Seen only once in coastal forested areas.
Red-knobbed Imperial-Pigeon	*Ducula rubricera*	Endemic (region) Sub-species *rufigula*	Scarce. Seen only in coastal forested areas.
Island Imperial-Pigeon	*Ducula pistrinaria*	Near Threatened. This species is classified as Near Threatened because analysis of rates of deforestation on New Britain (driven by oil palm plantations) suggest that it is likely to be undergoing a moderately rapid population reduction.	Seen regularly in coastal forested areas and flying along the coast.
STRIGIFORMES:	*Strigidae*		
West Solomons Boobook	*Ninox jacquinoti*	Endemic (region). Sub-species *jacquinoti*	A pair seen and frequently heard in the valley next to the camp. AT least tour pairs seen and heard in the upper forested area.
PODARGIDAE			
Solomons Frogmouth	*Rigidipenna inexpectata*	Endemic (region) as it occurs on Bougainville. Monotypic. This species has a small range in which the area, extent and quality of habitat are in decline, with a corresponding decline in the population suspected as a result. However, its population is not severely fragmented and it occurs at more than 10 locations. It is therefore listed as Near Threatened. Population size: 1500-7000	Scarce. Two or three birds heard calling and responding to play back in the upper forested area.
CAPRIMULGIFORMES:	*Apodidae*		
Uniform Swiftlet	*Aerodramus vanikorensis*	Widespread in Melanesia. Sub-species *lugubris.*	Seen regularly in small numbers in open areas.

SPECIES NAME	*SCIENTIFIC NAME*	CONSERVATION STATUS / ENDEMIC STATUS	STATUS ON SAN JORGE
CAPRIMULGIFORMES:	Hemiprocnidae		
Moustached Treeswift	*Hemiprocne mystacea*	Widespread across the Solomons to Eastern Indonesia. Sub-species *woodfordiana*	Scarce – a pair seen in open forest.
CORACIIFORMES:	*Alcedinidae*		
Common Kingfisher	*Alcedo atthis*	Widespread from N Africa, Asia and Europe. Sub-species *hispidoides* (resident)	Seen occasionally around the coast.
North Solomons Dwarf-Kingfisher	*Ceyx meeki*	Endemic (country). Monotypic. Recently separated taxonomically from Variable Dwarf-Kingfisher *Ceyx Lepidus*	Scarce. One seen and heard in the upper forested area.
Ultramarine Kingfisher	*Todiramphus leucopygius*	Endemic (country) Monotypic	Scarce. Seen in the upper forested area and adjacent open forest.
Sacred Kingfisher	*Todiramphus sanctus*	Widespread across the Melanesia, and from Indonesia to New Zealand.N Africa, Asia and Europe. Sub-species *sanctus* (resident)	Seen occasionally in open areas.
Beach Kingfisher	*Todiramphus saurophagus*	Widespread across Bismarks to Eastern Indonesia. Sub-species *saurophagus*	Seen occasionally around the coast.
CORACIIFORMES:	*Coraciidae*		
Dollarbird	*Eurystomus orientalis*	Widespread across Bismarks and from India to Japan and Australia. Sub-species *solomonensis* (resident)	Heard one in coastal forest.
PSITTACIFORMES:	*Cacatuidae*		
Solomon's (Ducorps's) Cockatoo	*Cacatua ducorpsii*	Endemic (country) monotypic	Commonly seen and heard in all terrestrial areas.
PSITTACIFORMES:	*Psittaculidae*		
Finsch's Pygmy-Parrot	*Micropsitta finschii*	Endemic (region) Sub-species *nanina*	Scarce seen and heard on 2 occasions in the upper forested area.
Song Parrot	*Geoffroyus heteroclitus*	Endemic (region) Sub-species *heteroclitus*	Seen occasionally in open coastal forest.
Cardinal Lory	*Chalcopsitta cardinalis*	Endemic (region) monotypic	Commonly seen and heard in all terrestrial areas.
PASSERIFORMES:	*Meliphagidae*		
Red-capped (Scarlet-naped) Myzomela	*Myzomela lafargei*	Endemic (country) Monotypic	Seen regularly in primary

SPECIES NAME	*SCIENTIFIC NAME*	CONSERVATION STATUS / ENDEMIC STATUS	STATUS ON SAN JORGE
			and open forest.
PASSERIFORMES:	*Campephagidae*		
White-bellied Cuckooshrike	*Coracina papuensis*	Widespread across Bismarks and from East Indonsesia to Australia. Sub-species *perpallida*	Regularly seen in open forest and forest edge.
Barred Cuckooshrike	*Coracina lineata*	Across the Bismarks and widely spread from New Guinea to Eastern Australia. Sub-species *nigrifrons*	Scarce. One male seen in upper forested area.
PASSERIFORMES:	*Pachycephalidae*		
Oriole Whistler	*Pachycephala orioloides*	Endemic (country) Sub-species *orioloides*	Regularly seen and more commonly heard in the upper forest and forested gullies.
PASSERIFORMES:	*Monarchidae*		
Chestnut-bellied Monarch	*Monarcha castaneiventris*	Endemic (country) Sub-species *castaneiventris*	Regularly seen and more commonly heard in the upper forest and forested gullies.
Solomons Pied Monarch	*Symposiachrus barbatus*	Endemic (region) as it also occurs on Bougainville Sub-species *barbatus.* Near Threatened.This species is likely to be experiencing a moderately rapid reduction in population size as logging intensifies within its range. It is therefore classified as Near Threatened.	Uncommon seen and heard in the upper forest and forested gullies.
Steel-blue Flycatcher	*Myiagra ferrocyanea*	Endemic (country) Sub-species *ferrocyanea*	Regularly seen and more commonly heard in the upper forest and forested gullies.
PASSERIFORMES:	*Corvidae*		
White-billed Crow	*Corvus woodfordi*	Endemic (country) Sub-species *vegetus*	Regularly encountered in all terrestrial habitats. Favours forest.
PASSERIFORMES:	*Hirundinidae*		
Pacific Swallow	*Hirundo tahitica*	Widespread across Bismarks and from Japan to Tahiti. Sub-species subfusca	Common in open areas around the coast.
PASSERIFORMES:	*Zosteropidae*		
Yellow-throated White-eye	*Zosterops metcalfii*	Endemic (region) Sub-species *metcalfii*	Regularly encountered in all

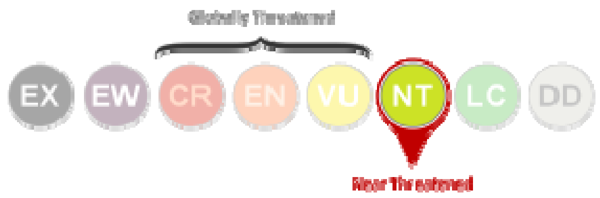
SPECIES NAME	*SCIENTIFIC NAME*	CONSERVATION STATUS / ENDEMIC STATUS	STATUS ON SAN JORGE
			terrestrial habitats. Favours forest.
PASSERIFORMES:	*Sturnidae*		
Long-tailed Myna	*Mino kreffti*	Endemic (region) Sub-species *sandfordi*	Occasionally seen on forest edges.
PASSERIFORMES:	*Dicaeidae*		
Midget Flowerpecker	*Dicaeum aeneum*	Endemic (country) Sub-species *aeneum*	Regularly encountered in all terrestrial habitats. Favours forest.
PASSERIFORMES: Nectariniidae			
Olive-backed Sunbird	*Cinnyris jugularis*	S.E.Asia – Australia widespread, Sub-species flavigaster	Regularly encountered in all terrestrial habitats. Favours forest.

	IUCN Near threatened
	Encdemic to the Solomon Islands / Region

Country Endemic – only found in the Solomon Islands

Regional Endemic - only found in the Bismark Region

IUCN RED LIST CATEGORIES



The IUCN Red List Categories and Criteria are an objective and widely accepted system for classifying species at high risk of extinction. BirdLife coordinates the assessment of the status of the world's birds using these categories and criteria and, as the official Red Listing Authority for birds for the IUCN Red List, submits this information to be included on the IUCN Red List along with that of other animals and plants. The IUCN Red List Categories and Criteria (in English, French or Spanish) can be viewed and downloaded at: http://www.iucnredlist.org/technical-documents/categories-and-criteria/2001-categories-criteria. Detailed guidelines on their use can also be seen at: http://www.iucnredlist.org/documents/RedListGuidelines.pdf. An overview of the categories is given below. See also IUCN Red List Criteria.

The categories, including the three globally threatened categories (Critically Endangered, Endangered and Vulnerable) are outlined below. For the total number of species in each category, see What's new.

EXTINCT (EX) - A species is Extinct when there is no reasonable doubt that the last individual has died. A species is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the species's life history.

EXTINCT IN THE WILD (EW) - A species is Extinct in the Wild when it is known only to survive in captivity or as a naturalized population (or populations) well outside the past range. A species is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the species's life history.

CRITICALLY ENDANGERED (POSSIBLY EXTINCT) CR (PE) - This is not an official category of the IUCN Red List, but a tag applied by BirdLife (and under review by the IUCN Red List) to identify those Critically Endangered species (see definition below) 'that are likely to be extinct, but for which there is a small chance that they may still be extant, and hence they should not be listed as Extinct until local or unconfirmed reports have been discounted, and adequate surveys have failed to find any individuals' (see below for further details).

CRITICALLY ENDANGERED (CR) - A species is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered (see IUCN Red List Criteria) and it is therefore considered to be facing an extremely high risk of extinction in the wild.

ENDANGERED (EN) - A species is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered (see IUCN Red List Criteria), and it is therefore considered to be facing a very high risk of extinction in the wild.

VULNERABLE (VU) - A species is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable (see IUCN Red List Criteria), and it is therefore considered to be facing a high risk of extinction in the wild.

NEAR THREATENED (NT) - A species is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

LEAST CONCERN (LC) - A species is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant species are included in this category.

DATA DEFICIENT (DD) - A species is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A species in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of species in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate. It is important to make positive use of whatever data are available. In many cases great care should be exercised in choosing between DD and a threatened status. If the range of a species is suspected to be relatively circumscribed, and a considerable period of time has elapsed since the last record of the species, threatened status may well be justified.

NOT EVALUATED (NE) - A species is Not Evaluated when it is has not yet been evaluated against the criteria. Note that all bird species have been evaluated in 2008, so this category has not been applied for any species.

References

BirdLife International and Handbook of the Birds of the World (2016) Bird species distribution maps of the world. Version 6.0. Available at http://datazone.birdlife.org/species/requestdis http://datazone.birdlife.org/species/requestdis [Species records]

BirdLife International and NatureServe (2011) Bird species distribution maps of the world. BirdLife International, Cambridge, UK and NatureServe, Arlington, USA. [Species records]

Hartert, E. 1929. Birds collected during the Whitney South Seas Expedition 8. Notes on birds from the Solomon Islands. Amer Mus. Novit. 364. [Distribution]

Hoyo, J del., A. Elliott & J Sargatal. 1996. Handbook of the Birds of the World Vol. 3. Lynx Edicions / Birdlife International. [Distribution]

Hoyo, J del., A. Elliott & J Sargatal. 1992. Handbook of the Birds of the World Vol. 1. Lynx Edicions / Birdlife International. [Distribution]

Mayr, E. & J. Diamond. 2001. Birds of Northern Melanesia. Oxford University Press, Oxford. [Distribution]

Mike Tarburton. 2014. Bird Checklists for 610 Melanesian Islands. http://www.birdsofmelanesia.net/ [Distribution]

Tristram, H.B. 1882. On birds from the Solomon Islands. Ibis (4)6: 133-146. [Distribution]

	
Cardinal Lory	**Cardinal Lory**
	
Chestnut-bellied Monarch	**Claret-breasted Fruit-dove**

Island Imperial Pigeon (near threatened)

Moustached Treeswift

Olive-backed Sunbird

Oriole Whistler

Red-knobbed Imperial Pigeon

Sacred Kingfisher

Solomons (Ducorps) Cockatoo

Solomons Pied Monarch (Near Threatened)

Song Parrot

Steel-blue Flycatcher

Ultramarine Kingfisher

Uniformed Swiftlet

Yellow-throated White-eye

West Solomons Boobook (Owl)

White-billed Crow

Midget Flowerpecker

Appendix Eiii - HERPETOFAUNAL DIVERSITY OF SAN JORGE ISLAND,

SOLOMON ISLANDS AUGUST, 2017

By Patrick Pikacha

Pacific Horizons

TABLE OF CONTENTS

Introduction and Methods

Limitations of Surveys

Description of significant habitats within the survey area

GPS referenced map of survey sites referenced to the methodological report

Results

Expanded species checklist indicating expected species

References

INTRODUCTION AND METHODS

Frogs form a key part of the vertebrate fauna in the Solomon Islands(Filardi 2004, Pikachaet al. 2016). On some islands, they along with fossorial lizards are the most abundant of terrestrial vertebrates(Filardi 2004). We sampled two sites on San Jorge Island, over two day and two nights. The sampling period occurred over two days, between 30 and 31st August, 2017. At each site, we conducted visual encounter surveys (VES) for frogs and reptiles. With VES, we walked around the two sampling sites, observing and recording each species of reptiles and frogs in the area. Our VES took the form of randomized walks. Randomized walks are normally used for rapid sampling where time and conditions do not allow for placement of quadrats or transects. However, this technique (VES), has many advantages for rapid surveys, which includes, providing "hands on experience", the observation of cryptic species and juveniles, and sampling multiple species within "heterogeneous habitats" (Pikachaet al. 2016). As a result, we were able to obtain a checklist, species richness, and abundance record of some common reptiles and frogs in the area.

During the survey, the main investigator (Patrick), walked around the area of interest, at site 1 (next to the swimming area near the camp), and site 2 (at the junction of the road in the centre of the island), over 3 hours each night, and for a distance of about 1 km at each site. The main investigator was accompanied by an assistant. We walked along a trail and road, searching both sides for reptiles and amphibians. We veered off the trail at times to cover other areas of forest, and grassland that are not on the trail, as some species may not be found along the path.

To improve the accuracy of visual identifications, we also set out 20 sticky boards to increase the changes of capturing cryptic reptiles, particularly skinks. Traps were placed mostly at Site 1 (14 sticky boards), with the rest placed randomly at Site 2 (6 sticky boards). They were placed approximately eight meters apart. When traps were damaged, they were either replaced, or if a lizard was caught on the edge of the sticky board, this section was cut out, and the rest of the undamaged sticky board placed back on the ground. We did not set out any arboreal sticky boards as there was no stable gun to attached this to a tree trunk or log.

LIMITATIONS OF SURVEYS

There was not ample time given to conduct a comprehensive survey of herpetofaunal diversity on San Jorge. Given the vastly distinct vegetation composition of the ultrabasic forests predominantly along the ridge lines, interspersed and dissected by deep ravines with floristic structures resembling that of highly complex lowland forests, and the lack of additional survey techniques (particularly to capture cryptic reptiles), it is evident this record of herpetofaunal diversity is an underestimate. If there was more time given to sampling, we would have added other survey methods to improve the accuracy of visual identifications, and to increase the chances of capturing more reptiles, particularly terrestrial skinks and snakes. This would include the use of funnels and pitfall traps with drift fences. A combination of these methods are advisable to ensure maximum species detection is achieved (Pikachaet al. 2016).

DESCRIPTION OF SIGNIFICANT HABITATS WITHIN THE SURVEY AREA.

The vegetation of the sampled sites, are a mixture of ultrabasic forests, open grassland areas, and lowland rainforest. Vegetation of Site 1, was a mixture of remnant forest adjacent to a stream, and open grassland areas, about 100 m from the main Axiom base camp.

Vegetation at both Site 1 and 2 (Figure 1) was ultrabasic/ultramafic forest. This forest type is distinct from typical Solomon Island lowland forest but does share some similarities in species composition and structural characteristics (Laveryet al. 2013). Dominant canopy trees are Xanthostemon melanoxylon, Gymnostoma papuana, Metrosideros salomonensis, M. collina, Gnetum gnemon, Podocarpus salomoniensis and Fagraea obtusifolia. The palms Actinorhytis calapparia and Hydriastele hollrungii are also common. The understorey contains Nastus obtusus, Lycopodium cernuum, Gleichenia linearis, G. oceanica, and Capitularia involucrata.

GPS REFERENCED MAP OF SURVEY SITES REFERENCED TO THE METHODOLOGICAL REPORT.

San Jorge, Southeast Isabel, and Southeast Choiseul are distinct from the rest of the Solomon Islands, for having a large variety of mafic rock types, including volcanic rocks (basalts and andesites), schists, and gabbroic rocks, and chrome rich sands (UNDP 1983, Berly 2005). This unique geological phenomenon is reflected in a highly unique vegetation structure and composition (Bennett 2000) dominated by Xanthostemon melanoxylon (Wilson and Pitisopa 2007) . We surveyed two sites.

Site 1. S-8.508938, E159.664987, San Jorge, Solomon Islands.

Site 1 was off a logging road.

Site 2. S-8.513019, E159.637014, San Jorge, Solomon Islands.

Site 2 was in intact ultrabasic forest.

Figure 1. Aerial image showing locations of Site 1, and Site 2, on San Jorge, Solomon Islands.

Figure 2. Aerial image showing locations of Site 1 (in a strip of forest adjacent to the Axiom camp base), and Site 2 (in intact unbroken ultrabasic forest), San Jorge, Solomon Islands.

RESULTS

Overview. We recorded 14 species out of a possible 34 species of herpetofauna at the two sites sampled (TABLE 1). All but three species, Cornufer (Discodeles) guppyi, Nactus multicarinatus and Emoia flavigularis, were rare. Most are common and widespread species occurring throughout the Solomon Islands. The largest tree frog in the archipelago, Cornufer hedigeri was found common on both sites (TABLE 1). Palmatorappia solomonis, a vulnerably listed species (IUCN redlist) found on mainland Isabel was not heard calling on San Gorge. However, the surveys were not intensive enough to justify their absence. The large water frog, Cornufer guppyi, was found along the stream adjacent to the Axiom camp site (Site 1). They were absent at Site 2, on the ridge. An endemic goanna, Varanus spinulosus, occurs on San Gorge. This also was not recorded during field surveys.

TABLE 1. Checklist including species not observed but otherwise expected from previous studies or literature. Relative abundance, habitat selection of two study sites on San Jorge Island, Isabel Province. Relative abundance: a = abundant (recorded daily in large numbers; c = common (encountered regularly by main observer each time in habitat); r = rare (encountered less than five times), and u = unknown (not recorded during surveys, but possibly present given proximity to, and a faunal assemblage affinity to the mainland – Isabel Island).

Family	Species	Relative Abundance Site 1	Relative Abundance Site 2
Frogs			
	Cornufer bufoniformis	u	u
	Cornufer guppyi	r	r
	Cornufer elegans	a	a
	Cornufer gigas	u	u
	Cornufer hedigeri	c	c
	Cornufer neckeri	u	u
	Cornufer guentheri	a	a
	Cornufer trossulus	u	u
	Cornufer vertebralisi	c	c
	Cornufer wolfi	u	u
	Cornufer (Discodeles) guppyi	r	u
	Litoria thesaurensis	a	c
	Litoria lutea	u	u
	Palmatorrapia solomonis	u	u
	Cornufer solomonis	c	c
	Cornufer weberi	a	a
	Rana kreffti	u	u
	Rhinella marianus	a	a
Reptiles			
Agamidae			
	Hypsilurus macrolepsis, Solomon Forest dragon	u	u
Gekkonidae			
	Gehyra oceanica, Oceanic Gecko	c	u
	Hemidactylus frenatus, Common House Gecko	c	u
	Lepidodactylus guppyi Guppy's Gecko	u	u
	Nactus multicarinatus, Solomons Slender-Toed Gecko	r	r
Scincidae			
	Corucia zebrata, Prehensile-Tailed Skink	u	u
	Emoia atrocostata, Reef Skink	u	u

	Emoia cyanogaster, Green-Bellied Tree Skink	u	u
	Emoia flavigularis, Yellow-Throated Skink	r	r
	Eugongylus albofasciolatus, White-Banded Sheen Skink	u	u
	Lamprolepis smaragdina, Emerald Tree Skink	u	u
	Sphenomorphus concinnatus, Elegant Forest Skink	c	c
	Sphenomorphous cranei, Crane's Skink	c	c
	Sphenomorphous solomonis	u	u
	Tribolonotus ponceleti, Poncelet's Crocodile Skink	u	u
Varanidae			
	Varanus indicus, Pacific Monitor	u	u
	Varanus spinulosus, Isabel Monitor	u	u
Typhlopidae			
	Ramphotyphlops depressus, Blind Snake	u	u
Boidae			
	Candoia paulsoni, Solomons Ground Boa	u	u
Acrochordidae			
	Acrochordus granulatus, Little File Snake	u	u
Colubridae			
	Boiga irregularis, Brown Tree Snake	u	u
	Dendelaphis calligaster, Solomons Tree Snake	u	u
Elapidae			
	Loveridgelaps elapoides, Solomons Black-Banded Krait	u	u
	Salomonelaps par, Solomons Red Krait	u	u

REFERENCES:

Bennett, J., 2000. Pacific forest: a history of resource control and contest in Solomon Islands, c. 1800 - 1997. The White Horse Press, Cambridge.

Berly, T., 2005. Ultramafic and mafic rock types from Choiseul, Santa Isabel and Santa Jorge (Northeastern Solomon Islands): Origins and Significance. Geochemistry. Universit´e JosephFourier - Grenoble I.

Filardi, C. 2004. Summary Results of a Biological Survey of the Proposed Kolombangara Nature Reserve 13 – 21 May 2004. American Museum of Natural History, New York.

Lavery, T., Pikacha, P. and Sirikolo, M., 2013. A Record of Reproduction in Anthops ornatus (Chiroptera: Hipposideridae), Ysabel Island, Solomon Islands. Memoirs of the Queensland Museum–Nature 56: 84-85.

Pikacha, P., Filardi, C., Morrison, C. and Leung, L. K.-P., 2016. Factors affecting frog density in the Solomon Islands. Pacific Conservation Biology 22: 223-235.

Pikacha, P., Lavery, T., Boseto, D., Sirikolo, M., Pikacha, D. J. and Pollard, E., 2016. Solomon Islands Ranger Skills Guide. University of Queensland, St Lucia, Brisbane, Australia.

UNDP, P. O. 1983. San Jorge Mineral Sands Survey, Solomon Islands COMMITTEE FOR CO-ORDINATION OF JOINT PROSPECTING FOR MINERAL RESOURCES IN SOUTH PACIFIC OFFSHORE AREAS (CCOP/SOPAC) WORK PROGRAMME CCSP-l/V A.4, CCSP-l/REG.9, CCSP-l/REG.28.

Wilson, P. and Pitisopa, F., 2007. Xanthostemon melanoxylon (Myrtaceae), a new species from the Solomon Islands. Telopea 11: 399-403.

Appendix F

Marine ecology species lists

Appendix Fi

IUCN Threatened Marine Species: Likelihood of Occurrence

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
MAMMALS						
DUGONGIDAE	*Dugong dugon*	Dugong, Sea Cow	VU	Dugongs inhabit coastal and island waters between East Africa and Vanuatu.	Habitat requirements for Dugongs include coastal areas, shallow to medium deep, warm waters (15-17°C minimum with behavioural thermoregulation), seagrass beds supporting sub-tropical and tropical species of seagrass, particularly low fiber species	Potential to occur due to the presence of suitable habitat in the form of seagrass beds.
PHYSETERIDAE	*Physeter macrocephalus*	Sperm Whale	VU	The sperm whale has a large distribution in oceanic regions of the world, including the Solomon Islands.	Oceanic habitat deeper than 1,000 m	Unlikely to occur due to lack of suitable habitat
REPTILES						
CHELONIIDAE	*Caretta caretta*	Loggerhead Turtle	VU	The Loggerhead Turtle is globally distributed throughout the subtropical and temperate regions of the Mediterranean Sea and Pacific, Indian, and Atlantic Oceans, including the Solomon Islands.	The Loggerhead Turtle nests on insular and mainland sandy beaches throughout the temperate and subtropical regions worldwide. Like most sea turtles, Loggerhead Turtles are highly migratory and use a wide range of broadly separated localities and habitats during their lifetimes. Upon leaving the nesting beach, hatchlings undergo an oceanic phase until recruiting to neritic developmental areas rich in benthic prey or epipelagic prey where they forage and grow until maturity. Upon attaining sexual maturity Loggerhead Turtles undertake breeding migrations between foraging grounds and nesting areas. During non-breeding periods adults reside at coastal neritic feeding areas that sometimes coincide with juvenile developmental habitats.	Potential to occur due to presence of suitable habitat

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
CHELONIIDAE	*Chelonia mydas*	Green Turtle	EN	The Green Turtle has a circumglobal distribution, occurring throughout tropical and, to a lesser extent, subtropical waters including the Solomon Islands.	Green turtles are highly migratory and use a wide range of broadly separated localities and habitats during their lifetimes. Upon leaving the nesting beach, it has been hypothesized that hatchlings begin an oceanic phase until recruiting to neritic developmental areas rich in seagrass and/or marine algae where they forage and grow until maturity. Upon attaining sexual maturity green turtles commence breeding migrations between foraging grounds and nesting areas that are undertaken every few years. During non-breeding periods adults reside at coastal neritic feeding areas that sometimes coincide with juvenile developmental habitats.	Potential to occur due to presence of suitable habitat
DERMOCHELYIDAE	*Dermochelys coriacea*	Leatherback Sea Turtle	VU	The Leatherback Sea Turtle is distributed circumglobally, including the Solomon Islands, with nesting sites on tropical sandy beaches and foraging ranges that extend into temperate and sub-polar latitudes.	The Leatherback Sea Turtle is an oceanic, deep-diving marine turtle inhabiting tropical, subtropical, and subpolar seas. Leatherbacks make extensive migrations between different feeding areas at different seasons, and to and from nesting areas. The Leatherback Sea Turtle feeds predominantly on jellyfishes, salps and siphonophores.	Potential to occur due to presence of suitable habitat

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
CHELONIIDAE	*Eretmochelys imbricata*	Hawksbill Turtle	CR	The Hawksbill Turtle has a circumglobal distribution throughout tropical and, to a lesser extent, subtropical waters of the Atlantic Ocean, Indian Ocean, and Pacific Ocean including the Solomon Islands.	The Hawksbill Turtle nests on insular and mainland sandy beaches throughout the tropics and subtropics. They are highly migratory and use a wide range of broadly separated localities and habitats during their lifetimes. Hatchlings enter the sea and are carried by offshore currents into major gyre systems where they remain until reaching a carapace length of some 20 to 30 cm. At that point they recruit into a neritic developmental foraging habitat that may comprise coral reefs or other hard bottom habitats, sea grass, algal beds, or mangrove bays and creeks or mud flats. As they increase in size, immature Hawksbills typically inhabit a series of developmental habitats, with some tendency for larger turtles to inhabit deeper sites. Once sexually mature, they undertake breeding migrations between foraging grounds and breeding areas at intervals of several years.	Potential to occur due to presence of suitable habitat
FISH						
ALBULIDAE	*Albula glossodonta*	Shortjaw Bonefish	VU	The Shortjaw Bonefish occurs from Hawaii and French Polynesia to the Seychelles in the western Indian Ocean, north to southern Japan and south to Lord Howe Island, Australia. It is native to the Solomon Islands	This species is found on shallow flats, sandy bottoms, seagrass beds, mangrove shorelines and reef and rubble habitats. Like A. vulpes, A. glossodonta may be closely associated with mangroves and seagrasses and other shallow coastal habitats	Potential to occur due the presence of suitable habitat including mangroves, seagrass beds and sandy substrate.

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
LABRIDAE	*Bolbometopon muricatum*	Green Humphead Parrotfish	VU	Recorded from the Red Sea east to the Line Islands and Tuamotu Archipelago (French Polynesia), north to Taiwan, the Yaeyama Islands (Japan), and Wake Island (United States Minor Outlying Islands), south to northwest Australia, the Great Barrier Reef and New Caledonia	Exposed reef crests are the primary habitat. In unfished areas, they may enter outer reef flats at depths of 1 to at least 30 m. Juveniles can be found in lagoons, while adults are in clear outer lagoon and seaward reefs at depths of at least 30 m. Very small individuals are restricted to the shallow inner lagoon in Solomon Islands. At Roviana Lagoon, Solomon Islands, juveniles are limited to the shallow inner lagoon environment, while larger individuals occur predominantly in passages.Feeds substantially on live coral and benthic algae.	Potential to occur due to the presence of suitable coral habitat
LABRIDAE	*Cheilinus undulatus*	Giant Wrasse	EN	The Giant Wrasse is widely distributed on coral reefs and inshore habitats throughout much of the tropical Indo-Pacific, including the Solomon Islands	Associated with reef or near-reef habitats of seagrass beds and mangrove areas, with juveniles typically inshore and the largest individuals found in deeper waters of outer reefs or lagoons. Juveniles occur in coral-rich areas of lagoon reefs, particularly among live thickets of staghorn, Acropora spp. corals, in seagrass beds, murky outer river areas with patch reefs, shallow sandy areas adjacent to coral reef lagoons, and mangrove and seagrass areas inshore	Potential to occur due to the presence of suitable habitats
EPINEPHELIDAE	*Cromileptes altivelis*	Humpback Grouper	VU	Cromileptes altivelis can be found in the western Pacific from southern Japan (Ogasawara) to Palau, Guam, New Caledonia, Fiji and southern Queensland (Australia)	The species is found in lagoons and seaward well developed coral reefs, typically in dead or silty areas. It also occurs in tide pools and can be caught at depths of 40 m. Juveniles (<15 cm) are found inshore, in lagoons and in fringing reefs and seagrass.	Potential to occur due to the presence of suitable habitats

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
EPINEPHELIDAE	*Epinephelus lanceolatus*	Brindle Bass	VU	It occurs throughout the Indo-Pacific region from the Red Sea to Algoa Bay (South Africa) and eastward to the Hawaiian and Pitcairn Islands throughout Micronesia	Inhabits lagoon and seaward reefs at a depth of a few to at least 50m. Individuals can be found in shallow inshore waters, including rocky areas, caves and wrecks, habours and estuaries and down to 100 m, althoughit is more often found in shallow water. It even swims into brackish areas. Specimens more than a meter long have been caught from close to shore and in harbours	Potential to occur due to the presence of suitable habitats
SYNGNATHIDAE	*Hippocampus kuda*	Spotted Seahorse	VU	Hippocampus kuda occurs from the Persian Gulf (Kuronuma and Abe 1986) to Southeast Asia, Australia, Japan, and some of the Pacific islands	Hippocampus kuda is found in shallow inshore waters normally between 0-8 m depth. It inhabits coastal bays, harbours and lagoons, sandy sediments in rocky littoral zones, macroalgae and seagrass beds, mangroves, muddy bottoms, and shallow reef flats. Also known to inhabit estuaries and brackish waters. H. kuda has also been recorded from open water and clinging to drifting Sargassum up to 20 km away from land	Potential to occur due to the presence of suitable habitats
ISTIOPHORIDAE	*Makaira nigricans*	Blue Marlin	VU	In the Eastern Pacific it is found from California to the southwestern and central eastern Gulf of California to Peru, including all of the oceanic islands.	It is found to 1,000 m depth but spends the highest percentage of its time at shallower depths, and is not usually seen close to land masses or islands, unless there is a deep drop-off of the shelf. eeds on squids, tuna-like fishes, crustaceans, and cephalopods	Unlikely to occur due to lack of suitable habitat

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
MOLIDAE	*Mola mola*	Sunfish	VU	Mola mola is circumglobally distributed throughout warm and temperate zones of all oceans including the Solomon Islands	Mola mola is an oceanodromous, pelagic-oceanic species that occurs in subtropical waters between depths of 30 and 480 m, but is usually between 30 and 70 m. Adults are found on slopes adjacent to deep water where they come in for shelter and to seek out cleaner fishes	Unlikely to occur due to lack of suitable habitat
POMACENTRIDAE	*Neopomacentrus aquadulcis*		EN	Only recorded from Tetepare Island in the Solomon Islands. Not known from Santa Isabel Island.	Occurs in clear streams and estuaries in highly fluctuating salinities at depths between about 0–3 m. The typical habitat consists of the lower, tidal reaches of freshwater streams in either pure fresh water or brackish water.	Unlikely to occur as Santa Isabel Island is outside its known distribution
EPINEPHELIDAE	*Plectropomus areolatus*	Spotted Coral Trout	VU	Plectropomus areolatus is an Indo-Pacific species, known from the Solomon Islands	inhabits lagoon and seaward reefs, in areas with rich coral growth. Most frequently encountered in channels along the reef front. Feeds exclusively on fishes	Potential to occur due to the presence of suitable habitat
EPINEPHELIDAE	*Plectropomus laevis*	Blacksaddled Coral Grouper	VU	Plectropomus laevis is widespread in the Indo-Pacific. Its range extends from the East African coast (Kenya to Mozambique) to the central and southern Pacific including the Solomon Islands.	Plectropomus laevis is conspicuous on outer coral reef slopes throughout the Indo-Pacific, occurring in depths between 4 and 90 m. Feeds mostly on fishes and occasionally on crustaceans	Potential to occur due to the presence of suitable habitat

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
SCOMBRIDAE	*Thunnus obesus*	Bigeye Tuna	VU	This species is circumglobal in tropical and temperate seas including in the Solomon Islands.	This is a pelagic and oceanodromous species. Juveniles and small adults school at the surface in monospecific groups or mixed with other tunas, and may be associated with floating objects. Adults stay in deeper waters. This species is mostly found above 500 m, but can dive deeper. This species feeds on a wide variety of fishes, cephalopods and crustaceans during the day and at night	Unlikely to occur due to lack of suitable habitat. The project site is located close to the coast.
RAYS and SHARKS						
CARCHARHINIDAE	*Carcharhinus longimanus*	Whitetip Shark	VU	This is one of the most widespread of shark species, ranging across entire oceans in tropical and subtropical waters, including the Solomon Islands.	It is usually found far offshore between about 30°N and 35°S in all oceans. It usually occurs deeper than 200 m. It has occasionally been recorded inshore, but is more typically found offshore or around oceanic islands and areas with narrow continental shelves	Unlikely to occur as oceanic habitat does not occur in the project site.
LAMNIDAE	*Isurus oxyrinchus*	Shortfin Mako	VU	This species is widespread in temperate and tropical waters of all oceans from about 50°N to 50°S. Its range includes the Solomon Islands.	The Shortfin Mako is an active, offshore littoral and epipelagic species, found in tropical and warm-temperate seas from the surface down to at least 500 m, seldom occurring where water temperature is <16°C. This shark occurs well offshore but penetrates the inshore littoral just off the surf zone in some areas.	Potential to occur, but unlikely as this species usually occurs further out to sea than the project site.
LAMNIDAE	*Isurus paucus*	Longfin Mako	VU	This species appears to be cosmopolitan in tropical and warm temperate waters including the Solomon Islands	A little-known epipelagic, tropical and warm-temperate shark. The species is apparently a deep-dwelling shark, although both sightings on the ocean surface and the species' diet suggest a much greater depth range	Unlikely to occur as deep oceanic habitats do not occur.

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
CARCHARHINIDAE	*Negaprion acutidens*	Sharptooth Lemon Shark	VU	Wide ranging in the Indian Ocean and western Central Pacific including the Solomon Islands	Occurs in tropical, shallow inshore and offshore waters near the bottom; often found on and around coral reefs and on sandy plateaus near coral, at depths down to at least 30 m. Often found inside coral lagoons but also on reef flats and reef edges. It is also known to occur around and within mangrove estuaries.	Potential to occur due to the presence of suitable habitat.
RHINIDAE	*Rhina ancylostoma*	Shark Ray	VU	Widely distributed in the Indo-west Pacific region including the Solomon Islands.	Generally occurs close inshore and around coral reefs to about 90 m, close to the seabed, mainly over sandy or muddy substrates.	Potential to occur due to the presence of suitable habitat.
RHINCODONTIDAE	*Rhincodon typus*	Whale Shark	VU	Whale Sharks are found in all tropical and warm temperate seas including the Solomon Islands (except the Mediterranean).	Whale Sharks are known to inhabit both deep and shallow coastal waters and the lagoons of coral atolls and reefs.	Potential to occur due to the presence of suitable habitat.
DASYATIDAE	*Urogymnus asperrimus*	Porcupine Ray	VU	Widespread but relatively uncommon in the Indo-West Pacific including the Solomon Islands.	It favors sand, coral rubble, and seagrass habitats in inshore waters to a depth of 30 m	Potential to occur due to the presence of suitable habitat.
ECHINODERMS						
HOLOTHURIIDAE	*Actinopyga echinites*	Brownfish, Deep Water Redfish	VU	This species can be found throughout the Western Central Pacific including the Solomon Islands	This species is found along outer reef flats, in the littoral zone, and in estuaries and lagoons. This species dwells in moderately shallow waters, mostly on reef flats of fringing and lagoon-islet reefs. It can be abundant in seagrass beds, on rubble flats, and compact flats where populations can reach high densities (up to 1/m)	Potential to occur due to the presence of suitable habitat.

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
HOLOTHURIIDAE	*Actinopyga mauritiana*	Surf Redfish	VU	This species is found throughout the central Pacific and Indian Oceans including the Solomon Islands	prefers outer reef flats and fringing reefs, mostly in the surf zone between 0-20 m. This species is characteristic of the outer reef flats, as part of the medio-littoral reef community. In the Solomon Islands, adults are commonly found around solid reef rock and scattered tables of the coral Acropora sp.	Potential to occur due to the presence of suitable habitat.
HOLOTHURIIDAE	*Actinopyga miliaris*	Blackfish, Harry Blackfish	VU	Widespread species whose range incorporates the Indo Pacific region including the Solomon Islands	In the Western Central Pacific Region, it prefers reef flats of fringing reefs and lagoon-islet reefs, rubble reefs and compact flats between 0-12 m	Potential to occur due to the presence of suitable habitat.
HOLOTHURIIDAE	*Holothuria fuscogilva*		VU	This species is widespread throughout the Indian and Pacific Oceans including the Solomon Islands	This species is found from 0 – 40 m, but is mostly encountered between 15 and 30 m, and may occur occur in deeper waters. In the Western Central Pacific, it inhabits outer barrier reefs and passes; it can also be found on shallow seagrass beds between 0 and 40 m	Potential to occur due to the presence of suitable habitat.
HOLOTHURIIDAE	*Holothuria lessoni*	Golden Sandfish	EN	This species is widespread in the Indo-Pacific including the Solomon Islands	In the Western Central Pacific, this species can be found in lagoons over sandy bottoms between 0 and 25 m, but occurs predominately from 0-10 m. It can be found over sandy and muddy areas and in reef flats.	Potential to occur due to the presence of suitable habitat.

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
HOLOTHURIIDAE	*Holothuria nobilis*	Black Teatfish	EN	This species is native to the Solomon Islands	This species is largely restricted to coral reef habitat. It occurs on reef flats and outer slopes and it is generally solitary. This species is common in shallow waters of reef bottom where there is no terrigenous action, at depths from 0 to 40 m. However, they are distributed mainly in shallow coral reef areas, on reef flats, slopes and shallow seagrass beds. They prefer sandy hard substrate.	Potential to occur due to the presence of suitable habitat.
HOLOTHURIIDAE	*Holothuria scabra*	Golden Sandfish, Sandfish	EN	This species is widespread in the Indo-Pacific including the Solomon Islands	This species is distributed mainly in low energy environments behind fringing reefs or within protected bays and shores. Individuals prefer ordinary coastal areas to coral reefs, particularly intertidal seagrass beds close to mangroves, however they are also found along inner reef flats and lagoons. This species is attracted to muddy sand or mud habitats.	Potential to occur due to the presence of suitable habitat.
HOLOTHURIIDAE	*Holothuria whitmaei*	Black Teatfish	EN	This species is found only in the Pacific, including the Solomon Islands	This species is found along slopes and passes within reef zones. It can be found in reef flats, slopes and shallow seagrass beds between 0 and 20 m. This species has been observed at 30 m, but may possibly occur in deeper waters to about 50 m	Potential to occur due to the presence of suitable habitat.
STICHOPODIDAE	*Stichopus herrmanni*	Curryfish	VU	This species is widespread throughout the Indo Pacific including the Solomon Islands	In the Western Central Pacific region, this species prefers seagrass beds, rubble and sandy-muddy bottoms between 0 and 25 m.	Potential to occur due to the presence of suitable habitat.

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
STICHOPODIDAE	*Thelenota ananas*	Prickly Redfish	EN	This species is widespread throughout the Indo Pacific including the Solomon Islands	This species is found along slopes and passes within reef zones and along outer reef flats to depths of 35 m, but is more common in waters from 10-20 m. They are distributed mainly in shallow coral reef areas, on reef flats, reef slopes and near passes on sandy or hard bottoms with large rubble and coral patches. It is common in shallow waters of reef bottom where there is no terrigenous action, at depths from 0 to 20 m. They prefer rubble and hard bottoms covered with a layer of coral sand.	Potential to occur due to the presence of suitable habitat.
MOLLUSCS						
TRIDACNIDAE	*Hippopus hippopus*	Bear Paw Clam	LR/cd	Native to the Solomon Islands	Hippopus hippopus is a large bivalve that lives unattached and exposed in shallow coral reef habitats.	Potential to occur due to the presence of suitable habitat
TRIDACNIDAE	*Tridacna derasa*	Southern Giant Clam	VU	This species has a broad range in the wild and is found in the Indo-Pacific, Central Pacific and South Pacific as well as the Coral Sea.	This species is found in most habitats, but most abundant in shallow, sheltered lagoonal and reef flat habitats at depths of 4 to 10 m on sandy or hard packed substrates.	Potential to occur due to the presence of suitable habitat
TRIDACNIDAE	*Tridacna gigas*	Giant Clam	VU	Native to the Solomon Islands	Giant clams occupy coral reef habitats, typically within 20 m of the surface. They are most common found in shallow lagoons and reef flats, and are typically embedded in sandy substrates or those composed of coral rubble.	Potential to occur due to the presence of suitable habitat
TRIDACNIDAE	*Tridacna maxima*	Small Giant Clam	LR/cd	Native to the Solomon Islands	Found living on the surface of reefs or sand, or partly embedded in coral	Potential to occur due to the presence of suitable habitat

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
TRIDACNIDAE	*Tridacna squamosa*	Fluted Clam	LR/cd	Native to the Solomon Islands	Found at the sandy bottom of coral reefs at depths of around 15 to 20 metres, the fluted clam is typically anchored amidst Acropora corals	Potential to occur due to the presence of suitable habitat
CORALS						
MUSSIDAE	*Acanthastrea bowerbanki*		VU	In the Indo-West Pacific, this species is found in the Central Indo-Pacific, north, east and west Australia, South-east Asia, Japan and East China Sea, oceanic West Pacific.	This species is found in lower reef slopes protected from wave action, to a depth of 20 m.	Potential to occur as is found in the Solomon Island region
MUSSIDAE	*Acanthastrea brevis*		VU	This species is found in the Central Indo-Pacific, Oceanic West Pacific. It is also found in the Great Barrier Reef, American Samoa and Fiji	This species is found in all reef habitats at depths of 1-20 m	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
MUSSIDAE	*Acanthastrea faviaformis*		VU	In the Indo-West Pacific, this species is found in the Red Sea and Gulf of Aden, Central Indo-Pacific, Micronesia and the Solomons.	This species is found in lagoons and upper reef slopes to depths of 12 m	Potential to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
MUSSIDAE	*Acanthastrea hemprichii*		VU	In the Indo-West Pacific, this species is found in many areas including the Solomon Islands	This species is found in mid-reef slopes at depths to 20 m	Potential to occur as is found in the Solomon Island region

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
MUSSIDAE	*Acanthastrea ishigakiensis*		VU	In the Indo-West Pacific, this species is found in many areas including the Solomon Islands	This species is found in depths of 1-20 m in all sheltered reef areas away from high wave action.	Potential to occur as is found in the Solomon Island region
MUSSIDAE	*Acanthastrea regularis*		VU	In the Indo-West Pacific, this species is found in the central Indo-Pacific, eastern Australia, oceanic West Pacific, the Solomons, and Fiji	This species is found in shallow tropical reef environments to a depth of 20 m.	Potential to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Acropora abrolhosensis*		VU	This species occurs in the central Indo-Pacific, Australia, Japan and the East China Sea, Great Barrier Reef, Coral Sea, Solomons, and the oceanic west Pacific.	This species is found on shallow reefs. It is also found in lagoons or reef slopes protected from strong wave action. This species is restricted to enclosed lagoons and protected reef slope habitats and thus may be missed on many reefs. This species is found from 2-18 m.	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora aculeus*		VU	In the Indo-West Pacific, this species is found in many areas including the Solomon Islands	This species is found on shallow reefs on upper reef slopes and lagoons. This species occurs through a broad depth range, from 5-35 m and often being found to a depth of 20 m on slopes and walls.	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora acuminata*		VU	This species is widespread and occurs in the Red Sea, the northern Indian Ocean, the central Indo-Pacific, Australia, Southeast Asia, Japan and the East China Sea, and the oceanic west Pacific.	This species occurs on shallow reefs. It also is found in turbid or clear water on upper or lower reef slopes. It is found from 5-20 m depth	Potential to occur as is found in the Solomon Island region

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Acropora anthocercis*		VU	This species is widespread, found in the Red Sea, the south-west and northern Indian Ocean, the central Indo-Pacific, Australia, Southeast Asia, Japan and the East China Sea, and the oceanic west Pacific	This species occurs on shallow reefs. It is found on upper reef slopes exposed to strong wave action. This species is found from 5 to ~10 m depth	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora aspera*		VU	This species is widespread, found in the northern Indian Ocean, the central Indo-Pacific, Australia, Japan and the East China Sea, the oceanic west Pacific	This species occurs on shallow reef flats. It occurs on reef flats and shallow lagoons, also exposed upper reef slopes and deep water. It is found from 0-5 m.	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora awi*		VU	This species is found in the central Indo-Pacific, Japan and the East China Sea, Southeast Asia, Micronesia and the Solomon Islands	This species is found on shallow reef slopes and fringing reefs. It is found on the shallow parts of protected sandy slopes (to 5 m) and submerged reefs	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Acropora batunai*		VU	This species is found in the central Indo-Pacific and the Solomon Islands	This species is found in shallow, protected reef environments. This species occurs subtidally to at least 44 m deep on slopes and ledges on walls. This species is found on submerged reefs and slopes, 10-40 m deep and may be found as shallow as 1 m deep.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)

**Table Fi	Likelihood of Occurrence of Threatened Marine Species within the Study Area**

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Acropora caroliniana*		VU	This species is found in the central Indo-Pacific, Australia, and the oceanic west Pacific	This species occurs in shallow, tropical reef environments. It is found on upper reef slopes. This species occurs subtidally on slopes, ledges on walls and submerged reefs from 5-25 m	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora dendrum*		VU	This species is found in the northern Indian Ocean, the central Indo-Pacific, Australia, Southeast Asia, Japan and the East China Sea, the oceanic west Pacific and Palau	This species occurs in shallow, tropical reef environments, especially reef margins exposed to strong wave action. This species is found between 5-20 m.	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora desalwii*		VU	This species is found in the central Indo-Pacific, and the Solomon Islands	This species occurs in shallow, tropical protected reef environments, subtidally on slopes or submerged reefs, mostly below 15 m. This species is found from 10-30 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Acropora donei*		VU	This species is widespread and occurs in the northern Indian Ocean, the central Indo-Pacific, Australia, Southeast Asia, and the oceanic west Pacific	This species occurs in shallow, tropical reef environments. It is restricted to shallow fringing reefs and upper reef slopes where Acropora spp. diversity is high and it is subtidal. This species is found from 5-20 m.	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora echinata*		VU	This species is widespread, found in many places including the Indo-Pacific and the Solomon Islands	This species occurs in shallow, tropical protected reef environments with clear water and a high Acropora spp. diversity, and is also found subtidally on protected sandy slopes and lagoon floors. This species is found from 8-25 m.	Potential to occur as is found in the Solomon Island region

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Acropora globiceps*		VU	This species is found in the central Indo-Pacific, the oceanic west Pacific, and the central Pacific.	This species occurs in shallow, tropical reef environments. It is found intertidally on upper reef slopes and reef flats. This species is found to 8 m depth.	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora hoeksemai*		VU	This species is found in the central Indo-Pacific and the Solomon Islands	This species occurs in shallow reef environments. It occurs subtidally on outer reefs, reef slopes, or ledges on walls and submerged reefs. This species is found from 8-20 m	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Acropora horrida*		VU	This species is found in many places including the central Indo-Pacific and the Solomon Islands	This species occurs in shallow, tropical reef environments. It is found in turbid water around fringing reefs, and subtidally on protected deepwater flats, lagoons, and sandy slopes. This species is found from 5-20 m	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora indonesia*		VU	This species is found in the central Indo-Pacific and the Solomon Islands	This species occurs in shallow, tropical reef environments. It is found on horizontal surfaces protected from wave action, found subtidally on surfaces such as submerged reef flats or ledges, or on very gentle slopes. This species is found between 10 and 20 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Acropora jacquelineae*		VU	This species is found in the central Indo-Pacific and the Solomon Islands	This species occurs in shallow, tropical reef slopes protected from wave action, subtidal on walls and ledges on walls from around 10 to 30 m depth. It is found on reef slopes and submerged reefs, 10-35 m deep.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Acropora kimbeensis*		VU	This species is found in the central Indo-Pacific and the Solomon Islands	This species occurs in shallow, tropical reef environments. It is found on upper reef slopes and in lagoons, also on patch reefs, typically seen between 3 and 12 m depth. It is also found on submerged reef flats. This species may be found to 15 m depth	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora kirstyae*		VU	This species is found in the central Indo-Pacific and the Solomon Islands	This species occurs in shallow, tropical reef environments. It is found in shallow water protected from wave action, only in protected, subtidal lagoons, and protected reef slopes. This species is found from 10-25 m	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora listeri*		VU	This species is found in many places including the central Indo-Pacific and the Solomon Islands	This species occurs in shallow, tropical reef environments. It is found on upper reef slopes, especially those exposed to strong wave action, also just subtidal shallow reef edges (Wallace 1999). This species is found from 3-15 m.	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora lokani*		VU	This species is found in many places including the central Indo-Pacific and the Solomon Islands	This species occurs in shallow reef environments. It occurs in sheltered lagoon patch reefs and shallow reef flats. This species is found from 8-25 m	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Acropora lovelli*		VU	This species is found in the northern Indian Ocean, the central Indo-Pacific, Australia, and the oceanic west Pacific	This species occurs in shallow, tropical reef environments. It is found in shallow, protected lagoons, and lagoon entrances, found subtidally in lagoons and calm-water reef shoals. This species is found from 1-10 m	Potential to occur as is found in the Solomon Island region

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Acropora microclados*		VU	This species is found in many places including the central Indo-Pacific and the Solomon Islands	This species occurs in shallow, tropical reef environments. This species is found on upper reef slopes. It occurs just subtidally at reef edges. This species is found from 5-20 m	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora multiacuta*		VU	This species is found in the northern Indian Ocean including the Solomon Islands, the central Indo-Pacific, Eastern Australia, and the oceanic west Pacific.	This species occurs in shallow, tropical reef environments. It is found in wave washed lagoon margins, subtidally on submerged reef tops, ledges in walls, and rocky slopes; it is often found in indentations or crevices in the reef surface. This species is found from 3-15 m	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Acropora palmerae*		VU	This species is found in many places including the central Indo-Pacific and the Solomon Islands	This species occurs in shallow, tropical reef environments on reef flats exposed to strong wave action and in lagoons, also intertidally or subtidally on shallow reef tops and edges, especially in areas of strong current. This species is found from 0-12 m	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora paniculata*		VU	This species is found in many places including the central Indo-Pacific and the Solomon Islands	This species occurs in shallow, tropical reef environments on upper reef slopes. It occurs just subtidally on reef edges and upper slopes as well as in sheltered lagoons. This species is found from 10-35 m	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora plumosa*		VU	This species is found in the central Indo-Pacific including the Solomon Islands	This species occurs in shallow, tropical reef environments. It is found on sheltered reef slopes, deep slopes and walls below 12 m. This species can be found from 10-30 m	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Acropora polystoma*		VU	This species is found in the central Indo-Pacific including the Solomon Islands	This species occurs in shallow, tropical reef environments. It is found on upper reef slopes exposed to strong wave action. This species appears to be confined to reef-edge habitats with good water circulation. This species is found from 3-10 m.	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora retusa*		VU	This species is found in the south-west and northern Indian Ocean, the central Indo-Pacific, the Solomons, the oceanic west Pacific, and the central Pacific	This species occurs in shallow, tropical reef environments. It is found on upper reef slopes and in tidal pools. This species is found from 1-5 m	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Acropora solitaryensis*		VU	This species is found in the central Indo-Pacific, Australia, Southeast Asia, Japan and the East China Sea, and the oceanic west Pacific	This species occurs in shallow, tropical reef environments. It is found in shallow reef environments and on rocky foreshores in subtropical locations. It occurs subtidally on reef slopes and walls and submerged reefs. This species is found from 5-25 m	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora speciosa*		VU	This species is found in the central Indo-Pacific including the Solomon Islands	This species occurs in shallow, tropical reef environments. It is found in protected reef environments with clear water and a high Acropora diversity. It occurs subtidally on walls and steep slopes, usually below 15 m, but occasionally shallower where shaded conditions exist. This species is found from 12-30 m	Potential to occur as is found in the Solomon Island region

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Acropora spicifera*		VU	This species is found in the central Indo-Pacific including the Solomon Islands	This species occurs in shallow, tropical reef environments. It is found on reef slopes. It occurs mostly intertidally on reef flats. This species is found from 2-10 m	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora striata*		VU	This species is found in the central Indo-Pacific including the Solomon Islands	This species occurs in shallow, tropical reef environments. It is found on shallow, rocky foreshores or shallow reef flats. This species is found from 10-25 m	Low probability to occur as it has been recorded in two of the nations part of the Coral Triangle (i.e. Indonesia and Papua New Guienea)
ACROPORIDAE	*Acropora turaki*		VU	This species is found in the central Indo-Pacific including the Solomon Islands	This species occurs in shallow reef environments. It is found in protected lagoons or sandy slopes. This species is found from 10-20 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Acropora vaughani*		VU	This species is found in the central Indo-Pacific including the Solomon Islands	This species occurs in shallow, tropical reef environments. It is found in turbid water around fringing reefs. It only occurs in protected subtidal habitats such as contained lagoons and sandy slopes. This species is found from 3-20 m	Potential to occur as is found in the Solomon Island region

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Acropora verweyi*		VU	This species is found in the central Indo-Pacific including the Solomon Islands	This species occurs in shallow, tropical reef environments. It is found on upper reef slopes, especially those exposed to wave action or currents. It is found in shallow reef top and reef edge habitats often filling in spaces between other Acropora species. This species is found from 2-15 m.	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora walindii*		VU	This species is found in the central Indo-Pacific and the oceanic west Pacific.	This species occurs in shallow, tropical reef environments. It is found on protected reef slopes, sandy areas, and deep, sandy reef slopes. This species is found from 8-30 m	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Acropora willisae*		VU	This species is found in the central Indo-Pacific including the Solomon Islands	This species occurs in shallow, tropical reef environments. It is found in a wide range of environments from lower reef slopes to lagoons. It occurs well below the low water mark on submerged reef flats and slopes. This species is found from 10-20 m	Potential to occur as is found in the Solomon Island region
PORITIDAE	*Alveopora allingi*		VU	This species is found in the central Indo-Pacific including the Solomon Islands	This species is found in protected reef environments. This species is most commonly reported at depth between 5 and 10 m. However, it has been recorded from dim light conditions suggesting that it can occur at depths greater than 10 m.	Low probability to occur as it has not being recorded in the Solomon Islands or in the Coral Triangle
PORITIDAE	*Alveopora fenestrata*		VU	This species is found in the central Indo-Pacific including the Solomon Islands	This species is found in shallow reef environments, generally to a depth of 30 m.	Potential to occur as is found in the Solomon Island region

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
PORITIDAE	*Alveopora marionensis*		VU	This species is found in the central Indo-Pacific, South-east Asia, eastern Australia, and oceanic West Pacific.	This species is only found in environments with moderate wave action, generally to depths of 30 m.	Low to moderate probability to ocurr as it has not being recorded previously in the Solomon Islands, but it is present in other nations part of the Coral Traingle
PORITIDAE	*Alveopora minuta*		EN	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species is found on rocky surfaces exposed to currents, generally to depths of 20 m.	Low to medium probability to ocurr as it has been recorded previously in the Solomon Islands and in Indonesia
PORITIDAE	*Alveopora verrilliana*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species is found in shallow reef environments, generally to a depth of 30 m.	Low probability to ocurr as it has not been recorded previously in the Solomon Islands, but it has been recorded in Papua New Guinea

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Anacropora matthai*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species occurs in shallow, tropical reef environments. It may cover extensive areas on horizontal muddy substrates with clear water. This species is found from 8-20 m	Potential to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Anacropora puertogalerae*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species occurs in shallow reef environments. This species is found from 5-20 m.	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Anacropora reticulata*		VU	This species is found in the central Indo-Pacific, Japan and the East China Sea, and Eastern Australia	This species occurs in shallow reef environments. This species is found from 3-15 m. It is generally found on soft substrates of lower reef slopes in clear or slightly turbid water.	Potential to occur as is found in the Solomon Island region
ACROPORIDAE	*Anacropora spinosa*		EN	This species is found in the central Indo-Pacific, Southeast Asia, Solomons, Japan and the East China Sea, and the oceanic west Pacific.	This species occurs in shallow reef environments. This species is found from 5-15 m. It is generally found on soft substrates of lower reef slopes in clear or slightly turbid water. In certain areas it may occur in extensive tracts	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Astreopora cucullata*		VU	This species is found in the Red Sea and Gulf of Aden, central Indo-Pacific, Southeast Asia, Eastern Australia, oceanic west Pacific	This species is found in shallow, tropical reef environments. This species is found from 5-15 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)

**Table Fi	Likelihood of Occurrence of Threatened Marine Species within the Study Area**

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Astreopora incrustans*		VU	This species is found in the central Indo-Pacific, Japan and the East China Sea, the Solomons, Eastern Australia.	This species is found in shallow tropical reef environments and rocky foreshores. This species is found from 1-10 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
FAVIIDAE	*Australogyra zelli*		VU	This species is found in Southeast Asia, Vietnam, South China Sea, Papua New Guinea, northeast Australia, and Solomon Islands	This species occurs in shallow, tropical reef environments. This species is found on the back slope, foreslope, and in lagoons. It is typically found in turbid to clear waters around high islands or in reef lagoons. This species is found to at least 15 m.	Potential to occur as it is found in the Solomon Island region
FAVIIDAE	*Barabattoia laddi*		VU	In the Indo-West Pacific, this species is found in the central Indo-Pacific, eastern Australia, and the oceanic west and south Pacific	It has been recorded from shallow lagoons, foreslope, back slope, and reef flats. This species is found to at least 10 m.	Low probability to occur at the Isabel Region as this species has not previously been recorded in the Solomon Islands. It has been recorded in Indonesia, but not in other islands part of the Coral Triangle

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
EUPHYLLIDAE	*Catalaphyllia jardinei*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species occurs in shallow, tropical reef environments. It occurs in protected, preferably turbid water. This species can be found from 0-40 m.	Low probability to occur at the Isabel Region as this species has not previously been recorded in the Solomon Islands or other neighbour island nations part of the Coral Triangle
FAVIIDAE	*Caulastrea curvata*		VU	In the Indo-West Pacific, this species is found in the central Indo-Pacific, Australia, Japan and the East and South China Sea, and the oceanic West Pacific.	This species occurs in shallow, tropical reef environments. It is found on slopes and flat substrates, often with C. furcata. This species is found in lagoons and inter-reef soft substrates. This species is found to at least 20 m.	Potential to occur as it is found in the Solomon Island region
FAVIIDAE	*Caulastrea echinulata*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species occurs in shallow, tropical reef environments. It is found on slopes and horizontal substrates protected from wave action and with turbid water. This species is found in lagoons. This species is found to at least 18 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
FAVIIDAE	*Cyphastrea agassizi*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species occurs in tropical, shallow reef environments. It is generally a small species. This species is found on the back slope and foreslope of reefs as well as in lagoons and can be found in the outer reef channel. This species is found to at least 20 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
FAVIIDAE	*Cyphastrea ocellina*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species occurs in shallow, tropical reef environments. It is found on upper reef slopes. This species is found in lagoons and can be found in the outer reef channel. This species is found to at least 20 m	Potential to occur as it is found in the Solomon Island region
PECTINIIDAE	*Echinophyllia costata*		VU	In the Indo-West Pacific, this species is known from two sites in Sulawesi, from the Solomons, and in Western Irian Jaya	Occurs around 10 m in protected areas. Shallow reef environments	Potential to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
EUPHYLLIDAE	*Euphyllia ancora*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species is found on reef slopes from mid reef to deeper water (30 m max). Large colonies are usually found in more sheltered areas.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
EUPHYLLIDAE	*Euphyllia cristata*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species can be found on all areas on a reef from depths of 1-35 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
EUPHYLLIDAE	*Euphyllia paraancora*		VU	In the Indo-West Pacific, this species is found in the central Indo-Pacific, central Indian Ocean, and the oceanic West Pacific.	This species occurs in shallow to deep reef environments in most areas of the reef. This species is found from 3-30 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
FAVIIDAE	*Favia rosaria*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species occurs in shallow reef environments.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
OCULINIDAE	*Galaxea acrhelia*		VU	In the Indo-West Pacific, this species is found in east Indonesia, the Philippines, north coast of Papua New Guinea, West Pacific and the Solomon Islands.	This species is usually found in reef slopes. The maximum size is 50 cm. This species is found from 3-15 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
OCULINIDAE	*Galaxea astreata*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species is found in reef environments protected from strong wave action. This species is considered to be a main reef-framework builder and is found from 3-30 m. The maximum size is over 2 m	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
FAVIIDAE	*Goniastrea ramosa*		VU	This species is found in Southeast Asia, Melville Island (Australia), Papua New Guinea, Solomon Islands, and Fiji.	This species occurs in shallow, tropical reef environments on reef flats sheltered from strong wave action. This species is found on the back and foreslope of the reef and also in lagoons. This species is found to 15 m	Potential to occur as its range was extended to the Solomon Islands by Green et. al. (2006)

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
PORITIDAE	*Goniopora burgosi*		VU	This species is found in the Red Sea, southwest Indian Ocean, northern Indian Ocean, central Indo-Pacific, Japan and East China Sea.	This species is found in shallow reef environments, generally to depths of 30 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
FUNGIIDAE	*Halomitra clavator*		VU	In the Indo-West Pacific, this species is found in eastern Indonesia, Philippines, and West Pacific. It has a patchy distribution.	This species is found on reef slopes and lagoons as a free-living with multiple mouths. The depth range is from 5-25 m.	Potential to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
FUNGIIDAE	*Heliofungia actiniformis*		VU	This species is found in the central Indo-Pacific, northwest, north and eastern Australia, south Japan and South China Sea, oceanic West Pacific	This species is usually found on reef flats and reef slopes as a free-living single polyp. The depth range is from 1-25 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
HELIOPORIDAE	*Heliopora coerulea*	Blue Coral	VU	This species is widespread in the Indo-Pacific region including the Solomon Islands.	This species occurs on shallow reef (generally less than 2 m), exposed reef locations, reef flats and intertidal zones. Can occur in generally disturbed or marginal habitat	Low probability of occurrence in the proposed development area as this species have not been reported previously in the Solomon Islands or in neighbour island nations part of the Coral Triangle

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Isopora crateriformis*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	It occurs in shallow, tropical reef environments, especially reef flats exposed to strong wave action. It is found subtidally on submerged reef tops (Wallace 1999). This species is found from 1-15 m.	Low probability of occurrence in the proposed development area as this species have not been reported previously in the Solomon Islands or in neighbour island nations part of the Coral Triangle
ACROPORIDAE	*Isopora cuneata*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species occurs in all shallow, tropical reef environments, especially upper reef slopes and reef flats. It is found intertidally or just subtidally on reef flats, reef tops or submerged reefs. This species is found to 15 m depth	Low probability of occurrence in the proposed development area as this species have not been reported previously in the Solomon Islands or in neighbour island nations part of the Coral Triangle
AGARICIIDAE	*Leptoseris incrustans*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species is found on reef slopes and on vertical walls. The maximum size is 20 cm. This species is found from 10-20 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
AGARICIIDAE	*Leptoseris yabei*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	It is usually found on lower slopes. Maximum size is over 1 m. This species is found from 6-20 m	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
MUSSIDAE	*Lobophyllia dentatus*		VU	In the Indo-West Pacific, this species is found from the Andaman Sea, central Indo-Pacific, southwest Pacific and north east Australia.	This species is found on the shallow upper reef slopes and lagoons. This species is found to 10 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
MUSSIDAE	*Lobophyllia diminuta*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species is found on upper reef slopes and lagoons. This species is found to 10 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
MUSSIDAE	*Lobophyllia flabelliformis*		VU	This species is found in the Central Indo-Pacific, southern Japan and East China Sea, north eastern Australia, Papua New Guinea and southwest Pacific.	This species is found in most shallow reef environments, especially clear waters. This species is found to 30 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
FAVIIDAE	*Montastrea multipunctata*		VU	In the Indo-West Pacific, this species is found in the central Indo-Pacific, Southeast Asia, Japan and the East China Sea, and the oceanic West Pacific.	This species is found in shallow, tropical reef environments. It forms sub-massive to massive colonies. This species is found on the back and foreslope of the reef and in lagoons. This species is found to 15 m.	Moderate to High probability of occurrence in the proposed development area as this species have previously been reported in the Solomon Islands and in Papua New Guinea
FAVIIDAE	*Montastrea salebrosa*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species is found in shallow environments, including reef flats and mid-depth slopes. It prefers tropical habitats. This species is found on the back and foreslope of the reef and in lagoons. This species is found to 20 m	Moderate to High probability of occurrence in the proposed development area as this species have previously been reported in the Solomon Islands and in Papua New Guinea

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Montipora altasepta*		VU	In the Indo-West Pacific, this species is found in the central Indo-Pacific, Japan and the east China Sea, and the oceanic west Pacific	This species occurs in shallow, tropical reef environments on protected reef slopes. This species is found to at least 10 m.	Moderate to High probability of occurrence in the proposed development area as this species have previously been reported in the Solomon Islands and in Papua New Guinea
ACROPORIDAE	*Montipora angulata*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species occurs in shallow, tropical reef environments. It is commonly found on fringing reef flats, and also other reef habitats. This species is found from 1 m to at least 20 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Montipora australiensis*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species occurs in shallow, tropical reef environments. It is found in shallow reef environments exposed to strong wave action. This species is found from 2 m to at least 30 m.	Moderate to High probability of occurrence in the proposed development area as this species have previously been reported in the Solomon Islands and in Papua New Guinea

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Montipora cactus*		VU	Southeast Asia, southern Japan, Papua New Guinea, and New Caledonia and the Solomon Islands.	This species occurs in shallow, tropical reef environments. It is found in sheltered environments, especially sheltered lagoons with turbid water and soft substrates. This species is found from 2 m to at least 20 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Montipora calcarea*		VU	This species is found on the coast of eastern Africa, northern Madagascar, the Red Sea, Chagos Archipelago, Thailand, Philippines, Australia, Papua New Guinea, and the central Pacific	This species occurs in shallow reef environments. It occurs on reef crests, outer reef flats and upper slopes. This species is found to at least 20 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Montipora caliculata*		VU	Many countries including the Solomon Islands	This species occurs in most shallow, tropical reef environments. This species is found to at least 20 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
ACROPORIDAE	*Montipora capricornis*		VU	In the Indo-West Pacific, this species is found in the central Indo-Pacific, Australia, and the oceanic west Pacific.	This species occurs in shallow, tropical reef environments. It is found mostly in lagoons. This species is found to at least 20 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
ACROPORIDAE	*Montipora cebuensis*		VU	In the Indo-West Pacific, this species is found in the Central Indo-Pacific, south-east Asia, Japan and the east China Sea, and the oceanic west Pacific.	This species occurs in shallow reef environments, especially lagoons. This species is found from 2 m to at least 20 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Montipora cocosensis*		VU	In the Indo-West Pacific, this species is found in the Red Sea, the central Indo-Pacific, and the oceanic west Pacific.	This species occurs in shallow reef environments and lagoons. This species is found to at least 15 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Montipora corbettensis*		VU	Many countries including the Solomon Islands	This species occurs in shallow reef environments, especially shallow to mid reef slopes. This species is found from 2 m to at least 20 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
ACROPORIDAE	*Montipora crassituberculata*		VU	In the Indo-West Pacific, this species is found in the northern Indian Ocean, the central Indo-Pacific, Australia, South-east Asia and the East China Sea.	This species occurs in shallow, tropical reef environments. It is found on upper and lower reef slopes. This species is found to at least 20 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
ACROPORIDAE	*Montipora delicatula*		VU	This species is distributed from Southeast Asia, in Vietnam and central Indo-Pacific, northwest Papua New Guinea, and the Solomon Islands.	This species occurs in shallow, tropical reef environments. It is restricted to shallow reef edges. This species is found to at least 15 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Montipora friabilis*		VU	Many countries including the Solomon Islands	This species occurs in shallow, tropical reef environments in turbid waters and in lagoons. It also occurs in clear-water habitats. This species is found to at least 20 m.	Potential to occur as its range was extended to the Solomon Islands by Green et. al. (2006)

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Montipora hodgsoni*		VU	This species is found in the central Indo-Pacific.	This species occurs in shallow, tropical reef environments on protected, upper reef slopes. This species is found to at least 20 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Montipora mactanensis*		VU	In the Indo-West Pacific, this species is found in the central Indo-Pacific, the Solomons, Japan and the East China Sea.	This species occurs in shallow reef environments. This species is found to at least 20 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Montipora malampaya*		VU	Southeast Asia, southern Japan, Papua New Guinea, and Solomon Islands.	This species occurs in shallow, tropical reef environments on upper reef slopes. This species is found to at least 15 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Montipora orientalis*		VU	Northeast Somalia, Mozambique, Madagascar, Seychelles, Mauritius, Chagos Archipelago, Southeast Asia, and Papua New Guinea, Solomon Islands.	This species occurs in shallow reef environments. This species is found to at least 20 m.	Potential to occur as its range was extended to the Solomon Islands by Green et. al. (2006)

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
ACROPORIDAE	*Montipora samarensis*		VU	In the Indo-West Pacific, this species is found in the central Indo-Pacific, Japan and the East China Sea, and the oceanic west Pacific.	This species is found on shallow, protected reef slopes. It prefers tropical reef environments. This species is found to at least 15 m.	Moderate to High probability of occurrence in the proposed development area as this species have previously been reported in the Solomon Islands and in Indonesia
ACROPORIDAE	*Montipora turtlensis*		VU	This species is found in Thailand, Southeast Asia, Vietnam, South China Sea, Papua New Guinea, Australia, Solomon Islands, Vanuatu, and New Caledonia.	This species occurs in shallow, tropical reef environments. It is found in turbid environments and also in clear water habitats. This species is found to at least 20 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
ACROPORIDAE	*Montipora verruculosus*		VU	This species is found in Vietnam, Southeast Asia, Papua New Guinea, Solomon Islands, and northeast Australia.	This species occurs in shallow, tropical reef environments. It is found on upper reef slopes and in lagoons that are protected from wave action. This species is found to at least 20 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
ACROPORIDAE	*Montipora vietnamensis*		VU	This species is found in Southeast Asia, Thailand, Vietnam, Papua New Guinea, and the Solomon Islands.	This species occurs in shallow tropical reef environments and on rocky foreshores. This species is found to at least 15 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)

Table Fi **Likelihood of Occurrence of Threatened Marine Species within the Study Area**

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
EUPHYLLIDAE	*Nemenzophyllia turbida*		VU	This species is found throughout the central Indo-Pacific.	This species occurs in shallow, tropical reef environments. It is found in turbid or sheltered reef environments. This species is found from 8-30 m.	Low probaility of occurrence in the proposed development area as this species has not previously been recorded in the Solomon Islands. It has been recorded in Indonesia.
AGARICIIDAE	*Pachyseris rugosa*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	It may develop into large mound-shaped colonies in shallow water, but smaller colonies occur in a wide range of habitats including those exposed to strong wave action. This species can be found from 5-20 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
AGARICIIDAE	*Pavona bipartita*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species occur on reef slopes and vertical walls. It may form large crusts over 1 m in diameter. This species may be found from 3-20 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
AGARICIIDAE	*Pavona cactus*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	It is usually found in lagoons and on upper reef slopes, especially those of fringing reefs, and in turbid water protected from wave action, where colonies are sometimes over 10 m across. It is commonly found from 3-11 m, rarely from 12-15 m. This species may be found from 3-20 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
AGARICIIDAE	*Pavona decussata*	Cactus Coral	VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species occurs in most reef environments from 3-11 m, rarely from 12-15 m	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
AGARICIIDAE	*Pavona venosa*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species occurs in shallow reef environments. The maximum size is approximately 50 cm. This species is found from 2-20 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
PECTINIIDAE	*Pectinia alcicornis*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	It is found in turbid water, especially on horizontal substrates. Also found in clear water. This species is found to 25 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
PECTINIIDAE	*Pectinia lactuca*	Lettuce Coral	VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	It is found in most reef environments, both in shallow and deep areas, especially lower reef slopes and turbid water habitats. This species is found from 3-15 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
PECTINIIDAE	*Pectinia maxima*		EN	This species is found in the Coral Triangle and the Solomon Islands	This species is found in shallow reef environments, protected from wave action and where the water is slightly turbid. This species is found from 3-25 m. Pectinia occurs in most reef habitats, both in shallow and deep areas.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
EUPHYLLIDAE	*Physogyra lichtensteini*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species occurs in shallow, tropical reef environments. It is found more often in turbid reef environments but may be found in most reef habitats. This species can be found from 1-20 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
FAVIIDAE	*Platygyra yaeyamaensis*		VU	This species is found in Myanmar, Thailand, Southeast Asia, Vietnam, South China Sea, China, southern Japan, Papua New Guinea, and Solomon Islands.	This species occurs in shallow, tropical reef environments. This species is found on the back and foreslope of the reef and in lagoons. This species is found to 20 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
EUPHYLLIDAE	*Plerogyra discus*		VU	This species is found in the central Indo-Pacific to the east Papua New Guinea and Solomon Islands.	It is found on lower protected reef slopes. This species is found in very turbid water usually in single colonies not more than 50 cm diameter. This species is found from 8-15 m.	Low probability of occurrence in the proposed development area as this species has not previously been recorded in the Solomon Islands. It has been recorded in Indonesia.
POCILLOPORIDAE	*Pocillopora danae*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species occurs in shallow, tropical reef environments on partly protected reef slopes. The maximum size is over 1 m across. This species is found to 15 m.	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
POCILLOPORIDAE	*Pocillopora elegans*		VU	In the Indo-West Pacific, this species is found in the Central Indo-Pacific, the Oceanic West Pacific, the Central Pacific, Solomon Islands and Papua New Guinea and the Eastern Pacific.	This species occurs in shallow reef environments. Pocillopora elegans occurs in all shallow water habitats on coral reefs and coral communities on rocky substrata to at least 20 m depth, but is most common between 1-10 m depth	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
PORITIDAE	*Porites attenuata*		VU	This species is found in the central Indo-Pacific, Japan, the South China Sea, and the oceanic west Pacific.	This species is found in shallow, protected reef environments, generally to depths of 20 m	Potential to occur as it is found in the Solomon Island region and in the Coral Triangle
PORITIDAE	*Porites cumulatus*		VU	This species occurs in the central Indo-Pacific, South-east Asia, South China Sea. Papua New Guinea	This species is found in shallow, protected reef environments, generally to depths of 20 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
PORITIDAE	*Porites eridani*		EN	This species is found in the central Indo-Pacific, southeast Asia, South China Sea. Palau and the Marianas Islands	This species is found in shallow, protected reef environments, generally to depths of 20 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
PORITIDAE	*Porites horizontalata*		VU	This species is found in the northern Indian Ocean, the central Indo-Pacific, PNG, southern Japan and the South China Sea, and the oceanic West Pacific.	This species is found in shallow reef environments. This species is found from less than 10 m to greater than 20 m.	Low probability to occur as this species has not been recorded previously in the Solomon Islands
PORITIDAE	*Porites nigrescens*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands.	This species is common on lower reef slopes and lagoons protected from wave action, generally to depths of 20 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
PORITIDAE	*Porites rugosa*		VU	This species occurs in the central Indo-Pacific. Currently it is known from only Sulawesi and Raja Ampats (Indonesia) and Milne Bay (Papua New Guinea).	This species is found in shallow reef environments, generally to depths of 15 m.	Unlikely to occur as it has not been recorded from the Solomon Islands
PORITIDAE	*Porites sillimaniana*		VU	This species is found in the southwest and central Indian Ocean, the central Indo-Pacific, southeast Asia, southern Japan, the South China Sea, and Palau	This species is found mostly on reef flats, generally to depths of 5 m.	Moderate to high probability to occur as it is found in the Solomon Island region and in the Coral Triangle

Table Fi **Likelihood of Occurrence of Threatened Marine Species within the Study Area**

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
PORITIDAE	*Porites tuberculosa*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands, and Pohnpei	This species is found in shallow, protected reef environments, generally to depths of 20 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
POCILLOPORIDAE	*Seriatopora aculeata*		VU	This species is found in the Central Indo-Pacific and the Oceanic West Pacific.	This species occurs in shallow reef environments. The maximum size is 20 cm across. This species is found to 40 m.	Moderate to high probability to occur as it is found in the Solomon Island region and in the Coral Triangle
POCILLOPORIDAE	*Seriatopora dendritica*		VU	This species occurs in the Central Indo-Pacific. Marshall Islands and Solomon Islands	This species is found in protected reef environments. The maximum size is 30cm across. This species is found to 40 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)
MUSSIDAE	*Symphyllia hassi*		VU	In the Indo-West Pacific, this species is found in the Gulf of Aden, northern and central Indian Ocean, northwestern Madagascar, central Indo-Pacific up to the Solomon Islands.	This species is found on upper reef slopes and reef flats. This species is found to 20 m.	Moderate to high probability to occur as its range was extended to the Solomon Islands by Green et. al. (2006)

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
DENDROPHYLLIIDAE	*Turbinaria mesenterina*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands	It is common in shallow turbid environments. This species is found to 20 m.	Moderate to high probability to occur as it is found in the Solomon Island region and in the Coral Triangle
DENDROPHYLLIIDAE	*Turbinaria patula*		VU	In the Indo-West Pacific, this species is found in the central Indo-Pacific, tropical and sub-tropical Australia, South China Sea, and the oceanic West Pacific.	It is found on inshore reefs and shallow rocky foreshores of subtropical locations. They form plates of over 1 m in diameter. This species is found from 7-20 m.	Moderate to high probability to occur as it is found in the Solomon Island region and in the Coral Triangle
DENDROPHYLLIIDAE	*Turbinaria peltata*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands	It occurs shallow on sandy reef flats and deep sandy reef bases. It forms plates of over 1 m. This species is found from 0.5-25 m.	Moderate to high probability to occur as it is found in the Solomon Island region and in the Coral Triangle
DENDROPHYLLIIDAE	*Turbinaria reniformis*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands	It may form large stands on fringing reefs where the water is turbid. It forms plates of over 1 m in diameter. This species is found from 2-15 m.	Moderate to high probability to occur as it is found in the Solomon Island region and in the Coral Triangle

Table Fi Likelihood of Occurrence of Threatened Marine Species within the Study Area

Family	Species Name	Common name	Red List status	Distribution	Habitat	Likelihood of Occurrence
DENDROPHYLLIIDAE	*Turbinaria stellulata*		VU	This species is found in the central Indo-Pacific, including the Solomon Islands	t may form conspicuous dome-shaped colonies on upper reef slopes. Unlike other Turbinaria, this species is seldom found in turbid waters. The maximum size is 50 cm. This species is found from 2-15 m.	Moderate to high probability to occur as it is found in the Solomon Island region and in the Coral Triangle

Appendix Fii

Marine Flora Species List

Table Fii **Potential Marine Flora Species Occurring within the Study Area**

		Confirmed Recordings for Santa Isabel Island			Other Potential Species
Species Name	*Common Name*	*SMM (2012)*	*Golder (2014)*	*PHCG (2015)*	*Isabel Province*
MANGROVES					
Acrostichum speciosum	mangrove fern		+		+
Aegiceras corniculatum	river mangrove				+
Araucaria sp.				+	+
Avicennia alba					+
Avicennia marina	grey mangrove				+
Barringtonia racemosa	brackish water mangrove		+		+
Bruguiera exaristata	rib-fruited orange mangrove	+			+
Bruguiera gymnorhiza	large-leafed orange mangrove	+	+		+
Bruguiera hainesii			+		+
Bruguiera parviflora	small-leafed orange mangrove		+	+	+
Bruguiera sexangula	upriver orange mangrove				+
Bruguiera sp.	Orange mangroves	+			+
Caulerpa lentilifera	seagrapes	+			+
Caulerpa racemosa	macroalga	+			+
Casuarina sp.				+	+
Ceriops sp.			+	+	+
Ceriops tagal	rib-fruited yellow mangrove	+	+		+
Chlorodesmis fastigiata	macroalga	+			+
Cymodocea rotunda	Seagrass			+	+
Cymodocea serulata	Seagrass			+	+
Dolichandrone spathacea	trumpet mangrove		+		+
Dictyota sp.	macroalga	+			+
Enhalis acoroides	seagrass	+			+

Table Fii Potential Marine Flora Species Occurring within the Study Area

		Confirmed Recordings for Santa Isabel Island			Other Potential Species
Species Name	*Common Name*	*SMM (2012)*	*Golder (2014)*	*PHCG (2015)*	*Isabel Province*
Excoecaria agallocha	milky mangrove				+
Halimeda discoidea	macroalga	+			+
Halimeda micronesica	macroalga	+			+
Heritiera littoralis	keeled-pod mangrove		+		+
Lumnitzera littorea	red-flowered black mangrove		+		+
Lumnitzera racemosa	white-flowered black mangrove				+
Lumnitzera sp.			+	+	+
Nypa fruticans	mangrove palm		+		+
Osbornia octodonta	myrtle mangrove				+
Padina gymnospora	macroalga	+			+
Rhizophora apiculata	corky stilt mangrove	+	+	+	+
Rhizophora conjugata					+
Rhizophora mangle	red mangrove				+
Rhizophora mucronata	upriver stilt mangrove		+		+
Rhizophora sp.	stilt mangrove	+			+
Rhizophora stylosa	long-style stilt mangrove	+	+		+
Rhizophora xlamarckii	hybrid stilt mangrove				+
Scyphiphora hyrophyllacea	yamstick mangrove				+
Sonneralia xgulngai	gulngai-hybrid apple mangrove				+
Sonneratia alba	white-flowered apple mangrove				+
Sonneratia ovata	apple mangrove				+
Sonneratia sp.				+	+
Terminalia brassii	Goba			+	+
Terminalis catappa				+	+

Table Fii **Potential Marine Flora Species Occurring within the Study Area**

		Confirmed Recordings for	Santa Isabel Island		Other Potential Species
Species Name	*Common Name*	*SMM (2012)*	*Golder (2014)*	*PHCG (2015)*	*Isabel Province*
Thalassia hemprichii	Seagrass	+		+	+
Turbinaria sp.	macroalga	+			+
Unidentified swamp/lowland trees			+		+
Xylocarpus granatum	cannonball mangrove		+		+
Xylocarpus granatum			+		+
Xylocarpus moluccensis	cedar mangrove		+		+
SEAGRASSES					
Cymodocea rotundata	smooth ribbon grass		+		+
Cymodocea sp.					+
Cymodocea serrulata					+
Halodule uninervis		+			+
Syringodium isoetifolium					+
Thasassodendron ciliatum			+		+
Enhalus acoroides	tape grass		+		+
Halophila decipiens					+
Halophina ovalis	paddle grass		+		+
Thalassia hemprichii	sickle grass		+		+
Zostera muelleri		+			+

Appendix Fiii

Marine Fauna Species List

Table Fiii **Marine Fauna Species List**

Family	Species Name	PHCG (2015) Survey	GHD (2014) Baseline Survey	SMM 2012	Tatamba (Site 4a) Green et al (2004)	Tirahi (Site 4b) Green et al(2004)	Tanabafe (Site 5) Green et al (2004)	Isabel Province
		Confirmed recordings for Isabel Province						Potentially occurring species
MAMMALS								
Balaenopteridae	*Balaenoptera borealis*			+				
Balaenopteridae	*Balaenoptera edeni*							+
Balaenopteridae	*Balaenoptera omurai*							+
Balaenopteridae	*Megaptera novaeangliae*							+
Delphinidae	*Delphinus capensis*							+
Delphinidae	*Delphinus delphis*							+
Delphinidae	*Orcinus orca*							+
Delphinidae	*Stenella attenuate*							+
Delphinidae	*Stenella coeruleoalba*							+
Delphinidae	*Stenella longirostris*							+
Delphinidae	*Tursiops aduncus*							+
Delphinidae	*Tursiops truncatus*							+
Dugongidae	*Dugong dugon*	+	+					+
Physeteridae	*Physeter macrocephalus*			+				
REPTILES								
Acrochordidae	*Acrochordus granulatus*							+
Chelonidae	*Chelonia midas*		+	+				+
Chelonidae	*Eretmochelys imbricata*		+	+				+
Chelonidae	*Lepidochelys olivacea*			+				+

Table Fiii **Marine Fauna Species List**

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Crocodylidae	*Crocodylus prosus*		+	+				+
Dermochelydae	*Caretta caretta*			+				+
Dermochelydae	*Dermochelys coriacea*			+				+
Elapidae	*Laticauda colubrine*							+
Elapidae	*Laticauda crockeri*							+
Elapidae	*Laticauda laticaudata*							+
FISH								
Acanthuridae	*Acanthurs sp2.*		+					+
Acanthuridae	*Acanthurus bariene*						+	+
Acanthuridae	*Acanthurus fowleri*		+					+
Acanthuridae	*Acanthurus lineatus*						+	+
Acanthuridae	*Acanthurus nigrofuscus*						+	+
Acanthuridae	*Acanthurus nigroris*	+						
Acanthuridae	*Acanthurus olivaceus*						+	+
Acanthuridae	*Acanthurus sp1.*		+					+
Acanthuridae	*Acanthurus triostegus*						+	+
Acanthuridae	*Ctenochaetus*		+					+
Acanthuridae	*Ctenochaetus binotatus*						+	+
Acanthuridae	*Ctenochaetus striatus*						+	+
Acanthuridae	*Ctenochaetus strigosus*	+						

Table Fiii Marine Fauna Species List

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Acanthuridae	*Naso lituratus*						+	+
Acanthuridae	*Naso sp.*		+					+
Acanthuridae	*Paracanthurus hepatus*						+	+
Acanthuridae	*Zebrasoma veliferum*				+		+	+
Anguillidae	*Anguilla spp.*			+				
Apogonidae	*Apogon celas*				+			+
Apogonidae	*Apogon coccineus*	+						
Apogonidae	*Apogon kallopterus*						+	+
Apogonidae	*Apogon sp.*		+					+
Apogonidae	*Cheilodipterus quinquelineatus*				+			+
Apogonidae	*Sphaeramia nematoptera*				+			+
Atherinidae	*Atherinomorus sp.*		+					+
Atherinidae	*Atherinomours endrachtensis*		+					+
Atherinidae	*Atherinomours lacunosus*		+					+
Atherinidae	*Hypoatherina barnesi*		+					+
Aulostomidae	*Aulostomus chinensis*						+	+
Balistidae	*Balistapus sp*		+					+
Balistidae	*Balistoides sp*							+
Balistidae	*Balistoides viridescens*						+	+
Balistidae	*Melichthys vidua*						+	+

Table Fiii Marine Fauna Species List

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Balistidae	*Pseudobalistes flavimarginatus*						+	+
Balistidae	*Rhinecanthus rectangulus*						+	+
Balistidae	*Rhinecanthus sp.*		+					+
Balistidae	*Rhinecanthus verrucosus*				+			+
Balistidae	*Sufflamen bursa*						+	+
Balistidae	*Sufflamen chrysoptera*				+		+	+
Belonidae	*Tylosurus sp*							+
Blenniidae	*Atrosalarias fuscus*				+			+
Blenniidae	*Blenniella chrysospilos*						+	+
Blenniidae	*Cirripectes castaneus*						+	+
Blenniidae	*Cirripectes stigmaticus*						+	+
Blenniidae	*Escenius prooculis*				+			+
Blenniidae	*Meiacanthus atrodorsalis*						+	+
Blenniidae	*Salarias segmentatus*				+			+
Caesionidae	*Caesio cuning*		+		+			+
Caesionidae	*Caesio lunaris*						+	+
Caesionidae	*Caesio sp.*		+					+
Caesionidae	*Dipterygonotus balteatus*		+					+
Caesionidae	*Pterocaesio marri*				+			+
Caesionidae	*Pterocaesio pisang*						+	+

Table Fiii Marine Fauna Species List

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Caesionidae	*Pterocaesio sp.*		+					+
Carangidae	*Carangoides bajad*				+			+
Carangidae	*Carangoides ferdau*		+					+
Carangidae	*Carangoides gymnostethus*			+				
Carangidae	*Carangoides orthogrammus*		+					+
Carangidae	*Carangoides plagiotaenia*						+	+
Carangidae	*Carangoides sp.*		+					+
Carangidae	*Caranx sexfasciatus*		+	+	+			+
Carangidae	*Caranx sp.*		+					+
Carangidae	*Elegatis bipinnulata*		+					+
Carangidae	*Gnathanodon speciosus*				+			+
Carangidae	*Selar crumenophthalmus*		+					+
Carangidae	*Selar sp.*		+					+
Carangidae	*Seriola spp.*			+				
Carcharhinidae	*Carcharhinus amblyrhynchos*						+	+
Carcharhinidae	*Carcharhinus melanopterus*		+					+
Chaetodontidae	*Chaetodon auriga*	+						
Chaetodontidae	*Chaetodon baronessa*						+	+
Chaetodontidae	*Chaetodon citrinellus*	+					+	+
Chaetodontidae	*Chaetodon kleinii*						+	+

Table Fiii Marine Fauna Species List

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Chaetodontidae	*Chaetodon lunula*						+	+
Chaetodontidae	*Chaetodon octofasciatus*				+			+
Chaetodontidae	*Chaetodon ornatissimus*						+	+
Chaetodontidae	*Chaetodon pelewensis*						+	+
Chaetodontidae	*Chaetodon reticulatus*	+						
Chaetodontidae	*Chaetodon semeion*				+		+	+
Chaetodontidae	*Chaetodon sp.*		+					+
Chaetodontidae	*Chaetodon trifasciatus*	+						
Chaetodontidae	*Chaetodon unimaculatus*						+	+
Chaetodontidae	*Forcipiger longirostris*						+	+
Chaetodontidae	*Heniochus acuminatus*				+			+
Chaetodontidae	*Heniochus dhrysostomus*				+		+	+
Chaetodontidae	*Heniochus singularius*						+	+
Chaetodontidae	*Heniochus varius*				+		+	+
Chanidae	*Channos sp*							+
Cirrhitidae	*Cirrhitichthys falco*						+	+
Cirrhitidae	*Cirrhitichthys oxycephalus*						+	+
Cirrhitidae	*Paracirrhites arcatus*						+	+
Cirrhitidae	*Paracirrhites forsteri*						+	+
Echeneidae	*Calumia godeffroyi*						+	+

Table Fiii Marine Fauna Species List

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Echeneidae	*Echeneis naucrates*		+					+
Glaucosomatidae	*Glaucosoma magnificum*		+					+
Gobidae	*Amblyeleotris steinitzi*				+			+
Gobidae	*Amblygobius decussatus*				+			+
Gobidae	*Amblygobius phalaena*				+			+
Gobidae	*Amblygobius rainfordi*				+			+
Gobidae	*Ancistrogobius yanoi*				+			+
Gobidae	*Cryptocentrus cinctus*				+			+
Gobidae	*Cryptocentrus inexplicatus*				+			+
Gobidae	*Ctenogobiops pomastictus*				+			+
Gobidae	*Eviota bifasciata*				+			+
Gobidae	*Eviota pellucida*				+			+
Gobidae	*Fusigobius neophytus*				+			+
Gobidae	*Fusigobius signipinnis*				+			+
Gobidae	*Macrodontogobius wilburi*				+			+
Gobidae	*Pleurosicya boldinghi*						+	+
Gobidae	*Pleurosicya elongata*				+			+
Gobidae	*Trimma griffthsi*				+			+
Gobidae	*Trimma naudei*				+			+
Gobidae	*Valenciennea muralis*				+			+

Table Fiii **Marine Fauna Species List**

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Gobidae	*Valenciennea sexguttata*				+			+
Gobidae	*Valenciennea strigata*						+	+
Haemulidae	*Plectorhinchis gibbosus*		+					+
Haemulidae	*Plectorhinchus sp.*		+	+				+
Holocentridae	*Myripristis adusta*						+	+
Holocentridae	*Myripristis kuntee*						+	+
Holocentridae	*Myripristis violacea*				+			+
Holocentridae	*Neoniphon argenteus*				+			+
Holocentridae	*Neoniphon opercularis*				+			+
Holocentridae	*Sargocentron caudimaculatum*							+
Holocentridae	*Sargocentron sp*						+	+
Istiophoridae	*Istiophorus platypterus*			+				
Kyphosidae	*Kyphosus sp*							+
Labridae	*Anampses caeruleopunctatus*						+	+
Labridae	*Anampses melanurus*						+	+
Labridae	*Anampses meleagrides*						+	+
Labridae	*Bodianus mesothorax*						+	+
Labridae	*Cheilinus fasciatus*				+			+
Labridae	*Cheilinus oxycephalus*						+	+
Labridae	*Cheilinus trilobatus*						+	+

Table Fiii Marine Fauna Species List

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Labridae	*Choerodon anchorago*				+			+
Labridae	*Coris gaimardi*						+	+
Labridae	*Diproctacanthus xanthurus*		+		+			+
Labridae	*Epibulus insidiator*				+		+	+
Labridae	*Halichoeres biocellatus*						+	+
Labridae	*Halichoeres chloropterus*				+			+
Labridae	*Halichoeres chrysus*						+	+
Labridae	*Halichoeres hortulanus*						+	+
Labridae	*Halichoeres leucurus*				+			+
Labridae	*Halichoeres margaritaceus*						+	+
Labridae	*Halichoeres marginatus*						+	+
Labridae	*Halichoeres prosopeion*						+	+
Labridae	*Halichoeres scapularis*				+			+
Labridae	*Halichoeres sp.*		+					+
Labridae	*Hemigymnus fasciatus*						+	+
Labridae	*Hemigymnus melapterus*				+		+	+
Labridae	*Macropharyngodon meleagris*						+	+
Labridae	*Macropharyngodon negrosensis*						+	+
Labridae	*Oxycheilinus celebicus*				+			+
Labridae	*Oxycheilinus diagrammus*						+	+

Table Fiii Marine Fauna Species List

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Labridae	*Parachelinus filamentosus*						+	+
Labridae	*Pseudocheilinops ataenia*				+			+
Labridae	*Pseudocheilinus evanidus*		+				+	+
Labridae	*Pseudocoris yamashiroi*						+	+
Labridae	*Pseudodax moluccanus*						+	+
Labridae	*Stethojulis trilineata*						+	+
Labridae	*Thalassom lunare*				+		+	+
Labridae	*Thalassoma amblycephalum*						+	+
Labridae	*Thalassoma hardwicke*						+	+
Labridae	*Thalassoma jansenii*						+	+
Labridae	*Thalassoma lutescens*		+					+
Labridae	*Thalassoma quinquevittatum*						+	+
Labridae	*Thalassoma sp.*		+					+
Leiognathidae	*Gazza minuta*		+					+
Leiognathidae	*Leiognathus sp.*		+					+
Lethrinidae	*Gnathodentes sp*							+
Lethrinidae	*Gnathodentes aurolineatus*						+	+
Lethrinidae	*Lethrinus atkinsoni*		+					+
Lethrinidae	*Lethrinus erythropterus*				+			+
Lethrinidae	*Lethrinus rubrioperculatus*		+					+

Table Fiii Marine Fauna Species List

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Lethrinidae	*Lethrinus sp.*		+	+				+
Lethrinidae	*Monotaxis sp*		+					+
Lutjanidae	*Aphareus sp*							+
Lutjanidae	*Aprion sp*			+				+
Lutjanidae	*Lutjanus argentimaculatus*		+					+
Lutjanidae	*Lutjanus bigutatus*						+	+
Lutjanidae	*Lutjanus bohar*						+	+
Lutjanidae	*Lutjanus carponotatus*				+			+
Lutjanidae	*Lutjanus malabaricus*			+				
Lutjanidae	*Lutjanus semicinctus*				+			+
Lutjanidae	*Lutjanus sp.*		+	+				+
Lutjanidae	*Macolor macularis*						+	+
Lutjanidae	*Macolor sp*		+					+
Lutjanidae	*Symphorichthys sp*							+
Malacanthidae	*Hoplolatilus cuniculus*						+	+
Monocanthidae	*Cantherhines dumerilii*	+						
Monocanthidae	*Cantherhines sp*							+
Monocanthidae	*Pseudomonacanthus sp.*		+					+
Mullidae	*Mulloidichthys flavolineatus*	+						
Mullidae	*Mulloidichthys sp.*		+					+

Table Fiii Marine Fauna Species List

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Mullidae	*Parupeneus bifasciatus*						+	+
Mullidae	*Parupeneus multifasciatus*	+					+	+
Mullidae	*Parupeneus pleurostigma*	+						
Mullidae	*Parupeneus sp.*	+	+					+
Mullidae	*Upeneus tragula*				+			+
Mullidae	*Upeneus vittatus*		+					+
Nemipteridae	*Gnathodentex*							+
Nemipteridae	*Pentapodus aureofasciatus*						+	+
Nemipteridae	*Pentapodus sp. 1*		+					+
Nemipteridae	*Pentapodus sp. 2*		+					+
Nemipteridae	*Pentapodus trivittatus*				+			+
Nemipteridae	*Scolopsis bilineatus*						+	+
Nemipteridae	*Scolopsis margaritifer*				+			+
Nemipteridae	*Scolopsis sp.*		+					+
Ostracidae	*Ostacion sp.*							+
Pinguipedidae	*Parapercis hexophtalma*		+					+
Pinguipedidae	*Parapercis millepunctata*						+	+
Pomacanthidae	*Centropyge bicolor*						+	+
Pomacanthidae	*Centropyge vroliki*						+	+
Pomacanthidae	*Chaetodontoplus mesoleucus*				+			+

Table Fiii **Marine Fauna Species List**

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Pomacanthidae	*Genicanthus melanospilos*						+	+
Pomacanthidae	*Pomacanthus sexstriatus*				+			+
Pomacanthidae	*Pygoplites diacanthus*						+	+
Pomacentridae	*Abudefduf sordidus*	+						
Pomacentridae	*Acanthochromis curacao*						+	+
Pomacentridae	*Acanthochromis leucogaster*						+	+
Pomacentridae	*Acanthochromis polyacantha*				+		+	+
Pomacentridae	*Amblyglyphidodon leucogaster*		+					+
Pomacentridae	*Amphiprion clarkii*						+	+
Pomacentridae	*Chromis alpha*						+	+
Pomacentridae	*Chromis amboinensis*						+	+
Pomacentridae	*Chromis delta*						+	+
Pomacentridae	*Chromis margaritifer*						+	+
Pomacentridae	*Chromis ovalis*	+						
Pomacentridae	*Chromis retrofasciata*						+	+
Pomacentridae	*Chromis ternatensis*				+		+	+
Pomacentridae	*Chromis verater*	+						
Pomacentridae	*Chromis weberi*						+	+
Pomacentridae	*Chromis xanthochira*						+	+
Pomacentridae	*Chromis xanthura*						+	+

Table Fiii Marine Fauna Species List

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Pomacentridae	*Chrysiptera brownriggtii*						+	+
Pomacentridae	*Chrysiptera cymatilis*				+			+
Pomacentridae	*Chrysiptera oxycephala*				+			+
Pomacentridae	*Chrysiptera rex*						+	+
Pomacentridae	*Chrysiptera rolandi*				+			+
Pomacentridae	*Chrysiptera talboti*						+	+
Pomacentridae	*Dascyllus melanurus*				+			+
Pomacentridae	*Dascyllus reticulatus*						+	+
Pomacentridae	*Dascyllus trimaculatus*						+	+
Pomacentridae	*Dischistodus perspicillatus*				+			+
Pomacentridae	*Dischistodus prosopotaenia*				+			+
Pomacentridae	*Hemiglyphidodon plagiometopon*				+			+
Pomacentridae	*Neopomacentrus filamentosus*				+			+
Pomacentridae	*Neopomacentrus nemurus*				+			+
Pomacentridae	*Plectroglyphidodon lacrymatus*						+	+
Pomacentridae	*Pomacentrus albimaculus*				+			+
Pomacentridae	*Pomacentrus amboinensis*						+	+
Pomacentridae	*Pomacentrus aurifrons*				+			+
Pomacentridae	*Pomacentrus bankanensis*						+	+
Pomacentridae	*Pomacentrus brachialis*						+	+

Table Fiii **Marine Fauna Species List**

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Pomacentridae	*Pomacentrus burroughi*				+			+
Pomacentridae	*Pomacentrus coelestis*						+	+
Pomacentridae	*Pomacentrus lepidogenys*						+	+
Pomacentridae	*Pomacentrus moluccensis*				+			+
Pomacentridae	*Pomacentrus nigromanus*				+			+
Pomacentridae	*Pomacentrus nigromarginatus*						+	+
Pomacentridae	*Pomacentrus pavo*				+			+
Pomacentridae	*Pomacentrus philippinus*						+	+
Pomacentridae	*Pomacentrus reidi*						+	+
Pomacentridae	*Pomacentrus simsiang*				+			+
Pomacentridae	*Pomacentrus vaiuli*						+	+
Pomacentridae	*Stegastes nigricans*				+			+
Pseudochromidae	*Pseudochromis fuscus*				+			+
Ptereleotridae	*Ptereleotris evides*						+	+
Ptereleotridae	*Ptereleotris heteroptera*						+	+
Ptereleotridae	*Ptereleotris microlepis*				+			+
Ptereleotridae	*Ptereleotris uroditaenia*				+			+
Ptereleotridae	*Ptereleotris zebra*						+	+
Scaridae	*Cetoscarus bicolor*						+	+
Scaridae	*Chlorurus bleekeri*		+					+

Table Fiii **Marine Fauna Species List**

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Scaridae	*Chlorurus microrhinos*				+			+
Scaridae	*Chlorurus sordidus*						+	+
Scaridae	*Chlorurus sp*						+	+
Scaridae	*Hipposcarus sp*		+					+
Scaridae	*Scarus dimidiatus*				+			+
Scaridae	*Scarus flavipectoralis*				+			+
Scaridae	*Scarus forsteni*						+	+
Scaridae	*Scarus globicepts*						+	+
Scaridae	*Scarus niger*						+	+
Scaridae	*Scarus psittacus*						+	+
Scaridae	*Scarus rubroviolaceus*						+	+
Scaridae	*Scarus sp.*		+	+				+
Scaridae	*Scarus spinus*						+	+
Scombridae	*Sarda spp.*			+				
Scombridae	*Scomberomorus spp.*			+				
Scombridae	*Thunnus sp.*			+				
Scorpaenidae	*Sebastapistes cyanostigma*						+	+
Serranidae	*Anyperodon leucogrammicus*						+	+
Serranidae	*Cephalopholis argus*						+	+
Serranidae	*Cephalopholis boenack*				+			+

Table Fiii Marine Fauna Species List

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Serranidae	*Cephalopholis cyanostigma*				+			+
Serranidae	*Cephalopholis sp.*	+	+					+
Serranidae	*Cephalospholis leopardus*						+	+
Serranidae	*Cephalospholis microprion*				+			+
Serranidae	*Cephalospholis spiloparaea*						+	+
Serranidae	*Cephalospholis urodeta*						+	+
Serranidae	*Diploprion bifasciatum*						+	+
Serranidae	*Plectropomus oligocanthus*				+			+
Serranidae	*Plectropomus sp.*		+	+				+
Serranidae	*Pseudanthias pleurotaenia*						+	+
Serranidae	*Pseudanthias sp.*		+					+
Serranidae	*Variola albimarginata*						+	+
Siganidae	*Siganus doliatus*				+		+	+
Siganidae	*Siganus puellus*						+	+
Siganidae	*Siganus sp.*		+					+
Sphyraenidae	*Sphyraena sp.*		+	+				+
Syngnathidae	*Doryrhamphus sp.*		+					+
Synodontidae	*Synodus sp.*		+					+
Tetraodontidae	*Arothon mappa*				+			+
Tetraodontidae	*Arothron nigropunctatus*		+		+			+

Table Fiii Marine Fauna Species List

Family	Species Name	PHCG (2015) Survey	GHD (2014) Baseline Survey	SMM 2012	Tatamba (Site 4a) Green et al (2004)	Tirahi (Site 4b) Green et al(2004)	Tanabafe (Site 5) Green et al (2004)	Isabel Province
		Confirmed recordings for Isabel Province						Potentially occurring species
Tetraodontidae	*Canthigaster epilampra*						+	+
Tetraodontidae	*Canthigaster papua*				+			+
Zanclidae	*Zanclus cornutus*				+		+	+
Zenarchopteridae	*Zenarchopterus dispar*	+						
CORALS								
Acroporidae	*Acropora spp.*		+					+
Acroporidae	*Anacronopora spp.*		+					+
Acroporidae	*Astreopora spp.*		+					+
Acroporidae	*Isopora spp.*		+					+
Acroporidae	*Montipora spp.*		+					+
Agariciidae	*Coeloseris spp.*		+					+
Agariciidae	*Gardineroseris spp.*		+					+
Agariciidae	*Leptoseris spp.*		+					+
Agariciidae	*Pachyseris spp.*		+					+
Agariciidae	*Pavona spp.*		+					+
Dendrophylliidae	*Tubastrea spp.*		+					+
Euphilliidae	*Euphyllia spp.*		+					+
Euphilliidae	*Physogyra spp.*		+					+
Euphilliidae	*Plerogyra spp.*		+					+
Faviidae	*Australogyra spp.*		+					+

Table Fiii Marine Fauna Species List

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Faviidae	*Caulastrea spp.*		+					+
Faviidae	*Cyphastrea spp.*		+					+
Faviidae	*Diploastrea spp.*		+					+
Faviidae	*Echinopora spp.*		+					+
Faviidae	*Favia spp.*		+					+
Faviidae	*Favites spp.*		+					+
Faviidae	*Goniastrea spp.*		+					+
Faviidae	*Leptastrea spp.*		+					+
Faviidae	*Leptoria spp.*		+					+
Faviidae	*Montastrea spp.*		+					+
Faviidae	*Moselya spp.*		+					+
Faviidae	*Oulophyllia spp.*		+					+
Faviidae	*Platygyra spp.*		+					+
Fungiidae	*Ctenactis spp.*		+					+
Fungiidae	*Cycloseris spp.*		+					+
Fungiidae	*Fungia spp.*		+					+
Fungiidae	*Halomitra spp.*		+					+
Fungiidae	*Heliofungia spp.*		+					+
Fungiidae	*Herpolitha spp.*		+					+
Fungiidae	*Polyphyllia spp.*		+					+

Table Fiii **Marine Fauna Species List**

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Fungiidae	*Sandalolitha spp.*		+					+
Merulinidae	*Hydnophora spp.*		+					+
Merulinidae	*Merulina spp.*		+					+
Merulinidae	*Paraclavarina spp.*		+					+
Milleporidae	*Millepora spp.*		+					+
Musiidae	*Acanthastrea spp.*		+					+
Musiidae	*Cynarina spp.*		+					+
Musiidae	*Lobophyllia spp.*		+					+
Musiidae	*Scolymia spp.*		+					+
Musiidae	*Symphyllia spp.*		+					+
Oculinidae	*Galaxea spp.*		+					+
Pectinidae	*Echinophyllia spp.*		+					+
Pectinidae	*Mycedium spp.*		+					+
Pectinidae	*Oxypora spp.*		+					+
Pectinidae	*Pectinia spp.*		+					+
Pocillioporidae	*Pocillopora spp.*		+					+
Pocillioporidae	*Seriatopora spp.*		+					+
Pocillioporidae	*Stylophora spp.*		+					+
Poritidae	*Alveopora spp.*		+					+
Poritidae	*Goniopora spp.*		+					+

Table Fiii Marine Fauna Species List

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Poritidae	*Porites spp.*		+					+
Rotulidae	*Heliphora spp.*		+					+
Siderasteridae	*Coscinaraea spp.*		+					+
Siderasteridae	*Psammocora spp.*		+					+
Stylasteridae	*Distichopora spp.*		+					+
Stylasteridae	*Stylaster spp.*		+					+
Trachyphyllidae	*Trachyphyllia spp.*		+					+
Tubiporidae	*Tubipora spp.*		+					+
OTHER INVERTEBRATES								
Bivalvia	*Polymesoda erosa*			+				+
Bivalvia	*Polymesoda espansa*							+
Decapoda	*Callinectes sp.*	+						+
Decapoda	*Conus spp*	+						+
Decapoda	*Nerita costata*	+						+
Decapoda	*Pinularus sp.*	+						+
Decapoda	*Portunus pelagicus*							+
Decapoda	*Scylla serrata*	+						+
Decapoda	*Scylla spp.*			+				
Decapoda	*Thais spp*	+						+
Decapoda	*Thalamita crenata*							+

Table Fiii Marine Fauna Species List

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Bivalvia	*Atrina vexillum*					+		+
Bivalvia	*Beguina semiorbiculata*					+		+
Bivalvia	*Hippopus hippopus*							+
Bivalvia	*Pinctada margaritifera*							+
Bivalvia	*Pinctada maxima*							+
Bivalvia	*Pinctada spp.*			+				
Bivalvia	*Pteria penguin*							+
Bivalvia	*Tridacna crocea*					+		+
Bivalvia	*Tridacna derasa*							+
Bivalvia	*Tridacna gigas*							+
Bivalvia	*Tridacna maxima*						+	+
Bivalvia	*Tridacna sp.*							+
Bivalvia	*Tridacna squamosa*		+					+
Cardiidae	*Trachycardium vertebratum*			+				
Decapoda	*Panulirus femoristiga*							+
Decapoda	*Panulirus ornatus*							+
Decapoda	*Panulirus pencillatus*							+
Decapoda	*Panulirus spp.*			+				
Decapoda	*Panulirus versicolor*							+
Gastropododa	*Caronia tritonis*							+

Table Fiii **Marine Fauna Species List**

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Gastropododa	*Cypraea sp.*		+					+
Gastropododa	*Lamis lambis*		+					+
Gastropododa	*Pyrazus ebeninus*			+				
Gastropododa	*Tectus pyramis*		+	+			+	+
Gastropododa	*Trochus maculates*			+				+
Gastropododa	*Trochus niloticus*			+			+	+
Gastropododa	*Turbo marmoratus*							+
Gastropododa	*Turbo spp 1*	+						+
Gastropododa	*Turbo spp 2*	+						+
Holothuridae	*Actinopyga crassa*							+
Holothuridae	*Actinopyga leacanora*							+
Holothuridae	*Actinopyga miliaris*							+
Holothuridae	*Bahadschia argus*							+
Holothuridae	*Bohadschia similes*							+
Holothuridae	*Bohadschia vitensis*							+
Holothuridae	*Holothuria atra*		+				+	+
Holothuridae	*Holothuria edulis*		+			+		+
Holothuridae	*Holothuria fuscogilva*						+	+
Holothuridae	*Holothuria fuscopunctata*							+
Holothuridae	*Holothuria nobilis*							+

Table Fiii Marine Fauna Species List

		Confirmed recordings for Isabel Province						Potentially occurring species
Family	**Species Name**	**PHCG (2015) Survey**	**GHD (2014) Baseline Survey**	**SMM 2012**	**Tatamba (Site 4a) Green et al (2004)**	**Tirahi (Site 4b) Green et al(2004)**	**Tanabafe (Site 5) Green et al (2004)**	**Isabel Province**
Holothuridae	*Holothuria scabra*			+				+
Holothuridae	*Pearsonothuria graeffei*		+				+	+
Holothuridae	*Stichopus chloronotus*							+
Holothuridae	*Stichopus germanni*					+		+
Holothuridae	*Stichopus pseudohorrens*							+
Holothuridae	*Thelenota ananas*							+
Holothuridae	*Thelenota anax*						+	+
Holothuridae	*Thelenota rubralineatus*							+
Ophidiasteridae	*Linckia sp.*	+						

Appendix G

Noise assessment

20 October 2017

Ground Floor, Suite 01, 20 Chandos Street
St Leonards, NSW, 2065
PO Box 21
St Leonards, NSW, 1590

T +61 2 9493 9500
F +61 2 9493 9599
E info@emmconsulting.com.au

www.emmconsulting.com.au

Ellie Thackray
Senior Environmental Scientist
EMM Consulting
Level 4, Suite 1, 87 Wickham Terrace
Spring Hill, Queensland 4000

Re: San Jorge Nickel project - Noise impact assessment

Dear Ellie,

1 Introduction

Axiom KB Limited (Axiom KB), a subsidiary of Axiom Mining Limited (Axiom), proposes to develop mineral deposits on San Jorge Island in the Isabel Province of the Solomon Islands (the project). The project will comprise extraction of approximately 2 million tonnes per annum (Mtpa) of nickel laterite deposits over a period of approximately seven to ten years.

EMM has prepared a noise impact assessment to accompany an EIS for the project. This report presents an assessment of potential noise impacts from the operation of the project on the surrounding noise-sensitive receivers.

The assessment has been prepared with reference to the following standards and guidelines:

- ISO (International Standards Organisation), Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation, ISO9613-2:1996, 1996; and
- IFC (International Finance Corporation) 2007, *Environmental, health and safety (EHS) guidelines - Section 1.7 Noise*.

2 Noise-sensitive receivers

The nearest noise sensitive receivers were identified to be village dwellings and traditional huts within the Talise village, to the north-west of the project site, and temporary settlements including a garden in Kogarutu and a coconut plantation in Loghutu, to the east and south-east of the project site, respectively. The nearest representative noise sensitive receivers considered in this assessment are listed in Table 1.

Table 1 Noise-sensitive receivers

Receiver	Description	MGA Coordinates (Zone 57 L)	
		Easting	Northing
R1 –Talise	Nearest dwelling to the project in Talise	569113 E	9062953 S
R3 – Kogarutu	Temporary settlement in Kogarutu	575445 E	9059212 S
R4 - Loghutu	Temporary settlement in Loghutu	575364 E	9056575 S

These noise-sensitive receivers represent those most likely to be affected by the project. Adherence with noise criteria at these locations would indicate that noise criteria will be met at other surrounding noise-sensitive locations.

3 Noise criteria

The following noise criteria for the project was established based on the IFC (2007) noise level guidelines, which recommend that noise levels at a sensitive location not exceed an increase of 3 dB over the ambient levels, or, that the following maximum noise levels not be exceeded:

- Residential, institutional and educational locations – $L_{Aeq,1\ hour}$ 55 dB during the daytime period (7:00 am-10:00 pm) and $L_{Aeq,1\ hour}$ 45 dB during the night-time period (10:00 pm-7:00 am).

- Industrial and commercial locations – $L_{Aeq,1\ hour}$ 70 dB (24 hours).

The criterion of $L_{Aeq,1\ hour}$ 55 dB for daytime and $L_{Aeq,1\ hour}$ 45 dB for night-time were adopted for this assessment.

4 Methodology

4.1 Noise modelling

The acoustic assessment has been completed using the noise prediction algorithm provided in ISO 9613-2:1996 *Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation*. It is an engineering method for calculating the attenuation of outdoor sound propagation and has been used to predict environmental noise levels from the project to nearest noise sensitive receivers. It predicts the equivalent continuous A-weighted sound pressure level under noise enhancing meteorological conditions from sources of known noise emission.

4.2 Noise impact assessment

This section presents the methods and assumptions used to model noise emissions from the project.

The model has considered factors such as:

- the location of the noise source;

- distance from the source to nearest potential receiver; and

- topography of the project site and surrounding area.

Noise modelling was based on the typical worst-case scenario, this assumes;

- 24 hours per day, 7 days per week operations;

- all plant and equipment operating at the nearest point of the disturbance area of the San Jorge Nickel project (ie the closest practical location to each noise-sensitive receiver);

- all mine equipment and plant operating concurrently; and

- downwind propagation to the receivers.

Potential noise levels from project operations were predicted using the aforementioned noise modelling method. The A-weighted sound power level (L_w) for each of the operational plant and equipment items has been sourced from an EMM database of similar equipment. Two port options have been modelled; with a base port option at the north of the project site and an alternative port option to the east of the project site.

The primary plant and equipment on site and their corresponding sound power levels can be seen in Table 2.

Table 2 Operational plant and equipment sound power levels

Plant and equipment	Quantity	Sound power level, $L_{Aeq,1\ hour}$, dB
70t excavator	1	107
90t excavator	3	116
24t dump truck	12	105
40t ADT (Articulated dump truck)	10	108
Small water cart	1	96
Track dozer	3	119
Soil compactor	1	116
Front end loader	5	115
Motor grader	1	108
Lighting plant	10	107
Pit dewatering pump	3	111
Service truck	1	110
Light vehicle / 4WD	10	76
Mobile crusher	1	114

5 Modelling results

The modelling results have been predicted at three noise-sensitive receivers; the nearest dwelling within the Talise village and one location at each of the temporary settlements at Kogarutu and Loghutu. The noise modelling results are summarised in Table 3.

Table 3 Noise modelling results

Receiver	Port Option	Noise level, $L_{Aeq,1\ hour}$, dB	Criteria, $L_{Aeq,1\ hour}$, dB	Exceedance, dB
R1 - Talise (Nearest dwelling)	Base	31	$L_{Aeq,1\ hour}$ 55 dB (Daytime) $L_{Aeq,1\ hour}$ 45 dB (Night-time)	Nil
	Alternative	31		Nil
R2 - Kogarutu (Garden)	Base	37	$L_{Aeq,1\ hour}$ 55 dB (Daytime) $L_{Aeq,1\ hour}$ 45 dB (Night-time)	Nil
	Alternative	N/A[1]		Nil
R4 - Loghutu (Coconut plantation)	Base	35	$L_{Aeq,1\ hour}$ 55 dB (Daytime) $L_{Aeq,1\ hour}$ 45 dB (Night-time)	Nil
	Alternative	45		Nil

Notes: 1. Under the alternative port option, this location is part of the project area and would be removed as a noise-sensitive receiver.

Under the base port option, noise modelling predicts that sound pressure levels received at the nearest noise sensitive locations would range between $L_{Aeq,1\ hour}$ 31 dB and $L_{Aeq,1\ hour}$ 37 dB. Under the alternative port option, predicted noise levels remain unchanged at R1 (Talise) and increase to $L_{Aeq,1\ hour}$ 45 dB at location R3 (Loghutu). Under the alternative port option, R2 (Kogarutu) is integrated into the project area and would be removed as a noise-sensitive receiver. Notwithstanding, all noise predictions are below the daytime and night-time IFC noise criteria adopted for this assessment.

The equipment used in the construction of the port/jetty facilities will be similar to the operational equipment employed; however there are lesser equipment requirements for the construction phase. Therefore, construction noise impacts are likely to be lower than operational impacts at the noise-sensitive receivers. As such, noise modelling of the projects construction activities was not undertaken.

6 Conclusion

EMM has prepared a noise impact assessment to accompany an EIS for the proposed San Jorge Nickel project in the Isabel Province of the Solomon Islands. This report presents an assessment of potential noise impacts from the operation of the San Jorge Nickel project on the surrounding noise-sensitive receivers.

Operational noise levels were assessed for the daytime and night-time periods. The assessment found that, for both port options, noise from project operations is predicted to satisfy IFC noise criteria for daytime and night-time periods at all identified noise sensitive receivers.

Construction noise impacts from the project are expected to be lower than operational impacts at the noise-sensitive receivers and, as such, is expected to satisfy IFC noise criteria.

We trust the above meets your requirements and if you have any further queries please contact our team.

Yours sincerely

Lucas Adamson
Acoustic Consultant
ladamson@emmconsulting.com.au
Review: NI (20/10/17)

Appendix H

Stakeholder consultation

Record of Community Consultations for South San Jorge Tenement

Date	Venue	Axiom Team Members	Community Members present	Matters discussed, Issues Raised	Issues Resolved/ Follow Up Actions	Remarks, Responsibility for Follow up
16-01-2016	Kolosori camp, Talise, Havihua, Lubiria	Baltazare Rongo	Stephenson carlos, Samuel Efulu, John, Michael Doko	Seek consensus from Land owners for the deployment of water monitoring devices	All given their approval for deployment of monitoring device	
17-01-2016	Sepi	Baltazare Rongo	Elson Bako	Seek consensus from Land owners for the deployment of water monitoring devices	Has objection for his block of land	GM Sustainability
21-01-2016 – 24-01-2016	Sigana, Suva, Sepi and Thathade, Vulavu, Lepi, Japuana, Vavina, Leleghia and Talise	Fr Lot Bako, Francis Waleanisia (contracted by Axiom)	More than 120 people talked to during this consultation	Resolving internal Bungusule dispute between Fr Lot Bako's group and Lawrence Maena's Group Also seeking views on including G1, G2, G3, G4, G5, G6, G25 and G 26 Groups within a new SAA with Axiom	- There is general agreement for a need to have a structure that is inclusive of everyone - People want benefits of mining but they want information and participation	- Appropriate structure for management and governance of the San Jorge tenement
29-01-2016	Kolosori Camp	John Kopana, Henning Coetzee, Carl Paton, Carlos Maelaua	Father Lot Bako	Arrangements for security of env. monitoring equipment to be installed on Bungusule land on San Jorge. Monitoring stations at Tanatola Bay is done without an SAA, but with an Axiom understanding that processes are in place for them to be included in the SAA. Security for these instruments is the responsibility of Axiom and the identified landowners.	- SAA (already signed and endorsed by the Bungusule) includes all env. monitoring on their land. - Recruitment for security must be done within the agreed structure. - Security jobs will have to be rotated between different villages (Talise and Sepi) to ensure fair sharing of benefits.	

Date	Venue	Axiom Team Members	Community Members present	Matters discussed, Issues Raised	Issues Resolved/ Follow Up Actions	Remarks, Responsibility for Follow up
					- The Bungusile model of engagement is being used for employment of personnel to look after the Tantola Bay equipment. Axiom to pursue completion of SAA with Tantola Bay landowners	GM Sustainability
29-02-2016 – 1-03-2016	Nagolau, Suva, Sepi, Lepi, Kamaosi, Vulavu, Sigana, Thathaje, Midoru, Japuana, Vulavu	These consultations were carried out by the respective tribal representative of G1, G2, G3, G4, G5, G6, G25 and G 26.	The tribal members of the groups were gathered in their villages	Matter discussed is whether the other groups are willing to be part of a new SAA for those specific groups	There was general consensus that Axiom should have a separate and new SAA with those groups	Dr Tagini to take up this matter and move to drafting SAA
14.03.2016	Kolosori Camp	Ernest Kolly, Molton Levo, Carlos Maelaua	Wilton Livua – Thathaje Joel Doma - Sepi Samuel Efulu - Talise Samuel Voti - Talise Amos Vae - Sepi Patterson Relly - Opi Paul Bonsley - Vulavu	- Discussions focus on work allocation surrounding securities on monitoring devices including creek, marine monitoring devices and weather station. - Informs coordinators that the instrument in Ghobu will have to be removed from site due to vandalism. This is until consultants are back on track and assess damage and repairs. Only the weather station will need security personnel at this stage	Issues of security personal hiring resolved.	Further meeting with CA officer – Baltazare Rongo

Date	Venue	Axiom Team Members	Community Members present	Matters discussed, Issues Raised	Issues Resolved/ Follow Up Actions	Remarks, Responsibility for Follow up
18.03.2017	IPG Conference Room, Buala		1. Hon James K Habu - Premier 2. John Lokumana Thompson Tavake Nicholas Kuli John Gao Edward Koti Lyndon Koti	SSJ land owners presentation to the IPG executive of their interest to develop the San Jorge Nickel project		
03.05.2016	Honiara Office	Dr. Phil Tagini, Baltazare Rongo, Carlos Maelaua, John Kopana	Eddy Koti, Asa ageage, Nicholas Kuli, John Sagede	Touch base with SSJ leaders and plan community awareness in the villages. Mainly to explain the decision of Court of Appeal, get views from people regarding our way forward together.		
04.06.2016	Sepi Village	Mr. Ryan Mount (CEO) Dr. Phil Tagini (General Manager Sustainability) Mr. John Kopana (Senior Mine Geologist) Mrs. Wendy Mount (Manager Administration and Logistics) Mr. Baltazare Rongo (Community Affairs Officer	More than 40 people, men, women, children	General awareness to people - After a lengthy process by law, the court rules that land registration process at Kolosori is invalid therefore the land title is invalidated by the court - Kolosori PL is affected by the court decision while South San Jorge Pl is not affected by this same court ruling - Axiom therefore has a valid license on south San Jorge and will proceed to sorting out the remaining SAA issues and will soon enter and carry out prospecting work at San Jorge.	Awareness well received	

Date	Venue	Axiom Team Members	Community Members present	Matters discussed, Issues Raised	Issues Resolved/ Follow Up Actions	Remarks, Responsibility for Follow up
04.06.2016	Talise village	Mr. Ryan Mount (CEO) Dr. Phil Tagini (General Manager Sustainability) Mr. John Kopana (Senior Mine Geologist) Mrs. Wendy Mount (Manager Administration and Logistics) Mr. Baltazare Rongo (Community Affairs Officer	More than 80 people, men, women, children	General awareness to people - After a lengthy process by law, the court rules that land registration process at Kolosori is invalid therefore the land title is invalidated by the court - Kolosori PL is affected by the court decision while South San Jorge PL is not affected by this same court ruling - Axiom therefore has a valid license on south San Jorge and will proceed to sorting out the remaining SAA issues and will soon enter and carry out prospecting work at San Jorge.	Awareness well received	
06 – 11/07/2016	Naholau, Sepi, Thathaje, Binaboli, Vulavu, Lepi, Japuana	Baltazare Rongo	Land owners of G1,G2,G3,G4,G5,G6, G25 & G26	Each G land owning groups have their own separate meeting and mandate their respective trustees to represent them in negotiations and other meetings call by the company as well as to manage their trust funds	All meetings successful	

Date	Venue	Axiom Team Members	Community Members present	Matters discussed, Issues Raised	Issues Resolved/ Follow Up Actions	Remarks, Responsibility for Follow up
13.08.2016	Heritage Park Hotel	Dr Phil Tagini, John Kopana, Ken Stein	Fr Lot Bako, David Siriu, Janet Tahi Wong, Joel Voda, Samuel Benora, John Foru, Dr Tagini, Ken Stein, John Kopana and Elmeleck Vamuke	- Exploration program for Bungusule; - Environmental and social impacts; - Tabu-site identification knowledgeable landowners; - Employment opportunities; - Landing and road development; - Other matters	- Issue of leadership within Bungusule is raised; - It is obvious there is disagreement over previous distributions of monies by Fr Lot; - Otherwise there is general agreement for exploration work to be carried out	CA team to work through the simmering issues of representation and reconcilitation
19.08.2016	Sepi Village	John Kopana, Phil Tagini, Ken Stein	Noel Nanate, Alice Ku'u, Wilton Livua, Andrew Manohegegna, Clement Voda, Simon Ngavi, Martha Bata, Amos Vae, Bako Sieke, Kokolo Thaba Ellison Bako, John Foru, and Elmeleck Vamuke (SIG)	Repeat of the Heritage Park presentation	- Similar issues as Heritage Park meeting	- Further information to assist in designing program for reconciliation and selecting new trustees
03.09.2016	Talise Village	John Kopana, Baltazare Rongo, Carl Paton, Carlos Maelaua	Edwin Ramo Samson Muaoli Samuel voti Samuel Efulu William Sago Moses Daniel Hugo Ladia Leonard Kibo	Following on from the 13th & 19th of August meeting. This meeting is to 1.Confirm validity of PL 01/15 2.Announce the proposed work program which plan to start this month	Meeting concluded successfully	

Date	Venue	Axiom Team Members	Community Members present	Matters discussed, Issues Raised	Issues Resolved/ Follow Up Actions	Remarks, Responsibility for Follow up
			Martin Maetadi Willy Doedoeke Peter Taguru Edith Kefu Abgiel Sofia Amena Bratha Olivia Bolei Teresa Merilyn Norman Rosi Junior Khibo Fanet Helen Rosemary Jessica Liza Sameta Charles Maetadi Hene John Usura Jessy Vido Kotha Evelyn (30 others) Alick Haegemana Adison Dohi Ela			

Date	Venue	Axiom Team Members	Community Members present	Matters discussed, Issues Raised	Issues Resolved/ Follow Up Actions	Remarks, Responsibility for Follow up
			Koula Alice Na'ae Sabela Joyce Venson Vageson Racheal Koti Jalinda Georgina George Rio Ambrose Gabriel Clera John Ghuru Joseph Susan Aunodi Rosa Lazilwin Japhet Joel Male Kafenoda Jomo Sisilia			

Date	Venue	Axiom Team Members	Community Members present	Matters discussed, Issues Raised	Issues Resolved/ Follow Up Actions	Remarks, Responsibility for Follow up
			Michael Andrew Rolbon Carolyn			
04.09.2016	Sepi village	John Kopana, Baltazare Rongo, Carl Paton	Joel Voda, Joel Voda, Clement Voda, Adrew Monogegna, Rolland Pade, Hugget lo'o, Wilton Livua, Amos Vae, Emy Kikolo, Anneth, Martha Bata, Joyce, Simon Ngavi, Richard Himane, Calvick Sobu, Rymond Kodala, Mike	Following on from the 13th & 19th of August meeting. This meeting is to 1.Confirm validity of PL 01/15 2.Announce the proposed work program which plan to start this month	Villagers (back by Rolland Pade) oppose the landing of land craft at Bungusule before the decision of the minerals board is made known to the public	
05.09.2016	Fr. Lot Bako's residence (Kamaosi School)	John Kopana, Baltazare Rongo	Samuel Vot,I, Hugget Lo'o, Fr. Lot Bako, Clement Voda, Japheth (Talise)	1. Confirmed access for Axiom to Bungusule land 2. Bungusule reps. to appoint their trustee representatives	Bungusule leaders confirmed their consent to allow access for Axiom into Bungusule land and also give a list of their mandated trustees. Land craft is allowed to land at Bungusule on the schedule date by Axiom	Issue resolved
21.09.2016	Bungusule Camp	Carlos Maelaua, Mikelyn Charly, Molton Levo	1. Frank Loni 2. Wilson Tohidi 3. Hugo Ladia 4. Walter Gagai 6. Joseph Heim 7. Paul Fota	Frank Loni and others have entered the camp and presented their concern to camp operation regarding their land ownership.	Issue noted and forwarded to Honiara office	Dr. Phil to make reply to these concerns

Date	Venue	Axiom Team Members	Community Members present	Matters discussed, Issues Raised	Issues Resolved/ Follow Up Actions	Remarks, Responsibility for Follow up
25.09.2016	Bungusule Camp	Baltazare Rongo	Casual workers	Make a formal presentation of their concern for Axiom to increase their wages and received by Baltazare on site. Make attempt to negotiate but the workers refuse	Issue noted and forwarded to Honiara office	To be discuss during the Forum
28.09.2016	Phone - Bungusule Camp	Baltazare Rongo	Frank Loni	1. Call received from Frank Loni by CA officer on site (Bala) threatening to disturb barge landing on Saturday. 2. Insist that Axiom must include him as trustees to Bungusule land	Issue noted and forwarded to Honiara office	To be discuss during the Forum
30.09.2016	Bungusule Camp	Baltazare Rongo, Ken Stein, Carlos Maelaua	Frank Loni	1. Intend to stop barge from unloading	Meeting resolved that axiom will continue to unload cargoe and keep at Kogarutu until after the LO forum	Await resolution during the LO Forum
02.10.2016	Kogarutu (Elison Bako's residence)	Dr. Phillip Tagini, Ken Stein, Baltazare Rongo, Jork	Chief E. Bako Fr. Lot Bako Hugget Lo'o Wilton Livua Clement Voda Japheth Humu Samuel Voti P.Relly C. Maetadi E.Ramhu Paul Chief M. Kokoi Wilson Tohidi Frank Loni Venson Mae Alick H	1. Awareness on work program 2. Announce work program for first 3 months 3. Environmental program to go along with drilling program 4. Call on all stake holders to work together especially chiefs & village leaders/elders 5. Frank Loni present his concerns of inclusion as signatories to SSJ	1. Meeting end successfully with one meeting the next day on site with casuals 2. Meeting resolved that Loni's issue be dealt as an internal matter by Bungusule land owners	Copies of required document to be made available during the next meeting – to be prepare by Baltazare

Date	Venue	Axiom Team Members	Community Members present	Matters discussed, Issues Raised	Issues Resolved/ Follow Up Actions	Remarks, Responsibility for Follow up
			Samson M Casper Rova William Sago Brian Zeva Leonard Khibo Norman Resi Reuben Male Silas Rane Geroge Konia Phillip Tana Walter Gagai TavakeDohi Walter Hobi Michael Doko Evan Kumo Andy Jimmy Habalu Joseph H Gigini Willy Renward Matesala Thompson Adison			
03.10.2016	Bungusule Camp site	Dr. Phillip Tagini, Ken Stein, Baltazare Rongo	9 local causals	Local casuals protest for pay increase from $70 per man per day.	Issue resolved. Company agreed to pay casuals at $130/man/day flat rate.	

Date	Venue	Axiom Team Members	Community Members present	Matters discussed, Issues Raised	Issues Resolved/ Follow Up Actions	Remarks, Responsibility for Follow up
05.10.2016	Vavula (old jetty)	Baltazare Rongo	Emy Kikolo, Chief Amos Vae, Rolland Pade, Two other elders, Rupat Bako, Sueti Kafa	Emy Kikolo expresses disagreement over Axiom's consultation with Fr. Lot and gives a 7 days stop work notice for company verbally	Issues noted	Fr. Lot & Dr. Phil to further explain to Emy Kikolo
08.10.2016	Phone	Baltazare Rongo	Frank Loni	Discuss over phone that his concerns must be address. The resolutions of the forum is not adequate	Issues noted	
24.10.2016	Phone – Bungusule Camp	Baltazare Rongo	Frank Loni	1. Call receive from Frank by CA officer between 10:30 – 11pm threatening to order axiom staff on site to pull off camp and leave Bungusule 2. Question why he has not heard anything from either Fr. Lot or Axiom regarding his request to be included as trustees for Bungusule 3. Levelled personal threats on me (CA officer) for not listening and addressing his concerns raised	Concerns noted difficult to explain things with him as he seems to be under influence of alcohol at that time	
01.11.2016	Phone – Bungusule Camp	Baltazare Rongo	Frank Loni	1. Call to enquire if Fr. Lot has already met with Bungusule leaders to address his concerns. 2. Order all axiom staff out of site immediately. 3. Make personal threats to CA officer on site	Concerns noted and reported to Senior geologist on site.	Precautions made know to all workers on site of possible intrusion by Frank and his supporters.
02.11.2016	Bungusule camp	Baltazare Rongo	1. Steward Kelly 2. Wilson Tohidi 3. Japheth Hamu	Make a strong request for Axiom to consider recruiting locals from Talise & not Sepi alone. Threaten to halt operation if this request is not considered.	Concern noted and reported to Honiara office	

Date	Venue	Axiom Team Members	Community Members present	Matters discussed, Issues Raised	Issues Resolved/ Follow Up Actions	Remarks, Responsibility for Follow up
08.11.2016	Bungusule Camp	Baltazare Rongo	Japheth hamu	Response to their concern letter was made to Japheth both formally and verbally	Issue resolved	
16.11.2016	Talise community hall	Dr. Phillip Tagini, Baltazare Rongo , Elmeleck Vamuke (SIG rep)	Fr. Lot Bako plus 60 other villagers	Reconcile the broken relationship between Bungusule – Talise people and Sepi people. SIG official confirms the validity of Pl 01/15 and restore good working relationship between the two Bugnusule groups of people and the company.	Meeting ends successfully	1. Villagers to have their own meeting in the afternoon 2. Work on camp to resume 3. Soil samples to be released by villagers
18-04-2017	Honiara	Dr Phil Tagini, Philip Riogano	Sam Spencer Voda	Disagreements with Fr Lot Bako as their trustee and over some payments they believe they are entitled to.	Internal group problem (need to be solved within the group itself). Bungusule LOGF needs to stand united. A reconciliation program for Bungusule LOGF scheduled for few weeks' time.	
20-04-2017	Honiara	Lyndon Bako, Philip Riogano	Martin Jaiki, John Gao, Asa Ageage and sisters (Furona village LOGF claiming G6,G26 &G1)	No family member represented as trustees in block G26, G6, G1 (They claim rightful owners)	Issue to be resolved by LOs and not company. Produce supporting legal documents to prove ownership or else those signing SAA still regarded as owners.	LOs from Furona to produce legal documents and submit to office as soon as possible.

Date	Venue	Axiom Team Members	Community Members present	Matters discussed, Issues Raised	Issues Resolved/ Follow Up Actions	Remarks, Responsibility for Follow up
22-04-2017 & 23-04-2017	Vulavu village	Dr Phil Tagini, Lyndon Bako, Philip Riogano	LOGF members of Bungusule(led by Fr Lot), LOGF members of Talise(Led by Hugo Ladia) and the trustees and/or their representatives and other ordinary community members around Vulavu village	Bungusule land and SSJ blocks landowners consultation meeting	Bungusule LOGF to reconcile and non-Bungusule will support and work together to progress project. Extensive consultations and meetings required	CA team of Axiom follow up and reconciliation achieved. MOU executed.
08-05-2017	Honiara	Dr Phil Tagini, Baltazare Rongo, Philip Riogano	Thompson Tavake, Edmond Gagahe,Lonsdale Gagahe, Martin Jaiki, Nelson Manepura, Asa Ageage	Payments for G1 Block to Thompson Tavake and Jaiki for their respective clan beneficiaries. Jaiki group request 50-50% share while Tavake group request 100% share to themselves.	Axiom has decided on the following: 70% of the $25,000 (minus $1000 used to open bank account or $16,500) to be paid into Thompson Tavake Group's trust account; 30% of the $25,000 ($7,500) to be paid into Martin Jaiki Group's trust account. This arrangement is to be an interim arrangement for 90 days (till 10 August 2017). If the Jaiki group wishes to challenge the other party's position they must lodge a case in the relevant court by 10 August 2017. If no party files a case to change this arrangement or no other agreement is	Meetings to be conducted

Date	Venue	Axiom Team Members	Community Members present	Matters discussed, Issues Raised	Issues Resolved/ Follow Up Actions	Remarks, Responsibility for Follow up
					reached by then between Thompson Tavake and Martin Jaiki's groups, then this will be made permanent after 10 August 2017) Payments will now be processed on the above bases and each group will be notified once payments are made to respective trust accounts.	
11-05-2017	Honiara	Dr Phil Tagini, Philip Riogano	Fr Lot Bako,	Project updates and requesting continuous support from Bungusule LOGF.	Willingness of Bungusule LOGF to participate in reconciliation.	
18-05-2017	Sepi	Philip Riogano	Hugget Lo'o, Forest Foko, Clement Voda, Emy Kikolo, Fransley Suety, Davidson, Edmond Zabana, Joyce Himane, Joel Voda	Whether or not it is relevant to conduct reconciliation in Honiara or should this be done at home? Will outstanding claims be paid as a result of the reconciliation?	1. Majority. Agreeing to travel to Honiara for the reconciliation. Come up with resolutions	Axiom KB to commit themselves Axiom to fulfill its obligation towards the compensation agreement. Reconciliation facilitated by axiom. Axiom KB to provide all payment transactions/vouchers with regards to Bungusule land from 2011-2017.
26-05-2017	Honiara	Dr Phil Tagini, Baltazare Rongo, Lyndon Bako, Philip Riogano	Bungusule trustees and LO group and families	Reconciliation ceremony for members of the Bungusule LOGF	Bungusule LOGF united; personal issues solved and prepare to discuss issues as one people	Chosen 6 trustees to follow up on their outstanding matters with axiom.

Date	Venue	Axiom Team Members	Community Members present	Matters discussed, Issues Raised	Issues Resolved/ Follow Up Actions	Remarks, Responsibility for Follow up
27-05-2017 & 29-05-2017	Honiara	Dr Phil Tagini, Baltazare Rongo, Lyndon Bako, Philip Riogano	Bungusule trustees and LO group and families	Memorandum of Understanding (MOU)- terms of the understanding	Reconciliation amongst Bungusule LO groups, Agreed on clear communication channels, Cooperation to resolves differences in the group, Share benefits, selecting agreed trustees, specific terms of the MOU, cooperation with SSJ non-Bungusule group, SSJ governance structure. MOU signing.	Selected trustees and CA team-axiom.
30-05-2017	Honiara	Dr Phil Tagini, Baltazare Rongo, Philip Riogano	SSJ (Bungusule & Non Bungusule) trustees.	Governance structure for SSJ tenement	Discussing the specifics of the draft governance structure for Axiom's San Jorge tenement. Continue with drafts	
26-08-2017 to 28-08-2017	Havihua, Talise, Vulavu.	Dr Phil Tagini, Lyndon Bako, Philip Riogano	Community members of Havihua, Talise, Vulavu, Lepi, Binaboli, Thathaje and few from Sepi.	Community consultations and updating of communities on project developments and what is expected in the near future	Clarify doubts and confusions existing in communities.	

SYDNEY
Ground floor, Suite 01, 20 Chandos Street
St Leonards, New South Wales, 2065
T 02 9493 9500   F 02 9493 9599

NEWCASTLE
Level 1, Suite 6, 146 Hunter Street
Newcastle, New South Wales, 2300
T 02 4907 4800   F 02 4907 4899

BRISBANE
Level 4, Suite 01, 87 Wickham Terrace
Spring Hill, Queensland, 4000
T 07 3839 1800   F 07 3839 1866

www.emmconsulting.com.au