Panguna Mine Legacy Impact Assessment

Phase 1 Assessment Report
Chapter 6 – Social, Human Health and Human Rights Characterisation

Panguna Legacy Assessment Company Limited

Reference: 754-MELEN305719_R03

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

6. SOCIAL CHARACTERISATION

This chapter characterises the social, human health and human rights environment of the study area. The information is primarily based on Investigation Report: Human Health Risk Assessment (Appendix G) and Social and Human Rights Characterisation Report (Appendix H).

6.1 CHARACTERISATION METHOD

This section describes the method used to characterise the social, human health and human rights environment, which comprised:

- Scoping of the Panguna Mine's credible impacts to focus the characterisation process, including Tetra Tech Coffey's social wellbeing framework
- Defining the study area and sampling strategy
- Data collection
- Evaluating data collected against screening criteria
- A human health risk assessment
- A human rights-based approach throughout.

6.1.1 Scoping and the social wellbeing framework

The scoping process developed an initial understanding of the Panguna Mine's credible social, human health and human rights impacts to support survey instrument design. The scoping phase was informed by the initial conceptual site model, the Complaint, published literature on the Panguna Mine and the Bougainville region and the Preparatory Phase Report. The preliminary understanding of social, human health and human rights impacts was incorporated into Tetra Tech Coffey's social wellbeing framework (Figure 6.1).

6.1.2 Study area and sampling strategy

The study area is separated into four domains:

- Mine
- River System
- Delta
- Port and Town.

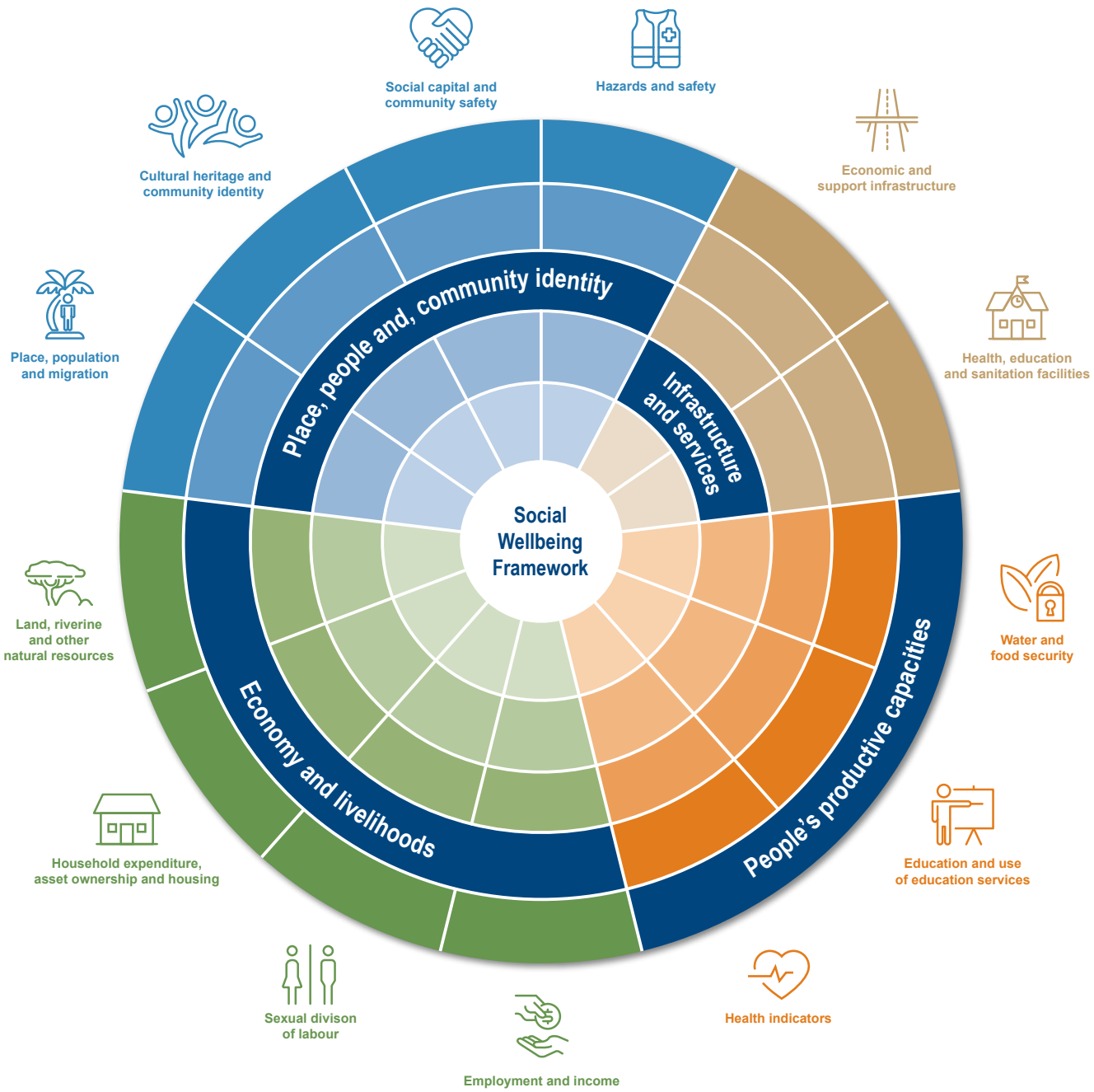
The Mine and the River System domains were separated into sub-domains based on existing community organisation and on an initial understanding of how impacts may differ within domains. Table 6.1 and Figure 6.2 detail the domains and sub-domains within the study area. Figure 6.3 shows the population density across the study area.

Representative communities were selected from within each domain based on:

- Areas identified by Complainants and local community as the most serious known likely impact areas.
- Review of the initial conceptual site model, aerial imagery and the results of the Preparatory Phase.
- Geographic spread of communities across the domain, to represent different geographical profiles and land uses.

Place, people and, community identity
Describes how a community defines itself in terms of civic participation, resilience, feelings of trust and safety and sense of belonging and place.

Infrastructure and services
Describes the infrastructure and services that meet the needs and priorities of the affected community including municipal and social infrastructure and associated services.



Economy and livelihoods
Describes how people make a living and the economic structure of the affected community.

People's productive capacities
Describes the skills, knowledge, and experience that are vital to survival and participation in society and its economy.

PANGUNA LEGACY ASSESSMENT COMPANY

PANGUNA MINE LEGACY IMPACT ASSESSMENT PHASE 1

FIGURE 6.1

Social wellbeing framework

SOURCE
Tetra Tech Coffey, 2024

TETRA TECH COFFEY

DATE: 30.10.24 PROJECT: 754-MELEN305719 FILE: 305719_R03_F06.01_GRA

DISCLAIMER: THIS FIGURE HAS BEEN PROVIDED FOR INFORMATION ONLY AND IS SUBJECT TO CHANGE. THE CREATORS DO NOT WARRANT THAT THIS FIGURE IS DEFINITIVE NOR FREE OF ERROR AND DO NOT ACCEPT LIABILITY ARISING FROM RELIANCE ON INFORMATION PROVIDED HEREIN. © COPYRIGHT TETRA TECH COFFEY 2024.
DOC REFERENCE: \\TT.LOCAL\COF\S772\S\GIS\305719_MELEN_PLAC_LEGACYIMPACTASSESSMENT\2_GRAPHICS\305719_R03\305719_R03_LIA_GRA019.AI_3 | SAVED BY: JO | 30.10.24

LEGEND

- Village
- Point of interest
- Road
- Watercourse
- Phase 1 study area

Domain area

- Domain A - Mine
- Domain B - River System
- Domain C - Delta
- Domain D - Port and Town

Village sub-domain

- Upper mine
- Lower mine
- Upper and mid tailings
- Lower tailings
- Delta
- Port
- Control

SOURCE
Villages, roads, watercourses, domains and study area from Tetra Tech Coffey.
Imagery from Woolpert (2023) and Google Earth (2020).

0 2.5 5 km

SCALE **1:325,000**
PAGE SIZE: **A4**
PROJECTION: **WGS 1984 UTM Zone 56S**

PANGUNA LEGACY ASSESSMENT COMPANY

PANGUNA MINE LEGACY IMPACT ASSESSMENT PHASE 1

FIGURE 6.2

Social, human health and human rights study area and selected communities

TETRA TECH COFFEY

DATE: **30.10.24** PROJECT: **754-MELEN305719** FILE: **305719_R03_F06.02_GIS**

DISCLAIMER: THIS FIGURE HAS BEEN PROVIDED FOR INFORMATION ONLY AND IS SUBJECT TO CHANGE. THE CREATORS DO NOT WARRANT THAT THIS FIGURE IS DEFINITIVE NOR FREE OF ERROR AND DO NOT ACCEPT LIABILITY ARISING FROM RELIANCE ON INFORMATION PROVIDED HEREIN. © COPYRIGHT TETRA TECH COFFEY 2024.

DOC REFERENCE: \\TT.LOCAL\COP\S772\S\GIS\305719_MELEN_PLAC_LEGACYIMPACTASSESSMENT\1_PLAC_LIA_GIS\APRX\305719_R03_FIG5_A.APRX LAYOUT:305719_R03_GIS020_5
SAVED BY: JASON.ORAM 30.10.24 3:25 PM

LEGEND

- Village
- Main dwelling structure
- Point of interest
- Road
- Watercourse
- Phase 1 study area

People per 100 hectare

40

0

SOURCE
Population density, villages, roads, watercourses and study area from Tetra Tech Coffey.
Imagery from Woolpert (2023) and Google Earth (2020).

0 2.5 5 km

SCALE **1:275,000**
PAGE SIZE: **A4**
PROJECTION: **WGS 1984 UTM Zone 56S**

PANGUNA LEGACY ASSESSMENT COMPANY

PANGUNA MINE LEGACY IMPACT ASSESSMENT PHASE 1

FIGURE 6.3

Population density

TETRA TECH COFFEY

DATE: **30.10.24** PROJECT: **754-MELEN305719** FILE: **305719_R03_F06.03_GIS**

DISCLAIMER: THIS FIGURE HAS BEEN PROVIDED FOR INFORMATION ONLY AND IS SUBJECT TO CHANGE. THE CREATORS DO NOT WARRANT THAT THIS FIGURE IS DEFINITIVE NOR FREE OF ERROR AND DO NOT ACCEPT LIABILITY ARISING FROM RELIANCE ON INFORMATION PROVIDED HEREIN. © COPYRIGHT TETRA TECH COFFEY 2024.

DOC REFERENCE: \\TT.LOCAL\COF\SYD72\S\GIS\305719_MELEN_PLAC_LEGACYIMPACTASSESSMENT\1_PLAC_LIA_GIS\APRX\305719_R03_FIGS_A.APRX LAYOUT:305719_R03_GIS021_3
SAVED BY: JASON.ORAM 30.10.24 3:41 PM

The representative communities were selected by Tetra Tech Coffey and endorsed by the Oversight Committee. Two control sites, non-mine impacted areas with similar social and environmental conditions, were selected. These communities were:

- Tokiai[1], a community located in a mountainous region with a similar natural landscape to the Mine Domain but in a different catchment from the Panguna Mine.
- Marowa[2], a community located on the west coast in a similar natural landscape to the Delta Domain in terms of topography, water access, and vegetation.

Table 6.1 Social, human health and human rights study area definition – domain, sub-domain and representative communities

Domain	Sub-domain	Representative community	Other communities within Domain
Mine Incorporates the SML area, including open pit, concentrator plant, waste rock dumps and processing infrastructure.	**Upper mine** These communities are located within and surrounding the pit and processing facilities.	• Panguna Town • In-pit • Moroni • Dapera.	• Guava.
	Lower mine These communities are located south of the mine and in proximity to the Kawerong River.	• Pirurari • Onove.	• Keirobi • Baiaruai • Ioro 2.
River System Kawerong-Jaba River system above and downstream of the mine. It includes mine impacted inflows, the rivers themselves and tailings deposition areas on surrounding floodplains.	**Upper and mid tailings** These communities are located along the access road and between the south side of the Jaba Pump Station levee and the north bank of the Kawerong-Jaba River.	• Barako • Jaba Pump Station • Gold Miners Camp • Konuku.	• Kokore (SML) • Taruruanau • Tengkona • Tempiri • Gold Miners (UT) • Toku • Derevai • Tavampai • Tairomana • Momau • Kirivia • Maton.
	Lower tailings These communities are located below Tailings Basin 1 and are within areas at risk of flooding due to the change in the course of the Jaba River and tailings deposition.	• Pem'ana • Namunsa • Mokerokeroai (Ambush Corner).	• Kokore (LT) • Kobalu • Kuneka • Katauli • Polamato • Wasikeuluma • Maile • Moirue • Moratona.

[1] Tokiai has a much lower level of multi-dimensional poverty than reported for Bougainville and PNG more broadly. This may limit the usefulness of this village as a control.
[2] Although Marowa was selected as a control site, during the field investigations this community reported concerns about the effect of mine tailings on the marine environment and reported a reduced ability to access marine resources due to this.

Domain	Sub-domain	Representative community	Other communities within Domain
Delta Jaba River Delta in Empress Augusta Bay including immediately offshore (within a kilometre) of the average mean sea level on the delta.	No sub-domains were established within this domain.	• Marau • Tagasi (1) • Koiare (1).	• Momarego • Matoga.
Port and Town The communities located in the area surrounding port facilities in Arawa Bay. Primary areas of interest include concentrate storage, hydrocarbon fuel storage, the power station, and dewatering facilities. Also includes the Port to Mine Access Road.	No sub-domains were established within this domain.	• Anewa Bay • Rorovana 3 • Metonai (2).	• Parakake • Pakia • Siredonsi • Pisinara • Bikora • Rorovana 1 • Rorovana 2 • Loloho • Tunura Mission • Sipusipu • Section 5 • Section 6 • Arawa.
Control sites Not a formal domain.		• Marowa • Tokiai (3).	

1. This includes the area known as Matoga village; one side of the river is Tagasi, and the other side is Matoga. This community closely interacts with Koiare as a social group. Given the size of these settlements, Matoga and Tagasi were sampled together, and Koiare was sampled to allow for a broader sample of the Delta Domain.
2. Metonai village was not part of the household/village surveys, it was included for human health investigation after identification of a possible mine-related waste source in the area.
3. Tokiai village is also referred to as Kerei.

6.1.3 Data collection

This section details data collected to develop the social, human health and human rights characterisation.

6.1.3.1 Desktop review

The desktop review of literature relevant to Bougainville and the Panguna Mine included:

- Demographic information published by the Papua New Guinean (PNG) National Statistical Office (NSO)
- Reports and plans, including but not limited to:
  - The Complaint (Human Rights Law Centre)
  - After the Mine: Living with Rio Tinto's Deadly Legacy (Human Rights Law Centre 2020)
  - The Panguna Listening Project (Catholic Diocese of Bougainville 2019)
  - Existing Legacy Impact Assessment-related reporting, including the assessment of the levee and Kuneka River flooding areas, which documented stakeholder engagement undertaken for this assessment
  - AGA (1989) Environmental and Socio-economic Public Health Review of Bougainville Copper Mine Panguna, BCL, New Zealand
  - Social Sustainability Services Pty Ltd (2015) Bougainville Socioeconomic and Cultural Baseline Desktop Study, Joint Panguna Negotiations Coordination Committee

- ‘The Results of the Soil Sampling in Panguna’ report published by Misereor the German Catholic Bishops’ Organisation for Development Cooperation (June 2022)
- Published academic and grey literature on the Panguna Mine and the social context of Bougainville.

The results from other Phase 1 investigations were reviewed to support the characterisation, particularly Investigation Report: Water Quality and Geochemistry (Appendix A), Investigation Report: Site Contamination (Appendix B) and Investigation Report: Hydrogeology (Appendix E).

6.1.3.2 Survey instrument design

The field investigations for the social, human health and human rights characterisation were conducted in an integrated manner using quantitative and qualitive survey instruments. The survey instruments used for the social and human rights characterisation were developed for the specific requirements of Phase 1. The survey instruments used for the human health risk assessment (Appendix G) were based on the instruments developed, field trialled and refined over several decades of use in PNG by the Centre for Environmental Health Pty Ltd. This allowed for comparison of the field campaign results to studies for other mining projects across PNG.

6.1.3.3 Field investigations

The social, human health and human rights field investigations were from 21 April to 19 May 2023 (field campaign 1) and 18 August to 3 September 2023 (field campaign 2). Table 6.2 provides a summary of data collection methods used in the field investigations in the 20 representative communities.

Tetra Tech Coffey’s specialists led the field investigation, with support from Bougainvillean enumerators and community facilitators employed by the Secretariat.

Table 6.2 Summary of data collection methods for the social, health and human rights investigation

Data collection method	Description
Village surveys	The village survey was designed to record the location and status of communal infrastructure within each village, including water source and supply points, electricity distribution, schools, churches, and health clinics. The village survey also recorded the location of perceived hazards. A village survey was completed in each representative community.
Household survey	The household survey was designed to collect household information on demographics, housing and assets, employment, income and expenditure, health and education, safety, resource use, and food consumption and security. The household survey included sections to understand drinking water sources at each representative village, water sources used for swimming, bathing and cleaning, food crops and garden beds, 24-hour dietary information, health symptoms and use of health facilities. A total of 425 households were surveyed in representative villages. Most household surveys were conducted during field campaign 1. The Port and Town Domain household surveys and additional visits to Moroni, Dapera, and Jaba Pump Station were conducted in field campaign 2.
Focus group discussions	Focus group discussions were held with community members in each village, including women, men, community leaders, and artisanal and small-scale mining (ASM) workers. Additional discussions using a tok stori (*to exchange stories*) method were used in each community to understand impacts experienced from the point of view of study area communities. A total of 20 focus group discussions and *tok stori* were undertaken. Additional focus group discussions were undertaken in Jaba Pump Station, Konuku, Namunsa, Pem’ana, Mokerokeroai and Marau to understand community concerns about flooding and food security. A total of six additional focus group discussions were held.

Data collection method	Description
Participatory mapping	Village participants were asked to identify on maps primary land uses including water sources, hunting areas, gardening areas, areas subject to flooding and other hazards, fishing areas, and cultural sites. Participatory mapping activities were undertaken in the representative.
Key informant interviews	Key informant interviews were designed to collect information from prominent community members, including church leaders, women's group leaders, clinic and hospital staff and teaching staff. A total of 14 key informant interviews were undertaken.
Market basket survey	Food samples were sourced from local village gardens, bush food gathering sites and local markets to analyse the concentrations of selected metals in the major diet components. A total of 219 primary food samples were collected and analysed. Food samples were collected during both field campaigns to capture samples from a range of food groups and to allow for seasonal variation in food sources.
Soil sampling	Garden soil samples were taken to understand the possibility of uptake of contaminants by plants where crops and produce were grown and also to understand the possibility of contamination uptake by livestock. A total of 91 garden soil samples (co-located samples) were collected in areas used for food production along with food samples from these areas in the representative communities.
Dust sampling	Dust deposition samples were collected to study how contaminants in the dust affect soils and other surfaces. Five dust deposition gauges were installed at Moroni, Dapera, Gold Miners Camp, Konuku, Pem'ana. These sites were selected as representative locations near identified waste rock and tailings sources. The gauges at Dapera and Konuku were vandalised and subsequently removed.
Drinking water resource sampling	Drinking water samples were collected at the point of consumption based on engagement with community representatives. A total of 72 drinking water sources were sampled in the representative communities. Where possible water samples were collected during field campaign 1 and 2 to capture seasonal variation in water quality or sources.

Table 6.3 summarises the communities surveyed during the field investigations. To determine how accurate and reliable the survey data was, the margin of error and confidence level[3] for the sample size were calculated. The overall sample size has a 3% margin of error and a confidence level of 85% for the study area. The sample margin of error and confidence level were based on an estimate of total households in the study area, which was completed through aerial photography review, supported by field verification. There is high uncertainty regarding the population size, particularly in the Mine Domain (Section 6.2.1.1).

Table 6.3 Summary of communities surveyed during field campaign 1 and 2

Sub-domain	Community	Estimated households (1)	Household surveys		FGD participation (2)	
			Household surveys completed	Estimated surveyed population	Male	Female
Upper mine	Panguna Town	691	52	279	7	1
	In-pit	46	15	63	5	6
	Moroni	77	22	80	10	9
	Dapera	98	34	160	14	12
Lower mine	Pirurari	41	12	59	9	1
	Onove	120	50	234	8	8

[3] The margin of error is a calculation of how much the survey results might vary from the actual population's opinion. A margin of error of 3% means that survey results say 60% of respondents like to undertake ASM; a 3% margin of error means the true number is likely between 57% and 63%.
An 85% confidence level means if the same survey was completed 100 times, 85 times the results would be within the 3% margin of error.

Sub-domain	Community	Estimated households [1]	Household surveys		FGD participation [2]	
			Household surveys completed	Estimated surveyed population	Male	Female
Upper and mid tailings	Barako	120	18	74	3	9
	Jaba Pump Station	41	17	76	9	11
	Gold Miners Camp	53	14	60	9	9
	Konuku	40	17	68	5	9
Lower tailings	Pem'ana	27	6	28	22	37
	Namunsa	123	14	77	27	18
	Mokerokeroai	27	10	35	15	15
Delta	Marau	12	6	12	5	8
	Tagasi	NA	10	39	NA [3]	NA[3]
	Koiare	NA	30	138	18	20
Port and Town	Anewa bay	14	14	59	8	10
	Rorovana 3	144	44	210	6	10
Control	Marowa	NA	25	80	16	24
	Tokiai	NA	15	62	7	10
Total	**20**	**1,674**	**425**	**1,893**	**203**	**227**

FGD – focus group discussions; NA – Not available.
1. Estimated total number of households in the community as per Appendix H.
2. Includes all participants involved in focus group discussions during field campaigns.
3. Focus group discussions were not completed in Tagasi as the community was already involved in discussions in Koiare.

6.1.4 Indicators

Indicators were selected for each social and human rights attribute within the social wellbeing framework. The selected indicators relate to:

- Current social conditions
- Social and human rights characteristics that may have been affected by the environmental impacts of the Panguna Mine since 1989.

This chapter summarises the results for select indicators, emphasising the indicators used to inform the sensitivity analysis presented in the social impact assessment (Chapter 11). Table 6.4 summarises these. A complete list of indicators is provided in the Social and Human Rights Characterisation Study (Appendix H).

Table 6.4 Social and human rights key indicators

Attribute	Potentially relevant human rights[1]	Indicator
Place, people and community identity		
Place	Not applicable.	• Main language spoken • Other languages spoken.
Population	Not applicable.	• Village population • Number of households • Number of persons resident within the household.
Migration and displacement	Not applicable.	• Migration.

Attribute	Potentially relevant human rights[1]	Indicator
Social capital and community safety	Cultural rights.	• Presence of community groups • Participation in general collective action • Support from community groups • Level of conflict and violence • Perception of safety • Perceived social disorder issues.
Cultural heritage and community identity	Cultural rights.	• Places of cultural significance and cultural heritage practices.
Hazards and safety	Right to life; right to health.	• Hazards.
Economy and livelihoods		
Land, riverine and other natural resources	Right to adequate food, housing and standard of living; cultural rights; right to a clean and healthy environment.	• Availability and quality of land that supports subsistence livelihoods (gardens, foraging, fishing, bush areas, hunting groups) • Description of land-based subsistence resources • Source of most village food • ASM activities.
Sexual division of subsistence and artisanal labour	Right to adequate food, housing and standard of living	• Description of land-based subsistence resources • ASM activities.
Employment and income	Right to adequate food, housing and standard of living	• Income sources • Type of employment and occupation.
Household expenditure and asset ownership	Right to adequate food, housing and standard of living	• Availability and cost of goods • Household expenditure on goods • Main assets.
Housing	Right to adequate food, housing and standard of living.	• Housing materials, sanitation and energy sources.
Infrastructure and services		
Health facilities	Right to health.	• Access to community health facilities, including health centres and aid posts.
Education facilities	Right to education.	• Access to education facilities, such as primary and secondary schools.
Economic and support infrastructure	Right to adequate food, housing and standard of living.	• Number of trade stores and village market locations • Primary village transport routes and travel to Arawa (mode, availability, time, cost).
Sanitation and waste disposal	Right to health.	• Village sanitation conditions • Village waste disposal practices.
People's productive capacity		
Health indicators	Right to health.	• Access to and use of health services • Self-reported illnesses • Maternal health and use of health services • Vector-borne disease control.
Education and use of education services	Right to education.	• Highest level of education • Literacy • Current school attendance.

Attribute	Potentially relevant human rights[1]	Indicator
Food security	Right to adequate food, housing and standard of living.	• Food security.
Water security	Right to adequate food, housing and standard of living; right to water.	• Village water supplies and water that supports livelihoods and community use (rivers, creeks etc.) • Drinking water source, availability and quality.

1. Only rights that are assessed in the human rights impact assessment are listed here. Data presented may inform an understanding of other rights, but this is outside of this chapter's scope and focus.

In addition to the wellbeing indicators that form part of the social and human rights characterisation in Table 6.4, water quality, soil, dust deposition and food indicators were selected to support the human health risk assessment (Table 6.5). The selected indicators are specific parameters that can indicate characteristics of environmental media (water, soil, dust) and food that may have been affected by the Panguna Mine since 1989 (including impacts present in 1989 that have persisted) that may affect human health.

Table 6.5 Water quality, soil, dust deposition and food indicators

Setting	Indicator	Objective
Water use		
Drinking water	Human health: Inorganic and organic contaminants [1] Aesthetic impacts	The objective for each indicator is the health or aesthetic guideline published by PNG, WHO or other appropriate agency. Raw drinking water guidelines may be appropriate where water is not treated.
Recreational use	Human health: Inorganic and organic contaminants [1]	Adjustment of the adopted drinking water guideline to be protective of incidental ingestion whilst undertaking washing or recreational activities.
Land use		
Residential	Human health: Inorganic and organic contaminants [1]	The objective for each indicator is the health investigation or screening level in the NEPM [2].
Agriculture	Human health Inorganic and organic [1] contaminants	Environmental and human health soil quality guideline/s in the Canadian Soil Quality Guidelines [2].
Dust deposition		
Dust deposition	Aesthetic impacts	Avoid nuisance dust deposited on washing, building structures.
Deposited dust composition	Human health: Inorganic and organic contaminants	The objective for each indicator is the soil health investigation or screening level in the NEPM.
Food type		
Terrestrial plant-based foods Animal food products Aquatic foods	Human health: Inorganic / organic contaminants	The objective for each indicator is the lowest published food standard for a chemical in edible plant and animal food products. Comparison with food concentration ranges in the PNG MBS database. This database is based on samples obtained in control villages from other areas within PNG and covers a broader range of foods and metals than the published food standards.

1. Organic contaminants are generally expected to only be detected near contaminant sources within the mine infrastructure areas. Screening criteria for organic contaminants such as selected Per- and polyfluoroalkyl substances (PFAS) and Polychlorinated Biphenyls (PCBs) are presented in this report, other organic compounds are presented in Appendix B and will be referenced where required.
2. Where contaminants of potential concern do not have a corresponding indicator or objective set by the NEPM (NEPC 2013) or CCME (2013), other international criteria such as those published by the United States Environmental Protection Agency (US EPA) has been adopted.

6.1.5 Human health risk assessment approach

A human health risk assessment was conducted to characterise the health risks to communities based on possible exposure to contaminants in the environment (in particular, soil, food, water and dust).

Papua New Guinea has not developed a human health risk assessment methodology or stipulated relevant international guidance. The human health risk assessment method was conducted in general alignment with the Australian National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (NEPM). The NEPM human health risk assessment framework is consistent with international risk assessment guidance published by agencies such as:

- World Health Organization (WHO)
- Food and Agricultural Organisation (FAO)
- United States Environment Protection Agency (US EPA)
- United Kingdom Environment Agency (EA)
- Canadian Council of Ministries for the Environment (CCME)
- Australian Environmental Health Standing Committee Guidelines (enHealth).

6.1.5.1 Screening criteria

Phase 1 of the Legacy Impact Assessment collected data suitable for a Tier 1 human health risk evaluation. A Tier 1 evaluation involves a risk-based analysis comparing site data with screening criteria for a particular end point population and media, e.g., drinking water for a village. Tier 1 evaluations require the least data and use generic exposure assumptions but apply the most conservative criteria. The Tier 1 screening criteria were selected and adjusted to be representative of end point populations and land use settings.

The human health risk screening assessment detailed in Investigation Report: Human Health Risk Assessment (Appendix G) involved the assessment of environmental health data against relevant international guidance for contaminants of concern in water, soil, dust and food. Where there are multiple criteria, the most conservative criteria was used. The screening criteria adopted for each indicator is summarised in the following sub-sections.

Water quality

To assess risks to human health from potential contaminants of concern in drinking water, surface water and groundwater, guideline values were adopted from:

- Environmental Code of Practice for the Mining Industry (OEC 2000)
- PNG Public Health (Drinking Water) Regulation 1984
- Drinking Water Guidelines, 4th Edition (WHO 2022)
- Australian Drinking Water Guidelines 6, National Health and Medical Research Council (Version 3.8) 2022
- PFAS National Environmental Management Plan (Version 2.0) 2020.

The adopted water quality screening criteria (Table 6.6) for the human health assessment included comparison of:

- Water used for drinking purposes from natural waterways, groundwater or rainwater tanks to the lowest drinking water screening criteria in either the PNG OEC Raw water criteria (OEC 2000), or the PNG (1984) and WHO (2022) or NHMRC (2022) drinking water criteria. The PNG OEC Raw water criteria (OEC 2000) is based on both health and aesthetic guidelines published by PNG, WHO and other agencies.

- Water used for recreation or other purposes such as bathing, cleaning, fishing or ASM activities to the minimum PNG, WHO or NHMRC drinking water guideline value adjusted by a factor of 10. This factor was based on the assumption that accidental ingestion while swimming would account for 10% of the two litres of water consumed per day per person, consistent with the Guidelines for Safe Recreational Water Environments (WHO 2003).

Table 6.6 Water screening criteria

Compound	Drinking Water Screening Criteria [mg/L]				Adopted Drinking Water Screening Criteria (2) [mg/L]	Recreation/Other Water Screening Criteria (3) [mg/L]
	PNG OEC Raw water (1)	PNG	WHO	NHMRC		
Antimony	0.003	0.02	0.02	0.003	0.003	0.03
Arsenic	0.007	0.01	0.01	0.01	0.007	0.07
Beryllium	NE	NE	NE	0.06	0.06	0.6
Cadmium	0.002	0.003	0.003	0.002	0.002	0.02
Chromium	0.05	0.05	0.05	0.05 (4)	0.05	0.5
Copper	1.0	2.0	2.0	2.0	1.0	10.0
Lead	0.01	0.01	0.01	0.01	0.01	0.1
Manganese	0.1	0.5	0.4	0.5	0.1	1
Mercury	0.001	0.006	0.006	0.001	0.001	0.01
Molybdenum	NE	NE	NE	0.05	0.05	0.5
Nickel	0.02	0.07	0.07	0.02	0.02	0.2
Selenium	0.01	0.01	0.04	0.01	0.01	0.1
Zinc (5)	3.0	3.0	3.0	3.0	3.0	30.0
PFOS + PFHxS (6)	NE	NE	NE	0.00007	0.00007	0.0007
PFOA (6)	NE	NE	NE	0.00056	0.00056	0.0056

NE – Not established.
1. Raw water based on untreated drinking water which may apply in rural and remote circumstances.
2. Selected based on the lowest drinking water screening criteria presented.
3. Adjusted based on the lower PNG, WHO or NHMRC drinking water criteria.
4. Based on the more toxic Cr VI, not total chromium.
5. Based on aesthetic quality. A health-based guideline has not yet been established.
6. DoH (2017) Health Based Guidance Values for PFAS

Soil, deposited dust and sediments

To assess risks to human health from contaminants of concern in soil, deposited dust or sediments, guideline values were adopted from:

- NEPM soil health investigation levels for a residential setting with garden/accessible soil. Assumes 10% of produce consumed is home grown (NEPC 2013).
- Regional screening levels developed for a residential setting (US EPA 2023).
- Soil Quality Guidelines for the Protection of Environmental and Human Health for agricultural land. Protective of human health, crop growth, livestock production and wildlife/flora (CCME 2022).
- PFAS National Environmental Management Plan Version 2.0 (HEPA 2020).
- Environmental Protection (Air) Policy 2008 (DES 2008).
- Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (NSW EPA 2017).

The screening criteria was dependent on the land use setting. This was based on information obtained during field investigations. The screening criteria included:

- **Residential (direct contact) health criteria** – A residential setting where no locally grown fruit/vegetables or locally raised animal produce is consumed and the primary exposure routes to soil were associated with direct contact (i.e., touching the soil, gardening in the soil, unintentionally swallowing small amounts of soil and the inhalation of dust). This criterion applies to the evaluation of human health risks from sediments and deposited dusts, from which the most common exposure is through direct contact.
- **Residential setting (low density) - garden/accessible soil** – A residential setting where locally grown fruit/vegetables are consumed. The consumption of locally raised animal produce is not included. The primary exposure routes to soil are direct contact (i.e., dermal contact, incidental ingestion and particulate inhalation) and indirect exposure through consumption of fruit/vegetables grown near the residential areas.
- **Agricultural setting** – An agricultural setting where crops are grown away from residential areas, residential settings where most of their food is obtained from the surrounding land or where people consume products from locally raised animals or poultry. There are two types of agricultural screening criteria used in this assessment:
    - **Agricultural human health screening criteria**. This included ingestion of home grown produce and animal products, and direct contact pathways with soil. The CCME agricultural health criteria was selected for the assessment of a residential setting where a higher proportion of foods consumed were home grown or locally raised.
    - **Agricultural ecological screening criteria**. This includes criteria that are protective of soil ecology, crop growth and livestock health. The agricultural criteria were developed for Canadian ecological end points, crop types and soil conditions which are not necessarily representative of those found in the study area, and which should be considered in interpreting any screening evaluation. This criterion has been used in the absence of PNG criteria. The CCME criteria protective of ecological and human health has been selected to evaluate possible impacts to soil quality.

Where criteria were not established in the NEPM, USEPA regional screening levels for a residential setting were adopted.

Food

The adopted food screening criteria specifies concentrations of potential mine-related contaminants (metals and chemicals) that may be present in foods. Two screening criteria have been used, the PNG MBS database screening criteria and the published food standards criteria.

The PNG MBS database provides screening criteria for metal levels generally found in foods consumed in PNG. It has been adopted as the primary screening evaluation in this assessment. The PNG MBS database was compiled by the Centre for Environmental Health Pty Ltd through studies in PNG between 2003 and 2017. The database comprises approximately 1,200 food composites obtained from control sites (non-mine impacted) in both highland and lowland-coastal regions. The dataset includes arsenic, cadmium, copper, lead, mercury, selenium and zinc concentrations in a wide range of foods including bush food, fish, molluscs, vegetables, tubers and store-bought food. The PNG MBS samples were prepared in a manner compliant with the Codex Alimentarius and analysed by the Queensland Health Forensic Science Services, the same laboratory that was used for the Investigation Report: Human Health Risk Assessment (Appendix G).

Food standards published by agencies such as the WHO, FAO or Food Standards Australia New Zealand (FSANZ) are based on food type. These criteria have generally been established for a limited number of metals based on their known toxicity and prevalence in the environment. Food standards for chemical compounds, such as PCBs, are typically based on the inherent toxicity of the substance and how much of the particular food a person typically eats. Therefore, uncertainties exist where a person may eat more than the standard amount.

The food standard screening criteria were selected from the following sources:

- FSANZ:
  - FSANZ – Generally Expected Levels for Metal Contaminants (FSANZ 2001, Abbott et al 2003 and FSANZ 2014).
  - The standards comprise the Australia New Zealand Food Standards Code – Standard 1.4.1 – Contaminants and Natural Toxicants (FSANZ 2016), Schedule 19 (FSANZ 2022).
  - Food Standards Australia and New Zealand - Perfluorinated chemicals in food (FSANZ 2017).
  - European Commission. Commission Regulation (EC) No 1881/2006. Consolidated amendment 2023/915, dated 25 April 2023 (EC 2023).
- Joint Expert Committee on Food Additives (JECFA): FAO/WHO. Food Standards Programme. Codex Alimentarius International Food Standards. General Standard for Contaminants and Toxins in Food and Feed. CSX 193-1995. Revised 2019. (JECFA 2019).

6.1.5.2 Food consumption and contaminants intake analysis

A semi-quantitative assessment was undertaken to characterise the human health risks associated with food consumption based on estimated contaminant intake of seven of the metals identified as of concern.

For the four contaminants of concern that are not considered to be essential nutrients (arsenic, cadmium, mercury and lead), toxicity reference values were selected to assess exposures associated with exposures associated with food. Recommended maximum intakes were adopted for the metals that are essential nutrients: copper, selenium, and zinc.

The calculated weekly daily intake of each metal/metalloid of concern is based on the average concentration in a food (based on the results of the MBS undertaken in this study), multiplied by the amount of that food consumed weekly from surrogate villages in PNG for each age group. Surrogate villages were selected for their similarities in garden crop and trade store food availability, consumption patterns, altitudes and levels of formal employment. The intake for each metal/metalloid is summed and compared to the adjusted toxicity reference value or recommended maximum intake.

6.1.5.3 Laboratory analysis

Food samples were obtained in the representative communities from four food groups: fruit, vegetables, nuts/grains, and protein sources such as animal products. The foods were prepared for export by removing the nonedible portions and cooking to kill any microbes that may pose an issue for Australian biosecurity.

Environmental and food samples were analysed by laboratories accredited under the National Association of Testing Authorities in Brisbane. ALS Environmental conducted the soil and water analyses and Queensland Health Forensic and Scientific Services conducted the food sample analysis. Table 6.7 summarises the laboratory analysis requested for the collected soil, water, dust and food samples.

Table 6.7 Summary of water, soil, dust and food analytical suites

Indicator	Water samples	Soil samples	Dust deposition samples	Market basket survey food samples	Food preparation water sample
pH	106	-	-	-	-
Electrical conductivity Total dissolved solids Total suspended solids	106	-	-	-	-
Total metals (aluminium, arsenic, boron, beryllium, cadmium, chromium, cobalt, copper, iron, manganese, molybdenum, nickel, lead, antimony, selenium, vanadium, zinc, mercury, silver)	106	88	-	-	-
Total metals (arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, mercury, manganese, nickel, lead, selenium, vanadium, zinc)	-	-	6	-	
Total metals (arsenic, cadmium, copper, mercury, lead, selenium, zinc)	-	-	-	216	15
PFAS	61	42	-	81	-
PCBs	13	2	-	22	-
Total solids	-	-	6	-	-

6.1.5.4 Human health risk evaluation

A Tier 1 evaluation of the reported concentrations in various media was compared with the selected screening criteria to understand the possible exposure risks. An assessment matrix was developed to rank the exposure health risks where exceedances of screening criteria occur (Table 6.8).

Table 6.8 Human health risk based screening assessment matrix

Media	Soil, dust, water or food	Food					Drinking water	Recreational water	Soil / dust
Screening outcome	Below detection limit (1)	Below health screening criteria	Below the PNG MBS database upper range	<30% (2) above PNG MBS database upper range	>30% (2,3) above PNG MBS database upper range	Exceeds food standard screening criteria	Exceeds adopted screening criteria	Exceeds adopted screening criteria (2)	Exceeds selected health screening criteria (2)
Exposure risk	Minimal risk	Low risk	Within range	Marginally above upper range	Above upper range	Possible risk	Possible risk	Possible risk	Possible risk

1. Where the laboratory limit of reporting is below the health screening criteria
2. Accounts for higher background levels in the study area compared to the PNG MBS database.
3. A concentration above the PNG MBS database range maximum does not necessarily indicate a health risk given that the toxicity, ingestion amount and frequency has not been considered.

6.1.6 Human rights-based approach

Table 6.9 summarises the human rights-based processes adopted in the social and human rights characterisation process. These are detailed in Chapter 4.

Table 6.9 Human rights-based processes adopted in the social and human rights characterisation process

Principles	Adopted processes
Participation	• Potentially affected communities were involved during each phase. The field investigation process engaged with potentially affected communities and their representatives (through the Oversight Committee) to identify communities most at risk and developed mechanisms to engage with them. • Participatory methods were utilised, including the use of participatory mapping and participatory photography. • A pre-awareness program was conducted prior to the field investigation to raise awareness and knowledge of the process and how communities can participate (see below). • Participation of communities and individuals in the investigation was contingent on informed consent prior to the commencement of data or sample collection (see Section 6.1.3.1).
Non-discrimination and equality	• Potentially vulnerable groups and those most at risk of discrimination and marginalisation were identified and methods developed to support their inclusion based on experience on previous projects in PNG (see Section 6.1.3.3). • Engagement with affected people and their representatives in accordance with guidance on cultural protocols provided by the Secretariat and feedback from pre-awareness activities and initial site investigations.
Transparency and accountability	• The Secretariat holds overall responsibility for approving and facilitating all engagement relating to the Legacy Impact Assessment, which incorporates an understanding of the purpose and scope of the process. The community engagement facilitated by the Secretariat has conducted four rounds of community dialogues to date and will continue to engage with affected communities throughout the Legacy Impact Assessment process. • Pre-awareness activities were completed to support community awareness of the purpose and bounds of the field investigation (see Chapter 4).

6.1.6.1 Ethics and informed consent

Ethical considerations incorporated into the social, human health and human rights characterisation process included protecting personal data, identifying possible risks to participants, and implementing an informed consent process.

Personal data was collected from participants during the field campaigns in the communities outlined in Section 6.1.2. Each survey instrument collected a different level of personal data and therefore there were different approaches to confidentiality, as follows:

- Household surveys collected demographic data, which was de-identified and presented in aggregate form.
- Key informant interviews gathered views on community issues and functions. Participants were informed that their information would support the Legacy Impact Assessment and that they might be identifiable in reports.
- Limited personal information was collected in the participatory photography process. As the process involved community facilitators, there were limited practical ways to provide for confidentiality. Cultural heritage site locations were collected but have not been published due to community feedback regarding their sensitivity.

All data was stored on secure servers or devices with standard backup protection protocols.

Informed consent was incorporated into all investigations for the social, human rights and health characterisation process based on the following criteria:

- Voluntary: the process was free from coercion. Participation was voluntary, and participants were informed that they could withdraw their participation at any time.
- Prior: communities were made aware of the Legacy Impact Assessment process through a re-awareness campaign before the social and human rights investigations were undertaken.
- Informed: the pre-awareness campaign and the initial site visit raised awareness of the Legacy Impact Assessment project and the social and human rights investigations.

All survey instruments that collected personal data began with a formal confirmation of informed consent.

6.1.6.2 Approach to including vulnerable groups

Social vulnerability is important to consider in a social and human rights impact assessment (Climent-Gil et al. 2018; Owen and Kemp 2020) as social vulnerability may mean that these groups will experience greater or different impacts. Based on the literature on vulnerability in PNG, the following groups were identified as possibly vulnerable:

- Households or groups with limited access to land, including those lacking customary land rights (e.g., resettled peoples, in-migrants undertaking ASM activities).
- Households reliant on subsistence agriculture with few avenues for cash income.
- Persons with a disability (as defined by the Convention on Rights of Persons with Disabilities).
- Illiterate persons.
- Female-headed households.
- Households mainly consisting of persons aged over 60 years.

The approach to identifying and including vulnerable groups was incorporated into the following survey instruments:

- The household survey included questions to identify households that are socioeconomically or otherwise vulnerable, including:
  - Age to identify households with high dependency levels.
  - Sex and household head to determine gender dynamics in households.
  - Literacy rates to assess educational vulnerabilities.
  - Migration to identify households affected by migration.
- Focus group discussions, participatory mapping and key informant interviews, which allowed for:
  - Separate male and female focus group discussions.
  - Participation from a range of age groups, such as youth and the elderly.
  - Key informant interviews with persons in roles relevant to vulnerable groups, such as women's group representatives, teachers, and health professionals.

6.1.7 Data limitations and uncertainty

Given the preliminary nature of Phase 1, a number of uncertainties exist related to social and human rights characterisation. Key limitations and uncertainties are as following (refer to Appendix H for further detail):

- **Sampling strategy:** The social and human rights characterisation process, as required by the scope of work for Phase 1, prioritises communities most affected by the actual and potential legacy impacts of the Panguna Mine. This means that not every community or household near a mine-affected environment was covered in the field investigation. The survey was based on sampling of representative communities across all domains. There may be variances and issues associated with communities not surveyed that have not been identified as part of Phase 1.
- **Field investigations:** Field investigations were undertaken once in the Port and Town Domain and two Mine Domain communities (In-pit and Panguna Town) during field campaign 2. This is not expected to have resulted in a material difference in the data collected for the following reasons:
  - Household surveys were only completed once in all surveyed study area communities, unless insufficient numbers were collected previously.
  - Community discussions, including focus group discussions and participatory mapping, were only completed once in all surveyed study area communities. Additional targeted focus group discussions were undertaken in six communities in the River System Domain.
- **Participation and interest:** There were different levels of participation and interest in the field investigation across the study area. Areas where signatories to the Complaint in the River System Domain live had high levels of awareness of the process. In other areas, such as the Delta Domain, there were lower levels of awareness of the Legacy Impact Assessment and in the Mine Domain, there were delays to the field investigation program because of concerns from a discrete portion of the community that required addressing to ensure support for access.
- **Community participation:** In some villages, the participation of women in household surveys was low as they were undertaking activities away from the village at the time of survey. This is generally reflective of the greater labour burden on women in this social context (FAO 2016; Eves et al. 2018). This issue was more prevalent in villages in the Upper-mid tailings area, where only 34% of the women of child-bearing age in the study sample completed the women's health survey. This has affected the collection of information relating to reproductive health issues and child's mortality, which were asked only of women of child-bearing age. A total of 208 women surveys were completed, representing 48% of the total number of reproductive-aged women in the sampled households. In focus group discussions however, more women than men participated.
- **Cultural heritage:** The investigation included questions on cultural heritage places. However, this is not a cultural heritage assessment and a cultural heritage subject matter specialist may be required in Phase 2 if there is further investigation on impacts to cultural heritage. The field investigation did not incorporate identifying or assessing the archaeological values of heritage places.
  In some areas, communities are living on leased land, and were reluctant to discuss cultural heritage sites that do not belong to them. Similarly, there was reluctance to notate areas of cultural heritage sites at risk, or to show these places to the field investigation team, as it would be unsafe for the field team without undertaking timely customary practices.
- **Aquatic and marine resource use surveys:** These surveys were outside of the scope for Phase 1, as such the availability and dependency of households on these resources was unable to be determined.

- **Control sites:** Tokiai has a much lower level of multi-dimensional poverty than reported for Bougainville and PNG more broadly. This may limit the usefulness of this village as a control. Although Marowa was selected as a Control site, during the field investigations this community reported concerns about the effect of mine tailings on the marine environment and reported a reduced ability to access marine resources due to this.
- **Potential social and human rights impacts:** social and human rights issues that are not directly related to the environmental impacts of the Panguna Mine were raised during the social and human rights characterisation process. Where this occurred, these have been noted in this report; however, the focus of the social and human rights characterisation process is on characterising the social and human rights context for identifying those impacts that are directly linked to the environmental impacts of the Panguna Mine.
- **Dust deposition sampling:** Dust deposition gauges were installed at five locations across the study area during field campaign 2, however only three locations remained following installation due to vandalism of the other two. Due to high rainfall conditions, some samples were unable to be analysed, and the data did not capture dust deposition levels under drier conditions.

6.2 CHARACTERISATION OF SOCIAL, HUMAN HEALTH AND HUMAN RIGHTS CONDITIONS

This section details the information collected during the 2023 field investigations to characterise the current social, human health and human rights conditions in the study area based on investigations in the representative communities.

6.2.1 Place, people and community identity

This section describes how a community defines itself and includes the following broad topics:

- Place
- Population
- Migration and displacement
- Social capital and community safety
- Community identity and cultural heritage
- Hazards and safety.

The social attributes discussed in this section provide context for understanding the following human rights:

- Right to life
- Right to health
- Cultural rights.

6.2.1.1 Place

Table 6.10 summarises the setting of each domain and the representative communities.

Table 6.10 Place description

Domain	Representative communities	Setting
Mine Domain	• Panguna Town • In-Pit • Moroni • Dapera • Pirurari • Onove.	• The Mine Domain is within the SML area. The headwaters of Kawerong River are located in the eastern portion of the Mine Domain area and the river flows through the domain. • BCL constructed Panguna Town and by 1971 the town had approximately 300 houses, a primary school, a hospital, and a trade store. Communities in this domain remain heavily influenced by the Panguna Mine infrastructure, including the open pit, concentrator plant, accommodation facilities and waste rock dumps. Infrastructure in Panguna Town shows significant signs of structural deterioration. Several new structures have been constructed in the previous decade. • Residential areas are generally located on flat terrain with smaller settlements scattered in the surrounding mountains. The original Moroni, Dapera and Pirurari villages were relocated for the Panguna Mine processing facility. • Communities are located along the Port to Mine Access Road which provides access to Arawa.
River System Domain	• Barako • Jaba Pump Station • Gold Miners Camp • Konuku • Pem'ana • Namunsa • Mokerokeroai.	• The Kawerong-Jaba River dominates the landscape, and the terrain is generally flat downstream of the confluence of the Kawerong and Jaba rivers. Other watercourses that flow through the domain are the Pagana River and Kuneka Creek. • Some of these communities are located along the road. Some communities, such as Gold Miners Camp, Konuku and Pem'ana, are located along the northern banks of the Kawerong-Jaba River and are accessible by river-crossings or foot bridges where available.
Delta Domain	• Marau • Tagasi • Koiare.	• The domain includes the Jaba River Delta on Empress Augusta Bay, located on the western coast of Bougainville, between 25 km and 30 km west of the SML. • Each community is located on a major watercourse: the Tuju/Marau River (Marau), Mariropa River (Tagasi), and the Wiereu River (Koiare). • Access is via boat from Marau village market where the main access road terminates.
Port and Town	• Anewa Bay • Rorovana 3.	• The Port and Town Domain is situated near historic BCL port facilities located along the Arawa Bay coastline, approximately 5 km northwest of Arawa township. The Pinei River flows from inland headwaters and enters Rorovana Bay near Rorovana 1 and 2. • Much of the BCL infrastructure associated with the port has been removed or shows signs of significant deterioration. In some areas, vegetation regrowth has obscured or partially obscured buildings or structures. • Access to the communities is provided through the Port to Mine Access Road, smaller access tracks and sea access.
Control sites	• Marowa • Tokiai.	• Marowa village is located on Empress Augusta Bay and is surrounded by swampland vegetation. The community is only accessible via boat. • Tokiai village is in steep mountainous terrain accessible by a small access track approximately 5 km inland from Arawa.

The predominant language groups present across the study area are Torau, Nasioi, Nagovisi, and Banoni. During the household survey, respondents were asked to identify the main language spoken daily. In addition to the language groups identified by traditional boundaries, Simbe'e was predominately spoken by around 8% of respondents in the Upper and mid tailings, and 2% of respondents in the Lower tailings. Tok Pisin was commonly identified as the main language spoken, particularly in the Lower tailings sub-domain and the Delta Domain.

6.2.1.2 Population

The NSO United Nations Population Fund (UNPF) (2023) recently published modelled population estimates for PNG, which have a high level of uncertainty. The estimate indicates that Bougainville's population in 2021 increased to 641,431, a 158% increase from 2011. This suggests an average annual population of over 10% which is higher than during the mining period and likely overstated. The uncertainty around population estimates reflects the reliance on remote sensing data for the 2021 estimate, and issues with the 2011 Census.

Modelled population estimates from WorldPop, the NSO, and UNPF (2023) suggest a population of 149,621 within the study area. This is based on selecting the community level government areas that are in the study area, although only two community level government areas are wholly within the study area, limiting the value of this data for understanding the population in the study area.

A high-level population estimate for the study area was created by identifying and classifying residential structures on high resolution aerial imagery. These structures were classified based on an aerial photo classification model, which GIS and social specialists manually reviewed. Building classification types were then ground-truthed in the field using a custom-developed software program. Population estimates were derived by applying a household population size at the sub-domain area to residential structures based on the outcomes of the 2023 household survey. This approach has some uncertainty and is not as robust as a complete household census.

Table 6.11 summarises the results of this population estimate, including the number of households, population, and population density, based on the sub-domain areas. Figure 6.3 shows the building footprints as a heat map to illustrate population density across the study area. The total population within the study area is estimated to be approximately 43,000. This supports that there has a substantive population increase in the study area between 2011 and 2023.

The highest levels of population density in the study area are:

- In the Port and Town Domain villages along the coast, particularly in Arawa.
- In the Upper mine sub-domain, particularly around Panguna Town.
- In the Lower mine sub-domain, clustered around the Kawerong River and Tailings Basin 1.

The remaining population in the study area is mainly distributed across the Upper and mid tailings sub-domain and Lower tailings sub-domain, although the Lower tailings sub-domain has a population density of less than half of that shown in the Upper and mid tailings sub-domain. The Delta Domain has a very low population density.

Table 6.11 Population estimate for the study area

Sub-domain	Number of households	Population	Density (people per km^2)
Port and Town	3,281	18,238	269
Arawa urban area	*1,845*	*11,568*	*3,220*
Port area	*1,298*	*5,994*	*105*
Other areas	*138*	*621*	*89*
Upper mine	1,761	8,665	130
Lower mine	1,337	6,248	159
Upper and mid tailings	1,171	5,032	102
Lower tailings	1,021	4,832	42
Delta	39	160	9
Total	**8,610**	**43,120**	**122**

'Other areas' is the area between Arawa and the Mine along the Port to Mine Access Road. It has been presented separately as the primary area investigated in Appendix H was the Port area.

Table 6.12 summarises the surveyed population, which was used to develop a high-level population estimate within the representative villages. This estimate was developed based on the average household size in the surveyed population and an estimate of the total households in each of these villages.

Table 6.12 Population estimates within representative villages

Domain/sub-domain	Village	Number of households	Average household size	Estimated population
Port and Town	Anewa Bay	14	4.2	59
	Rorovana 3	144	4.8	691
	Subtotal	***158***	***4.7***	***750***
Upper mine	Panguna Town	691	5.4	3,731
	In-pit	46	4.2	193
	Moroni	73	3.6	263
	Dapera	98	4.7	461
	Subtotal	***908***	***5.1***	***4,648***
Upper mine	Pirurari	41	4.9	201
	Onove	120	4.7	564
	Subtotal	***161***	***4.8***	***765***
Upper and mid tailings	Barako	120	4.4	528
	Jaba Pump Station	41	4.5	185
	Gold Miners Camp	53	4.3	228
	Konuku	40	4.0	160
	Subtotal	***254***	***4.3***	***1,101***
Lower tailings	Pem'ana	27	4.7	127
	Namunsa	123	5.5	677
	Mokerokeroai	27	3.5	95
	Subtotal	***177***	***5.1***	***899***

Domain/sub-domain	Village	Number of households	Average household size	Estimated population
Delta	Marau	12	2.0	24
	Tagasi(1)	-	-	-
	Koiare(1)	-	-	-
	Subtotal	***12***	***2.0***	***24***
Total		**1,670**	**4.9**	**8,187**

1. No population estimate was able to be calculated for this area.

6.2.1.3 Migration and displacement

Between 1962 and 1987, mine-related displacements occurred in 28 villages and hamlets across the study area (AGA 1989). This includes villages that were surveyed as part of this study, including Moroni, Dapera, Pirurari, Namunsa and Mokerokeroai. Post 1989, it is estimated that up to 70,000 people were displaced during the conflict.

Communities reported enduring issues from mine-related displacement, particularly when they were relocated to land that does not customarily belong to them. Communities in the study area reported similar concerns as part of previous investigations (for example Catholic Diocese of Bougainville 2019). For example, community members from the Upper mine and Upper-mid tailings sub-domains reported the following concerns:

- I can remember we were displaced from our original village when CRA came to Panguna. Most of the people in my age group have passed on. Children nowadays think that this was our village and most of them will not know the story. Our children are thinking that how we are living now is a norm for our children. We miss our original village.
- And the damage you see, gravel had covered our original village, even our secret [sacred] places along the riverbanks, sediment [from] the mine has already covered it, and in the mountains and the bushes are covered by the gravel… And when they relocate us, they hang us like flying fox in the mountains, the mountains where they relocated us when they did the blasting the ground is not stagnant.

Displaced communities raised issues associated with relocation during the mine construction. This included concerns over their social wellbeing and fear of losing identity and of land that belonged to them, as well as gardening land shortages which have resulted in people moving to steep hills to garden, increasing population in some areas and damaging existing land.

Current drivers of migration that were reported in the survey were: marriage; ASM; returning to family land; and employment opportunities. In cultures in the study area and across much of Bougainville, couples live with or near to the wife's family after getting married. This was reflected in the household survey, where marriage was stated as the most common reason for residents moving. The exception to this in in the Upper and mid tailings sub-domain area, where ASM was the primary reason for relocation (56%). Other reported reasons for migration in the study area communities were returning to the land of parents or other relatives and employment opportunities other than ASM.

6.2.1.4 Social capital and community safety

The term social capital refers to the value of social networks, bonding similar people and bridging between diverse people with norms of reciprocity (Claridge 2004). In the Papua New Guinean and Bougainvillean context, traditional social institutions (e.g., *kastom*[4], *wantok*[5], clan lineage support) are central to social capital (Slater and Holmes 2012), and provide an underlying basis for the creation of social bonds, particularly at the clan lineage and village level. These customs are strongly linked to social organisation customs that pertain to land ownership (Slater and Holmes 2012). Issues with land availability are discussed in Section 6.2.2.1.

Several questions in the household survey can be used to indicate social capital. Table 6.13 shows the first of these, which details whether respondents were able to receive support from a social group in the previous year. Support from clan groups was the most common source of support in the Mine and Delta domains, while religious groups were the dominant form of social support in the Port and Town and River System domains. All domain and sub-domains reported lower levels of support than the Control sites.

Table 6.13 Social capital – support from social groups

Social group	Port and Town	Upper mine	Lower mine	Upper-mid tailings	Lower tailings	Delta	Control
Community association	10.7%	7.5%	4.9%	9.2%	13.8%	8.9%	20.0%
Religious group	21.1%	12.5%	10.0%	23.1%	14.3%	2.2%	25.6%
Women's group	14.3%	5.0%	6.7%	4.7%	7.1%	2.3%	22.5%
Clan	17.5%	15.8%	27.4%	9.2%	3.6%	18.2%	22.5%
Did not receive any support	65.5%	74.0%	70.5%	74.2%	80.0%	77.8%	57.5%

This table presents the outcomes derived from multiple-choice responses where participants could select more than one option. As a result, the percentages across all categories may exceed 100%. The percentages of those who did not receive any support may include households that did not seek support, potentially inflating the reported figures.

Safety perceptions generally increased (i.e., people felt safer) westwards across the study area. Violence was perceived to have decreased substantially in the last five years in the Delta Domain (69%) and Lower tailings sub-domain (50%). More people felt their community was either very or moderately unsafe than the Control sites in the Upper, Mid, and Lower tailings sub-domains. All domains/sub-domains except the Delta Domain had higher proportions of households that reported their community to be very unsafe compared to the Control sites, the highest of which was the Lower tailings sub-domain (23%).

Participants in focus group discussions and key informant interviews reported a pattern of active disputes in some villages in the Lower tailings sub-domain. These issues may explain why people in these communities are less able to rely on others for matters such as food security (see Section 6.2.4.4).

Participants often pointed to a clan dispute or conflict with another village that had occurred as the basis for violence. As part of key informant interviews, participants were asked to identify the most common community issues in the study area. Informants also raised poor school attendance, poor child nutrition, prostitution and sorcery related violence as common social issues across the study area. The responses reaffirm the issues raised by communities during household surveys (Table 6.14).

[4] *Kastom* (custom) is a broad term that encapsulates cultural practices that are specific to a locality and *wantok* group, including Indigenous leadership norms (Nanau 2011).
[5] *Wantok (*one talk) refers to the relationships and obligations between people who share some or all of the following: a language, a kinship group, a geographical area of origin, common social associations (e.g., a church group) (De Renzio 2000).

Table 6.14 Safety issues of most concern

Safety issues of most concern	Port and Town	Upper mine	Lower mine	Upper-mid tailings	Mid tailings	Delta	Control
Relationship breakdown	15.5%	26.0%	29.0%	13.6%	6.7%	21.7%	12.5%
Drinking and drug abuse	51.7%	47.2%	38.7%	40.9%	16.7%	52.2%	42.5%
Conflict	13.8%	31.7%	53.2%	30.3%	26.7%	43.5%	17.5%
Sorcery	8.6%	29.3%	46.8%	27.3%	10.0%	41.3%	27.5%

This table presents the outcomes derived from multiple-choice responses where participants could select more than one option (or no options). As a result, the percentages across all categories do not total 100%, reflecting the distribution and frequency of each response rather than a proportion of a whole.

Safety issues of concern varied across the study area, with the Mine and Delta domains reporting higher levels of concern on most issues compared to other sub-domains and the Control sites. Drinking and drug abuse were the most prevalent concerns across the study area, including the Control sites, except for the Lower mine and Mid tailings domains. Among the Lower mine households, conflict (53%) and sorcery (47%) were the primary safety concerns. The Mid tailings domain reported the least safety concerns and were generally lower than the Control sites.

Other social issues reported included drug (e.g., marijuana) and alcohol (e.g., homebrew) use, domestic violence and physical violence (as a result of alcohol use), teenage pregnancy and community disputes. The trauma of the conflict and a lack of education and employment opportunities may have exacerbated the incidences of drug and alcohol use and crime in communities.

6.2.1.5 Cultural heritage and community identity

Cultural heritage encompasses both tangible and intangible elements that form a symbiotic relationship crucial for maintaining cultural identity. Tangible cultural heritage includes physical artifacts, traditional dwellings, and sites of significance, which reflect the deep connection between the people and their environment. Intangible cultural heritage includes practices and traditions such as language, traditional music and dance, and rituals.

As part of the village survey, informants were asked to identify significant cultural events within their community. Responses reaffirm the blended nature of Bougainvillean culture, with respondents raising the importance of church-related celebrations, and a range of traditional cultural events, including mortuary rituals. During focus group discussions, some communities reported that traditional customs had diminished in their community, as a result of interaction with outsiders, mining, and the death of elderly people who had not passed on their knowledge.

Three main types of cultural heritage sites were raised during engagement:

- Burial grounds
- Initiation areas (male and female segregated and non-segregated)
- *Masalai*/*tambu* sites (sites predominantly associated with the environment or with an ancestral spirit).

The majority of sites identified during engagement had been destroyed by mining activities (e.g., destroyed during construction or impacted by dispersal of tailings into the Kawerong and Jaba rivers). The destruction of sites was reported across the study area as irremediable:

> Once the spirits have gone, it is not possible for them to come back.

Knowledge of these sites and customary practices associated with them connects people to their ancestors and land and reinforces bonds within a clan or lineage. In this way, cultural heritage sites and the customs associated with them have a strong influence on community identity and social capital. Communities reported that the loss of initiation sites has meant that initiation is no longer occurring in some areas, resulting in some people's loss of clan identity.

Cultural heritage sites and associated customary practices also influence social organisation and control, between groups and at the lineage level. Customary knowledge of sites and a relationship to the spirits is a source of power (Ogan 1972). It grants clans and lineages social control over land.

6.2.1.6 Hazards and safety

Flooding was the most common hazard identified by communities across the study area, except for the Port and Town Domain and Control sites. Communities reported that flooding affected houses, gardening land and access to/from the community. For example:

- Flooding affects the road, and movement in and out of the community, especially during emergency medical situations.
- The flooding blocked this area, and the flood waters came into the village. This last flood in April [2023] lasted for 1 week from 1 month of continuous rain.

Flooding and its effect on gardening is discussed further in Section 6.2.2.1.

Other hazards commonly identified by communities included:

- Landslides were the most common environmental hazard identified by communities in the Port and Town Domain and were also identified by communities in the control sites and the Upper and lower mine sub-domain areas. These communities noted that issues with landslides primarily affected the productive capacity of gardening land. Additionally, the safety of the levee was raised as a concern by communities in the Upper and Mid tailings sub-domain.
- Historic chemical storage facilities associated with the mine (e.g., bulk fuel storage and chemical containers), were identified by communities in the Port and Town Domain and Upper mine sub-domain. Communities raised concerns that the chemicals may have entered their environments and affected their health and reported that some past interactions with chemicals had resulted in fatalities.
- Rising sea levels and high tides, were identified as commonly occurring environmental hazards by communities in the Port and Town and Delta Domain areas.

The effect of hazards on access to services, such as health care and education is discussed in Section 6.2.3.

6.2.2 Economy and livelihoods

This section describes how people make a living and the economic structure of the communities within the study area.

The social attributes discussed in this section provide context for understanding the following human rights:

- Right to adequate food, housing and standard of living
- Right to a clean and healthy environment.

6.2.2.1 Land, riverine and other natural resources

Livelihoods in the study area are primarily derived from natural resources. Prior to the development of the Panguna Mine, most communities depended on subsistence gardening, collection of bush and riverine resources and cash cropping.

Gardening

The development of the mine resulted in a large-scale change in subsistence production due to the loss of productive land to the mine. The loss of land and population increase (resulting from in-migration and an increase in the birth rate) intensified agricultural land use in unaffected areas (AGA 1989; Ogan 2015). This limited the capacity of affected households to rotate their garden blocks and fallow periods and was associated with an increase in plant disease and decreased output AGA (1989). In addition, AGA (1989) reported the following concerns regarding the impact of mining on gardening land:

- Large areas were being replaced by swamp / swamp vegetation in the Jaba Valley below Bato and near old Kuneka, particularly adjacent to the “first and second sedimentation basins”. This resulted in loss of land, bush and bush resources.
- The effect of tailings deposition on the productive capacity of gardening land. The deposition of tailings had created an environment that was unfavourable for plant growth because the tailings:

> *do not hold sufficient water, they contain metals which are toxic to plants and they are deficient in the major plant nutrients…progression back to a vegetation cover would take a very long time, possibly many or perhaps hundreds of years. It is unlikely that the tailings in particular would ever be covered by the vegetation community of the Panguna area because the habitat on the tailings is flat, well-drained and sandy, whereas the surrounding country-side is steep and the soils are well-developed on volcanic ash.*

The negative impacts identified above resulted in the use of more distant and steeply sloping land (.ibid). In some areas, the loss of land had resulted in a dramatic reduction in gardening, and in Dapera, ‘dependence on the agricultural economy in any form has virtually ended because of the loss of village land’ (.ibid).

Subsistence gardening remains the dominant food source across the study area with over 60% of households stating that gardens were their primary food source (Table 6.15). The sale of gardening surplus is also a common way that households and women in particular, earn cash incomes, with 44% of households across the entire study area selling subsistence surplus in the last year.

Table 6.15 Primary source of food

Primary source of food	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control
Garden	46.6%	52.5%	75.8%	85.7%	53.8%	75.6%	82.1%
Market	36.2%	27.9%	3.2%	3.6%	16.9%	15.6%	10.3%
Trade store	17.2%	19.7%	21.0%	10.7%	29.2%	8.9%	7.7%

The household survey asked several questions to identify gardening issues. The first was whether respondents had sufficient land for gardening (Table 6.16). Between 30% (Lower tailings) and 60% (Delta) of surveyed households reported that they did not have sufficient gardening land. This was consistently higher than the Control sites (Marowa, 17% and Tokiai, 0%). Fallow periods across all domains/sub-domains were substantially lower (two years to four years) than those reported following the conflict (Bourke et. al. 2002) of between four and eight years, indicating that there has been widespread intensification of gardening in the last 20 years.

Table 6.16 Gardening land availability and fallow periods

Indicator	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control
Percentage of households reporting no access to sufficient gardening land	37.0%	41.5%	32.8%	35.0%	29.6%	60.0%	11.1%
Fallow periods (years)	2.3	3.1	3.6	3.2	3.3	3.7	3.4

Barriers to gardening

Respondents were asked to report on the quality[6] of their gardening land (Table 6.17). Much larger proportions of respondents from the study area sub-domains stated that they had poor quality land than the Control sites (Marowa, 12% and Tokiai, 0%). Households were also asked to nominate barriers to gardening (if any). Contaminated land was the most commonly raised barrier to gardening nominated by communities. Soil fertility was raised as an issue by almost a third of households. In focus group discussions, contamination, soil fertility and tailings were strongly linked by participants. For example:

- The effect of the tailings can be seen here. Whatever produce we try to grow like sweet potatoes and banana takes longer to be ready and we think it is contaminated.
- As for myself, we can't grow good foods, the soil is damaged.
- Food crops including cassava do not yield good crops where there was mine pollution in my garden.

The results of soil testing are discussed in Section 6.2.4.4.

Households also raised flooding as a barrier to gardening, particularly in the Delta Domain (71%) and Lower tailings (58%) sub-domain, with food shortages raised as a consequence of flooding.

Table 6.17 Land quality and barriers to gardening

Indicator	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control
Land quality							
Poor quality	27.8%	25.5%	29.0%	44.6%	25.0%	48.9%	8.1%
Average quality	59.3%	71.6%	59.7%	46.4%	50.0%	44.4%	51.4%
High quality	11.1%	2.9%	11.3%	8.9%	25.0%	6.7%	40.5%
Barriers to gardening (1)							
Contaminated land	30.2%	46.6%	65.6%	49.1%	50.0%	47.7%	17.5%
Pests	37.7%	34.0%	70.5%	54.7%	30.8%	36.4%	50.0%
Poor soil fertility	39.6%	37.9%	27.9%	39.6%	23.1%	43.2%	30.6%
Flood	5.7%	16.5%	18.0%	11.3%	57.7%	70.5%	30.6%
Landslides	15.1%	37.9%	26.2%	0.0%	0.0%	0.0%	5.6%

1. Multiple choice question. Responses may be greater than 100%.

[6] There is a discrepancy between responses to the quality of gardening land and barriers to gardening discussed below, with people stating that they had average or even good gardening land, while also nominating multiple barriers. This may stem from translation issues between Tok Pisin and English, where when responding to a question about quality, respondents may be indicating that the land is similar to that of others in their community.

Cash cropping

Before the Panguna Mine was established, cash crops were the main source of income in Bougainville (Lummani 2015). Cash cropping remains a key livelihood strategy in the study area, with 51% of households selling cash crops in the last year.

Cash cropping has a spatial dimension, with households selling the following cash crops:

- The Upper and mid tailings (54%), Lower tailings (73%) sub-domains and Control sites (62%) predominantly selling cocoa.
- The Lower mine sub-domain selling the most vanilla (50%) and betel nut (48%).
- Delta Domain selling the most copra (33%).

In general, the Port and Town, Upper mine subdomains and Delta reported the lowest rates of cash cropping (21%, 30%, and 52% respectively), compared to approximately 60 to 80% of households in the other areas. These areas also had the highest proportions of households that reported that they had insufficient land for gardening (Table 6.15), indicating that land availability may be an issue.

The rates of cash cropping of cocoa, betel nut, vanilla and copra in the surveyed villages are generally below that reported from the South Bougainville region (Schmidt et al. 2019).

Hunting and fishing

Hunting, fishing, and gathering materials from the bush and river, while secondary to subsistence gardening, are important livelihood activities and have cultural significance (Oliver 1973 in Moulik 1977; Ogan 2015; Oliver undated in Bourke et al. 2002). In 1989, AGA reported that bushland degradation and the use shotguns had reduced the variety and volume of hunted species. It was also reported that freshwater fishing in areas inland had declined because of chemical contamination and sediment loads from the Panguna Mine (AGA 1989). BCL paid compensation for the loss of fish resources to the villages affected.

Table 6.18 summarises current levels of hunting, fishing and resource gathering in the study area. Around 16% of households in the study area participated in hunting, with the Lower mine and Lower tailings sub-domains and the Delta Domain, reporting greater participation in hunting than those in the Mine and Port and Town domains. Participants in some focus group discussions attribute this to the loss of forested areas. The impact of the mine on vegetation and the effect on animals and hunting was raised in focus group discussions and through participatory photography (Plate 6.1 and Plate 6.2).

Fishing was undertaken in most households in the Port and Town (78%) and Delta (89%) domains, consistent with historical patterns. Fishing was also reported in 54% of households surveyed in the Lower tailings sub-domain, where a number of communities noted that the Jaba River supports tilapia, which has ‘taken over’ and is perceived to have driven out more desirable species. No fishing was undertaken in households in the Upper and Lower mine sub-domains; only a small portion of households fished in the Upper and mid tailings sub-domains (13%). This is consistent with historical patterns and an outcome of the ongoing effect of mine-related impacts on surface water quality in the Kawerong-Jaba River system.

Communities in the Port and Town Domain raised concerns regarding possible contamination of the fish from crude oil and other chemical waste that remained in the port area. Communities in the Delta Domain and the coastal Control site (Marowa) reported that people must travel further out to sea to catch fish than in the past due to reefs being covered by tailings.

"The land has been damaged and all the resources (wild animals) have disappeared"

Photo credit: Community participatory photography, 2023

Plate 6.1
Participatory photography photo and quote showing damaged land in Barako

"The bushland is cleared and there are no more trees. There are no more protein for us in the bush like pigs, cuscus and birds. There is no bushland in this area"

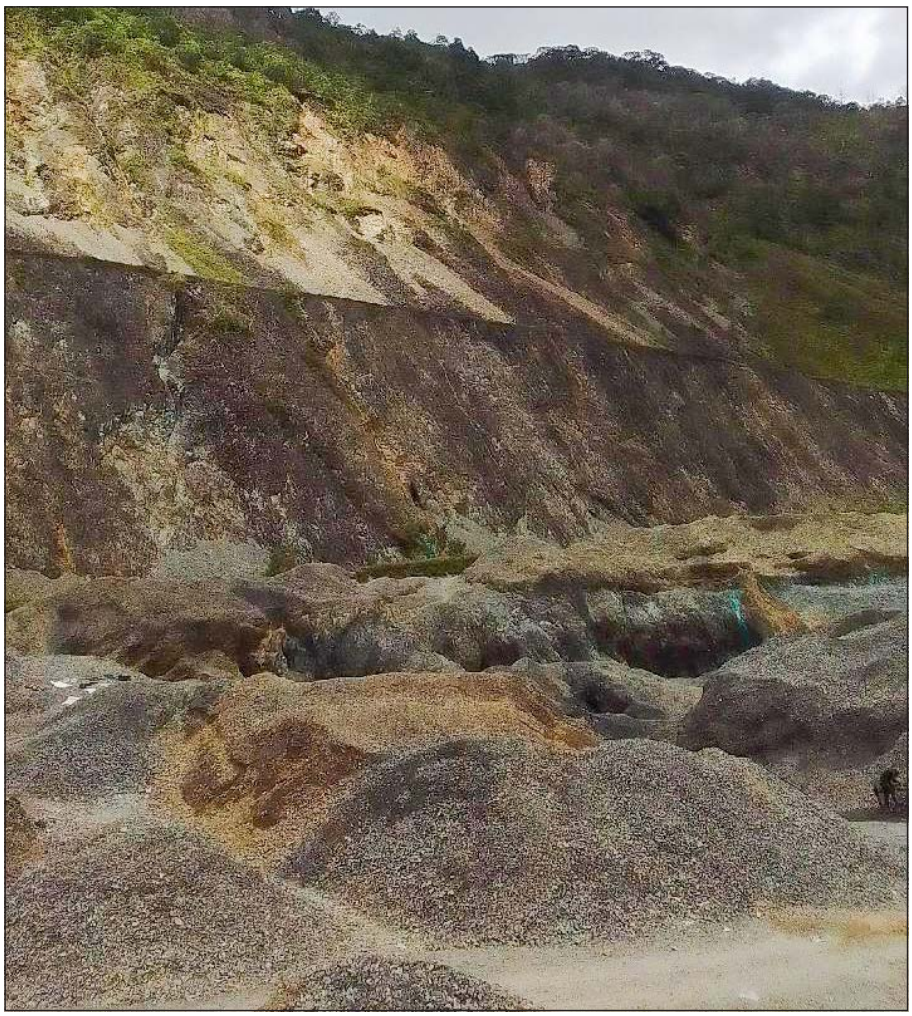


Photo credit: Community participatory photography, 2023

Plate 6.2
Participatory photography photo and quote showing lack of bush resources around open pit

Table 6.18 Hunting, fishing and resources gathering

Activity type	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control
Households engaged in hunting activity	1.7%	13.9%	23.3%	3.2%	29.6%	36.4%	15.0%
Households engaged in fishing activity	77.6%	0.0%	0.0%	12.7%	53.6%	88.6%	57.5%
Household gathering from bush	74.1%	74.0%	82.3%	62.5%	62.1%	88.6%	85.0%
Household gathering from river	0.0%	2.4%	3.2%	4.7%	34.5%	40.9%	10.0%

Bush and river resource collection

Most households in the study area gathered bush materials, although only the Delta Domain (89%) and Lower mine (85%) sub-domains reported levels close to that of the Control sites (85%) (Table 6.19). Participants in focus group discussions reported that although bush collection occurred, there were differences in the quality and types of resources collected from before mining started. Gathering materials from the river was common in the Delta Domain (41%) and Lower tailings sub-domain (35%), and was limited elsewhere, including at the Control sites.

Communities reported in the Complaint that the effect of impacts to Konaviru Wetlands have reduced the area available for collecting bush materials, including but not limited to:

- Wood for burning and building
- Different parts of the sago palm – including sago palm leaves, which are used for house construction, and the pith which is eaten
- Hunting and fishing.

Table 6.19 Bush and river resources

Resources collected	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control
Bush							
Firewood	97.7%	98.9%	96.1%	97.5%	100.0%	94.7%	88.2%
Vegetables	58.1%	70.3%	80.4%	67.5%	55.6%	73.7%	70.6%
Building material	37.2%	42.9%	74.5%	75.0%	77.8%	60.5%	55.9%
Materials for household use	32.6%	39.6%	68.6%	55.0%	50.0%	63.2%	32.4%
Medicines	30.2%	41.8%	56.9%	55.0%	50.0%	52.6%	41.2%
Fruits	20.9%	24.2%	47.1%	25.0%	22.2%	52.6%	47.1%
River							
Edible plants	0.0%	33.3%	50.0%	33.3%	60.0%	52.9%	25.0%
Materials for household use	0.0%	33.3%	50.0%	66.7%	40.0%	47.1%	50.0%
Building materials	0.0%	0.0%	100.0%	66.7%	40.0%	41.2%	25.0%
Logs for canoe making	0.0%	0.0%	0.0%	0.0%	30.0%	47.1%	0.0%

Artisanal and small-scale mining

ASM gold mining is a prominent economic activity in the study area and across Bougainville. ASM is thought to have commenced in 1997-98 in Bougainville due to limited income-earning opportunities during the conflict (O'Faircheallaigh et al. 2017). Initially focused near the Panguna Mine, ASM was observed at more than 50 locations across Bougainville by 2017, although operations remain concentrated around the Panguna Mine (.ibid). As a consequence, Panguna Town and the Mine subdomains have developed as socioeconomic hubs, where ASM supports various businesses such as food markets, fuel suppliers, and repair shops.

ASM activity is generally controlled by landowners, who either conduct mining themselves or give permission for others to do so. In Panguna, land access involves both landowning groups and migrants. Some believe all Bougainvilleans have rights to the land in Panguna Town and surrounds due to blood being shed during the conflict, allowing migrants to mine, though this view is not universally accepted (O'Faircheallaigh et al. 2017). In some cases, communities have reported that the lack of effective government and police presence has forced landowners to allow mining (.ibid).

ASM, though demanding and sometimes hazardous, is considered more lucrative than other local income sources, such as cocoa production, which has suffered from issues like the cocoa pod borer. Declining income from crops like cocoa and copra, along with rising gold prices and increasing living costs, have contributed to the growth of ASM in Bougainville. At the same time, land access arrangements that welcome in-migrants contribute to the growing influx of people into mining areas in Bougainville.

Household participation in ASM activities was highest in the Upper and mid tailings (77%) sub-domains, followed by the Upper mine (74%) and Lower mine (61%) sub-domain areas (Table 6.20). Of these, most respondents stated that they undertake ASM at least once a week, indicating that ASM is their primary source of income. Some survey participants in the Upper and mid tailings and Delta sub-domains temporarily migrated into the area to undertake ASM for additional income for events and to pay school fees. Other survey respondents reported that diminished gardening capacity meant they instead rely on ASM for income.

The most common ASM method reported during the household survey was a sluice box and panning, followed by handheld panning and hydro-sluicing. The use of mercury and other chemicals, such as nitric acid in ASM activities was reported widely. Concerns were raised by communities about health issues associated with ASM; these concerns were not raised consistently, indicating limited knowledge of the health risks associated with chemical use in ASM processing.

Table 6.20 Indicators of ASM activities

Indicators	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control
Surveyed households with at least one member engaged in ASM activities	1 (1.7%)	91 (74.0%)	38 (61.3%)	51 (77.3%)	9 (30.0%)	1 (2.2%)	1 (2.5%)
Method of ASM							
Sluice box and panning	100.0%	41.6%	45.5%	60.0%	57.1%	100.0%	100.0%
Panning	0.0%	20.2%	33.3%	17.8%	42.9%	0.0%	0.0%
Hydro-sluicing	0.0%	6.7%	9.1%	6.7%	0.0%	0.0%	0.0%
Hard rock mining	0.0%	10.1%	0.0%	0.0%	0.0%	0.0%	0.0%

6.2.2.2 Sexual division of subsistence and artisanal labour

Table 6.21 summarises the well-known sexual division of labour for subsistence activities in Bougainville and PNG (FAO 2019). These divisions result in women's labour burden being much greater than that of men (Moulik 1977; FAO 2019). Although this study did not collect data on labour divisions for subsistence activities, participation in focus group discussions reflected the patterns described in Table 6.21.

Responses to the household survey show that both sexes participate in ASM. Of those households that undertake ASM, there was a slightly higher level of participation by men (50%) compared to women (41%). A small proportion of these households stated that males (6%) and females (3%) younger than 16 years of age participated in ASM.

Table 6.21 Sexual division of labour – general overview

Activity	Women's activities	Men's activities
Gardening	Daily and weekly maintenance; planting, harvesting.	Clearing land, supporting weekly maintenance.
Cash cropping	Maintenance	Occasional support.
Hunting	Not applicable	Almost exclusively a men's activity.
Fishing	Women may undertake fishing activities, especially gleaning and river fishing.	Primarily a men's activity, particularly for open sea fishing.
Foraging	Almost exclusively a women's activity.	NA

Source: Tetra Tech Coffey after Hill et. al. (2022) and Togolo (2023)

6.2.2.3 Employment and income

Most respondents reported that they had not been employed in the last 12 months, ranging from 60% (Control villages) to 77% (Upper mine sub-domain) (Table 6.22). Among those employed, the majority (between 65% (Port and Town Domain) and 100% (Delta Domain) of respondents were engaged in informal employment, such as agriculture, selling subsistence products and unskilled manual jobs (Table 6.23). This is consistent with informal work patterns observed elsewhere in Bougainville.

Table 6.22 Employment and unemployment

Employment status	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control	Bougainville (1)
Not employed in the past 12 months	70.1%	77.0%	61.4%	71.5%	65.5%	68.3%	60.3%	53.9%
Employed in the past 12 months	20.1%	9.5%	8.4%	16.0%	18.2%	9.6%	23.3%	45.6%
Unknown/Not sure	9.7%	13.5%	30.1%	12.5%	16.4%	22.1%	16.4%	0.5%

1. NSO and IFC 2019

Table 6.23 Occupation type of those employed

Occupation type	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control	Bougainville (1)
Informal employment(2)	64.9%	69.4%	89.5%	81.8%	91.7%	100.0%	70.8%	66.2%
Formal employment	35.1%	30.6%	10.5%	18.2%	8.3%	0.0%	29.2%	33.8%

1. NSO and IFC 2019
2. Informal employment is defined as all informal jobs carried out in formal sector enterprises, informal sector enterprises or households (Hussmanns 2004).

Across the study area, 21 households (5% of surveyed households) reported that a household member younger than 16 years old was engaged in labour, with the highest levels reported in the Lower tailings (13%) and Upper and mid tailings (10%) sub-domains. The most common type of child labour was undertaking ASM with parents (52%), followed by selling food at the market (24%) and harvesting cocoa (14%) (Table 6.24). Based on field observations, this is likely an underestimate, as children were regularly observed assisting in ASM activities. Some communities and key informants raised concerns that children were not attending school due to engaging in ASM activities.

Table 6.24 Summary of self-reported child labour

Indicator	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control	Study area
Households with a member younger than 16 years old engaged in labour	3 (5.2%)	3 (2.5%)	4 (6.7%)	6 (9.5%)	4 (13.3%)	0 (0.0%)	1 (2.6%)	21 (5.1%)
Type of labour								
ASM activities	0.0%	100.0%	75.0%	83.3%	0.0%	0.0%	0.0%	52.4%
Selling food or fish at market	100.0%	0.0%	25.0%	0.0%	25.0%	0.0%	0.0%	23.8%
Harvesting cocoa	0.0%	0.0%	0.0%	0.0%	75.0%	0.0%	0.0%	14.3%
Other	0.0%	0.0%	0.0%	16.7%	0.0%	0.0%	100.0%	9.5%

The median fortnightly household income in the study area ranged from PGK150 (Port) to PGK900 (Upper and mid tailings) (Table 6.25). Most surveyed households reported earning income in the previous fortnight. The Port Domain area had the highest proportion of surveyed households with no reported income (26%), which is consistent with the Port Domain having the lowest median income. Surveyed households reported earning income from various sources, with the most common being from the sale of cash crops (e.g., cocoa, vanilla), subsistence surplus and gold.

A higher proportion of households in the Lower mine (83%) and Lower tailings (80%) sub-domain areas reported earning income from cash cropping. The Upper mine and Upper and mid tailings sub-domain areas reported a lower percentage of households earning income from the sale of subsistence surplus, 29% and 36% respectively. These sub-domain areas also reported the highest levels of ASM engagement and reported relatively high issues accessing gardening land. Households involved in ASM-related activities earnt a substantial amount more compared to households that did not, demonstrating the importance of ASM activities to the local cash economy.

Table 6.25 Household income levels and sources

Indicator	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control
Median income (PGK)[1]	150	600	810	900	690	215	670
Income range (PGK)	20 – 2,900	20 – 5,630	100 – 5,350	104 – 9,050	20 – 4,265	4 – 6,700	34 – 6,700
Proportion of households with no income earnt	25.9%	12.2%	3.2%	6.1%	0.0%	6.5%	5.0%
Percentage of households earning income from[2]:							
Sale of cash crops	27.9%	34.3%	83.3%	62.9%	80.0%	55.8%	81.6%

Indicator	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control
Sale of subsistence surplus	46.5%	28.7%	60.0%	35.5%	63.3%	65.1%	68.4%
Sale of gold	2.3%	84.3%	65.0%	90.3%	33.3%	2.3%	0.0%
Wage employment	30.2%	11.1%	16.7%	9.7%	6.7%	2.3%	21.1%
Business operations	4.7%	10.2%	18.3%	19.4%	10.0%	7.0%	21.1%
External remittances	14.0%	10.2%	23.3%	4.8%	3.3%	18.6%	15.8%

1. Median household incomes have been calculated based on the self-reported income for each of the overarching income sources, i.e., households that have not earnt income from a source have been excluded from calculations.
2. Multiple choice question. Responses may be greater than 100%.

6.2.2.4 Household expenditure and asset ownership

Generally, the median fortnightly household expenditure was less than the median household income, except in the Port and Town and Delta domains. This is likely due to data being presented as a median and may indicate response bias.

Surveyed households in the study area reported that food, cultural costs, and transportation costs were the primary household expenses. In several domains and sub-domains (Port and Town, Upper mine, Upper and mid tailings and Delta), most households (between 91% and 94%) purchased food in the previous fortnight. The percentage of households who reported incurring transport costs was considerably higher in the Marowa control village (77.5%) and Delta Domain (71.7%). This is likely because these communities are located a long way from service centres such as Arawa and Buka. Similarly, the Port and Town Domain reported considerably higher transport costs (74.1%). Other annual expenses reported by surveyed households included school fees and purchasing capital items, such as generators and boats.

During the village survey, respondents were asked to identify the cost of basic goods commonly sold in trade stores, including rice, water, cooking oil, tinned fish and meat, fuel, kerosene, and batteries. To understand the affordability of goods, the total cost of a basket of goods was calculated to compare costs within the study area, and compared to an urbanised area (Arawa). The cost of goods in each sub-domain area was consistently higher compared to Arawa (PGK52), ranging from PGK62 (Lower mine) to PGK70 (Delta). While costs were highest in the Delta Domain and Upper and mid tailings sub-domains, they were not significantly higher than areas closer to urban areas, such as the Port and Town Domain, or other areas that also hosted ASM activities, which can have an inflationary effect on the cost of goods.

The most common household assets are mobile phones, garden machinery and livestock, which can support future income-generating opportunities. Similarly, ownership of ASM equipment is prevalent in the Upper mine (47%) and the Upper and mid tailings (46%) sub-domains. Higher proportions of households in the study area own other assets (e.g., computers, refrigerators and trucks) compared to rural PNG households (NSO, 2019), particularly in the Upper and mid tailings sub-domain where asset ownership consistently exceeds that of Rural PNG. Households in the Lower mine sub-domain reported lower levels of asset ownership than that of Rural PNG.

6.2.2.5 Housing

The Social and Human Rights Characterisation Report (Appendix H) categorises housing in the study area as improved and unimproved. The walls and roof of improved housing are constructed with finished materials (i.e., metal, tiles, wood planks) and the flooring is constructed (e.g., not bare ground), while unimproved housing is mainly made from bush materials (i.e., natural ground, thatch and palm leaf) (NSO 2019; OPHI 2021).

Most housing in the Lower tailings sub-domain (97%) and Delta Domain (96%) was unimproved, likely due to their rural location, lower accessibility to building materials and lower cash incomes. Examples of houses in these areas are shown in Plate 6.3. In comparison, a large proportion of houses in the Port and Town Domain (78%) and Upper mine (58%) sub-domain were improved, likely influenced by people living in historic BCL buildings (Plate 6.4).

Village survey respondents were asked about the condition of housing in their community. Overall, housing conditions were reported to be fair to good, except for Panguna Town which was reported to be fair to poor. From field observations, BCL buildings that are being used as homes are in a dilapidated condition. Poor housing conditions were observed in areas that house transitory ASM populations, such as the Gold Miners' Camp, such as the lack of an external *haus kuk*. No households in the study area are connected to mains electricity, although hydropower was available in some communities in the Mine Domain and Tokiai Control site. Consequently, most households rely on lanterns, picosolar, and generators.

6.2.3 Infrastructure and services

This section describes the infrastructure and associated services in the study area, including:

- Community infrastructure such as healthcare and education facilities, sanitation, and waste disposal.
- Economic, transport and communication facilities.

Access to educational and health services and economic infrastructure such as markets, supports households and communities in improving their living conditions (Hanson et al. 2001). The quality and extent of the road network play a crucial role in determining access to community infrastructure and services. Most roads in the study area are unsealed, except for the Port to Mine Access Road, which BCL originally sealed. Consequently, most of the road network to the southwest of Panguna town is in poor condition.

Access to infrastructure and services generally declines, travelling south and then west across the study area, with some communities having no local education or health service. Communities with no local services must travel to more populated areas to access services and support. For communities located in remote areas (i.e., further from Arawa) in the southwest of the study area, the poor quality of road infrastructure increases the time, costs and hazards associated with accessing services. Communities in the west of the Delta Domain reported that accessing Buka by boat was a cheaper and more reliable way to access services.

Infrastructure and service access in the study area is greatest in the Port and Town and Mine domains, which can easily reach host health, education, or economic infrastructure in Arawa. Access to infrastructure and services generally declines travelling west across the study area, with some communities having no aid post, school, and no mobile phone reception.

The social attributes discussed in this section provide context for understanding the following human rights:

- Right to education
- Right to health.

6.2.3.1 Health facilities

The primary health facilities that service the study area are the Arawa District Hospital, the Panguna Health Centre, and the Moratona Health Centre (Figure 6.4). None of the surveyed villages in the study area had a functioning and staffed aid post. Consequently, most people must travel between one to three hours to access health services. In general, there is an increase in travel time to a hospital or health centre towards the west of the study area, with the highest travel times reported in the Lower tailings sub-domain and Delta Domain.

Photo credit: Tetra Tech Coffey, 2024

Plate 6.3
Two dwellings and one *haus kuk* in Lower tailings sub-domain area

Photo credit: Tetra Tech Coffey, 2024

Plate 6.4
Residences in historic BCL building in the Mine Domain

LEGEND

- Village
- Point of interest
- Arawa hopital
- Health centre
- Aid post
- Road
- Watercourse
- Phase 1 study area

SOURCE
Infrastructure approximate locations compiled from Tetra Tech Coffey.
Villages, roads, watercourses, domains and study area from Tetra Tech Coffey.
Imagery from Woolpert (2023) and Google Earth (2020).

0 2.5 5 km

SCALE **1:275,000**
PAGE SIZE: **A4**
PROJECTION: **WGS 1984 UTM Zone 56S**

PANGUNA LEGACY ASSESSMENT COMPANY

PANGUNA MINE LEGACY IMPACT ASSESSMENT PHASE 1

FIGURE 6.4

Health facilities

TETRA TECH COFFEY

DATE: **30.10.24** PROJECT: **754-MELEN305719** FILE: **305719_R03_F06.04_GIS**

DISCLAIMER: THIS FIGURE HAS BEEN PROVIDED FOR INFORMATION ONLY AND IS SUBJECT TO CHANGE. THE CREATORS DO NOT WARRANT THAT THIS FIGURE IS DEFINITIVE NOR FREE OF ERROR AND DO NOT ACCEPT LIABILITY ARISING FROM RELIANCE ON INFORMATION PROVIDED HEREIN. © COPYRIGHT TETRA TECH COFFEY 2024.

DOC REFERENCE: \\TT.LOCAL\COF\SYS772\S\GIS\305719_MELEN_PLAC_LEGACYIMPACTASSESSMENT\1_PLAC_LIA_GIS\APRX\305719_R03_FIGS_A.APRX LAYOUT:305719_R03_GIS022_2
SAVED BY: JASON.ORAM 30.10.24 3:41 PM

The most cited barrier to accessing health services was distance (Table 6.26). This was followed by financial constraints, particularly in the Delta (61%) and Port and Town (59%) domains, and the Lower mine (45%) sub-domain. Hazards (e.g., heat, steep terrain, and flooding) were also raised as a barrier to accessing healthcare, particularly in the Delta Domain (30%), Upper mine (14%) and Lower mine (13%) sub-domains.

Table 6.26 Barriers accessing health care services

Barriers	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control	Bougainville (1)
No problem	*27.8%*	*26.3%*	*19.4%*	*18.2%*	*10.0%*	*8.7%*	*13.2%*	*NA*
Distance	48.1%	50.0%	74.2%	77.3%	80.0%	89.1%	81.6%	42.5%
Financial constraint	59.3%	48.2%	45.2%	30.3%	36.7%	60.9%	23.7%	50.8%
Hazards	7.4%	14.0%	12.9%	7.6%	6.7%	30.4%	2.6%	NA

1. This data in NSO and IFC (2019) is reported for women only, whereas the household survey for Social and Human Rights Characterisation Report (Appendix H) is reported at a household level.
NA – not available.

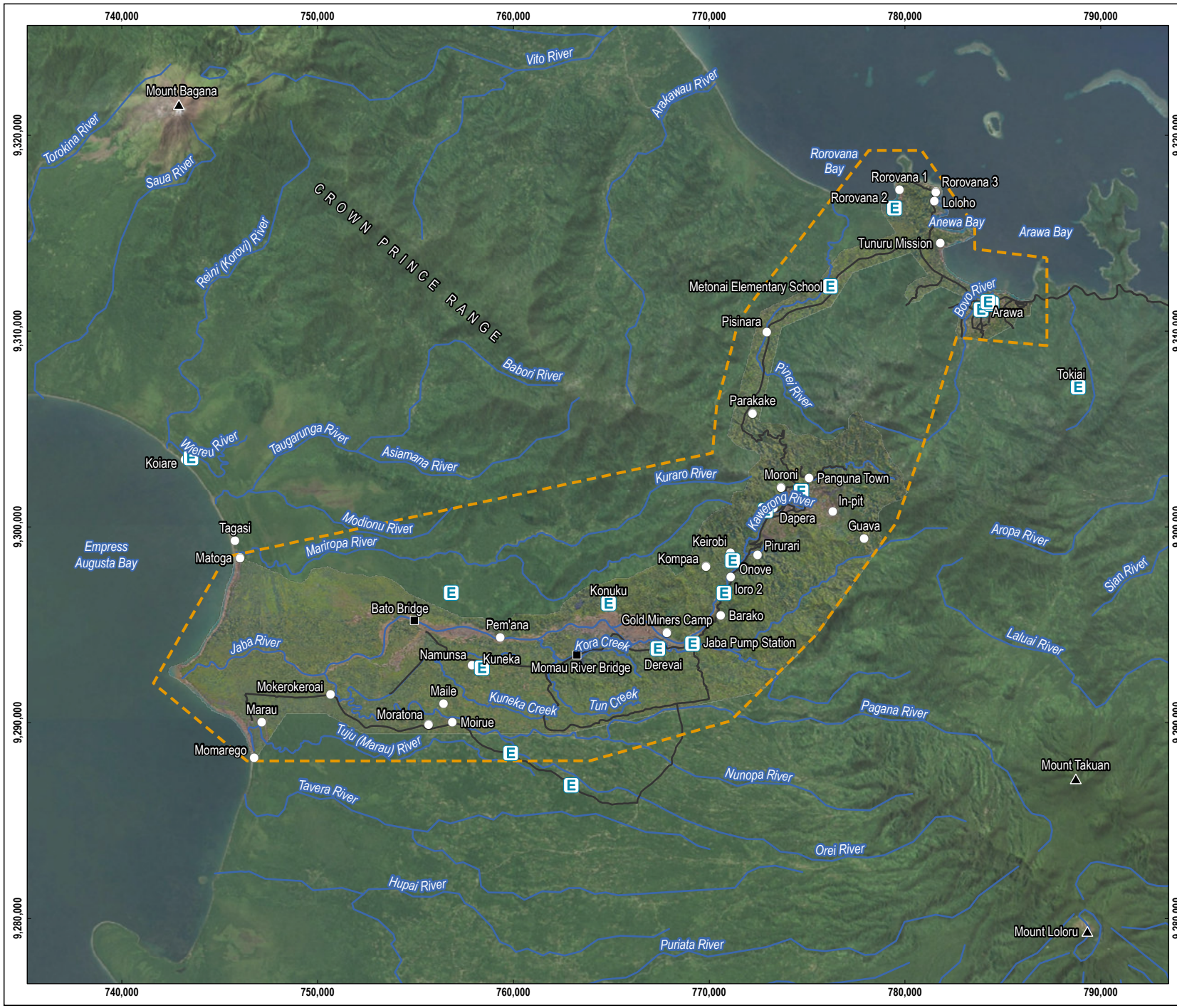
An additional barrier raised during the household survey was medicine shortages, and poor-quality health service. Discussions with health centre and hospital staff indicate that funding, staffing, and medical supplies are challenges for health service delivery. These features are not specific to the study area, and characterise the Bougainville and PNG health system broadly (Grundy et al. 2019).
Capacity to respond to emergencies caused by a hazard event is limited in the study area, reflecting broader constraints in service capacity in Bougainville and PNG. There are no formal emergency response services in the study area: there is no fire brigade, and the Arawa Hospital does not have an ambulance. Typically, community members act as ‘first responders’, sometimes aided by health and police services, depending on access and staff availability. However, health and police services are also constrained by staff and equipment shortages.

6.2.3.2 Education facilities

Elementary and primary schools that were used by households in the study area are in Rorovana 2, Arawa, Panguna, Dapera, Oune, Ioro 2, Jaba Pump Station, Kuneka and Koiare (Figure 6.5). All schools except for those in Jaba Pump Station, Panguna, and Arawa were run by a church. Access for children who do not have a school within their community generally requires walking an hour for children in the Upper mine, Upper and mid tailings, Lower tailings and Delta sub-domains. In the Lower mine sub-domain, it takes children 2 hours to walk to their school.

Secondary schools are limited to Arawa and Bana. High school places are limited, and placements are competitive. Consequently, it is not a certainty that a student will attend high school. A recent survey (Goro 2023) reported that education facilities in Bougainville are in dire need of resources, including learning material, and that “poor conditions makes teaching difficult”. A similar situation was reported across the study area, with many schools thought to have inadequate teaching supplies.

When floods occur, areas without safe water crossing points like bridges, can become inaccessible. Communities reported that flooding on the Kawerong-Jaba River system results in some children being unable to access school. This interruption, though temporary, may occur multiple times per year, depending on the level of rainfall. Communities stated that access can be disrupted for up to several days.



LEGEND

- Village
- Point of interest
- Education facility
- Road
- Watercourse
- Phase 1 study area

SOURCE
Infrastructure approximate locations compiled from Tetra Tech Coffey.
Villages, roads, watercourses, domains and study area from Tetra Tech Coffey.
Imagery from Woolpert (2023) and Google Earth (2020).

0 2.5 5 km

SCALE **1:275,000**
PAGE SIZE: **A4**
PROJECTION: **WGS 1984 UTM Zone 56S**

PANGUNA LEGACY ASSESSMENT COMPANY

PANGUNA MINE LEGACY IMPACT ASSESSMENT PHASE 1

FIGURE 6.5

Education facilities

TETRA TECH COFFEY

DATE: **30.10.24** PROJECT: **754-MELEN305719** FILE: **305719_R03_F06.05_GIS**

DISCLAIMER: THIS FIGURE HAS BEEN PROVIDED FOR INFORMATION ONLY AND IS SUBJECT TO CHANGE. THE CREATORS DO NOT WARRANT THAT THIS FIGURE IS DEFINITIVE NOR FREE OF ERROR AND DO NOT ACCEPT LIABILITY ARISING FROM RELIANCE ON INFORMATION PROVIDED HEREIN. © COPYRIGHT TETRA TECH COFFEY 2024.

DOC REFERENCE: \\TT.LOCAL\COFS\772\S\GIS\305719_MELEN_PLAC_LEGACYIMPACTASSESSMENT\1_PLAC_LIA_GIS\APRX\305719_R03_FIGS_A.APRX LAYOUT:305719_R03_GIS023_2 SAVED BY: JASON.ORAM 30.10.24 3:41 PM

6.2.3.3 Economic and support infrastructure

Trade stores were established in all surveyed villages, which provide basic goods, such as rice, cooking oil, tinned meat and fish, soap, kerosene, fuel and batteries. From field observations, ASM activities stimulate trade store establishment. For example, compared to other sub-domains more trade stores were established in the Upper and mid tailings and the Upper mine sub-domain, where around 40% of trade store owners interviewed stated that gold sales were used to establish the trade store. Likewise, informal discussions noted that ASM was the source of many businesses in this area.

There are small markets in Panguna Town, Barako, Dapera, Konuku, Jaba Pump Station, and Moroni. Established markets that are used widely in the study area include those at Marau (close to but a separate site to Marau), Morgan Junction, and Arawa. Access to Arawa (i.e., the main service centre) is provided by a public motor vehicle (PMV), which traverse the road network. Transport costs reported in the village survey increased the further the village was from Arawa (Table 6.27).

Table 6.27 Transport costs

Area	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control [1]
PMV cost to Arawa (PGK)	3-6	20	20	20	40-50	40	5

1. Cost based on information from Tokiai, as the information was not provided by Marowa but would have been significantly higher than this.

6.2.3.4 Sanitation and waste disposal

Improved sanitation facilities separate human waste from human contact, and include plumbed toilets, pit toilets with concrete slabs, and ventilated improved pit (VIP) toilets (Table 6.28). Households in the study area have greater levels of unimproved sanitation than those reported across Bougainville and the Control sites. This can have a detrimental effect on health, and is an indicator of multi-dimensional poverty.

Table 6.28 Household sanitation facilities

Facilities	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control	Bougainville [1]
Improved sanitation	6.9%	23.8%	3.3%	3.0%	0.0%	2.2%	32.5%	15.5%
Plumbed toilet	5.2%	15.6%	3.3%	0.0%	0.0%	2.2%	25.0%	NA
Pit toilet with concrete slab	0.0%	5.7%	0.0%	0.0%	0.0%	0.0%	5.0%	NA
VIP toilet	1.7%	2.5%	0.0%	3.0%	0.0%	0.0%	2.5%	NA
Unimproved sanitation	93.1%	76.2%	96.7%	97.0%	100.0%	97.8%	67.5%	84.6%
Open defecation (e.g., sea, bush, river)	91.4%	48.4%	55.0%	40.9%	23.3%	65.2%	25.0%	57.0%
Open pit toilet	1.7%	27.0%	41.7%	56.1%	66.7%	32.6%	42.5%	27.6%

1. NSO and IFC (2019). NA – not available.

6.2.4 People's productive capacity

This section describes the wellbeing and environmental conditions conducive to survival and participation in society and its economy, sometimes referred to as human capital. The social attributes discussed in this section provide context for understanding the following human rights:

- Right to adequate food, housing and standard of living
- Right to health
- Right to water
- Right to education
- Right to a clean environment.

6.2.4.1 Health indicators

During *tok storis* and focus group discussions, communities in the Mine and River System domains raised concerns about health issues associated with undertaking ASM activities:

- We experience illness from being in the water panning from gold. Illnesses such as cough, cold and fever, malaria, itchy skin and grille [tinea imbricata]. There is also diarrhoea here.
- Yes and mainly getting cold from being in the river for too long, malaria and some have very dry foot after that. We use mercury but we don't know if that has affected our health too.
- I work for gold as a full time job previously. I had sores like grille [tinea imbricata] on my foot and that stopped me from continue working.

These concerns were not consistently raised, with some focus group discussions stating that they had no health concerns or issues associated with ASM.

Although the latest malaria rates in south and central Bougainville are relatively low (i.e., between 0-100 infections per 1,000 persons), the risk remains sufficient to warrant the use of disease control. Few houses in the study area are vector proof. This is due to the 'unimproved construction type' of the housing using traditional and bush materials (Section 6.2.2.5). The Port and Town (3%), Lower tailings (3%) and Delta (7%) sub-domains had the lowest rates of vector-proof housing and were substantially below the rates in the Control sites (25%). The Mine Domain had higher rates of vector-proof houses, which is likely influenced by the higher proportion of people living in improved housing (Section 6.2.2.5).

Mosquito nets are the most effective response for malaria-prevention when a house is not vector proof. All sub-domain areas, except the Lower mine, reported a higher proportion of households with adults sleeping under treated mosquito nets. A lower proportion of households in the Port Domain, Upper mine, Lower mine sub-domain areas and Control sites reported that children under five years old slept under a treated mosquito nets compared to Bougainville data. Most households removed stagnant water from areas surrounding houses, and a small proportion of households used repellents or insecticides.

Self-reported illnesses

Household survey respondents were asked to nominate the illnesses experienced in the previous two weeks (Table 6.29). Cough was the most reported illness, followed by stomach pains and cramps, malaria, diarrhoea and skin sores. Health service providers reaffirmed the prevalence of these issues. These conditions are often environmentally influenced: they are spread from living in close contact with others, and having poor housing, water and sanitation conditions.

Table 6.29 Self-reported illnesses experienced in the past two weeks by households

Illness	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control
Cough	32.8%	30.9%	43.5%	25.8%	23.3%	30.4%	35.0%
Stomach pains / cramps	12.1%	21.1%	38.7%	21.2%	26.7%	21.7%	15.0%
Malaria	6.9%	17.9%	27.4%	18.2%	20.0%	28.3%	15.0%
Diarrhoea	6.9%	13.0%	29.0%	16.7%	23.3%	15.2%	17.5%
Skin sores	5.2%	17.9%	22.6%	10.6%	13.3%	17.4%	15.0%
Broken bone(s)	0.0%	6.5%	17.7%	6.1%	6.7%	13.0%	7.5%
Jaundice	0.0%	4.9%	17.7%	3.0%	3.3%	10.9%	7.5%
COVID-19	0.0%	4.9%	17.7%	3.0%	3.3%	10.9%	7.5%

All data is self-reported. No medically qualified personnel were involved in the collection of this data.

Maternal health and use of health services

Table 6.30 provides a summary of maternal health service indicators for study area communities. The majority of births take place in a hospital or health centre. The Lower mine (33%) and Upper and mid tailings (50%) sub-domains reported the highest levels of births taking place in the village. Between 95% and 100% of surveyed women who had given birth reported attending an antenatal clinic during pregnancy responses, which was higher than for Bougainville (88%) (NSO 2019). The exception was the Lower mine sub-domain area where 83% of women reported attending an antenatal clinic, which is consistent with the higher proportion of village births in the area.

Having a trained birth attendant supervise and assist women with labour and delivery has been found to improve maternal morbidity and mortality in other remote areas of PNG (Bettiol, Griffin and Heard 2004). In the Upper and mid tailings sub-domain, village births were primarily overseen by a trained village birth attendant (60%). Births in a village were primarily overseen by the woman's mother, representing 100% of births in the Lower mine and 63% in the Upper mine sub-domains.

Table 6.30 Self-reported childbirth location

Location	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control	Bougainville[1]
Hospital	95.5%	41.0%	0.0%	20.0%	0.0%	0.0%	85.7%	67.5%
Health centre	0.0%	38.5%	66.7%	30.0%	100.0%	100.0%	14.3%	
Village	4.5%	20.5%	33.3%	50.0%	0.0%	0.0%	0.0%	27.3%

1. Source: NSO (2019)

As part of the household survey, women of reproductive age (i.e., aged between 17 and 45 years old) were asked questions to characterise reproductive health. Around 48% of eligible women completed the survey and in some sub-domains less than 30 women responded. As such, it was deemed inappropriate to present the data disaggregated into sub-domains. The level of miscarriage was below the normal range of miscarriage reported internationally (13% to 19%) (Quenby et al. 2021). Further, the response was inconsistent which indicates women may not have understood the question. This may lead to the data being misleading or underrepresenting the issues.

During focus group discussions and *tok storis* communities in the Upper and mid tailings and Lower tailings sub-domains raised maternal health concerns associated with ASM, which included miscarriages, difficulties during pregnancy and childbirth. These were attributed by some to exposure to chemicals in the river during ASM activities and in Arawa Bay from legacy mine infrastructure. Others noted concerns about exposure to mercury when undertaking ASM activities.

Across the study area, 11 women reported that a child under five had passed away. The reasons for the child's death were reported as cough and other unknown illnesses. Due to the sensitive nature of the topic and lower participation of women in the household survey, this is likely an underestimation.

6.2.4.2 Human health characterisation

The Investigation Report: Human Health Risk Assessment (Appendix G) characterises human health risks that may be related to social and human rights impacts that are directly connected to environmental impacts caused by the Panguna Mine. This characterisation is based on the results of the field investigations for soil, water, dust and food resources. The Human Health Risk Assessment also considers the results of field investigations undertaken for the Investigation Report: Site Contamination (Appendix B) and Investigation Report: Water Quality and Geochemistry (Appendix A).

A summary of the human health characterisation is provided in the following sections and data uncertainties are described where relevant. An assessment of possible health risks is provided in Chapter 11 and Chapter 12.

Water

Water quality samples were collected from community identified water sources, i.e., the locations where the people that participated in the surveys at representative villages nominated as their primary and secondary water sources. Water quality samples were also collected from other waterbodies, such as rivers and creeks, that are likely used for recreational and other purposes.

Community identified water sources

The measured total suspended solids (TSS) were below the limit of reporting (<5 mg/L) for 92% of samples from community identified water sources tested, indicating that the turbidity is very low in these water sources. Of the seven water samples that reported TSS above the limit of reporting, the concentrations ranged from 5 mg/L to 16 mg/L. While there are no screening criteria for TSS, these levels indicate that the suspended solids are low.

The study found that all samples from community identified water sources were below the adopted recreational water health screening criteria for mine-related contaminants (Table 6.30).

All samples from community identified water sources were also below the adopted drinking water health screening criteria for mine-related contaminants (Table 6.30), with two exceptions:

- **In-pit (Upper mine sub-domain):** Three water sources identified by the In-pit community reported molybdenum concentrations (0.09 mg/L to 0.321 mg/L) above the adopted drinking water health criteria (0.05 mg/L). These water sources are piped from a watercourse outside of the open pit, and are used for domestic (drinking and bathing) as well as ASM purposes.
- **Kuneka (Lower tailings sub-domain):** One exceedance of manganese was detected in a water source identified in Kuneka. The manganese concentration reported in the wet season (0.329 mg/L) exceeded the drinking water health criteria (0.1 mg/L) but was below the recreational/other water use health screening criteria (1 mg/L). The local community described this water source as "*murky and cloudy*" and was not used for drinking but for bathing and laundry purposes. The sampling of this location in dry season reported manganese concentrations below the drinking water criteria.

Other waterbodies

In addition to the community identified water sources, water samples were also collected from other waterbodies, such as rivers and other surface waterbodies that may be used for drinking and recreational purposes, or other uses.

The household survey reported that some households relied on river water for their primary or secondary drinking water source. Six households reported using river water year-round. None of these households were using mine affected river water sources apart from three households in the Lower tailings sub-domain (Mokerokeroai). The river water source identified at Mokerokeroai was the Pagana River, which did not exceed the adopted drinking water screening criteria (Table 6.31).

Water samples collected from 13 sampling locations along the Kawerong-Jaba River had concentrations of mine-related contaminants above the adopted drinking water screening criteria (see Table 5.35). These sampling locations are shown in Chapter 5 (see Figure 5.4). Concentrations of arsenic, cadmium, copper, lead, manganese, molybdenum and nickel exceeded the adopted drinking water screening criteria which is based on both health and aesthetic guidelines.

Around 15 households in the Gold Miners Camp reported using the Kawerong-Jaba River only during the dry season periods. Riverine water quality samples were collected from one site near these households. Concentrations of copper (1.1 mg/L to 3.7 mg/L) and manganese (0.248 mg/L to 0.786 mg/L) exceeded the adopted drinking water screening criteria (1 mg/L for copper and 0.1 mg/L for manganese) in the Kawerong River (northern side of Tailings Basin 1) near the Gold Miners Camp.

Based on the sampling undertaken for the Investigation Report: Water Quality and Geochemical Assessment (Appendix A) and the Investigation Report: Human Health Risk Assessment (Appendix G), most water samples collected from the Kawerong-Jaba River were below the adopted recreation/other water screening criteria (see Table 5.35). Concentrations of metals exceeded the recreation/other water screening criteria in the following locations:

- **Waste rock dump drainage and the Kawerong River** (before Pirurari bridge): Concentrations of copper and manganese exceeded the recreation/other water screening criteria. The waste rock dump drainage line and this section of the Kawerong River were not identified as a drinking water source by surveyed communities in this domain; however, households from Pirurari reported undertaking ASM in the waste rock dump drainage line.
- **Kawerong River** (from Onove footbridge to Barako, approximately 3 km): Concentrations of manganese in this section of the river exceeded recreation/other water screening criteria. This area was identified by households as being used for ASM activities.
- **Tailings Basin 1 seepage:** Copper, manganese and molybdenum were identified at levels above recreation/other water screening criteria in seepage from tailings. This seepage is shallow surface water and would not be used for recreation but the broader area is likely used for ASM.

No exceedances of the recreation/other water screening criteria were observed in the limited number of marine water samples collected from Anewa Bay or Empress Augusta Bay.

Table 6.31 Human health screening assessment for community identified primary and secondary water sources during wet and dry seasons [mg/L]

Compound	Adopted drinking water screening criteria	Adopted recreation/ other water screening criteria	Sub-domain						Control	
			Port and town	Upper mine	Lower mine	Upper-mid tailings	Lower tailings	Delta	Tokiai	Marowa
Antimony	0.003	0.03	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001 – 0.003
Arsenic	0.007	0.07	<0.001	<0.001 - 0.002	<0.001 - 0.003	<0.001	<0.001 - 0.004	<0.001	<0.001	<0.001 – 0.003
Beryllium	0.06	0.6	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	0.002	0.02	<0.0001	<0.0001 - 0.0003	<0.0001	<0.0001 - 0.0003	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	0.05	0.5	<0.001	<0.001	<0.001	<0.001 – 0.0004	<0.001 – 0.001	<0.001	0.002 – 0.003	<0.001
Copper	1.0	10.0	<0.001 - 0.007	<0.001 - 0.112	<0.001 - 0.003	<0.001 - 0.836	<0.001 - 0.011	<0.001 - 0.004	0.001 - 0.003	<0.001 - 0.005
Lead	0.01	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	0.1	1	<0.001 - 0.015	<0.001 - 0.085	<0.001 - 0.033	<0.001 - 0.035	<0.001 - **0.329**[1]	<0.001 - 0.096	<0.001 - 0.002	<0.001 - 0.093
Mercury	0.001	0.01	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	0.05	0.5	<0.001	<0.001 - **0.321**[3]	<0.001	<0.001 - 0.002	<0.001 - 0.005	<0.001	<0.001	<0.001
Nickel	0.02	0.2	<0.001	<0.001 - 0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	0.01	0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	3.0	30.0	<0.005 - 0.006	<0.005 - 0.032	<0.005 – 0.009	<0.005 - 0.038	<0.005 - 0.313	<0.005 - 0.706	<0.005	<0.051 – 0.087
PFOS + PFHxS	0.00007	0.0007	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PFOA	0.00056	0.0056	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001

Note: **Bold** indicates an exceedance of the adopted drinking water screening criteria (see Table 6.6).
[ ] Indicates the number of sampling locations that exceed the screening criteria.

Uncertainty

Due to the preliminary nature of the Phase 1 characterisation process, uncertainties exist related to water quality data (see Section 5.2.2). Key uncertainties include:

- The water sampling methodology undertaken for the Investigation Report: Site Contamination (Appendix B) and Investigation Report: Water Quality and Geochemistry (Appendix A) used targeted sampling only and did not seek to comprehensively delineate contamination.
- Primary and secondary water sources were identified by surveyed households in representative villages. However, it is possible other water sources were used by other households in the community that were not sampled in the Phase 1 investigations.
- Microbiological testing (e.g., *E. coli*) of water was not undertaken as part of Phase 1 investigations as it is not directly related to mine-related environmental contamination.
- Water samples were collected from sources on two occasions and may not indicate the full range of water quality throughout the year (including during or following flood events).

Soil

As part of fieldwork to support Investigation Report: Human Health Risk Assessment (Appendix G), 91 garden soil samples were collected. The results from these samples were compared against the residential (direct contact) health screening criteria where the primary exposure routes are associated with direct contact (i.e., incidental ingestion, dermal contact and the inhalation of dust) (see Section 6.1.5.2).

Of the 91 soil samples collected, 87 locations (96%) had concentrations of all metals analysed below the residential (direct contact) health screening criteria (Table 6.32). Exceedances of the residential (direct contact) health screening criteria are summarised as follows (Figure 6.6):

- **Anewa Bay:** Two exceedances of lead in two gardens, and one exceedance of iron in one garden bed.
- **Dapera:** One exceedance of iron in one garden bed.

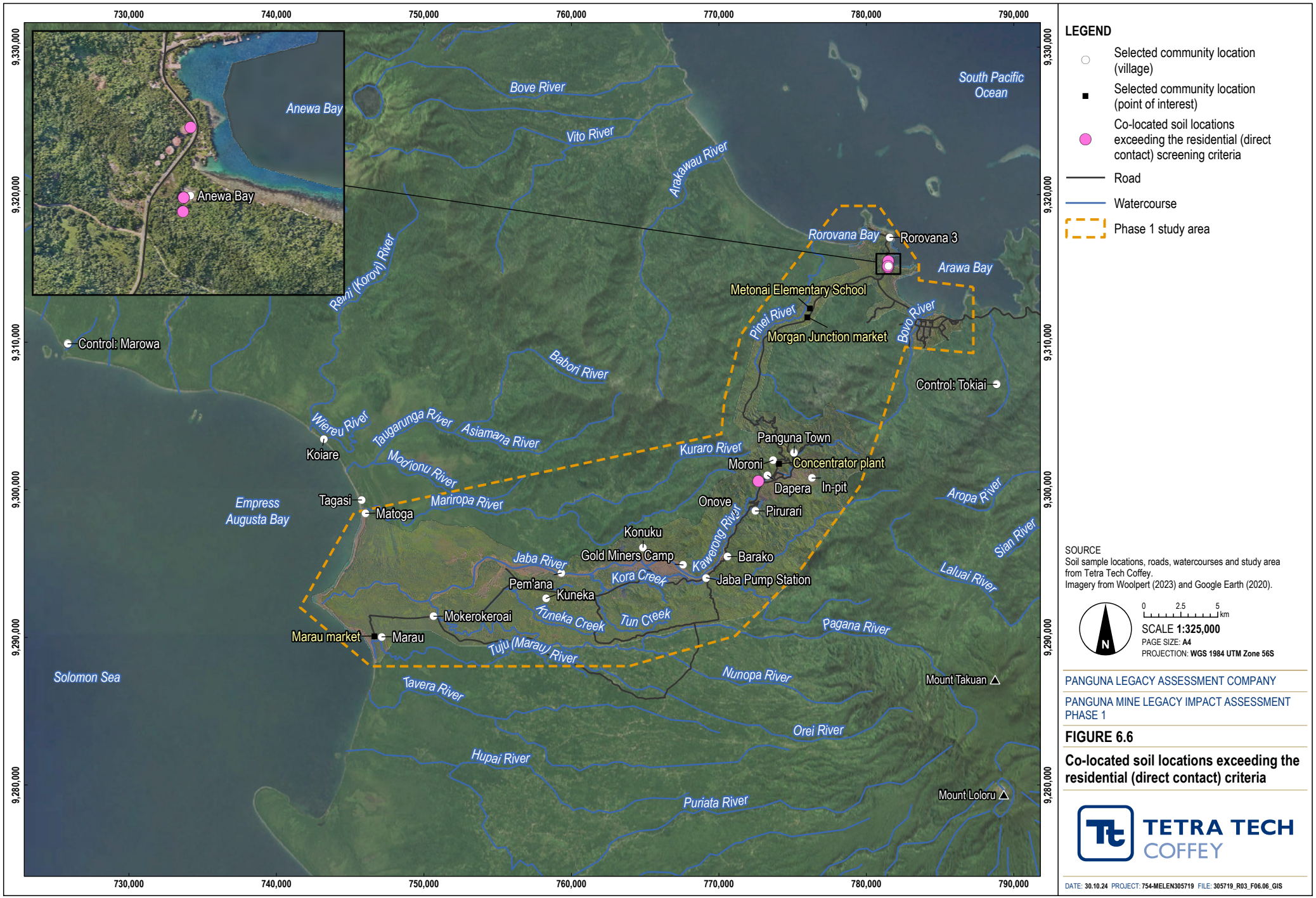
Soil samples collected as part of the Investigation Report: Site Contamination (Appendix B) targeted soil in industrial areas of the mine, predominantly in the Port and Town, Mine and River System domains. The residential (direct contact) health screening criteria was exceeded in the following areas:

- **Processing and milling area:** Exceedances of copper, iron, PCBs and lead were identified in soils in this area. This is consistent with the historic use of the area during mining operations.
- **Pit and central workshops:** Metals including cadmium, iron, lead, antimony, molybdenum, nickel and zinc, PCBs and hydrocarbons were detected in this area. This is consistent with supporting different industrial processes during mining operations.
- **Switchyard:** PCBs, which were common additives to transformer oils prior to the 1970s and 1980s, were detected in soil samples.
- **Jaba Pump Station:** Concentrations of cadmium, iron, lead and PCBs were detected in soils at the former Jaba Pump Station.
- **Reagent storage tanks**: Concentrations of lead, PCBs and hydrocarbon fractions were identified in soil samples.
- **Loloho fire station:** PFAS compounds, which are associated with firefighting foam, were detected in the forecourt area. This is consistent with the historic use of the area during mining operations.
- **Bulk fuel store area:** Concentrations of hydrocarbon fractions were identified. As the hydrocarbons have aged and weathered, the proportion of volatile compounds is expected to be reduced.
- **Shell oil fuel storage terminal:** Lead, iron and hydrocarbon concentrations was identified, consistent with the historic use of the area during mining operations.

Table 6.32 Co-located soil residential (direct contact) screening criteria

Parameter	Residential (direct contact) criteria	Domains and sub-domain						Control	
		Port and Town	Upper mine	Lower mine	Upper- mid tailings	Lower tailings	Delta	Tokiai	Marowa
Aluminium	77,000	2,700 – 27,400	6,720 – 45,100	-	10,200 – 27,300	10,000 – 19,400	6,930 – 10,200	-	-
Arsenic	100	<5 - 26	<5 - 47	<5 - 12	<5 - 10	<5 - 8	<5	<5 - 7	<5
Barium	15,000	20 - 120	10 - 230	-	20 - 160	20 - 160	10 – 90	-	20 – 30
Beryllium	70	<1 - 1	<1	<1	<1	<1	<1	<1	<1
Cadmium	45	<1	<1 - 3	<1	<1 - 9	<1 - 9	<1	<1	<1
Chromium	100	<2 - 52	<2 - 52	4 - 10	2 – 20	<2 - 20	<2 – 25	7 - 17	5 - 6
Cobalt	165	<2 - 25	3 - 21	4 - 22	<2 - 19	<2 - 13	<2 – 13	7 – 12	2 – 3
Copper	8,000	12 - 964	63 – 4,630	48 - 544	18 - 555	24 – 1,150	5 – 247	36 – 64	16 - 22
Iron	55,000	2,570 – **56,700**	8,320 – **64,800**	-	5,830 – 19,300	8,460 – 11,900	5,390 – 15,000	-	-
Lead	300	<5 – **13,000**	<5 - 157	<5 - 6	<5 - 13	<5 - 20	<5 – 34	<5 – 6	<5
Manganese	7,500	92 – 1,430	174 – 1,720	-	331 - 986	264 - 481	191 – 1,680	-	-
Mercury	45	<0.1 - 0.1	<0.1 - 2.1	<0.1 - 0.1	<0.1 - 0.5	<0.1 - 0.2	<0.1	<0.1 - 0.1	<0.1
Molybdenum	390	<2 - 3	<2 - 23	<2-11	<2 - 10	<2 – 4	<2	-	<2
Nickel	540	<2 - 206	<2 - 24	<2 - 5	<2 - 6	<2 – 8	<2 – 34	4 – 5	<2 - 4
Selenium	360	<5	<5	<5	<5	<5	<5	<5	<5
Zinc	10,000	18 - 641	26 - 792	29 - 118	17 - 244	22 - 125	10 - 58	46 - 88	20 - 27
PFOS + PFHxS	0.01	<0.0002 - 0.0112	<0.0002 - 0.0065	-	<0.0002 - 0.0006	<0.0002	<0.0002	-	-
PFOA	0.1	<0.0002 - 0.0008	<0.0002 - 0.0004	-	<0.0002	<0.0002	<0.0002	-	-
PCBs	1	<0.1	-	-	-				

Bold indicates an exceedance of the Residential setting direct contact pathways criteria.



LEGEND

- Selected community location (village)
- Selected community location (point of interest)
- Co-located soil locations exceeding the residential (direct contact) screening criteria
- Road
- Watercourse
- Phase 1 study area

SOURCE
Soil sample locations, roads, watercourses and study area from Tetra Tech Coffey.
Imagery from Woolpert (2023) and Google Earth (2020).

0 2.5 5 km

SCALE **1:325,000**
PAGE SIZE: **A4**
PROJECTION: **WGS 1984 UTM Zone 56S**

PANGUNA LEGACY ASSESSMENT COMPANY

PANGUNA MINE LEGACY IMPACT ASSESSMENT PHASE 1

FIGURE 6.6

Co-located soil locations exceeding the residential (direct contact) criteria

TETRA TECH COFFEY

DATE: **30.10.24** PROJECT: **754-MELEN305719** FILE: **305719_R03_F06.06_GIS**

DISCLAIMER: THIS FIGURE HAS BEEN PROVIDED FOR INFORMATION ONLY AND IS SUBJECT TO CHANGE. THE CREATORS DO NOT WARRANT THAT THIS FIGURE IS DEFINITIVE NOR FREE OF ERROR AND DO NOT ACCEPT LIABILITY ARISING FROM RELIANCE ON INFORMATION PROVIDED HEREIN. © COPYRIGHT TETRA TECH COFFEY 2024.

DOC REFERENCE: \\TT.LOCAL\COF\S772\S\GIS\305719_MELEN_PLAC_LEGACYIMPACTASSESSMENT\1_PLAC_LIA_GIS\APRX\305719_R03_FIGS_G.APRX LAYOUT:305719_R03_GIS050_4 SAVED BY: JASON.ORAM 30.10.24 3:56 PM

Uncertainty

Due to the preliminary nature of the Phase 1 characterisation process, uncertainties exist related to the soil data collected (see Section 5.1.2). Key uncertainties include:

- Soil results are based on often only one or two non-intrusive samples on a larger site. Contaminant extent and concentrations may be greater or lesser than reported.
- The co-located soil samples may not be representative of the whole garden bed or for different plant root architecture, particularly the location of the plant's fine roots, which can vary in depth and lateral extent.
- The reported soil results may not be representative of plant uptake even where co-located in the fine root zone due to other factors that affect soil chemistry or soil properties, the chemical form of the metal in soil and its availability for uptake.
- There is insufficient information to delineate between mine-related contamination, ASM-related contamination, natural mineralisation or other sources for some of the contaminants.

Food

As detailed in Section 6.2.2.1, communities raised concerns that pollution from the Panguna Mine has resulted in the contamination of their food. The Investigation Report: Human Health Risk Assessment (Appendix G) characterised the existing levels of contaminants in sources of food and staple crops.

A summary of the food characterisation is provided in the following sections. An assessment of possible health risks is provided in Chapter 11 and Chapter 12.

Food standard comparison

Food samples were analysed for seven metals/metalloids, selected for their known toxicity and abundance in mineralised areas: arsenic, cadmium, copper, lead, mercury, selenium and zinc. The analysis of the 209 food samples collected in the market basket survey found 24 food samples exceeded the food standard screening criteria for one or more metals/metalloids. Foods exceeding the food standards were observed in all domains/sub-domains (Table 6.34).

Three of the bird meat samples and a crab sample exceeded the food standard for two or more metals/metalloids. Key results include:

- Almost all animal meats analysed for the market basket survey exceeded the food standard for selenium, an essential nutrient for humans. The source of selenium has not been determined as all garden bed soils reported selenium at levels below the laboratory limit of reporting (LOR), noting the LOR was above the agricultural ecological screening criteria. Based on the PNG MBS database, selenium is commonly found in bird meat in PNG above the screening criteria, where the upper range is 0.46 mg/kg. This upper range was only exceeded by one chicken sample in the study area (see Table 6.33).
- The other metals reported in meat samples (cadmium, copper, and mercury) were generally marginal exceedances of the food standard, indicating a low health risk. The exception was lead measured in duck meat obtained from Dapera, which was more than an order of magnitude above the food standard. Based on field observation from the meat sample collection, this exceedance may be related to lead gunshot rather than mine-related contamination.
- Nine fish/seafood samples were analysed with three reporting exceedances of zinc, one exceedance of copper and one sample with exceedances of both metals. Copper and zinc are both essential nutrients for humans and are regulated by the body. All exceedances were more than 2-fold higher than the food standard. The reported exceedances indicate a possible health risk may be present if these foods are consumed on a regular basis.
- The exceedances of metals in market basket foods were predominantly found in foods high in protein such as animal/poultry meats (pork, chicken, duck) and fish/seafood. The exceedances indicate a

possible health risk may be present if these foods are consumed on a regular basis. Food standards have not been established for all food groups and for all metals, and poultry meat was compared to criteria derived for bovine meats.

Table 6.33 Summary of food standard exceedances per sub-domain and animal/aquatic meats

Domain/ sub-domain	No. food samples analysed	No. of total food exceedances	No. animal / fish / seafood analysed	No. of animal / fish / seafood meat exceedances	Percentage of exceedances related to animal / fish /seafood meats
Port and Town	38	2	3	1	50%
Upper mine	40	8	4	4	50%
Lower mine	21	2	3	2	100%
Upper and mid tailings	36	6	5	5	83%
Lower tailings	20	2	2	2	100%
Delta	38	3	5	3	100%
Control: Marowa	9	1	1	0	0%
Control: Tokiai	7	0	0	0	0%
Total no. of samples	*209*	*24*	*23*	*17*	

PNG MBS Database comparison

Metal/metalloid contaminants in foods were also compared to the upper concentration ranges in the PNG MBS database to understand whether the reported concentrations in foods were above those found elsewhere in PNG (Table 6.33). Metal concentrations measured in food above the PNG MBS Database upper range does not necessarily pose a possible health risk. Where the upper range concentration for a metal in food is the same or greater than the food standard screening criteria for that food group, these should be considered further. This is the case for some metals in foods as such animal meats, fish, crustacea and molluscs, and lead in fruit and most vegetables.

Co-located soil linkages

As detailed in Section 6.2.2.1, the Investigation Report: Human Health Risk Assessment (Appendix G) sought to understand if the contamination of soil is related to the contamination of food. Co-located soils sample exceedances of the agricultural human health screening criteria were compared with food sample exceedances of the food standard (where the standard exists for a given contaminant/food) and food sample exceedances of the maximum concentration in the PNG MBS database. A summary of these results is presented in Table 6.34.

Exceedances in soil poorly correlated with exceedances in the food that was grown in the soil. None of the soil concentrations that exceeded the agricultural human health screening criteria showed a corresponding food sample exceedance of the food standard. There were occasional exceedances in soil that had a marginal elevation in the food samples compared to the maximum concentrations in the PNG MBS database. These exceedances related to zinc in noni fruit (Anewa Bay) and aibika (Rorovana 3), and arsenic in sweet potato, banana and taro root (Dapera). There were no other soil sample exceedances of the agricultural human health screening criteria that had a corresponding exceedance of the PNG MBS database range maximum.

Many of the food exceedances did not have co-located soil concentrations where the food was purchased at a market, provided from a village kitchen, free roaming livestock/poultry or related to aquatic foods.

The lack of exceedances of the same metal measured in soil and co-located food suggests that contaminant intake in plants and raised animals is complex and dependent on multiple factors that have not been evaluated in this study. Uncertainties in the dataset, screening criteria and other factors as outlined in

Investigation Report: Human Health Risk Assessment (Appendix G), should be considered when interpreting the relationship between soil and plant contamination.

Estimation of food consumption and contaminants intake

Based on the contaminant intake evaluation (Section 6.1.5.2), the calculated weekly intakes of identified metals in foods pose a low or minimal health risk to adults within the selected study area communities.

A possible health risk associated with cadmium intake for young children (less than six years old) in the Mine Domain was identified. Further investigation would improve understanding of the health risk given the consumption dataset for children under six years is less robust than other age groups, due to variable periods of breast feeding and introduction of solids. A summary of exceedances of human health criteria for co-located soil and food is presented in Table 6.35.

Uncertainty

Due to the preliminary nature of the Phase 1 characterisation process, uncertainties exist related to the food samples, co-located soil samples and contaminant intake analysis (Appendix G). Key uncertainties include:

- Based on information provided by the local community, food samples, and co-located soils, were collected from gardens/crops located in flood zones or areas of potential mine related waste rock, tailings or contamination wherever possible. This may not be representative of contaminant levels in soil or food across the area where villages source all their foods and is therefore a conservative approach.
- There is insufficient information to delineate between mine-related contamination, ASM-related contamination, natural mineralisation or other sources for some of the contaminants.
- The availability of some food sources, such as protein and plant-based foods, were not available in some instances. However, this is likely a reflection of the community's regular diet.
- The generally poor correlation of metals reported in soils and collocated foods suggests this metal concentrations in soils may not be a good indicator of metal uptake into plants and the relationship is more complex.
- It is recognised that certain exposure assumptions and background exposures may differ in the residential settings considered in this study that may not be representative of the various communities in the study area.
- The use of a 24-hour recall for food consumption does not account for the seasonality of food consumption. This method is typically used as food recall beyond this period is understood to have significant limitations in accuracy. As a result, the food consumption data collected during this household survey may not accurately represent overall patterns of consumption due to variations in food choices and availability throughout the year.

.

Table 6.34 Summary of foods above the PNG MBS database range concentrations by food group and sub-domain

Food group and location	Number of samples	Arsenic	Cadmium	Mercury	Lead	Copper	Selenium	Zinc
Fruits								
Port and Town	13	-	-	-	-	Noni	Banana	Noni
Upper mine	13	-	Cocoa pod, avocado		Cocoa pod	Cocoa pod, avocado	-	Avocado
Lower mine	4	-	-	-	-	-	-	-
Upper-mid tailings	10	-	Cocoa pod	-	-	Cocoa pod	Cocoa pod	-
Lower tailings	7	-	-			-	-	
Delta	9	-	-	-	Citrus	-	-	-
Control: Tokiai	3	-	-	-	Guava	-	-	Passionfruit
Control: Marowa	4	-	-	-	-	-	-	-
Vegetables: Leafy, fruiting, legumes								
Port and Town	7	-	Aibika	-	-	Pumpkin Leaves	Choko	Aibika, Pumpkin Leaves
Upper mine	6	-	Other green veg, Spring onion, Watercress	-	-	Choko, Watercress	Choko, watercress (2)	Choko, spring onion, watercress (2), other green veg.
Lower mine	5	-	-	-	Spring onion	Valangur, other green veg (2), Spring onion	-	Valangur, other green veg, Spring onion
Upper-mid tailings	7	-	-	Aibika, Choko		Choko	-	Choko (2), pumpkin tips
Lower tailings	3	-	-	-			-	Kang kong
Delta	6	Aibika	Spring onion	-	Spring onion	Spring onion (2)	-	Spring onion (2)
Control: Tokiai	1	-	-	-	-	-	-	-
Control: Marowa	2	-	Tomato	-	Aibika	-	-	Aibika

Food group and location	Number of samples	Arsenic	Cadmium	Mercury	Lead	Copper	Selenium	Zinc
Roots and Tuber Vegetables								
Port and Town	12	Sweet potato	Cassava (2)	-	-	Cassava	Cassava, taro	Cassava
Upper mine	16	Sweet potato, Taro	Cassava, Taro	Cassava	-	-	Sweet potato	Cassava (2)
Lower mine	7	-	-		-	-	-	-
Upper-mid tailings	8	Cassava	Cassava	Cassava	-	-	-	Cassava
Lower tailings	7	-	Cassava	-	-	-	-	Cassava
Delta	12	-	-	-	-	-	-	-
Control: Tokiai	2	-	-	-	-	-	-	-
Control: Marowa	1	-	-	-	-	-	-	-
Animal products								
Port and Town	4	Bird meat	-	-	-	Fish	Fish	-
Upper mine	4	Bird meat	-	-	-		-	-
Lower mine	3	Bird meat	-	-	-	-	-	-
Upper-mid tailings	5	Bird meat (4)	-	-	-	-	Bird meat	Bird meat
Lower tailings	2	-	Fish	-	-	Fish	-	Fish
Delta	7	Turtle eggs [(1)], Crab	Turtle eggs[(1)], Fish, Kina[(2)]	-	-	Fish, crab, kina[(2)]	Turtle eggs[(1)]	Fish, Kina[(2)]
Control: Tokiai	0	-	-	-	-	-	-	-
Control: Marowa	2	-	-	-	-	-	-	-

Food group and location	Number of samples	Arsenic	Cadmium	Mercury	Lead	Copper	Selenium	Zinc
Other foods								
Port and Town	4	-	-	-	-	Peanuts	-	Peanuts, sugarcane juice
Upper mine	1	-	-	-	-	-	-	-
Lower mine	2	-	-	Sugarcane	-	-	-	-
Upper-mid tailings	7	-	Rice (3)	-	Peanuts, rice	Rice (3)	Rice	Rice (3)
Lower tailings	5	-	-	-	-	-	-	-
Delta	8	-	-	-	Peanuts	-	-	-
Control: Tokiai	0	-	-	-	-	-	-	-
Control: Marowa	2	-	-	-	-	-	-	-

Where there is more than one type of that food, the number of food samples are shown in brackets ().
1. Compared with wild bird eggs in the PNG MBS database as no specific metal profile available for this food in the database.
2. Compared with fresh fish in the PNG MBS database as no specific metal profile available for this food in the database.

Table 6.35 Summary of exceedances of human health criteria for co-located soil and food

Community	Chemical exceedance in soil	Health guideline exceedance	Food Std guideline exceedance	Above PNG MBS database range max.	Food type
Dapera	Lead, arsenic [1], cadmium, zinc [1]	Agricultural setting	No	Yes [2]	Sweet potato
	Arsenic [1], copper [1], zinc [1]	Agricultural setting	No	No	Papaya
	Arsenic [1], copper [1]	Agricultural setting	No	Yes [2]	Banana
	Arsenic [1], copper [1], zinc [1]	Agricultural setting	No	Yes [2]	Taro root
	Arsenic [1], copper [1], zinc [1]	Agricultural setting	No	No	Taro root
Panguna Town	Arsenic [1]	Agricultural setting	No	No	Watercress
	Arsenic [1]	Agricultural setting	No	No	Taro root
	Zinc [1]	Agricultural setting	No	No	Banana
Moroni	Arsenic [1]	Agricultural setting	No	No	Banana
In pit	Copper [1]	Agricultural setting	No	No	Pumpkin
	Copper [1]	Agricultural setting	No	No	Sweet potato
Jaba Pump Station	Zinc [1]	Agricultural setting	No	No	Sugarcane
Mokerokeroai	Cadmium	Agricultural setting	No	No	Aibika
Pem'ana	Copper [1]	Agricultural setting	No	No	Sweet potato
Anewa Bay	Lead	All residential settings	No	No	Aibika
	Lead	Agricultural setting	No	No	Taro root
	Zinc [1]	Agricultural setting	No	No	Cassava tuber
	Zinc [1]	Agricultural setting	No	Yes [2]	Noni
Metonai Elementary School	Arsenic [1], lead [1], nickel [1], zinc [1]	Agricultural setting	No	No	Banana
Rorovana 3	Arsenic [1]	Agricultural setting	No	No	Paw paw
	Lead, zinc [1]	Agricultural setting	No	No	Cassava tuber
	Zinc [1]	Agricultural setting	No	Yes [2]	Aibika

1. No food standard criteria established for this chemical for this food group.
2. Marginally above the maximum range concentration by 30% or less.

Dust deposition

Dust monitoring was undertaken at three locations: Moroni, Gold Miners Camp and Pem'ana (Appendix G).

Dust deposition collections were during the periods between:

- First collection: mid-August 2023 to mid-October 2023
- Second collection: mid-October 2023 to mid-November 2023
- Third collection: mid-November 2023 and mid-January 2024.

The dust deposition rates are presented in Table 6.36. No exceedances of the dust deposition screening criteria were observed at the three locations sampled.

Table 6.36 Dust deposition in the Mine and River System domains (mg/m^2/day)

Substances	Averaging period	Screening criteria	Upper/Mid tailings sub-domain		Lower tailings sub-domain
Dust deposition	Monthly	120 mg/m^2/day (1,2)	20	97	100

Bold indicates an exceedance of the screening criteria.
1. Maximum increase in deposited dust level above background levels.
2. Calculated based on a 30-day period.

A comparison of the metal content in the dust samples to the soil health screening criteria is presented in Table 6.37. One exceedance of the residential screening criteria was found associated with cadmium above the agricultural health setting, located in Gold Miners Camp in the Upper/mid tailings sub-domain.

Uncertainty

Dust deposition gauges were installed at five locations across the study domains during field campaign 2, however only three locations remained following installation due to vandalism of the other two. Additionally, only one sample obtained from Gold Miners Camp in the first collection had sufficient sample to determine the dust deposition. All three samples in the second collection were discarded by the laboratory in Australia due to very high volumes of water and illegibility of some of the sample IDs. Due to uncharacteristic high rainfall conditions during the dry season, the data did not capture dust deposition levels under drier conditions. Therefore, dust deposition data was limited across the study area both spatially and temporally and was considered inadequate to inform impact assessment. Further investigations of dust have been recommended as part of Phase 2 to address this (Chapter 13).

Summary of human health characterisation

A summary of the results presented in the above sections is provided in Table 6.38.

Table 6.37 Total metal concentrations in dust [mg/kg]

Substance	Screening criteria			Domain/sub-domain		
	Residential setting: Direct contact pathways	Residential setting with garden/ accessible soil	Residential in an Agricultural setting	Mine	Upper/Mid Tailings	Lower tailings
				No. Samples: 1	No. Samples: 2	No. Samples: 1
Arsenic	100	100	12	<0.006	<5	0.014
Barium	15,000	15,000	6,800	<0.001	32	<0.001
Beryllium	70	60	75	<0.001	<5	<0.001
Cadmium	45	20	1.4	<0.002	6	<0.002
Chromium(1)	100	100	220	<0.001	19	<0.001
Cobalt	200	100	40	<0.001	<5	<0.001
Copper	8,000	6,000	1,100	<0.002	469	<0.002
Lead	300	300	140	<0.002	92	<0.002
Manganese	7,500	1,800	NE	<0.00003	57	<0.00003
Mercury	45	40	6.6	<0.0001	<5	<0.0001
Nickel	540	400	200	<0.01	10	<0.01
Selenium	360	200	80	<0.01	<5	<0.01
Zinc	10,000	7,400	10,000	0.033	1,470	0.003

Bold indicates an exceedance of the Agricultural Residential criteria (assumes 50% produce is locally grown).

Table 6.38 Human health risk characterisation summary

Sub-domain	Water[1]			Residential (direct contact) screening		Food consumption and contaminant intake	Dust deposition
	Community identified water sources	Other drinking water sources	Recreational / other water uses	Garden soil	Mine-related areas		
Upper mine	3 exceedances of Mo [24 samples]	-	-	1 exceedance of Fe [20 samples]	21 exceedances of Mo, TRH, Sb, Fe, Ni, Zn, Cd, Cu, Pb, PCBs [21 samples]	Marginal exceedance for Cd in children (<6 years old) based on contaminant intake [61 food samples]	No exceedances [1 sample]
Lower mine	No exceedances [11 samples]	No exceedances [4 samples]	4 exceedances of Cu and Mn [9 samples]	No exceedances [6 samples]	-		-
Upper and mid tailings	No exceedances [29 samples]	3 exceedances of Cu and Mn [10 samples]	1 exceedance of Cu, Mn, Mo [10 samples]	No exceedances [17 samples]	4 exceedances of Cd, Fe, Pb, PCBs [4 samples]	No exceedances [37 samples]	1 exceedance [2 samples]
Lower tailings	No exceedances [9 samples]	1 exceedance of Mn [4 samples]	1 exceedance of Mn [5 samples]	No exceedances [14 samples]	-	No exceedances [25 samples]	No exceedances [1 sample]
Delta	No exceedances [13 samples]	-	No exceedances [3 samples]	No exceedances [12 samples]	-	No exceedances [38 samples]	-
Port and Town	No exceedances [5 samples]	-	No exceedances [2 samples]	3 exceedances of Fe and Pb [15 samples]	6 exceedances of TRH, PFAS [6 samples]	No exceedances [38 samples]	-
Control: Tokiai	No exceedances [3 samples]	-	-	No exceedances [2 samples]	-	No exceedances [7 samples]	-
Control: Marowa	No exceedances [1 sample]	No exceedances [2 samples]	No exceedances [1 sample]	No exceedances [2 samples]	-	No exceedances [9 samples]	-

A dash (-) indicates where no samples were collected for this attribute.

1. Includes water quality results of field investigations for the Investigation Report: Site Contamination (Appendix B) and Investigation Report: Water Quality and Geochemistry (Appendix A).

Cu = copper; Cd = cadmium; Fe = iron; Mo = molybdenum; Mn = manganese; Ni = nickel; Pb = lead; PCBs = polychlorinated biphenyls. Sb = antimony; TRH = total recoverable hydrocarbons; Zn = zinc;

Low or minimal human health risk

Possible human health risk

6.2.4.3 Education and use of education services

Attendance to both primary and secondary school is reported to be lower than attendance for Bougainville (NSO, 2019):

- **Preparatory/elementary/primary school:** between 58% (Upper and mid tailings) and 76% (Lower tailings) of children were reported as attending school compared to 95% attendance in Bougainville.
- **Secondary school:** between 5% (Lower mine) and 15% (Delta) of youth were reported as attending secondary school compared to 27% attendance in Bougainville.

Lack of attendance is likely exacerbated by the limited secondary schools within the study area and the competitiveness of securing a place. This is consistent with the household survey which found the main reasons provided by respondents regarding reasons for not attending or completing school were lack of money for school fees and distance to school. Another reason provided was responsibilities to assist parents, which is consistent with reports by teachers that males were more likely to leave school than females to undertake ASM activities.

All sub-domain areas reported substantially lower literacy rates for both males and females compared to Bougainville, with literacy being lowest in the Lower tailings sub-domain area, 25% for males and 29% for females, followed by the Upper and mid tailings and Lower mine. These sub-domains also reported the longest travel time to education facilities.

The most common level of education achievement across the study area was reported to be preparatory, elementary or primary school, followed by secondary school. Educational outcomes differ between sub-domain areas and generally followed similar patterns of current school attendance. Minor differences in educational outcomes existed between males and females, with a higher proportion of males completing secondary school compared to females.

Reported levels of education achievement across the study area are consistently higher compared to Bougainville. This is likely due to a larger proportion of older people participating in the household survey compared to younger, therefore increasing the levels of education achievement.

6.2.4.4 Food security

Access to food

Food security was assessed through several household survey questions and focus group discussions in selected communities during field campaign 2. These communities were selected as they had raised food security concerns as part of community discussions during field campaign 1.

Skipping a meal in the last 12 months is used to identify moderate food insecurity (FAO 2023). Over half (53%) of all surveyed households were concerned about their ability to access food over the last 12 months. The highest proportion of households that reported this issue was within the Lower tailings (63%), Lower mine (55%) and the Delta (53%) sub-domains. This suggests that there is low to moderate food insecurity in households across the study area.

Focus group discussions were held in seven communities to understand the preferability of coping strategies nominated in the household survey from a local perspective (Maxwell et al. 2003).

Table 6.39 presents the coping strategies that households reported when they do not have enough to eat, with strategies ordered based on their preferability (from most to least). The results indicate these communities employ a range of strategies that indicate a level of food insecurity. The most prevalent response was to eat less, with levels in the Lower mine (49%), Lower tailings (36%) and Delta (61%) above that of the Control sites (31%). This indicates that households in these areas are adopting a moderately undesirable strategy. In the Upper and mid tailings, Lower tailings, and Upper mine sub-domains food security is generally managed through ease of access to income from ASM which indicates that even with this as an alternative, households are undertaking a less desirable strategy. Regardless, these communities employ a range of strategies that indicate a level of food insecurity.

Table 6.39 Food insecurity – coping strategies

Coping strategy	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control
Eat with others	19.3%	19.5%	28.8%	12.3%	32.0%	22.7%	20.5%
Eat less	**28.1%**	**34.7%**	**49.2%**	29.2%	**36.0%**	**61.4%**	**30.8%**
Buy from store	0.0%	5.1%	6.8%	9.2%	16.0%	6.8%	12.8%
Borrow money / buy food on credit	19.3%	13.6%	10.2%	**33.9%**	8.0%	4.5%	7.7%
Do not eat	1.8%	0.0%	1.7%	1.5%	0.0%	4.5%	2.6%
Did not have food shortages	31.6%	27.1%	3.4%	13.8%	8.0%	0.0%	25.6%

Bold text indicates which coping strategy was the most prevalent in that sub-domain

Communities that live along the Jaba and Kawerong rivers in the River System Domain consistently reported concerns about increased flooding and food security. All six communities engaged in focus group discussions in field campaign 2 stated their gardening land is affected by flooding from one of the rivers. Communities have stated that flood events damage gardens, resulting in households having to depend on store food and difficulties in accessing food sources when flooding is prolonged. When a flood event occurs, households undertake food coping strategies that are socially unfavourable, such as eating less and borrowing money.

Soil productivity

As described in Section 6.2.2, soil fertility was raised as an issue by almost a third of households. Soil fertility and plant growth is dependent on many factors such as organic matter content, soil structure, as well as the level and availability of nutrients and contaminants.

As part of field work to support the Human Health Risk Assessment, soil samples were collected from within the root zone for every plant or livestock food collected for the market basket survey. This soil is known as co-located soil. Priority was given to soil around crops and garden areas that were known to be in a flood zone or where waste rock or tailings was potentially deposited. Ninety-one co-located soil samples were collected in each of the identified target communities. Co-located soil samples were generally taken from 0.1 to 0.3 m depth in gardens or crop areas.

Of the 91 samples collected, 63 samples (or 69% of soil samples) exceeded the agricultural ecological screening criteria (see Section 6.1.5.2). These exceedances were localised in the Mine, River System and Port and Town domains, and can be summarised as follows for each sub-domain:

- **Upper mine sub-domain:** exceedances of arsenic, cadmium, copper, iron, lead, molybdenum, and zinc identified in 19 garden soil samples.
- **Lower mine sub-domain:** exceedances of copper and molybdenum identified in five garden soil samples.

- **Upper and mid tailings sub-domain:** exceedances of copper and molybdenum identified in 13 garden soil samples.
- **Lower tailings sub-domain**: exceedances of cadmium and copper in three garden soil samples.
- **Port**: exceedances of arsenic, copper, iron, lead, nickel and zinc identified in 13 garden soil samples.

These agricultural ecological screening criteria exceedances indicate that soil productivity may be reduced. However, the level of effect can differ depending on the soil type, and the crop or plants being grown, among other factors (Mohanta, Pradhan and Behera 2023).

Uncertainty

Due to the preliminary nature of the Phase 1 characterisation process, uncertainties exist related to food security. Key uncertainties include:

- The household survey did not provide for a food insecurity experience scale to be developed and is therefore not able to be used to benchmark food security against national and international data.
- The degree of impact to soil productivity in gardening land from metal concentrations and from flooding events cannot be determined based on the data collected as part of the Phase 1 investigations.
- Information relating to the level of households' reliance on identified gardening land with reduced soil productivity was not collected as part of the Phase 1 investigations.
- Background levels of metals/metalloids due to natural mineralisation in soils across the study area are not able be determined based on data collected during Phase 1.

6.2.4.5 Water security

This section describes the water sources identified within each representative village and characterises the level of water security experienced.

Villages surveyed in the study area rely on a number of drinking water sources depending on their geographic location, and the sources differ depending on the season (Figure 6.7). The most common drinking water sources were piped water from nearby sources, springs and creeks and communal rain water tanks. Overall, the self-reported reliability of drinking water sources in the study area was identified as good to satisfactory.

The Availability, Accessibility, Acceptability and Quality (AAAQ) framework (Danish Institute for Human Rights 2014) was used to understand and conceptualise water security in each of the selected communities. The first indicator of water security was whether the village drinking water sources were available during wet and dry seasons (Table 6.39). Respondents to the village survey in the Lower tailings sub-domain area indicated that the reliability of drinking water sources during the dry season was poor. For example, respondents from Pem'ana indicated that the reliability of all drinking water sources was poor during the dry season.

To determine the accessibility of drinking water sources, the household survey asked respondents how long it generally took to collect water. According to the WHO Guidelines for Drinking-water Quality (2022), basic access is defined as delivery of water within 1 km or within 30 minutes of total collection time.

Table 6.40 presents the proportion of households that reported the total drinking water collection time to take less than 30 minutes. Most households in each sub-domain area, between 78% (Lower tailings) and 98% (Port) had basic access to drinking water (i.e., total drinking water collection time took less than 30 minutes). Except for the Lower tailings sub-domain area, this is consistently higher than the data for rural PNG, indicating that 84% of households have access to drinking water within 30 minutes or less.

What is the main source of drinking water for household members?	Season	Sub-domains						Control
		Port	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	
Piped water	Wet	15.5%	77.2%	54.1%	53.0%	10.0%	2.2%	30.0%
	Dry	36.2%	78.0%	45.9%	43.9%	13.3%	0.0%	32.5%
Communal tank water	Wet	63.8%	1.6%	0.0%	0.0%	16.7%	60.9%	30.0%
	Dry	31.0%	0.8%	1.6%	1.5%	0.0%	8.7%	17.5%
Spring/creek water	Wet	5.2%	13.0%	37.7%	43.9%	43.3%	0.0%	2.5%
	Dry	20.7%	17.9%	42.6%	45.5%	50.0%	2.2%	12.5%
Household tank or drum	Wet	15.5%	6.5%	4.9%	1.5%	20.0%	34.8%	37.5%
	Dry	6.9%	1.6%	3.3%	0.0%	0.0%	15.2%	15.0%
River water	Wet	0.0%	0.8%	1.6%	1.5%	10.0%	0.0%	0.0%
	Dry	0.0%	1.6%	4.9%	9.1%	30.0%	0.0%	2.5%
Dug well	Wet	0.0%	0.0%	0.0%	0.0%	0.0%	2.2%	0.0%
	Dry	5.2%	0.0%	0.0%	0.0%	3.3%	71.7%	20.0%
Other water source	Wet	0.0%	0.8%	1.6%	0.0%	0.0%	0.0%	0.0%
	Dry	0.0%	0.0%	1.6%	0.0%	3.3%	2.2%	0.0%

SOURCE
Tetra Tech Coffey, 2024

PANGUNA LEGACY ASSESSMENT COMPANY

PANGUNA MINE LEGACY IMPACT ASSESSMENT PHASE 1

FIGURE 6.7

Primary drinking water sources, wet and dry season

TETRA TECH COFFEY

DATE: 30.10.24 PROJECT: 754-MELEN305719 FILE: 305719_R03_F06.07_GRA

DISCLAIMER: THIS FIGURE HAS BEEN PROVIDED FOR INFORMATION ONLY AND IS SUBJECT TO CHANGE. THE CREATORS DO NOT WARRANT THAT THIS FIGURE IS DEFINITIVE NOR FREE OF ERROR AND DO NOT ACCEPT LIABILITY ARISING FROM RELIANCE ON INFORMATION PROVIDED HEREIN. © COPYRIGHT TETRA TECH COFFEY 2024.
DOC REFERENCE: \\TT.LOCAL\COF\S772\S\GIS\305719_MELEN_PLAC_LEGACYIMPACTASSESSMENT\2_GRAPHICS\305719_R03_LIA\305719_R03_GRA024.AI_3 | SAVED BY: JO | 30.10.24

Table 6.40 Water security

Indicator	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control
Self-reported reliability [1]							
Reliability of drinking water sources in wet season	Good	Good	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Good
Reliability of drinking water sources in dry season	Satisfactory	Good	Satisfactory	Satisfactory	Poor	Satisfactory	Satisfactory
Household survey - access – wet season							
Households with a drinking water source located within 30 minutes	98.3%	98.2%	88.0%	90.9%	78.3%	84.2%	86.1%
Time travelled by households where the water source is located longer than 30 minutes (minutes)	60	120	70	80	60	60	60
Household survey - access – dry season							
Households with a drinking water source located within 30 minutes	96.6%	98.2%	90.0%	90.6%	62.5%	81.6%	67.6%
Time travelled by households where the water source is located longer than 30 minutes (minutes)	90	120	70	60	60	60	60

1. Data is based on the results of the village survey.

Respondents to the household survey were asked to report on the quality of their drinking water sources (Table 6.41). The most common issue raised in the Port Domain, Upper mine, Lower mine, Upper and mid tailings sub-domain areas was sedimentation. Bad taste and discolouration were the most commonly raised concerns in the Lower tailings sub-domain and Delta Domain areas.

Complaints of gastrointestinal issues from drinking water were the highest in the Delta Domain (26%) and Lower tailings (17%) sub-domain areas. These areas also reported the highest use of rainwater tanks (e.g., communal or household tanks).

Table 6.41 Self reported drinking water quality and issues

Indicator	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control
Drinking water quality							
Poor quality	15.5%	32.5%	23.3%	39.1%	58.6%	45.7%	20.0%
Satisfactory quality	63.8%	55.3%	51.7%	31.3%	34.5%	34.8%	25.0%
Good quality	20.7%	12.2%	25.0%	29.7%	6.9%	19.6%	55.0%

Indicator	Port and Town	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Control
Quality issues							
Sedimentation	50.0%	65.2%	85.7%	77.8%	86.2%	51.4%	40.6%
Bad taste	31.0%	57.4%	59.2%	48.1%	93.1%	97.1%	40.6%
Discoloured	25.9%	38.3%	57.1%	46.3%	65.5%	45.7%	21.9%
Odour	8.6%	22.6%	34.7%	29.6%	51.7%	54.3%	28.1%
No issue	22.4%	13.9%	0.0%	1.9%	0.0%	0.0%	43.8%
Gastro/stomach problems	1.7%	7.8%	6.1%	5.6%	17.2%	25.7%	0.0%

Water security is also reportedly affected by flooding events. Communities living along the Jaba and Kawerong rivers in the Upper and mid and Lower tailings sub-domains consistently expressed concerns about the effects of flooding on drinking water. All six communities who engaged in focus group discussions during field campaign 2 reported that flooding from the nearby river systems affected their drinking water sources, meaning they had to rely on alternative less desirable drinking water sources, such as collecting rainwater in containers and tanks, until the water levels subside.

Uncertainty

Due to the preliminary nature of the Phase 1 characterisation process, uncertainties exist related to water security. Key uncertainties include:

- Water sources were sampled based on consultation with representatives from each community. Other water sources may be used by some households that were not identified and sampled.
- Water samples were collected from sources on two occasions and may not indicate the full range of water quality throughout the year (including during or following flood events).
- The level and frequency of use of water sources identified by communities for recreation cannot be determined based on the data collected as part of the Phase 1 investigations.

6.2.5 Multidimensional poverty

The Multidimensional Poverty Index (MPI) provides a globally standardised measure for deprivation, encompassing the various deficiencies individuals living in poverty experience in three dimensions: health, education, and living standards (Hamago et al. 2023a). Ten indicators are used to measure the three dimensions. These include two health indicators, two education indicators and six indicators for living standards. Each dimension is equally weighted at a third, and each indicator is also equally weighted within its respective dimension. Under the MPI framework a household is considered poor if they lack basic necessities in at least one-third of the indicators measured, which are grouped into health, education, and living standard indicators.

The household survey results were analysed against the MPI framework to indicate how many people are poor and the severity of their deprivation at a sub-domain level. The overall MPI score was based on:

- The proportion of the population that is multidimensionally poor (H), multiplied by:
- The average proportion of dimensions in which poor people are deprived (A).

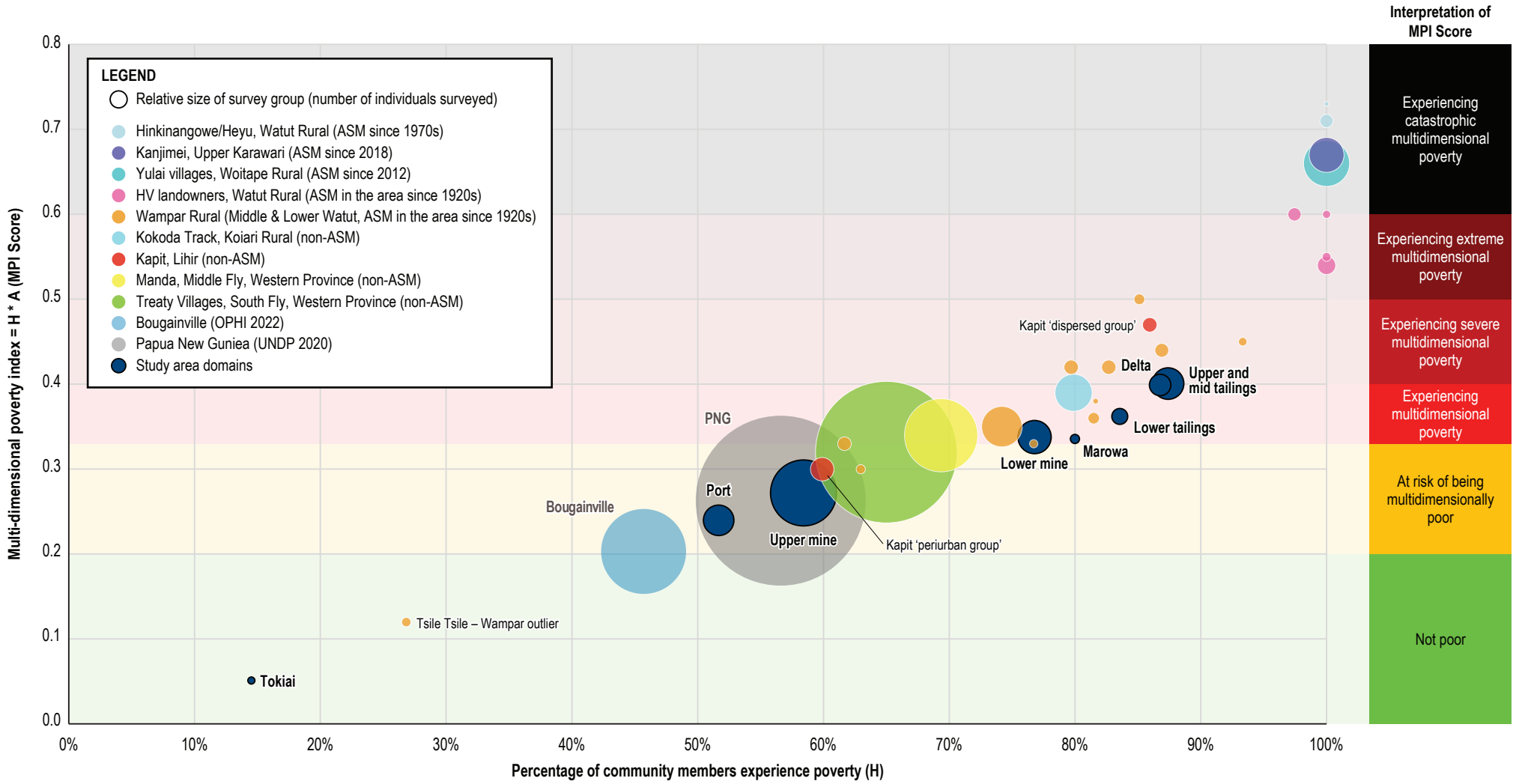
The most recent national MPI score for PNG was 0.26, where urban areas scored 0.08, whole rural areas scored 0.26, indicating poverty is concentrated in rural areas. The MPI score for Bougainville was 0.20 (UNDP and OPHI, 2022).

The MPI results for the study area at the sub-domain level were (Figure 6.8):

- The Upper and mid tailings (0.40) and the Delta (0.40) sub-domains were experiencing severe multi-dimensional poverty.
- The Lower tailings (0.36), the Lower mine (0.34) sub-domains and Marowa (0.34), a Control village, were experiencing multidimensional poverty.
- The Port (0.24) and Upper mine (0.27) sub-domains were at risk of multidimensional poverty.
- Tokiai (0.05), a Control village, was not poor.

Figure 6.8 shows the breakdown of the MPI indicators at a household level. At a dimensional level:

- Educational indicators have limited contribution to poverty. The level of education reported in the study area is much greater than in Bougainville. However, the responses to this question do not align with the other qualitative data collected, as abandoning school attendance for ASM activities was commonly reported and distance to schools affected attendance (see Section 6.2.2.3 and Section 6.2.3.2). This indicates response bias may have reduced the reported incidence of educational poverty.
- Health indicators demonstrate high levels of nutritional poverty. All sub-domains across the study area reported greater poverty levels than the Control sites. Poor nutrition can have far reaching social wellbeing effects, and contribute to incidences of morbidity, mortality and broader socioeconomic outcomes, particularly for vulnerable groups (children, women and the elderly). Additionally, the child mortality indicator might have been under-reported given the household survey had a high non-response rate to this question. When modelled using a simulated child mortality score, the MPI scores for the sub-domains could be lifted by approximately 0.03 but this does not change the poverty ratings for the sub-domains.
- Living standards indicators demonstrate high levels of poverty across the study area. Access to electricity is limited to communities in the Upper mine sub-domain that have hydropower; outside of these communities, electricity is almost non-existent (see Section 6.2.3.3). Cooking fuel is often indicative of development and can have significant implications for a household's respiratory health and firewood collection is typically undertaken by women contributing to their labour burden.
- Housing indicators demonstrate most households in the study area are not vector-proof, increasing the risk of mosquito-borne disease, which is indicative of access to building materials and cash for improvements (see Section 6.2.2.4). Relatedly, the asset ownership indicator was limited across the study area and was also limited in the Control sites, indicating people's engagement with the cash economy is insufficient to contribute to their development, with incomes being diverted to immediate needs (see Section 6.2.2.2).
- Access to drinking water within 30 minutes of the home was common across the study area (see Section 6.2.4.4), although households in the Lower tailings reported relatively high levels of deprivation. Safe water access reduces exposure to water-borne diseases, which in turn contribute to people's productive capacity and their broader nutritional and health outcomes.
- Access to improved sanitation reduces people's vulnerability to disease by separating human waste from human interaction. As noted in Section 6.2.4.1, much of the study area is deprived in this regard, creating environmental conditions that are conducive to diarrheal disease.



SOURCE
Tetra Tech Coffey, 2024
Bougainville and PNG MPI scores from UNDP and OPHI (2022)
Hamago, J. et al. (2023) 'Multidimensional poverty and small-scale mining in the shadow of large-scale mines in Papua New Guinea', Journal of Rural Studies, 101, p. 103045.

PANGUNA LEGACY ASSESSMENT COMPANY
PANGUNA MINE LEGACY IMPACT ASSESSMENT PHASE 1

FIGURE 6.8

MPI score and percentage of population experiencing MPI poverty

TETRA TECH COFFEY

DATE: 30.10.24 PROJECT: 754-MELEN305719 FILE: 305719_R03_F06.08_GRA

DISCLAIMER: THIS FIGURE HAS BEEN PROVIDED FOR INFORMATION ONLY AND IS SUBJECT TO CHANGE. THE CREATORS DO NOT WARRANT THAT THIS FIGURE IS DEFINITIVE NOR FREE OF ERROR AND DO NOT ACCEPT LIABILITY ARISING FROM RELIANCE ON INFORMATION PROVIDED HEREIN. © COPYRIGHT TETRA TECH COFFEY 2024.
DOC REFERENCE: \\TT.LOCAL\COF\S772\S\GIS\305719_MELEN_PLAC_LEGACYIMPACTASSESSMENT\2_GRAPHICS\305719_R03_LIA\305719_R03_GRA025.AI_3 | SAVED BY: JO | 30.10.24

A recent publication by Hamago et al. (2023a) provides an overview of community-level poverty at locations across PNG. This publication demonstrates two features of poverty in PNG relevant to the study area:

- **Access to infrastructure and services is essential to lift households out of poverty.** Where groups share characteristics ease of access to infrastructure and services differentiates the level of poverty between these groups. For example, the Wampar villages in the Morobe Province are all characterised by their reliance on a mixture of subsistence farming, cocoa cash cropping and ASM. The MPI score of Wampar villages is largely determined by the ease of access to Lae, shown by the MPI score increasing the longer it takes to reach Lae from the village. As detailed in Section 6.2.3, the villages in the Delta and Lower tailings in particular are remote from health, education, and most economic infrastructure. The lack of ease of access limits the development of these households and therefore influences their MPI score.
- **There are aspects of ASM that are likely to predispose these communities to poverty.** These factors include but not are limited to the inflationary effect of gold on goods and services, and that ASM is labour intensive and incomes are unstable, meaning participants' time and income to support community projects may be limited. Such factors contributes to poverty in these communities, despite raising cash incomes. Results within the study area reinforce that ASM households are more likely to report MPI scores than non-ASM households. In simpler terms, participation in ASM is not enough to lift households out of poverty, even though ASM may offer much greater opportunities to participate in the cash economy.

There is a strong view from the community that the environmental effects of the Panguna Mine have affected people's gardening land, contributing to a decline in their social wellbeing. The characterisation results indicate that people who report experiencing these issues have higher levels of poverty than those who do not. Figure 6.9 shows the percentage of surveyed households with deprivations by sub-domain.

Dimensions	Indicators	Sub-domains						Control		Bougainville
		Port	Upper mine	Lower mine	Upper and mid tailings	Lower tailings	Delta	Marowa	Tokiai	
Education	Years in schooling	3.4%	5.1%	0.0%	3.8%	5.9%	0.0%	5.0%	0.0%	8.7%
	School attendance	10.3%	15.0%	4.2%	22.2%	6.7%	0.0%	0.0%	7.1%	31.8%
Health	Nutrition	31.0%	46.3%	68.3%	55.4%	57.1%	72.1%	48.0%	7.1%	-
	Child mortality	8.0%	5.8%	11.1%	7.9%	0.0%	5.9%	0.0%	0.0%	2.3%
Standard of living	Cooking fuel	94.8%	98.4%	100.0%	98.5%	100.0%	100.0%	100.0%	93.3%	45.8%
	Sanitation	93.1%	76.2%	96.7%	97.0%	100.0%	97.8%	96.0%	20.0%	43.9%
	Drinking water	25.9%	22.0%	54.1%	59.1%	90.0%	76.1%	68.0%	6.7%	23.4%
	Electricity	100.0%	86.5%	100.0%	100.0%	100.0%	100.0%	100.0%	20.0%	42.9%
	Housing	96.6%	74.8%	80.0%	87.9%	96.7%	93.5%	80.0%	66.7%	39.7%
	Assets	93.1%	94.3%	100.0%	89.4%	93.3%	82.6%	76.0%	93.3%	33.1%

SOURCE
Tetra Tech Coffey, 2024

PANGUNA LEGACY ASSESSMENT COMPANY

PANGUNA MINE LEGACY IMPACT ASSESSMENT PHASE 1

FIGURE 6.9

Percentage of surveyed households with deprivations, by sub-domain

TETRA TECH COFFEY

DATE: 30.10.24 PROJECT: 754-MELEN305719 FILE: 305719_R07_F06.09_GRA

DISCLAIMER: THIS FIGURE HAS BEEN PROVIDED FOR INFORMATION ONLY AND IS SUBJECT TO CHANGE. THE CREATORS DO NOT WARRANT THAT THIS FIGURE IS DEFINITIVE NOR FREE OF ERROR AND DO NOT ACCEPT LIABILITY ARISING FROM RELIANCE ON INFORMATION PROVIDED HEREIN. © COPYRIGHT TETRA TECH COFFEY 2024.
DOC REFERENCE: \\TT.LOCAL\COF\S772\S\GIS\305719_MELEN_PLAC_LEGACYIMPACTASSESSMENT\2_GRAPHICS\305719_R03_LIA\305719_R03_GRA026.AI_3 | SAVED BY: JO | 30.10.24