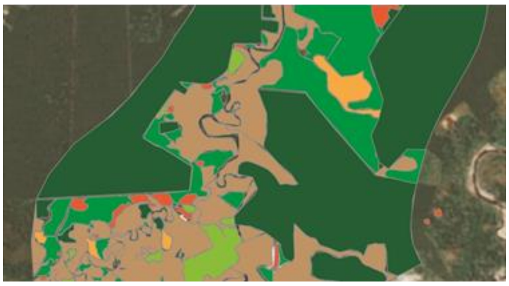
Baseline assessment of water quality and aquatic ecology downstream of Gold Ridge Mine, Solomon Islands, February 2016



Simon Albert

Alistair Grinham

Patrick Pikacha

David Boseto

Joshua Kera

Solomon Islands Government

Ministry of Environment, Conservation, Climate Change, Disaster Management and Meteorology

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

School of Civil Engineering

Executive summary

This report outlines a baseline assessment of the water quality, sediment quality and aquatic ecology of the Metapona River system downstream of Gold Ridge Mine, Guadalcanal, Solomon Islands. The assessment was conducted on behalf of the Ministry of Environment, Conservation, Climate Change, Disaster Management and Meteorology in the Solomon Islands Government. This assessment will provide the framework to establish an integrated environmental monitoring program for the Metapona River system. This will ensure that any possible contamination of downstream ecosystems from controlled dewatering or uncontrolled discharge from the Tailings Storage Facility can be quantified and managed to ensure human and environmental impacts are minimised.

Over the past 15 years the river systems downstream of Gold Ridge mine have been influenced by increased loads of sediment and metals as a result of mining operations. However, the Charivungo and Chovohio River systems are naturally enriched in metalloids such as Arsenic due to the geochemistry of the gold-bearing rock in the catchment. Hence differentiating natural loads of contaminants from anthropogenic sources is difficult.

Results from February 2016 indicate that the concentration of dissolved Arsenic within the Tailings Storage Facility (TSF) has increased substantially to 0.087 mg/L since previous assessments in 2014 and 2015 (0.023 and 0.27 mg/L respectively). This has coincided with the water level within the TSF reaching the highest level since the dam was constructed in 1998. Due to the lapse in operation of the Gold Ridge mine since April 2014, cyanide levels within the TSF water have reduced to undetectable levels (less than 0.004 mg/L). However, of concern are relatively high concentrations of Free Cyanide (0.021 mg/L) measured within the TSF Sump downstream of the main embankment. This Cyanide contamination is likely to have leached through shallow groundwater systems into the TSF sump, to date no elevated levels of Cyanide or Arsenic have been detected in any river systems.

Turbidity within the river systems downstream of Gold Ridge varied from relatively low turbidity waters of the Tinahulu (5-10 NTU), high turbidity of the Charivunga river (268 NTU), moderate turbidity of the Chovohio river (50-100 NTU), before increasing again in the lower reaches of the Metapona to 100-150 NTU due to resuspension of fine sediments.

The ecological assemblage within the river systems downstream of Gold Ridge are typical of disturbed ecosystems. A total of 36 species of fish, 20 species of birds, 12 species of crustaceans, 3 species of reptiles and 6 species of dragonfly were documented during the surveys. The highest diversity and abundance of species found within the relatively un-impacted Tinahulu River.

Contact: Dr. Simon Albert s.albert@uq.edu.au +61 415111744

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Background

The Gold Ridge mine in Solomon Islands was first developed in 1997 by Ross Mining and was in production from August 1998 to June 2000 prior to being shut-down due to civil unrest. The mine was re-commissioned in 2010 and re-started production in March 2011 prior to suspending operations in April 2014 due to a combination of high operating costs, local tensions and severe weather. The Gold Ridge mine is situated at 550 m ASL on the island of Guadalcanal in Solomon Islands, 25 km SE of the capital Honiara (Figure 1). Rainfall at the mine site is estimated to be 4,076 mm PA, with a wet season from November-April and a drier period from May-October.

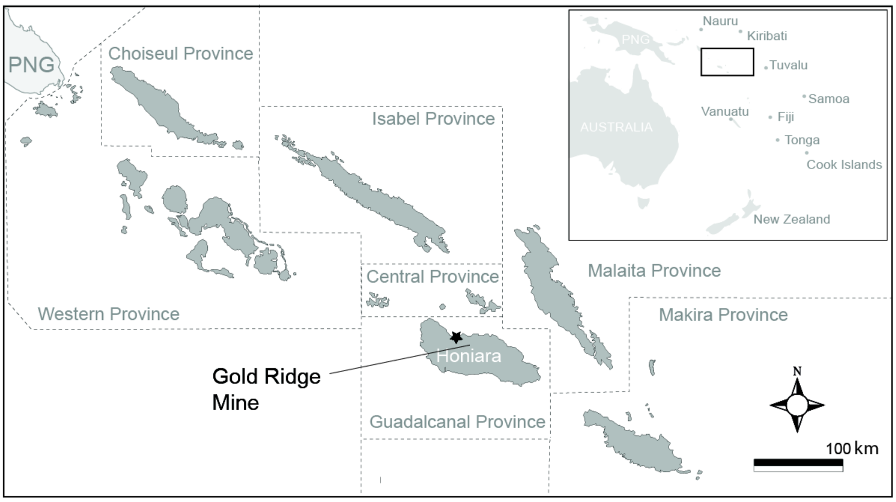

Figure 1: Map of Solomon Islands with Gold Ridge Mine indicated

In addition to the development and operation of the commercial open pit gold mine, modification of upper catchment areas has occurred through selective logging and artisanal gold panning within the streambed. Extensive modification of the lower catchment areas has occurred through historic rice plantations, the large-scale development of oil palm plantations and industrial alluvial mining operations. Past catchment modification is likely to increase the rate of sediment delivery to the lower reaches of the river and adjacent coastal zone. This is especially important in the upper catchment areas where the relatively high rainfall and steep topography can result in major sediment mobilisation from exposed areas. Landslips are an additional feature of this landscape and these may occur in natural, undeveloped areas of catchments and greatly increase sediment delivery from affected areas. The increased delivery of sediment is further impacted by the relatively high arsenic content in sediments in areas currently used for artisanal mining in the upper catchment, where mobilisation of relatively small quantities of these sediments can result in relatively large arsenic loading to downstream areas. The disposal of mine tailings in the tailings storage facility provides a potential source of heavy metal and cyanide loading through the refinement process. Mobilisation of sediments from the tailings dam and release of untreated surface waters risks releasing these chemicals of concern into the environment. An ecology, sediment and water quality survey was conducted in order to better understand the current situation surrounding sediment and metal delivery in the upper and lower catchment areas of the Metapona River. Results from this study can form the basis of long term environmental monitoring programs within the region to determine how catchment modification is impacting the lower river reaches and coastal zone.

Study sites

In order to undertake a baseline survey it is important to understand the likely relative contribution between all sub-catchments within the Metapona River system. There are 5 broad sub-catchments within the system, the upper systems of Charivunga, Chovohio, Kwara and Tinahula catchments which all flow into the lower Metapona River (Figure 2). The relative catchment landuse of each river differs greatly between different systems as does the likely sediment and chemical loading. The Charivunga River has been highly modified by industrial mining with over 30% of the total surface area now exposed after mining. In addition, informal alluvial panning occurs within the stream bed of this system as well as direct spraying of the banks with high pressure hoses to mobilise sediments. The Chovohio River has far less catchment disturbance with limited industrial mining and waste rock exposing less than 1% of the catchment area. Informal alluvial panning occurs within the stream bed upstream of the Chovohio and Charivunga River confluence. The establishment of a tailings storage facility within the Kwara River catchment has dammed catchment flows within this sub-catchment. The Tinahula River system has no industrial or alluvial mining activities. The lower Metapona River is highly modified by large plantation agriculture (oil palm) and smaller scale subsistence agriculture across the fertile alluvial plains.

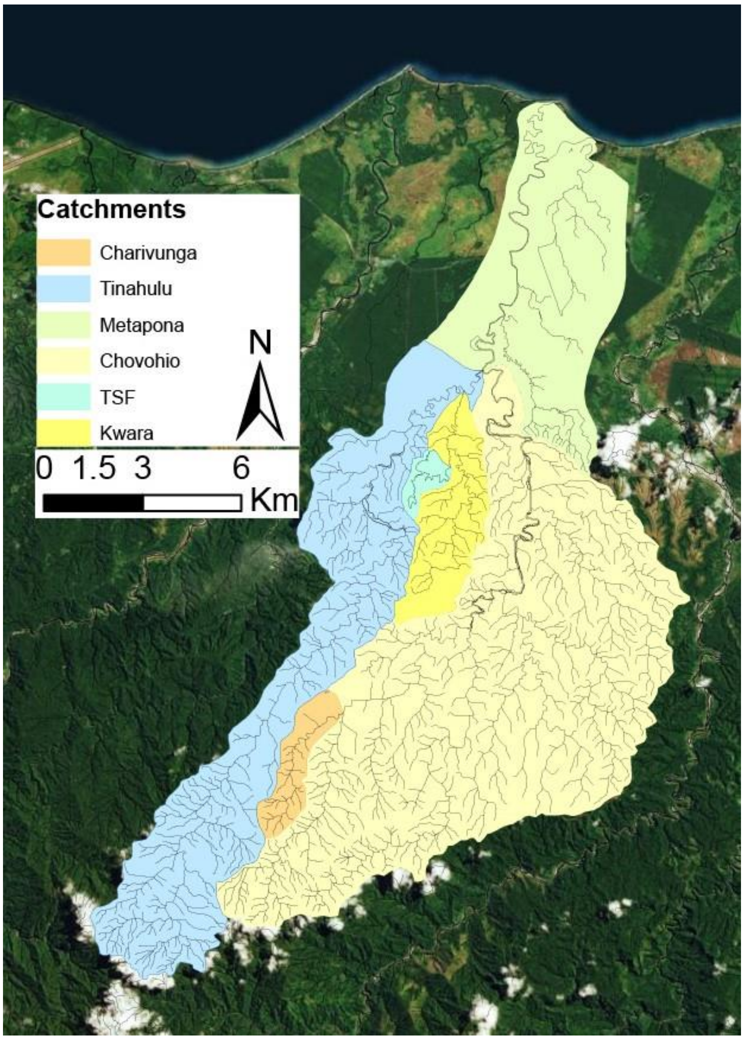

Figure 2: Map of the six major catchments that comprise the Metapona/Tinahulu/Chovohio River system

The relative catchment size of each river differs greatly between different systems with the combined Charivunga and Chovohio catchment system almost double the size compared with the Tinahula and Kwara catchment system (Table 1). These data suggest that under similar rainfall distribution there will likely be greater contribution from the Chovohio and Charivunga system into the lower Metapona.

Table 1: Catchment area of the sub-catchments that comprise the Metapona river system

	Catchment area (km^2)
Tinahulu	50.9
Charivunga	4.53
Chovohio	102.9
Kwara	10.90
TSF	1.67
Lower Metapona	35.7
Total	**206.5**

The Kwara River catchment extends from Obo Obo village in the upper reaches down to the TSF and joins the Tinahulu River at the village of Kwara adjacent to Pitikoli (Figure 3). The catchment is primarily forested with some garden areas in the lower reaches. Water seeping through the TSF wall or overflowing over TSF spillway will enter the Kwara river and flow into the Tinahulu River at Kwara village before flowing into Metapona River.

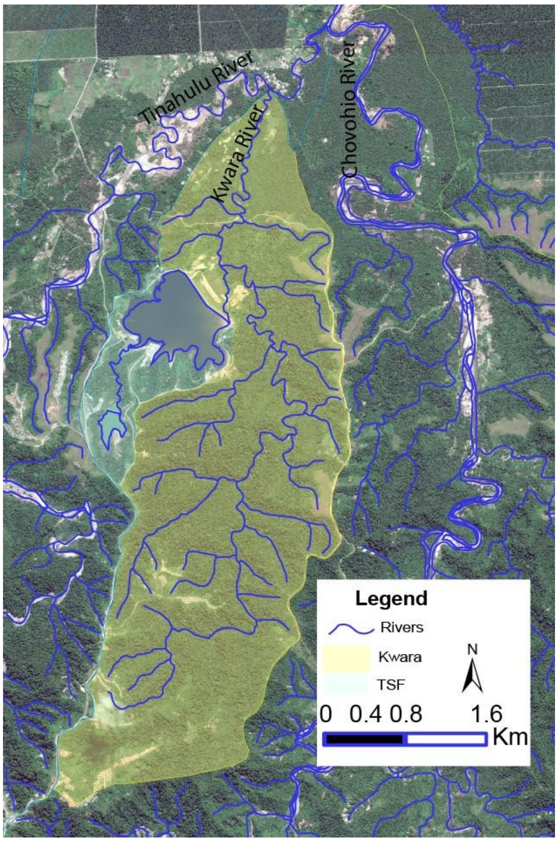

Figure 3: Kwara River and Tailings Storage Facility (TSF) catchments

The catchment topography clearly shows the steep nature of the headwaters of Charivunga, Tinahula and Chovohio catchments (Figure 4). In addition, the rapid changes in elevation will likely increase rainfall in the headwater areas due to orographic lift. The steep catchment in headwater region and relatively high region rainfall suggest that flow events through the entire river system will be relatively rapid.

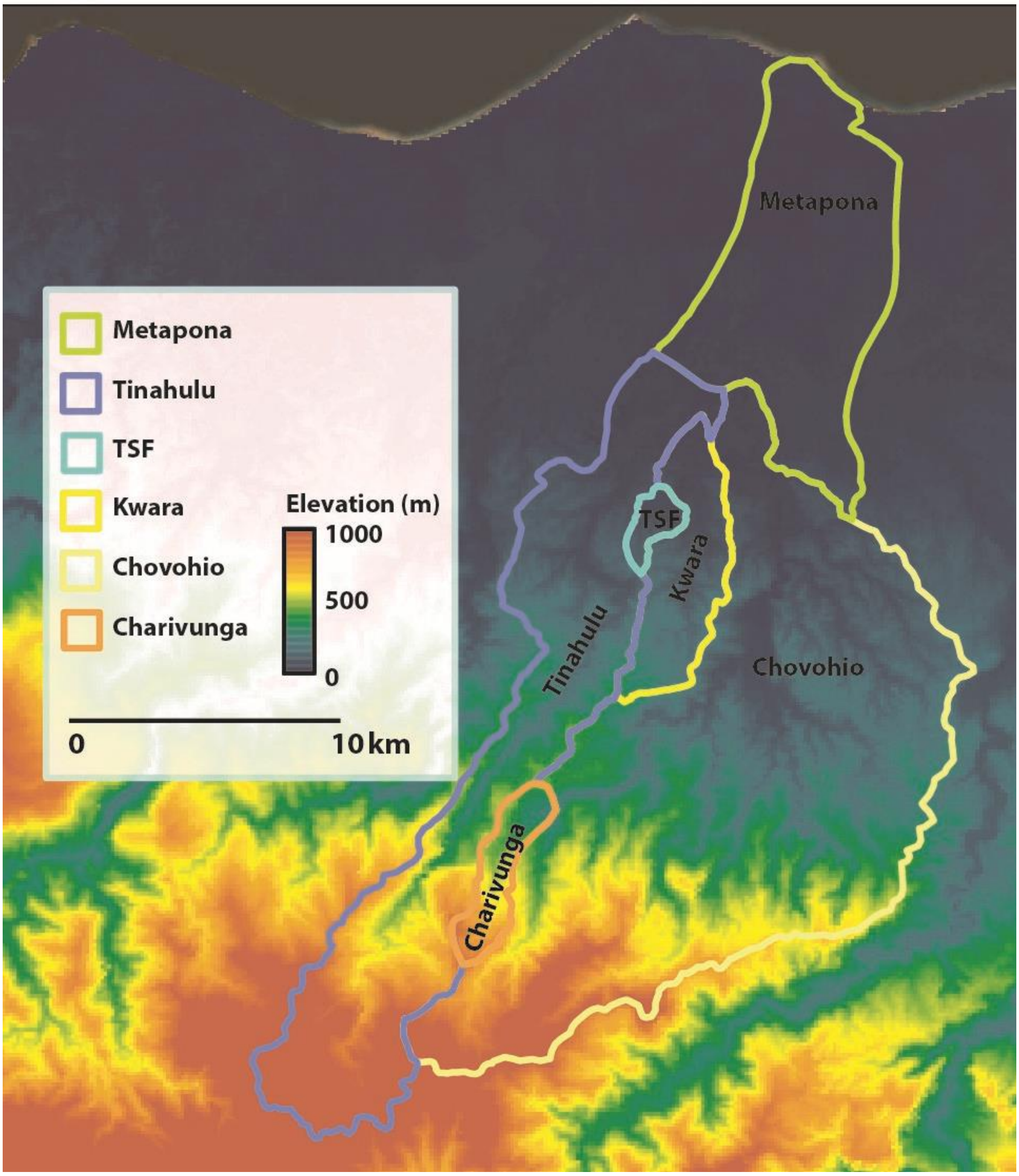

Figure 4: Topographic map of the Metapona catchment

In order to establish a baseline of the whole river system 19 sites were sampled for water quality, sediment quality and aquatic ecology from the upstream reaches of the Charivunga and Chovohio Rivers, the Tinahulu River, Kwara river to the lower Metapona River (Figure 5, Table 2). In addition, water quality of five groundwater wells for drinking water were sampled along the lower Metapona River (Figure 5) as these are the primary source of drinking water during low rainfall periods.

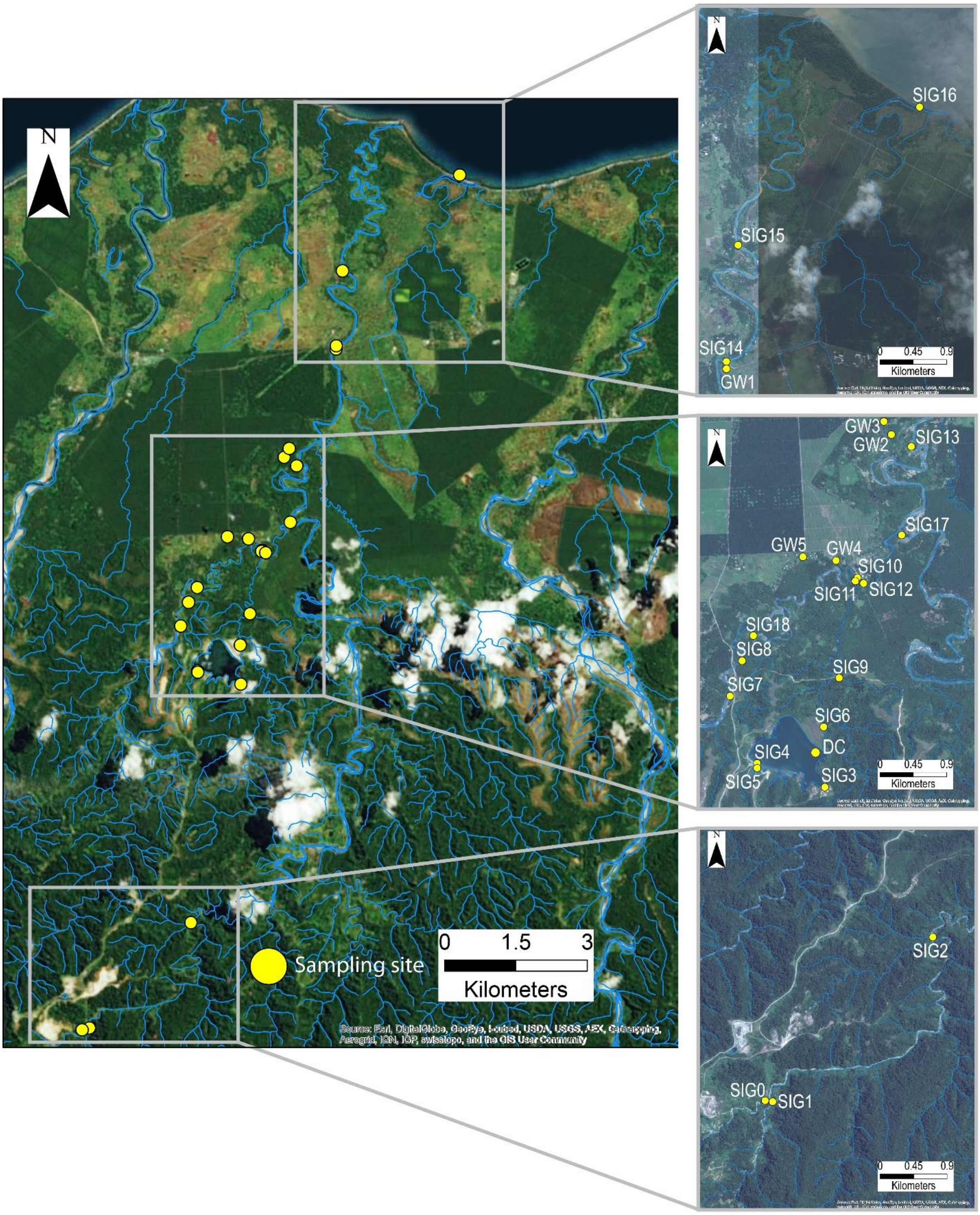

Figure 5: Map of sampling sites within rivers and groundwater downstream of Gold Ridge Mine

Table 2: Study sites used for baseline assessment

SIG site	GRML site	UQ site	Description	Latitude	Longitude
SIG0		UQGR1	Charivungo river downstream of Mine pits	-9.58444	160.13851
SIG1	SW05	UQGR2	Chovohio river upstream of Charivungo confluence (i.e. not impacted by Gold Ridge)	-9.58444	160.13851
SIG2	SW08	UQGR3	Compliance point on Chovohio River	-9.56453	160.15768
SIG3	TSF-spillway	UQGR6	TSF Spillway	-9.51949	160.16708
SIG4	TSF-treatment plant	UQGR7	TSF at Treatment Plant	-9.51696	160.15929
SIG5			Discharge Pond	-9.5173	160.15898
SIG6			TSF Sump	-9.51212	160.167
SIG7	SW13	UQGR8	Tinahulu 100m upstream of TSF discharge	-9.50851	160.15577
SIG8	SW14	UQGR9	Tinahulu river 100m downstream of TSF discharge point	-9.50407	160.15719
SIG9	TSF06	UQGR10	Kwara river bridge downstream of TSF sump	-9.50622	160.16883
SIG10		UQGR20	Tinahulu river upstream of Kwara confluence	-9.49424	160.17112
SIG11		UQGR21	Kwara river upstream of Tinahulu confluence	-9.49444	160.17103
SIG12		UQGR22	Tinahulu river downstream of Kwara confluence	-9.49473	160.1718
SIG13	Keamami	UQGR11	Metapona river between bridge and confluence of Tinahula/Chovohio	-9.47829	160.17762
SIG14	SW17	UQGR13	Bridge on Matepono river	-9.45564	160.1851
SIG15	Komindi	UQGR14	Metapona river between bridge and diversion at Komindi	-9.4415	160.18628
SIG16		UQGR18	Metapona diversion mouth at Tetere	-9.42342	160.20842
SIG17		UQGR5	Chovohio river upstream of Tinahulu confluence	-9.48894	160.17644
SIG18		UQGR17	Tinahulu river 400m downstream of discharge point	-9.50268	160.1578
DC			Sediment core collected from TSF	-9.51555	160.1663
GW1			Pumped Groundwater well at Matepoana bridge	-9.45625	160.18505
GW2			Shallow well at Keamame village	-9.47672	160.17527
GW3			Pumped Groundwater well at Keamame village	-9.47544	160.17465
GW4			Pumped Groundwater well at Pitikoli	-9.43765	160.03163
GW5			Pumped Groundwater well at Pitikoli	-9.49168	160.16456

Methodology

An intensive field sampling program was undertaken to minimise the rapid changes in water flow and quality that can occur within these systems. The water quality survey was undertaken over a three day period following relatively low rainfall. Samples were collected on the following days:

- February 6 2016: SIG 16, SIG 15, SIG 14, SIG 10, SIG 11, SIG 12, SIG 17 GW 1
- February 7 2016: SIG 13, SIG 7, SIG 8, SIG 18, SIG 9, SIG 3, SIG 4, SIG 5, GW 2, GW 3
- February 8 2016: SIG 0, SIG 1, SIG 2, GW 4, GW 5

An additional water quality sampling round occurred after relatively high rainfall on February 12 (120 mm) at three selected sites (SIG8, SIG9 and SIG14). This was undertaken to capture the likely range in water quality that can be experienced under high flow conditions.

Water quality

Turbidity, dissolved oxygen, pH, conductivity and temperature of surface waters were assessed using an EXO2 YSI multiparameter water quality probe. Nitrate, nitrite, ammonia, total and dissolved metal samples were collected using a sterile 60 mL plastic syringes and placed in sterile 60 mL high-density polyethylene (HDPE) sample bottles. Alkalinity and total suspended solids were collected in a 500 mL bottle. Samples were kept on ice to limit biological processing of metals and nutrients prior to analysis. Samples were analysed by using NATA accredited methods at ALS laboratories in Brisbane, Australia. Samples for microbiologicals and Biochemical Oxygen Demand were collected and transferred to the National Public Health Laboratory in Honiara within 24 hours of collection.

Water Flow

At each site a cross river profile was conducted using a Leica Disto 410 laser distance meter and measuring staff. At each 1 m interval a time averaged (40 seconds) assessment of water speed at mid-water column was taken using a Sontek Flowtracker. The cross sectional surface area and current speed was then calculated following the "Japanese" method and a velocity co-efficient of 0.85 to account for reduced flows over the coarse bottom of these streams (Figure 6).

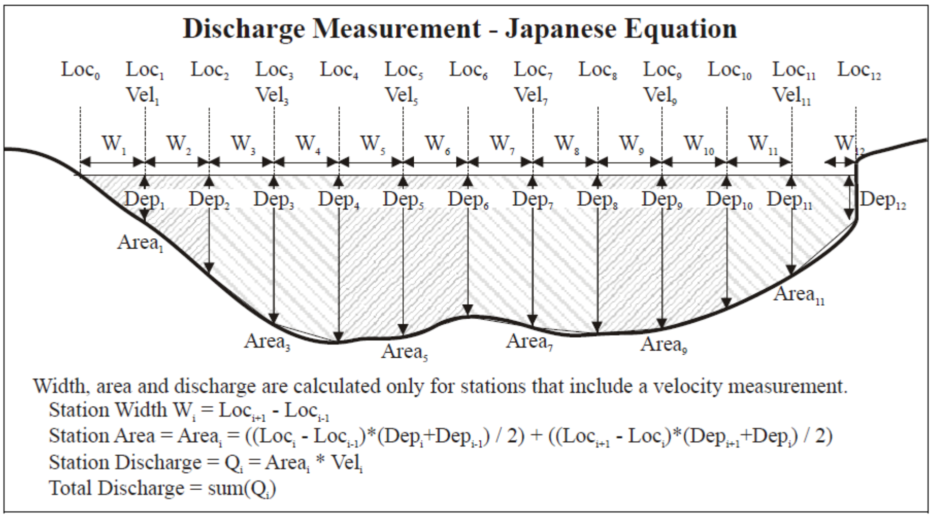

Figure 6: Equations used to calculate stream discharge

Figure 7: Assessing river flow at SIG 18 on Tinahulu River

These point measurements provide a useful snapshot of flow conditions, longer term flow sampling was undertaken at a single key site, SIG14, to better understand the nature of flow events. A timelapse camera was placed on the stream bank facing the water surface collecting an image every 4 hours for approximately 8 months prior to this sampling event (Figure 8). Using the relatively height of the streambank it is possible to observe the frequency and relative magnitude of flow events at this key site.

Figure 8: View of Metapona River from timelapse camera installed at SIG 14

Sediment quality

River-bed sediments were collected into a 250 mL sterile jar. In order to standardise sampling between sites the fine sediment fractions were sampled within each site. Pebble gravel, cobbles and boulders were observed and all sites, however, these fractions were excluded as they are not associated with declines in water and sediment quality. Rather the fine sediment fractions were selected as changes particularly in silt and clay fractions are likely to change both sediment and surface water quality.

The chemical composition of tailings can differ depending on the ore rock and processing at the time of production, therefore to gain a deeper understanding of the likely range in tailings composition a deep core was collected in the historical placement area within the tailings storage facility Figure 5. A 3.0 m sediment core was collected using a 90 mm core barrel driven into the sediment. The core barrel was extruded and immediately sub sampled at the sediment surface, 1.5 m depth and 3.0 m depth. Teflon-lined plastic lids were placed on jars filled with sediment and samples kept on ice between sampling and analysis for particle size and metals. Samples were analysed using NATA accredited methods at ALS laboratories in Brisbane, Australia.

Aquatic ecology

For a total of nine days from February 14 to February 19 and March 5 to March 7, 2016 the aquatic team collected invertebrates and vertebrates within the river systems downstream of Gold Ridge Mine as part of a baseline assessment before dewatering of the tailings dam. Ecological assessments were conducted at the same 19 sites as water quality along the Metapona to Gold Ridge corridor. All the sites (SIG0-18) are accessible by vehicle or by walking along a trail and this easy access allows for future long term monitoring sites established by the Solomon Islands Government. During the collection, the weather was mostly overcast, and rainy as a result of a cyclone southeast of Guadalcanal. All sites are described as highly disturbed, except for SIG 2, below Obo Obo village where below the gardens, there is an area of tall stands of native trees in particular *Pometia pinnata*. Site 16, the entrance of the Metapona River, is also predominately disturbed habitat with villages, on both sides of the river, and a palm oil plantation (GPPOL), to the east. Gardens dominate most of the lower corridor downstream of confluence of Chovohio and Tinahulu rivers.

Terrestrial vertebrates and invertebrates

Visual encounter techniques were used to survey frogs (Pikacha et al 2008) and reptiles (McCoy 2015), and invertebrates (dragon flies) (Marinov and Pikacha 2013). An average of one hour at each site. Observers recorded the presence of animals by walking a predefined area, along the stream or adjacent forest edge.

Macroinvertebrates

Macroinvertebrate samples were collected from each site using a kick net (mesh 0.3 mm). This survey method was employed to allow an assessment of macroinvertebrate density at selected sites and to compile a comprehensive list of taxa for all sites. The collected samples were preserved in a 500 ml jar (kick-net samples) in 75% ethanol. The following describes the quantitative and qualitative sampling methods:

Quantitative and Qualitative assessment – five replicate samples were collected from each site using a kick-net (mesh 0.3 mm) within the range of habitats at each site. This included slow flowing edge habitats for taxa that prefer these conditions (e.g., snails and damselflies), 10m edge length (5m on each edge) pools, and ripples. Macroinvertebrates were collected by placing the kick-net downstream of water flow and the habitat disturbed by standardised kicking methodology to dislodged aquatic organisms to be washed downstream and collected in the rectangular kick-net. At some sites with overhanging vegetation or within slow pools and the tailing dam, a kick nets was scooped under the vegetation on the river edges or side of the pool to collect macroinvertebrates in a method more appropriate for collecting additional invertebrates that would be missed by kick sampling alone.

Macroinvertebrate samples were preserved in 75% ethanol prior to identification by a NATA certified laboratory in Australia (Ecoscope Environmental).

Figure 9: Sampling macroinvertebrates in Tinahulu River

Figure 10: Sorting of aquatic macroinvertebrate samples

Aquatic Vertebrate (Fish) Sampling

A portable electro-fisher (Model No: E-Fish 500W) was used for sampling of fish. The electric fishing machine was powered by a 12-volt battery that gives an output of 200 W, frequency of 100Hz or 150 Hz and a duty cycle of 50%. Electric fishing was performed in wadeable streams by progressing in an upstream direction to keep the water in front of the operators clear. The electric fishing survey was concentrated on fast ripples and river edges with vegetation's hanging over the streams. The fishing electrode created an electric field within a radius of a one-meter zone under average condition. When fish come in contact with the electric field it is stunned and can be caught easily with a hand net. Electric fishing was conducted in most sites except for TSF sites and River sites with very high turbidity (SIG 3, SIG 4, SIG 5, SIG 6, SIG 15 and SIG 16). A seine net (50 mm X 2500mm x 1200 mm) was used to collect fish at Site SIG 16. Fish that could be identified in the field were counted and then released alive back into the stream, whereas fish that required further identification were collected and stored in 75% ethanol while in the field. The following references Keith et al 2010 and Keith et al 2015 were used for fish identification and species confirmation.

The objective of field sampling is to collect a representative sample of the freshwater fauna. The information collected for invertebrates and vertebrate assemblages in rivers provides attributes like species composition and relative abundance.

Collection methods used at each site:

Electrofishing and Kick Net: SIG 0, SIG 1, SIG 2, SIG 7, SIG 8, SIG 9, SIG 10, SIG 11, SIG 12, SIG 13, SIG 14, SIG 17, SIG 18

Seine Net and Kick Net: SIG 16

Kick Net: SIG 3, SIG 4, SIG 5, SIG 6, SIG 15

Figure 11: Electrofishing in Charivunga River at SIG0

Results

Water quality

Generally, the water quality of sites located within the Chovohio River catchment were lower compared with those located in the Tinahula and Kwara River catchments. The Metapona River was also of generally low water quality which is likely a reflection of the higher flow and larger catchment within the Chovohio River resulting in a greater contribution to the Metapona system. Water temperature ranged from 21.2°C in the upper reaches of the Chovohio River with intact riparian vegetation to 26.2°C in the Tinahulu River and 33.5°C within the TSF. All riverine sites had low conductivity (<200 µS/cm) and slightly alkaline pH (7-9) typical of tropical rivers. Turbidity and Total suspended solids (TSS) varied from the clear waters of the Tinahulu River (5.7 NTU, 7 mg/L) to the highly turbid mine site runoff into the Charivunga River at SIG 0 (268 NTU, 298 mg/L). Turbidity declined towards the lower reaches of the Chovohio (SIG 17) and mid Metapona (SIG 13) before increasing again due to resuspension of fine sediments on river bed in lower Metapona (SIG14, 15, 16) (Figure 12). Ammonia, Nitrite and Nitrate concentrations were low (<0.1 mg/L) in all riverine sites (Table 3).

Table 3: Physiochemical water quality parameters for each site

SITE	TEMP °C	SPCOND µS/CM	TOTAL ALKALINITY AS CACO3 (MG/L)	PH	DISSOLVED OXYGEN MG/L	TURBIDITY NTU	TSS (MG/L)	AMMONIA AS N (MG/L)	NITRITE + NITRATE (MG/L)
CHOVOHIO									
SIG0	24.1	143.1	70	8.2	8.0	268	298	0.02	0.09
SIG1	21.2	118.0	82	8.4	8.4	66	11	0.01	0.06
SIG2	23.5	111.2	74	8.7	8.0	94	24	0.01	0.06
SIG17	25.5	118.4	64	7.9	7.7	58	46	<0.01	0.07
TSF/KWARA									
SIG3	33.5	343.7	75	8.8	7.7	14.9	42	0.02	<0.01
SIG4	32.5	353.2	76	8.8	7.8	3.5	<5	0.02	<0.01
SIG5	32.1	281.0	65	8.3	7.5	3.4	9	0.02	<0.01
SIG6	28.7	241.0	348	6.9	5.9	5.2	16	0.05	<0.01
SIG9	25.6	135.5	82	7.7	6.8	18.1	8	0.06	0.04
SIG11	24.4	175.2	95	7.9	6.8	19.4	13	0.03	0.05
TINAHULU									
SIG7	26.7	183.8	118	8.7	8.1	5.7	7	0.02	0.04
SIG8	25.6	187.6	119	8.6	8.4	7.3	9	0.01	0.04
SIG18	26.2	199.3	81	8.6	8.3	9.1	<5	<0.01	0.04
SIG10	26.3	187.8	109	8.4	7.8	35.9	26	0.01	0.06
SIG12	26.5	185.2	108	8.4	7.8	36.9	23	<0.01	0.06
METAPONA									
SIG13	23.1	142.4	94	8.1	8.0	32.1	38	0.01	0.06
SIG14	23.3	133.1	74	8.1	7.9	103	188	0.01	0.08
SIG15	22.4	130.0	73	8.1	8.0	104	39	<0.01	0.08
SIG16	22.5	136.0	70	8.1	7.9	152	140	0.03	0.09
GROUNDWATER									
GW1	25.8	273.8	317	6.9	3.2	0.3	<5	<0.01	0.06
GW2	25.1	266.1	277	7.0	0.6	0.27	6	0.08	0.05
GW3	24.6	189.3	157	7.8	3.5	0.55	<5	<0.01	<0.01
GW4	29.4	223.6	201	7.1	3.0	7.46	8	0.02	0.22
GW5	27.0	159.2	199	8.1	5.6	0.21	<5	0.17	0.47

Turbidity

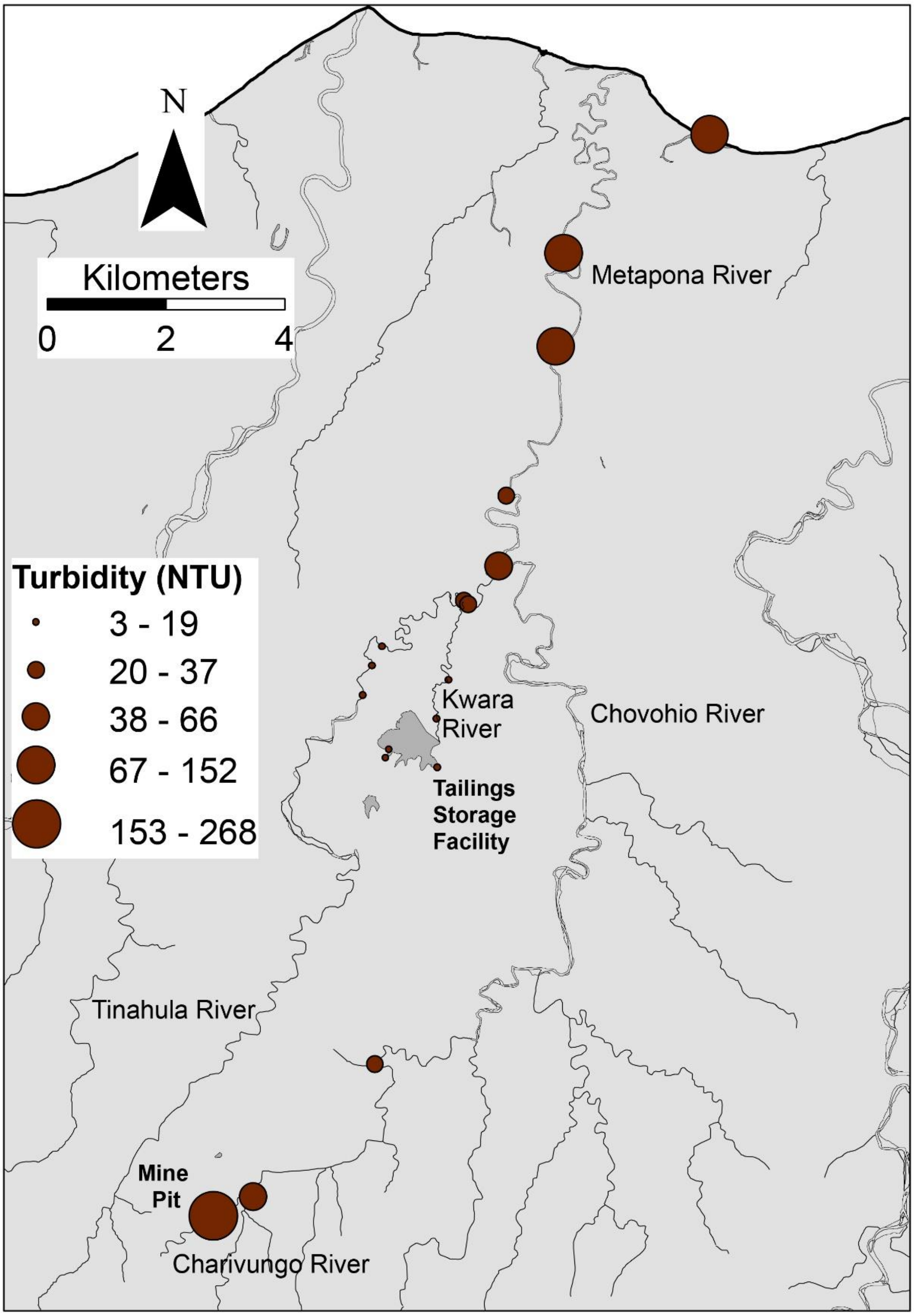

Figure 12: Map of turbidity within river systems downstream of Gold Ridge Mine

Dissolved and Total Metal Concentrations

Due to the naturally high Arsenic geology of the Gold Ridge area and the increase in mobility of Arsenic rich sediments from industrial and alluvial mining, the concentrations of Arsenic vary substantially across the Matepona River system. Dissolved Arsenic concentrations are highest within the TSF (0.087 mg/l). Concentrations of dissolved Arsenic are below detectable levels in the Tinahulu River (<0.001 mg/l) and below the World Health Organisation drinking water guideline (<0.01 mg/l) in the Chovohio and Matepona Rivers (Figure 13).

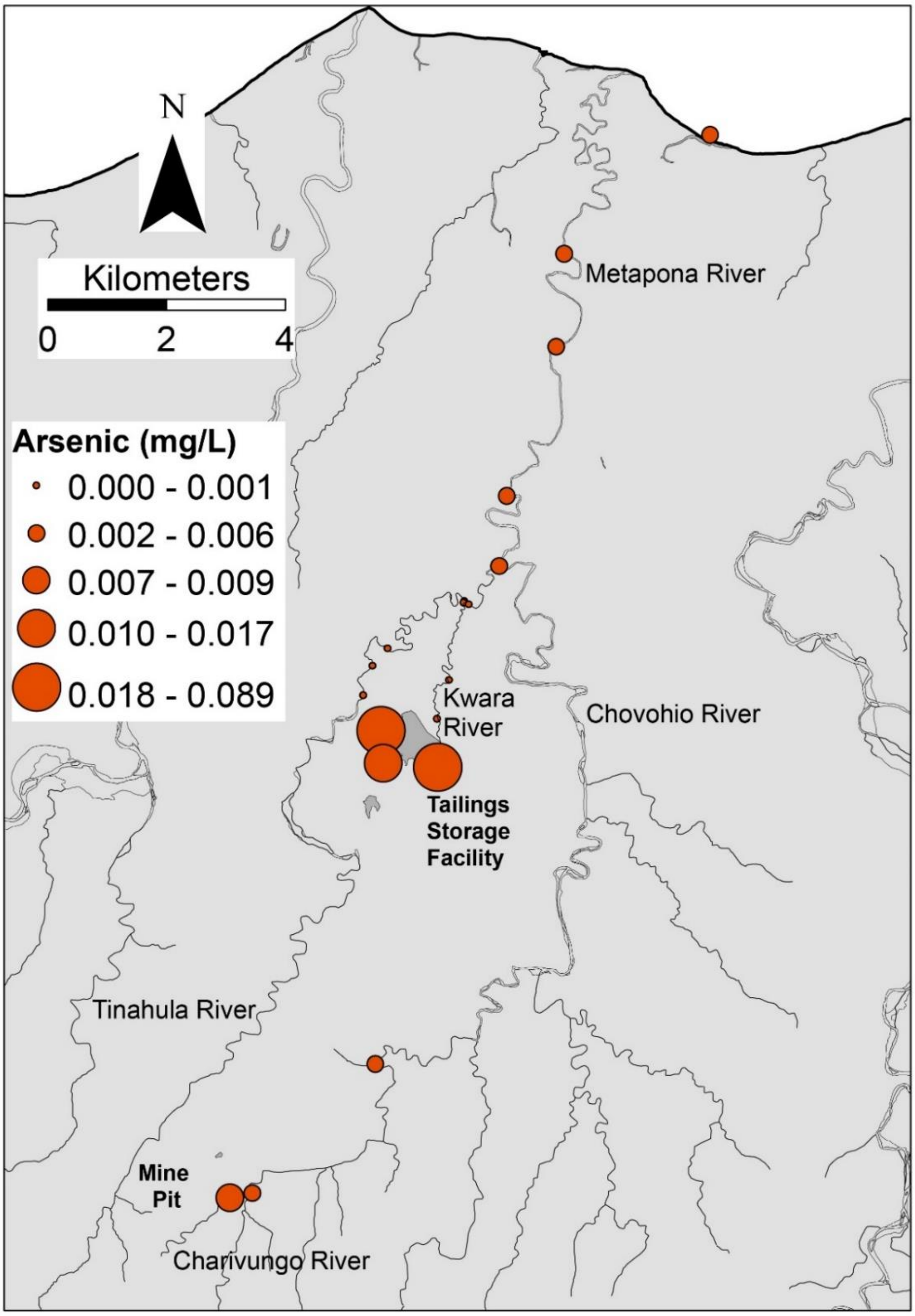

Figure 13: Dissolved Arsenic concentrations (mg/L)

Arsenic

The Charivunga River contains the highest concentration of Total Arsenic (0.102 mg/l) resulting from runoff from exposed ore and mobilisation of Arsenic rich fine sediments by alluvial mining activities. Total Arsenic concentrations reduced to 0.007-0.017 mg/l in the lower Chovohio and Metapona. Despite these moderately high concentrations of total Arsenic throughout the Chovohio and Metapona River systems, dissolved Arsenic concentrations across all riverine sites remain below the World Health Organisation guideline (<0.01 mg/l). From four sampling events over the past 18 months dissolved and total Arsenic trends have remained similar in Riverine sites. The most significant trend over time is the increase in Arsenic within the TSF from 0.03 mg/l over the 2014 and 2015 periods to 0.087 mg/L in February 2016 (Table 4, Figure 14). The likely source of this additional Arsenic is release from tailings sediments into the water column under low dissolved oxygen conditions.

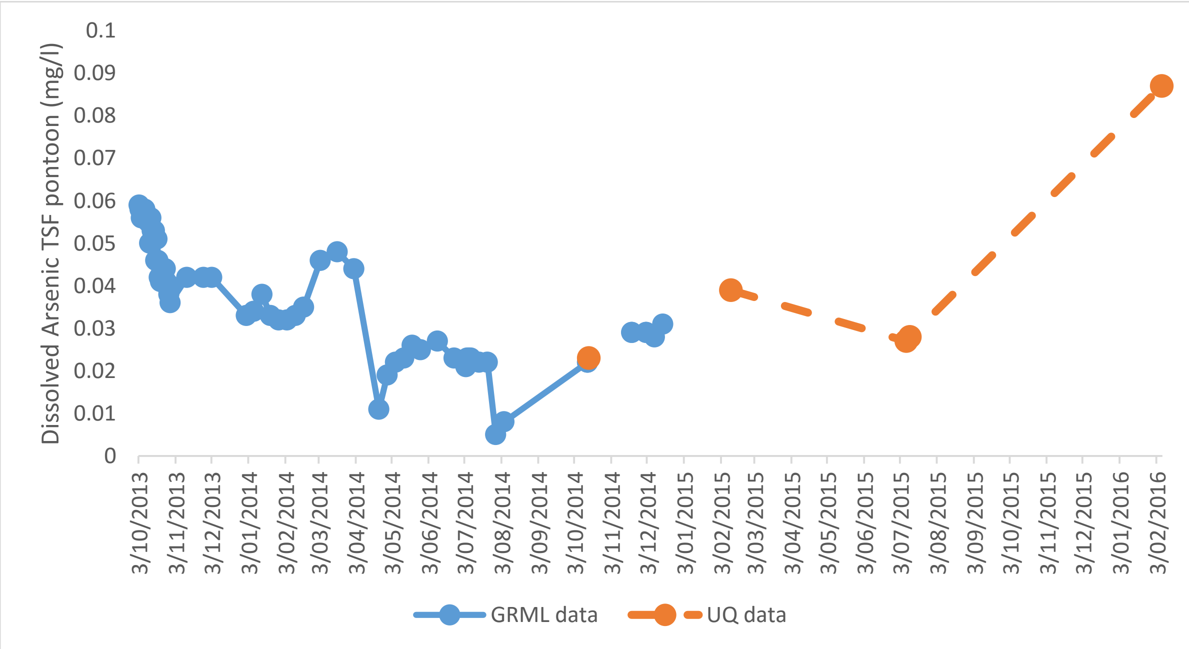

Figure 14: Dissolved Arsenic concentration in TSF (at inlet pipe adjacent to treatment plant) from October 2013 to February 2016

Table 4: Total and dissolved (Diss.) Arsenic concentrations (mg/L) in October 2014, February 2015, July 2015, February 2016. Orange highlight indicates total fraction above WHO guideline (0.01 mg/L), red highlight dissolved fraction above WHO guideline (0.01 mg/L). nd = no data

	October 2014		February 2015		July 2015		February 2016	
Site	Total	Diss.	Total	Diss.	Total	Diss.	Total	Diss.
Chovohio								
SIG0	0.11	0.018	0.137	0.010	0.141	0.009	0.102	0.009
SIG1	0.004	0.003	0.030	0.015	0.008	0.002	0.011	0.002
SIG2	0.013	0.01	0.034	0.009	0.008	0.005	0.016	0.006
SIG17	nd	nd	nd	nd	nd	nd	0.01	0.005
TSF/Kwara								
SIG3	nd	nd	0.041	0.040	0.025	0.030	0.089	0.086
SIG4	0.026	0.023	0.040	0.039	0.030	0.027	0.089	0.087
SIG4 3m	nd	nd	0.039	0.038	0.031	0.029	0.084	0.083
SIG5	nd	nd	nd	nd	nd	nd	0.018	0.017
SIG6	nd	nd	nd	nd	nd	nd	0.001	0.001
SIG9	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SIG11	nd	nd	nd	nd	0.001	<0.001	<0.001	<0.001
Tinahulu								
SIG7	0.002	0.001	0.002	0.002	0.001	<0.001	0.001	0.001
SIG8	0.002	0.001	0.002	0.002	0.001	<0.001	0.001	0.001
SIG18	nd	nd	nd	nd	nd	nd	0.001	0.001
SIG10	nd	nd	nd	nd	0.001	0.001	0.001	0.001
SIG12	nd	nd	nd	nd	0.002	0.001	0.002	0.001
Metapona								
SIG13	0.009	0.007	0.008	0.007	0.006	0.004	0.007	0.004
SIG14	0.008	0.005	0.008	0.007	0.005	0.004	0.01	0.004
SIG15	0.008	0.006	0.013	0.007	0.007	0.004	0.012	0.004
SIG16	0.007	0.005	<0.050	<0.025	0.009	0.007	0.017	0.005
Groundwater								
GW1	nd	nd	nd	nd	nd	nd	<0.001	<0.001
GW2	nd	nd	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
GW3	nd	nd	nd	nd	0.002	0.002	0.005	0.005
GW4	nd	nd	nd	nd	nd	nd	<0.001	<0.001
GW5	nd	nd	nd	nd	nd	nd	0.002	0.002

Aluminium

High concentrations of Aluminium are present attached to suspended sediments in the Chovohio River (2.09-5.74mg/l). Dissolved concentrations are lower (0.06-0.3 mg/l) in the Chovohio and moderate (0.29-0.72mg/L) in the Kwara and Metapona Rivers.

Table 5: Total and dissolved (Diss.) Aluminium concentrations (mg/L) in October 2014, February 2015, July 2015, February 2016. Orange highlight indicates total fraction above ANZEC 95% guideline (0.055 mg/L), red highlight dissolved fraction above ANZECC 95% guideline (0.055 mg/L). nd = no data

	October 2014		February 2015		July 2015		February 2016	
Site	Total	Diss.	Total	Diss.	Total	Diss.	Total	Diss.
Chovohio								
SIG0	1.26	0.04	17.1	0.09	17.6	0.14	5.74	0.09
SIG1	0.15	0.02	3.73	0.08	2.42	0.05	2.09	0.06
SIG2	1.22	0.07	5.81	0.06	0.72	0.02	2.48	0.07
SIG17	nd	nd	nd	nd	nd	nd	3.17	0.3
TSF/Kwara								
SIG3	nd	nd	0.07	<0.01	0.11	<0.01	0.35	0.01
SIG4	0.02	<0.01	0.06	<0.01	0.18	<0.01	0.05	<0.01
SIG5	nd	nd	nd	nd	nd	nd	0.1	0.01
SIG6	nd	nd	nd	nd	nd	nd	0.13	<0.01
SIG9	0.38	<0.01	0.18	0.01	0.88	0.04	1.38	0.72
SIG11	nd	nd	nd	nd	0.45	0.04	1.26	0.28
Tinahulu								
SIG7	2.84	0.02	0.17	0.01	0.52	<0.01	0.28	0.02
SIG8	1.03	0.03	0.16	0.01	0.58	<0.01	0.28	0.02
SIG18	nd	nd	nd	nd	nd	nd	0.19	0.02
SIG10	nd	nd	nd	nd	0.66	<0.01	1.93	0.05
SIG12	nd	nd	nd	nd	0.71	0.02	2.19	0.04
Metapona								
SIG13	1.97	0.02	0.74	0.02	1.53	<0.01	2.53	0.09
SIG14	1.89	0.02	0.94	0.31	1.27	0.04	4.42	0.29
SIG15	2.61	<0.01	1.16	0.02	1.63	0.02	7.89	0.34
SIG16	0.82	<0.01	<0.50	<0.25	2.03	<0.01	10.9	0.44
Groundwater								
GW1	nd	nd	nd	nd	nd	nd	0.01	<0.01
GW2	nd	nd	0.03	<0.01	0.01	<0.01	0.07	<0.01
GW3	nd	nd	nd	nd	0.01	<0.01	0.17	<0.01
GW4	nd	nd	nd	nd	nd	nd	0.06	<0.01
GW5	nd	nd	nd	nd	nd	nd	<0.01	<0.01

Antimony

Concentrations of Antimony were below detectable limits (<0.001 mg/l) across the majority of sites except for SIG 0, SIG 3 and SIG 4 (0.001 mg/l).

Table 6: Total and dissolved (Diss.) Aluminium concentrations (mg/L) in October 2014, February 2015, July 2015, February 2016. nd = no data

	October 2014		February 2015		July 2015		February 2016	
Site	Total	Diss.	Total	Diss.	Total	Diss.	Total	Diss.
Chovohio								
SIG0	0.002	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.001
SIG1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SIG2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SIG17	nd	nd	nd	nd	nd	nd	<0.001	<0.001
TSF/Kwara								
SIG3	nd	nd	0.003	0.003	0.001	0.001	0.001	0.001
SIG4	0.005	0.004	0.003	0.003	0.001	0.002	0.001	0.001
SIG5	nd	nd	nd	nd	nd	nd	<0.001	<0.001
SIG6	nd	nd	nd	nd	nd	nd	<0.001	<0.001
SIG9	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SIG11	nd	nd	nd	nd	<0.001	<0.001	<0.001	<0.001
Tinahulu								
SIG7	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SIG8	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SIG18	nd	nd	nd	nd	nd	nd	<0.001	<0.001
SIG10	nd	nd	nd	nd	<0.001	<0.001	<0.001	<0.001
SIG12	nd	nd	nd	nd	<0.001	<0.001	<0.001	<0.001
Metapona								
SIG13	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SIG14	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SIG15	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SIG16	<0.001	<0.001	<0.010	<0.010	<0.001	<0.001	<0.001	<0.001
Groundwater								
GW1	nd	nd	nd	nd	nd	nd	<0.001	<0.001
GW2	nd	nd	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
GW3	nd	nd	nd	nd	<0.001	<0.001	<0.001	<0.001
GW4	nd	nd	nd	nd	nd	nd	<0.001	<0.001
GW5	nd	nd	nd	nd	nd	nd	<0.001	<0.001

Copper

Total copper concentrations were highest at SIG 0 (0.028 mg/l) with moderate concentrations of 0.004-0.007 mg/l through the Chovohio River and mid-Metapona. Concentrations of total copper increased towards the mouth of the Metapona River. Dissolved copper across all riverine sites was <0.001 mg/l except the three lower Metapona sites with 0.002 mg/l. The majority of copper within the TSF was in the dissolved form with four times the ANZECC guideline detected at SIG 4 (0.006 mg/l).

Table 7: Total and dissolved (Diss.) Copper concentrations (mg/L) in October 2014, February 2015, July 2015, February 2016. Orange highlight indicates total fraction above ANZECC 95% guideline (0.0014 mg/L), red highlight dissolved fraction above ANZECC 95% guideline (0.0014 mg/L). nd = no data

	October 2014		February 2015		July 2015		February 2016	
Site	Total	Diss.	Total	Diss.	Total	Diss.	Total	Diss.
Chovohio								
SIG0	0.01	<0.001	0.074	<0.001	0.079	<0.001	0.028	<0.001
SIG1	0.001	<0.001	0.016	<0.001	0.007	<0.001	0.004	<0.001
SIG2	0.004	<0.001	0.017	<0.001	0.002	<0.001	0.006	<0.001
SIG17	nd	nd	nd	nd	nd	nd	0.007	0.001
TSF/Kwara								
SIG3	nd	nd	0.009	0.007	0.012	0.008	0.008	0.005
SIG4	0.013	0.01	0.008	0.007	0.012	0.007	0.007	0.006
SIG4 3m	nd	nd	0.01	0.007	0.014	0.008	0.008	0.005
SIG5	nd	nd	nd	nd	nd	nd	0.002	0.002
SIG6	nd	nd	nd	nd	nd	nd	<0.001	<0.001
SIG9	0.003	0.001	<0.001	<0.001	0.002	<0.001	0.003	0.002
SIG11	nd	nd	nd	nd	0.001	<0.001	0.003	0.002
Tinahulu								
SIG7	0.008	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
SIG8	0.004	0.002	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
SIG18	nd	nd	nd	nd	nd	nd	<0.001	<0.001
SIG10	nd	nd	nd	nd	0.002	<0.001	0.004	<0.001
SIG12	nd	nd	nd	nd	0.002	<0.001	0.005	<0.001
Metapona								
SIG13	0.008	0.001	0.002	<0.001	0.004	<0.001	0.006	<0.001
SIG14	0.007	<0.001	0.003	0.002	0.004	<0.001	0.013	0.002
SIG15	0.01	<0.001	0.003	<0.001	0.005	<0.001	0.018	0.002
SIG16	0.005	<0.001	<0.050	<0.025	0.006	0.001	0.024	0.002
Groundwater								
GW1	nd	nd	nd	nd	nd	nd	0.002	0.002
GW2	nd	nd	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
GW3	nd	nd	nd	nd	0.002	0.001	<0.001	<0.001
GW4	nd	nd	nd	nd	nd	nd	<0.001	0.001
GW5	nd	nd	nd	nd	nd	nd	<0.001	<0.001

Lead

Total lead concentrations were below the ANZECC guideline (0.034 mg/l) across all sites except SIG 4 in February 2016. No dissolved lead was detected at any of the sampling sites. The high total lead (0.081 mg/l) within the TSF highlights the importance of maintaining low turbidity levels during dewatering activities.

Table 8: Total and dissolved (Diss.) Lead concentrations (mg/L) in October 2014, February 2015, July 2015, February 2016. Orange highlight indicates total fraction above ANZECC 95% guideline (0.034 mg/L), red highlight dissolved fraction above ANZECC 95% guideline (0.034 mg/L). nd = no data

	October 2014		February 2015		July 2015		February 2016	
Site	Total	Diss.	Total	Diss.	Total	Diss.	Total	Diss.
Chovohio								
SIG0	0.002	<0.001	0.02	<0.001	0.032	<0.001	0.009	<0.001
SIG1	<0.001	<0.001	0.005	<0.001	0.004	<0.001	0.001	<0.001
SIG2	<0.001	<0.001	0.005	<0.001	0.089	0.016	0.001	<0.001
SIG17	nd	nd	nd	nd	nd	nd	0.008	<0.001
TSF/Kwara								
SIG3	nd	nd	<0.001	<0.001	0.007	<0.001	<0.001	<0.001
SIG4	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	0.081	<0.001
SIG4 3m	nd	nd	<0.001	<0.001	0.054	<0.001	<0.001	<0.001
SIG5	nd	nd	nd	nd	nd	nd	0.029	<0.001
SIG6	nd	nd	nd	nd	nd	nd	<0.001	<0.001
SIG9	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SIG11	nd	nd	nd	nd	0.188	<0.001	<0.001	<0.001
Tinahulu								
SIG7	<0.001	<0.001	0.002	<0.001	0.001	<0.001	<0.001	<0.001
SIG8	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SIG18	nd	nd	nd	nd	nd	nd	0.002	<0.001
SIG10	nd	nd	nd	nd	0.001	<0.001	<0.001	<0.001
SIG12	nd	nd	nd	nd	<0.001	<0.001	<0.001	<0.001
Metapona								
SIG13	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001
SIG14	<0.001	<0.001	0.001	0.002	0.002	<0.001	<0.001	<0.001
SIG15	<0.001	<0.001	<0.001	<0.001	0.006	<0.001	0.002	<0.001
SIG16	<0.001	<0.001	<0.010	<0.010	<0.001	<0.001	0.002	<0.001
Groundwater								
GW1	nd	nd	nd	nd	nd	nd	<0.001	<0.001
GW2	nd	nd	<0.001	<0.001	0.036	<0.001	<0.001	<0.001
GW3	nd	nd	nd	nd	<0.001	<0.001	<0.001	<0.001
GW4	nd	nd	nd	nd	nd	nd	<0.001	<0.001
GW5	nd	nd	nd	nd	nd	nd	<0.001	<0.001

Nickel

Both total and dissolved Nickel concentrations were below ANZECC guidelines at all sites in February 2016.

Table 9: Total and dissolved (Diss.) Nickel concentrations (mg/L) in October 2014, February 2015, July 2015, February 2016. Orange highlight indicates total fraction above ANZECC 95% guideline (0.011 mg/L), red highlight dissolved fraction above ANZECC 95% guideline (0.011 mg/L). nd = no data

	October 2014		February 2015		July 2015		February 2016	
Site	Total	Diss.	Total	Diss.	Total	Diss.	Total	Diss.
Chovohio								
SIG0	0.003	<0.001	0.031	<0.001	0.024	<0.001	0.008	<0.001
SIG1	<0.001	<0.001	0.004	<0.001	0.002	<0.001	0.001	<0.001
SIG2	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	0.001	<0.001
SIG17	nd	nd	nd	nd	nd	nd	0.004	<0.001
TSF/Kwara								
SIG3	nd	nd	0.004	0.004	0.003	0.004	0.003	0.002
SIG4	0.009	0.007	0.004	0.004	0.004	0.003	0.002	0.002
SIG4 3m	nd	nd	0.005	0.004	0.004	0.003	0.002	0.002
SIG5	nd	nd	nd	nd	nd	nd	<0.001	0.001
SIG6	nd	nd	nd	nd	nd	nd	0.002	0.001
SIG9	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
SIG11	nd	nd	nd	nd	<0.001	<0.001	0.002	<0.001
Tinahulu								
SIG7	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SIG8	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SIG18	nd	nd	nd	nd	nd	nd	<0.001	<0.001
SIG10	nd	nd	nd	nd	<0.001	<0.001	0.001	<0.001
SIG12	nd	nd	nd	nd	<0.001	<0.001	0.002	<0.001
Metapona								
SIG13	0.003	<0.001	<0.001	<0.001	0.001	<0.001	0.003	<0.001
SIG14	0.002	<0.001	0.002	<0.001	0.002	<0.001	0.005	<0.001
SIG15	0.003	<0.001	0.001	<0.001	0.002	<0.001	0.01	<0.001
SIG16	0.001	<0.001	<0.050	<0.025	0.003	<0.001	0.014	<0.001
Groundwater								
GW1	nd	nd	nd	nd	nd	nd	0.007	0.007
GW2	nd	nd	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
GW3	nd	nd	nd	nd	<0.001	<0.001	<0.001	<0.001
GW4	nd	nd	nd	nd	nd	nd	<0.001	<0.001
GW5	nd	nd	nd	nd	nd	nd	<0.001	<0.001

Cyanide

All forms of Cyanide (Total, Free, weak-acid dissociable) were below the levels of detection (<0.004 mg/L) in all sites except for the TSF sump (SIG 6). The TSF sump contained 0.027 mg/L of total cyanide, 0.021 mg/L of free cyanide and 0.019 mg/L of weak acid dissociable cyanide. These concentrations of free cyanide are over 2.5 time the ANZECC 95% protection level for freshwater fauna (0.007 mg/L). The cyanide present within the TSF sump is likely seeping from the tailings sediment at base of TSF, underneath the TSF embankment and into the sump. Given the unprecedented high water level within the TSF and added pressure a further investigation of the flow rates of water into the TSF sump should be conducted.

Discharge rates

The discharge rates of each section of river varies considerably, with the Chovohio providing the highest contribution (15.2 m^3/s at SIG17) to the Metapoana system. The Tinahulu had a discharge of 4.9 m^3/s at the TSF discharge point below the brige and 8.2 m^3/s at SIG 12 prior to confluence with Chovohio. The Kwara River had a discharge of only 0.6 m^3/s at SIG 11 prior to its confuence with Tinahulu making it particulary suceptible to any large increases in discharge from overtopping of the TSF spillway. The Metapona River discharge ranged from 14.2 m^3/s in the mid-Metapona at SIG13 to 28.2 m^3/s at the river mouth at SIG 16 (Figure 15). These discharges in February 2016 could be considered typical for February and are slightly lower than the mean for February in 2011 from GRML data (Table 10).

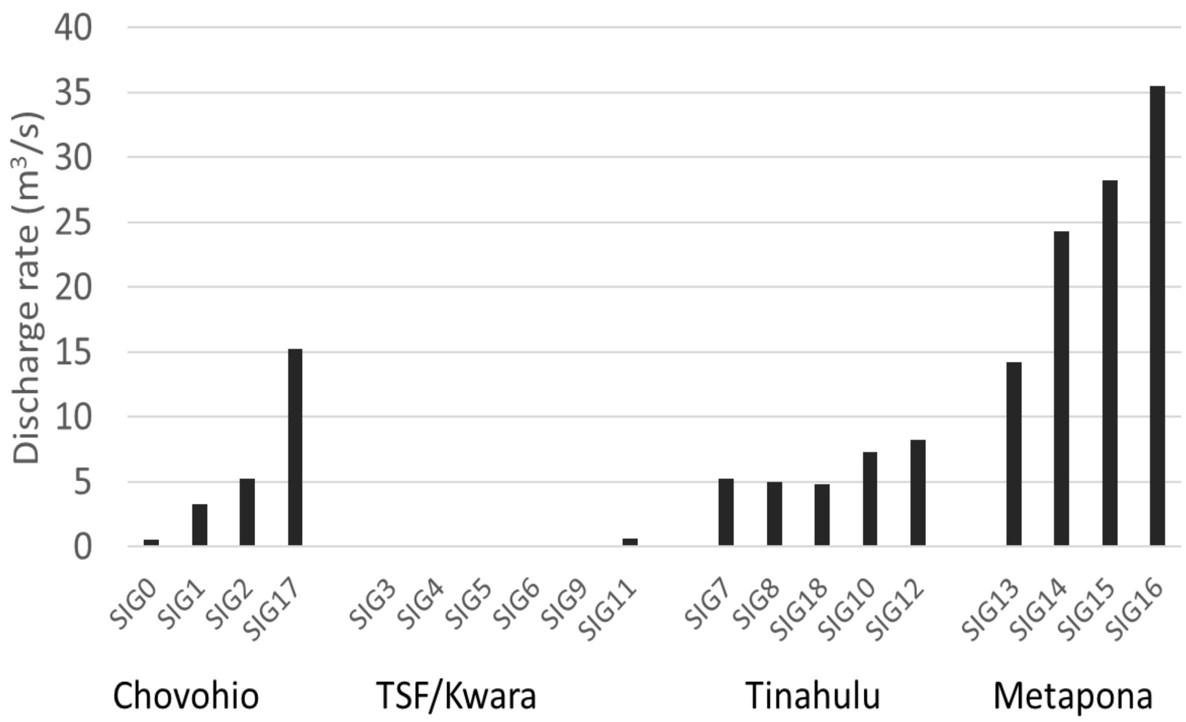

Figure 15: Discharge rate of rivers

Table 10: Discharge rates for Tinahulu river in 2011 (GRML data)

		2011 Tinahulu discharge (m^3/s)		
Month	**Number of records**	**Maximum**	**Minimum**	**Average**
Jan	6,010	91.21	0.47	2.48
Feb	4,351	105.19	0.58	7.09
March	5,651	10.96	0.88	1.70
April	2,925	7.79	0.85	1.50
May	2,401	50.22	0.68	3.61
June	796	1.73	0.21	0.47
July	9,792	4.59	0.08	0.32
Total	**31,926**	**105.19**	**0.08**	**2.23**

Variations with rainfall events

Whilst a focus of water quality monitoring programs and guidelines is often on the concentration of contaminants and metals within river systems, the parameter that varies most in tropical systems is stream discharge. In 2011 average discharge rates of the Tinahulu river measured by GRML varied 0.32 m^3/s in July to 7.09 $m^3/2$ in February with peak flows of over 100 m^3/s recorded. These high low events can dominate the loading of elements such as Arsenic and Copper into the ecosystem from both flood borne sediments deposited onto garden areas and flood plumes transported into marine environments. The time lapse camera installed on the Metapona River at SIG14 captured this variability in December 2015 (Figure 16).

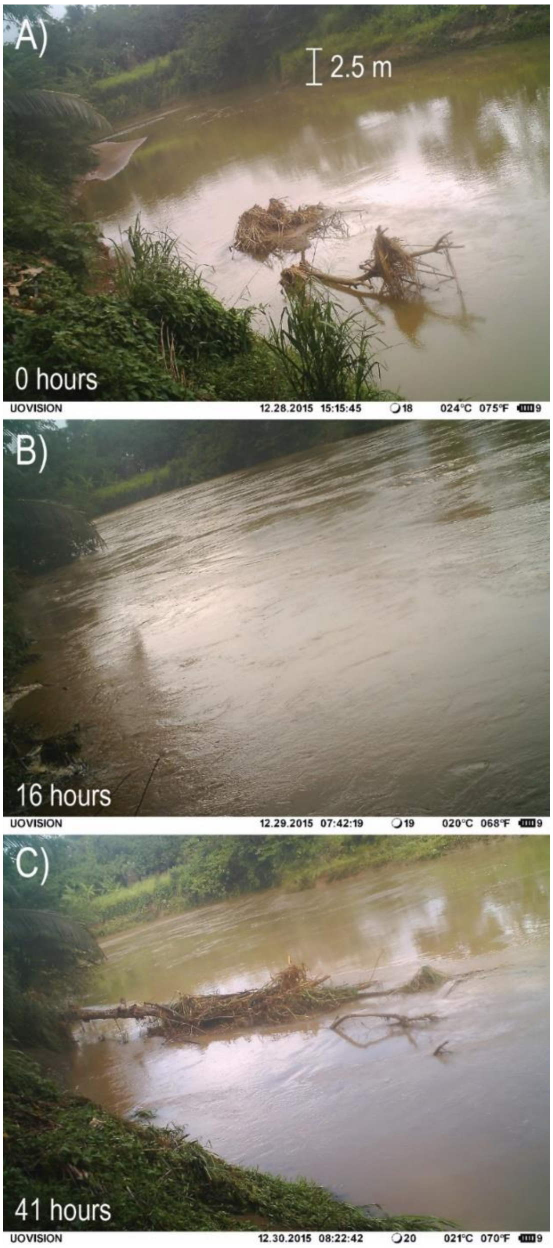

Figure 16: Time-lapse imagery of rapid variations in water level during flood of Metapona River (SIG13)

Load of pollutants

The loads of various elements delivered from each section of the river system can be assessed by multiplying the concentration by flow rate to yield load on a kilogram per day basis. This approach highlights that although the flow rate of the Chovohio catchment is only double the Tinahulu, the suspended sediment load of the Chovohio is almost four-fold the Tinahulu with 60 tonnes of suspended sediment delivered from Chovohio into the Metapona River per day. Consequently, the Metapona River is exporting over 95 tonnes of suspended sediment per day into the marine environment. Likewise, the Chovohio River is delivering over 13 kilograms of Arsenic into the Metapona River daily with 4.6 kilograms of this sourced from the Charivunga river system as a result of artisanal panning and mine site runoff. The load of Arsenic and Copper from treated dewatering would be 220 g and 20 g per day respectively assuming discharge rates of 500 m^3/hr (Table 11).

Table 11: Load of suspended sediment, copper and arsenic from the 5 main components of the Metapona River system and the proposed dewatering from discharge pond

		Concentration (mg/L)			Load kg/day		
	Flow rate (m3/s)	Suspended sediment	Copper (total)	Arsenic (total)	Suspended sediment	Copper (total)	Arsenic (total)
Charivunga	**0.52**	**298**	**0.028**	**0.102**	**13,451**	**1.26**	**4.60**
Chovohio	**15.23**	**46**	**0.007**	**0.010**	**60,538**	**9.21**	**13.16**
Kwara	**0.63**	**13**	**0.003**	**0.0005**	**704**	**0.16**	**0.03**
Tinahulu	**8.19**	**23**	**0.005**	**0.002**	**16,274**	**3.54**	**1.42**
Metapona	**28.25**	**39**	**0.018**	**0.012**	**95,179**	**43.93**	**29.29**
Dewatering	**0.14**	**9**	**0.002**	**0.018**	**109**	**0.02**	**0.22**

Sediment quality

Sediment Metals

Sediment metal content varied greatly between different river systems, with the Chovohio/Charivunga river sites containing relatively high arsenic, copper, lead and antimony compared with sediments from the Kwara and Tinahula river sites (Table 12). The Chovohio/Charivunga river sites containing relatively low sediment aluminium compared with sediments from the Kwara and Tinahula river sites. The metal content of sediments in the lower Metapona River reflected loading from all upstream catchments with aluminium, arsenic, copper, lead and antimony values lying between those found in the upper catchment. Sediment arsenic and copper content exceed trigger levels in the Chovohio/Charivunga and Metapona River sites, whilst trigger levels for nickel were exceeded in all river systems (Table 12).

The arsenic, copper, nickel, lead, antinomy and cyanide content of sediment tailings were highly elevated relative to all the sediment from all other river systems. Trigger values for arsenic copper, nickel, antimony and cyanide were exceeded in sediment tailings. This pattern of elevated sediment arsenic, copper, nickel, lead, antinomy and cyanide content was reflected in the surface and deeper tailings' layers in both deep cores collected to date. Of concern is the highly enriched arsenic content of the tailings, these were between 15 and almost 100 times the trigger levels. Any discharges from the tailings storage facility should ensure no tailings' sediments are released. In addition, the relatively high sediment arsenic content can be remineralised into soluble forms of arsenic and then be released into the tailings surface waters, particularly during times of water column stratification. The elevated cyanide content is of interest as the tailings storage facility sump was the only surface water site where cyanide was detected. This suggests that sediment porewaters may be diffusing through the tailings main wall and enriching the downstream surface waters.

Table 12: Total sediment metal and cyanide content from river and tailings storage facility (TSF) sites. Units for all parameters are all mg kg^{-1}. Red highlight indicates value above guideline trigger level: Arsenic 20 mg kg^{-1}; Copper 65 mg kg^{-1}; Nickel 21 mg kg^{-1}; Lead 50 mg kg^{-1}; Antimony 2 mg kg^{-1}; Total Cyanide (CN) 50 mg kg^{-1}. nd = no data. Please note historical TSF samples are included from February 2015.

Site	Aluminium mg/kg	Arsenic mg/kg	Copper mg/kg	Nickel mg/kg	Lead mg/kg	Antimony mg/kg	Total CN mg/kg
Chovohio							
SIG0	11 900	265	90	26.6	15.1	1.6	<1
SIG1	12 300	179	80.8	18	14.9	0.9	<1
SIG2	10 800	182	65.5	20.5	9.8	1.3	<1
SIG17	17 500	40.9	38.4	27.1	2.9	0.3	<1
TSF/Kwara							
SIG3	31 000	10	64.9	72.3	3	<0.1	<1
SIG4	18 100	3.8	43.4	19.1	1.2	<0.1	<1
SIG5	31 000	4.7	64.7	31	2.4	<0.1	<1
SIG6	46 400	9.3	79	59.1	2.8	<0.1	<1
SIG9	25 300	2.7	41	31	2.4	<0.1	<1
SIG11	31 900	5.3	61.9	30.5	1.7	<0.1	<1
Tinahulu							
SIG7	20 300	4.5	39.3	21.4	1.3	<0.1	<1
SIG8	22 200	4	38.3	19	1.1	<0.1	<1
SIG18	24 000	6.7	42.9	18.4	1.1	<0.1	<1
SIG10	14 300	2.2	26.4	17.1	0.9	<0.1	<1
SIG12	25 800	3.6	42.5	23.2	1.3	<0.1	<1
Metapona							
SIG13	19 800	20.8	36.4	24.4	2.1	0.2	<1
SIG14	33 100	6.4	55	41.3	1.7	<0.1	<1
SIG15	34 200	43.9	71.4	39.4	4.2	0.2	<1
SIG16	20 400	10.2	26.6	42.7	1.3	<0.1	<1
TSF sediment core and deep sediments							
Core DC1 0 m	8 050	353	101	24.5	11.5	nd	8
Core DC2 1.5 m	6 880	1 160	118	27.7	24.9	6.4	24
Core DC3 3 m	4 730	939	85.7	28.4	27.5	6.5	15
Core Feb 15 0 m	10 800	377	107	23.2	12.6	2.8	63
Core Feb 15 1.2 m	6 260	1 940	81.4	24.3	16.3	11.6	70
Deep Feb 15	11 100	308	89.4	26.4	19.3	2.4	5

Sediment particle size and composition

Both sediment particle size and composition varied across all sites monitored, with the sediments of Chovohio/Charivunga and Kwara River sites containing smaller particles and higher mud content compared with the Tinahula River sites. This may be a reflection of the relatively unimpacted nature of the Tinuhula River catchment where there has been minimal disturbance surface disturbance due to industrial or informal mining practices.

Table 13: Particle size and % mud, sand, gravel of the riverbed sediments at each site

System	Site	Fine sediment particle size (µm)			Sediment composition		
		D10%	D50%	D90%	Mud (%)	Sand (%)	Gravel (%)
Chovohio	SIG0	3.2	86.4	391.5	38.0	48.1	13.9
	SIG1	6.9	331.2	742.4	24.3	66.0	9.8
	SIG2	12.2	357.4	723.8	17.5	76.9	5.6
	SIG17	164.2	300.0	491.0	5.5	94.5	0.0
TSF/Kwara	SIG3	1.5	10.4	46.9	94.9	5.1	0.0
	SIG4	2.3	15.2	69.6	88.2	11.8	0.0
	SIG5	1.6	9.1	60.8	90.5	9.5	0.0
	SIG6	2.5	17.2	133	78.2	21.8	0.0
	SIG9	2.6	21.5	363.3	67.2	32.8	0.0
	SIG11	3.3	34.6	134.1	67.2	32.8	0.0
Tinahulu	SIG7	59.9	220.5	455.5	10.4	89.6	0.0
	SIG8	200.9	460.2	777.1	3.6	50.5	45.9
	SIG18	95.2	324.9	597.2	9.1	90.9	0.0
	SIG10	213.9	367.1	624.9	0.0	100.0	0.0
	SIG12	70.6	191.9	384.1	9.0	91.0	0.0
Metapona	SIG13	2.0	16.6	186.8	76.1	23.9	0.0
	SIG14	4.9	77.3	324.7	45.3	54.7	0.0
	SIG15	4.2	53.6	147.7	55.9	44.1	0.0
	SIG16	154.2	327.5	591.0	5.4	94.6	0.0

The lower Metapona River sediments contained relatively small particles and high mud content with the exception of the river mouth site (SIG16). It is likely the highly dynamic nature of water flow at this particular site, with wave energy, tidal and river inflow currents, results in continual resuspension of smaller sediment particles. Evidence to support this is the relatively high water column turbidity values found at this site.

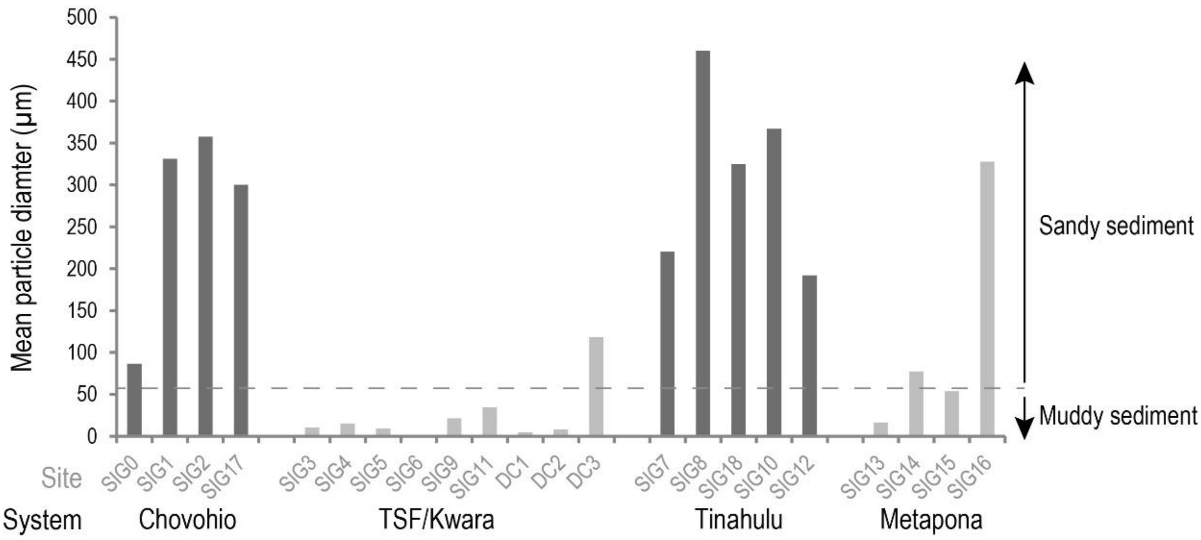

Figure 17: Mean particle size of riverbed sediments

Tailings' sediments were dominated by small particles in the upper layers with relatively larger particles and higher sand content found in the deepest layer measured. The prevalence of small particles especially in the surface sediment layers is of concern as these would be the most likely to be released during discharges and would be able to travel large distances as the particle settling rates would relatively slow (< 1 m d^{-1}). Moisture content reduced and bulk density increased through the sediment core, from the surface to deeper layers, as tailings from deeper depths are compressed by overlying materiel.

Table 14: Particle size, composition, moisture content and bulk density of the surface, 1.5m down and 3m down in a core taken from TSF

Label	Core Depth (m)	Sediment particle size (µm)			Sediment composition			Moisture Content (%)	Bulk density ($g\ cm^{-3}$)
		D10%	D50%	D90%	Mud (%)	Sand (%)	Gravel (%)		
DC1	0	1.0	4.9	91.9	86.8	13.2	0	33.2	0.9
DC2	1.5	1.1	8.0	111.4	82.8	17.2	0	31.1	1.0
DC3	3	2.3	118.4	405.6	39.2	60.8	0	25.1	1.2

Tailings Storage Facility

The high water level within the Gold Ridge Tailings Storage Facility has been one of the key drivers of concern for the Solomon Islands Government, downstream communities and international agencies. The drivers of water level within the TSF are a complex interaction between mine operations (tailings input, return water re-use), hydrology (rainfall, evaporation, seepage, catchment run-off), TSF volume (tailings sediment level) and dewatering. Whilst the mine was non-operational between 2000 and 2009 there was a steady increase in the TSF water level due to rainfall. In 2010, prior to mining operations starting, a dewatering program was conducted to lower the TSF water level down to 39 m RL. During the 2011-2013 period the mine was operating with significant volume of tailings introduced into the TSF, this combined with rainfall led to a rapid increase in TSF water levels to over 50 m RL. To compound these high water levels a series of low pressure systems and cyclones in 2013 delivered significant volumes of rainfall to the TSF catchment. In response to this a treated dewatering process was initiated in late 2013 and water levels were briefly dropped below 50 m RL (Figure 18). However, an unprecedented rainfall event of >1000 mm of rain in 4 days in early April 2014 led to a series of events including the company abandoning the management of TSF, and a rise in water levels to over 51 m RL and eventual sale of Gold Ridge Mining Limited to a local landowner company (GCIL). Whilst the April 2014 rainfall was the trigger for these events and the current state of critically high TSF water levels, the underlying drivers are related to the significant volume of tailings introduced to TSF from 2011-2014, the lack of dewatering and minimal re-use of supernatant between 2011-2013, and the failure to raise the main TSF embankment in sync with the lost dam volume due to tailings output (as per original design). Following heavy rain in February 2016 the water level within the TSF reached 52.189 m RL, less than 20 mm from the lowest point on spillway (Figure 19). Whilst there has been no overflow of TSF waters over spillway to date, treated dewatering of the TSF waters will be required in the short-term to prevent an uncontrolled release of TSF water over the spillway into Kwara River. Whilst dewatering represents an important short-term solution, medium to long term consideration should be given to either raising the main embankment or decommissioning and rehabilitation of the dam.

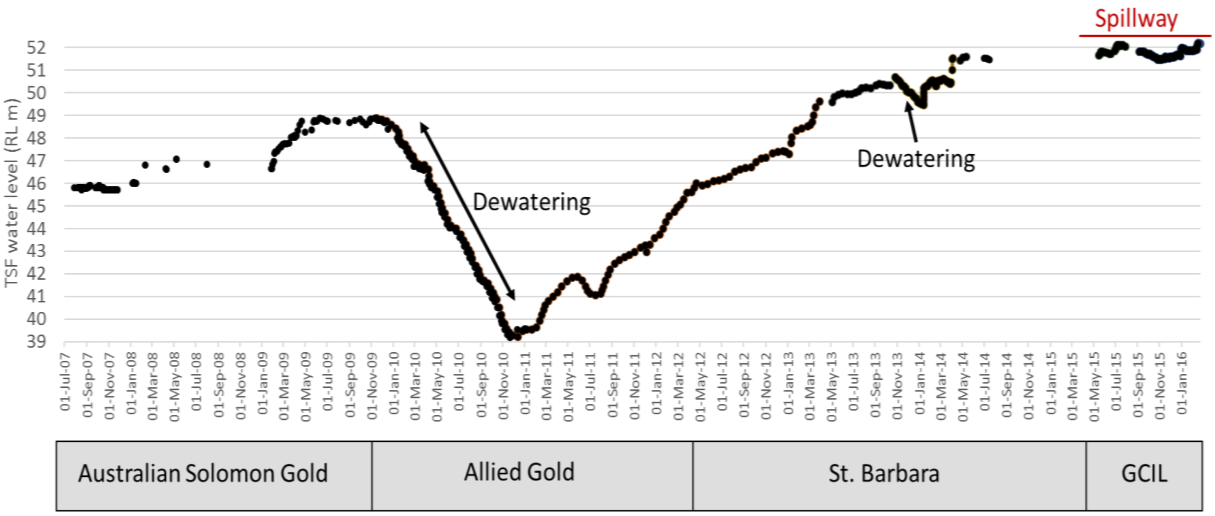

Figure 18: Water level in Tailings Storage Facility from July 2007 to February 2016 with ownership of Gold Ridge Mine over time indicated below graph

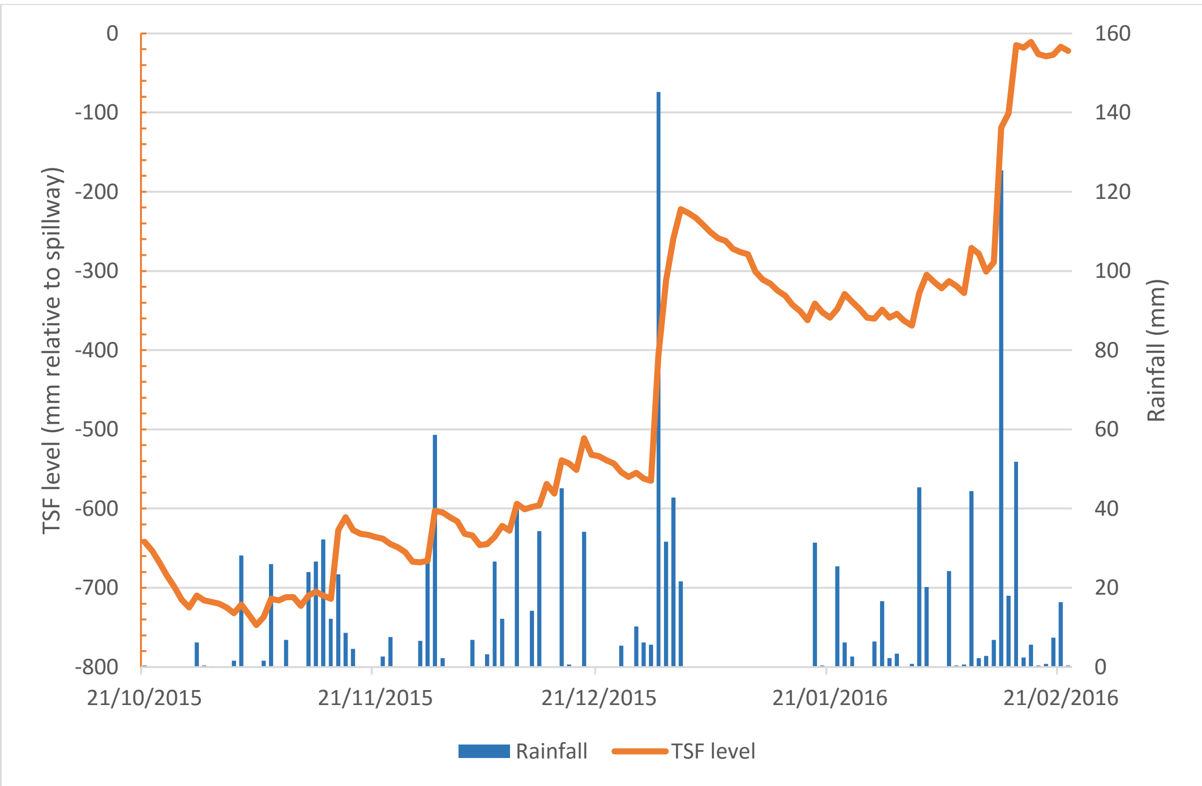

Figure 19: Rainfall and TSF water level (relative to spillway) from October 2015 to February 2016

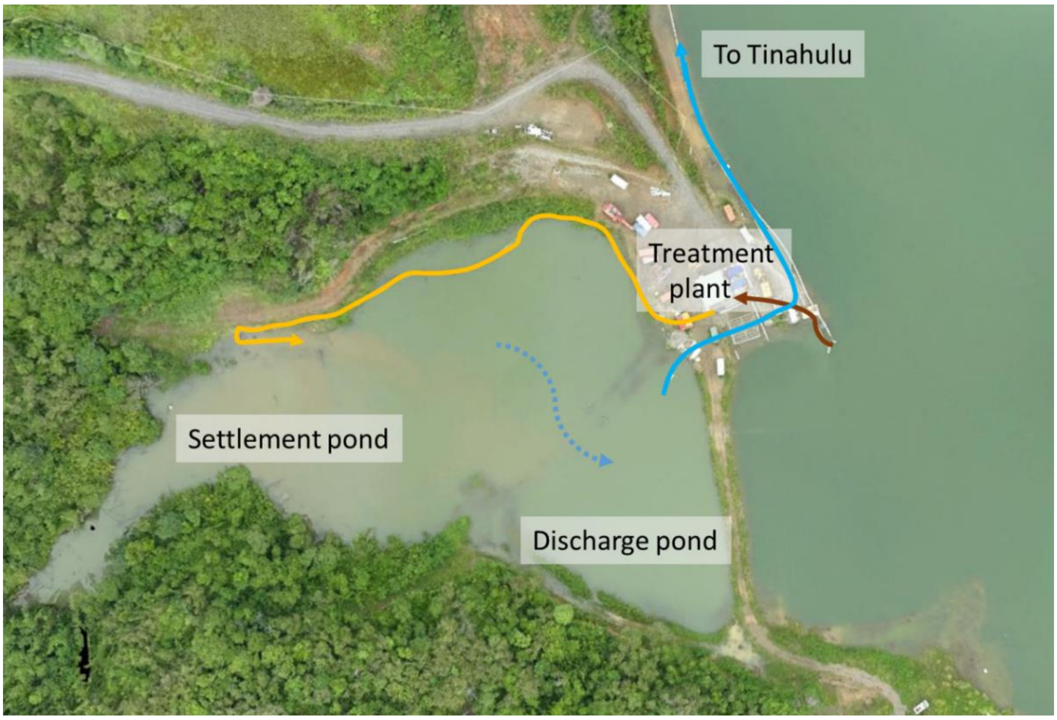

Figure 20: Aerial image of TSF treatment ponds February 13 2016 with schematics of treatment and discharge process indicated

Microbiology

E.coli

Concentrations of E. coli cells were high (>100 cells per 100 ml) across all riverine sites. Two of the shallow groundwater wells (GW1 and GW2) also had relatively high concentrations of E. coli (Figure 21). However, the holding time between collection of samples and laboratory analysis was >48 hrs for the majority of samples and is likely to have resulted in an overestimation of cell counts.

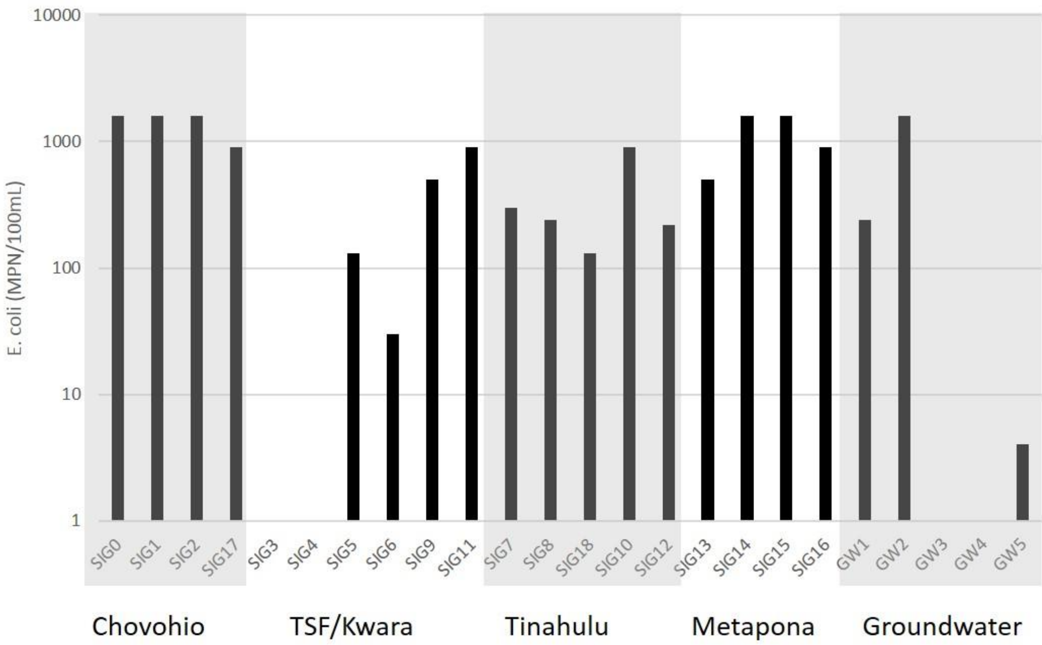

Figure 21: *E.coli* (cells per 100 mL) in river and groundwater samples

Biochemical oxygen demand

The relatively low biochemical oxygen demand suggests there is relatively limited biodegradable organic matter across all sites monitored. Biochemical oxygen demand values less than 1 mg/l are considered healthy natural water bodies. The negative values detected are effectively 0 and are considered to be within the error range of the method (±0.3 mg/l).

Table 15: Biochemical oxygen demand of the major areas within Metapona River system

	BOD (mg/L)
Chovohio (SIG17)	-0.03
Discharge Pond (SIG5)	0.13
Metapona (SIG14)	-0.07
TSF (SIG4)	-0.11
Coastal (SIG16)	-0.28
Tinahulu (SIG8)	-0.24

Aquatic ecology

Terrestrial vertebrates and invertebrates

A total of 6 species of dragonflies were recorded. Most were recorded at SIG2, below Obobo village (Table 16). Our surveys recorded a lower number of around the TSF and the Kwara River than would be expected in similar disturbed habitats, and from similar past surveys in Solomon Islands (Milen and Pikacha 2013).

Table 16: Presence (green highlight) of dragonfly species at each site

		Chovohio				TSF/Kwara						Tinahulu					Metapona			
Common name	**Scientific name**	**0**	**1**	**2**	**17**	**3**	**4**	**5**	**6**	**9**	**11**	**7**	**8**	**18**	**10**	**12**	**13**	**14**	**15**	**16**
Dragonfly	*Agrionoptera insignis similis*					■	■		■									■		
Dragonfly	*Neurothemis stigmatizans bramina*			■					■											
Dragonfly	*Nososticta salomonis*			■																
Dragonfly	*Orthetrum villosovittatum*			■																
Dragonfly	*Rhinocypha liberata*			■																
Dragonfly	*Tapeinothemis boharti*			■																

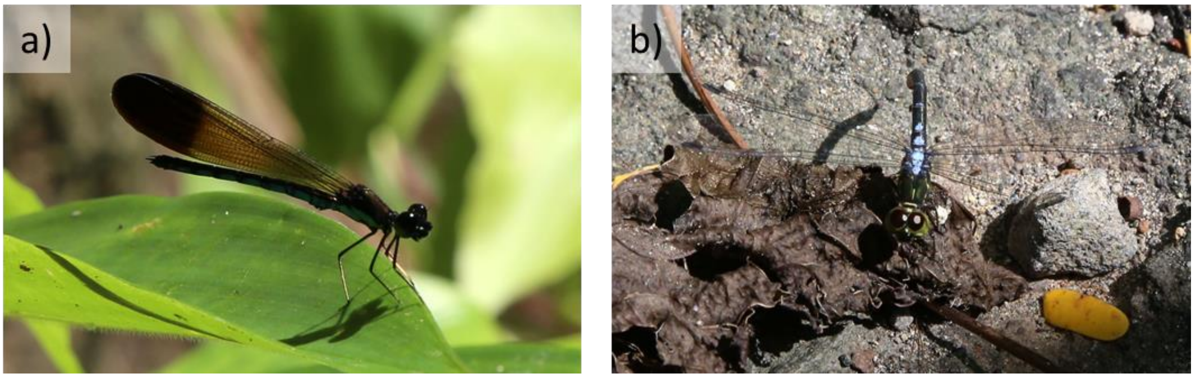

Figure 22: Two dragonfly species (a) Rhinocypha liberata and (b) Tapeinothemis boharti

Three species of frogs and reptiles were recorded at these sites. The cane toad was recorded in most sites (Table 17). These thrive in extremely disturbed areas. The other two were skinks, and recorded along the river's edge. Both species *E. cynura*, and *E. nigra* are common lizards of highly disturbed areas, and in villages.

Table 17: Presence (green highlight) of reptile species at each site

		Chovohio				TSF/Kwara						Tinahulu					Metapona			
Common name	**Scientific name**	0	1	2	17	3	4	5	6	9	11	7	8	18	10	12	13	14	15	16
Brown-Tailed Copper-Striped Skink	*Emoia cyanura*					(green)					(green)				(green)					
Pacific Black Skink	*Emoia nigra*										(green)				(green)					
Cane Toad	*Rhinella marinus*			(green)		(green)			(green)	(green)	(green)	(green)		(green)	(green)	(green)		(green)	(green)	(green)

Figure 23: Brown-Tailed Copper-Striped Skink (Emoia nigra)

Twenty species of birds were recorded (Table 18). Most were recorded along the river mouth of the Metapona, and several forest birds were recorded at SIG2. Birds identified are typical of open and disturbed habitats (Dutson 2011). Open areas and grasslands recorded much lower diversity. The Willie Wagtail (*Rhipidura leucophrys*) and Olive-backed Sunbird (*Cinnyrus jugularis*)were common birds of open and disturbed areas. Survey time generally took place during the mid-morning (10am) to mid- afternoon (3pm). It is likely other passerines and transient forest birds would be recorded at dawn, particularly at forests edges like site SIG2.

Table 18: Presence (green highlight) of bird species at each site

		Chovohio				TSF/Kwara						Tinahulu					Metapona			
Common name	**Scientific name**	**0**	**1**	**2**	**17**	**3**	**4**	**5**	**6**	**9**	**11**	**7**	**8**	**18**	**10**	**12**	**13**	**14**	**15**	**16**
Pacific Black Duck	*Anas superciliosa*																			
Metallic Starling	*Aplonis metallica nitida*																			
Buff-headed Coucal	*Centropus milo*																			
Olive-backed Sunbird	*Cinnyrus jugularis*																			
Cardinal lories	*Chalcopsitta cardinalis*																			
White-bellied Cuckooshrike	*Coracina papuensis*																			
Glossy swiftlet	*Collocalia esculenta*																			
White-billed crow	*Corvus woodfordi*																			
Island Imperial Pigeon	*Ducula pistrinaria*																			
Eclectus Parrot	*Eclectus roratus*																			
Pacific reef heron	*Egretta sacra*																			
Brahminy Kite	*Haliastur indus girrenera*																			
Solomons Sea Eagle	*Haliastur sandfordi*																			
Little pied cormorant	*Microcarbo melanoleucos*																			
Long-tailed Myna	*Mino kreffti*																			
Eastern Osprey	*Pandion cristatus*																			
Little pied cormorant	*Phalacrocorax carbo*																			
Pacific Golden Plover	*Pluvialis fulva*																			
Willie Wagtail	*Rhipidura leucophrys*																			
Coconut Lorikeet	*Trichoglossus haematodus*																			

Macroinvertebrates

A total of 792 invertebrates were collected from 19 surveyed sites. These were comprised of 41 species across 12 orders of aquatic macroinvertebrates. Overall the diversity of macroinvertebrates within the Gold Ridge area is rather low. The Metapona River (SIG13-16) had the highest abundance of Decapoda (crayfish, crabs, shrimps) of which some are edible species. The tailings storage facility did not contain any crustaceans or mayflies which are susceptible to poor water quality. One species of gastropod (*Thiara amarula*) has a defensive spine that can become lodged in humans stepping on it or handling it, causing pain and irritation.

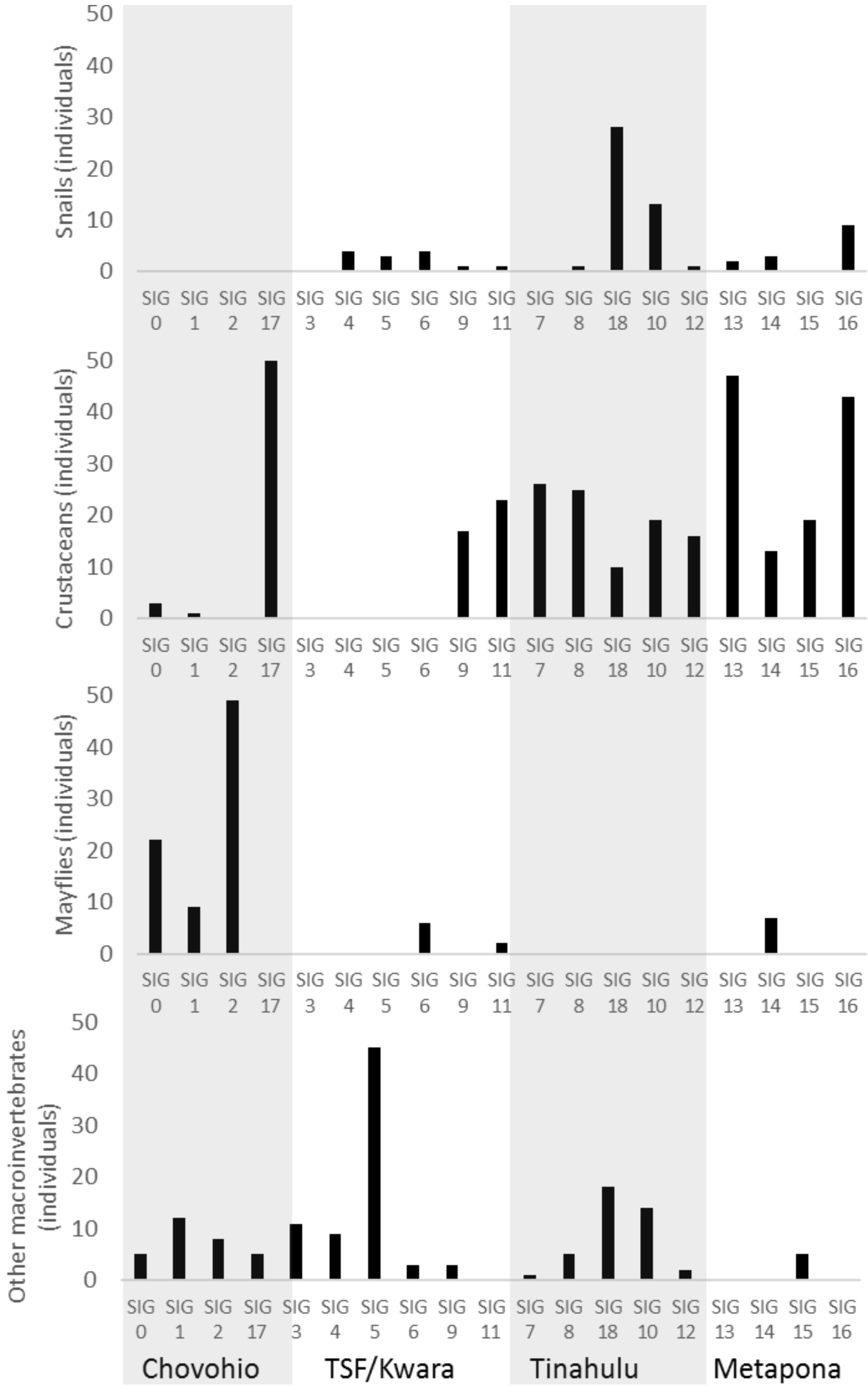

Figure 24: Abundance of macroinvertebrates at each sampling site

Table 19: Abundance of macroinvertebrate species identified microscopically

			Chovohio				**TSF/Kwara**						**Tinahulu**					**Metapona**			
Order	**Family**	**Identification**	**0**	**1**	**2**	**17**	**3**	**4**	**5**	**6**	**9**	**11**	**7**	**8**	**18**	**10**	**12**	**13**	**14**	**15**	**16**
Amphipoda	Melitidae	Undetermined sp	2																		
Aranae	Pisauridae	Dolomedes sp	1				3		13							2					
	Salticidae	Undetermined sp																		1	
Gastropoda	Thiaridae	Balanochochlis glans						4	1										2		
		Melanoides aspirans										1				1	1	2	1		
		Melanoides terulosa							2	3					12	1					3
		Melanoides tuberculate									1										4
		Melanoides sp								1				1	5						
		Tarebia granifera													10						
		Thiara amarula													1	11					
	Potamididae	Undetermined sp																			2
Coleoptera	Dytiscidae	Rhantus					1	2	3												
		Hyphydrus						1													
	Ptilodactylidae	Undetermined sp							1												
	Hydraenidae	Undetermined sp								2											
Diptera	Muscidae	Undetermined sp	2	2	1																
	Simuliidae	Undetermined sp			1					1											
Decapoda	Atyidae	Caridina sp				49					5	16	15	23	6	13	13	17	11	19	40
	Palaemonidae	Macrobrachium placidulum		1								7	11		2	6		28	2		
		Macrobrachium sp	1			1					11						3				1
		Macrobrachium gracillirostre																2			
	Grapsidae	Varuna litterata									1			2	1						
	Sesarmidae	Labuanium trapezoideum													1						
	Coenobitidae	Coenobita sp																			2
Ephemeroptera	Caenidae	Undetermined sp			8																
	Baetidaee	Acentrella	22	9	41					6									3		
	Leptophlebiidae	Undetermined sp										2									
		Undetermined sp																	4		
Hemiptera	Gerridae	Lemnometra sp							2							1					
	Ochteridae	Undetermined sp	1																		
	Mesovellidae	Mesovelia sp		2					3				1								
	Veliidae	Microvelia sp							2												
Hymenoptera	Formicidae	Undetermined sp	1	3	4				4												
Lepidoptera	Crambidae	Undetermined sp		2				3	1		1				1		1				
Odonata	Coenagrionidae	Undetermined sp			1	5	3	2						1			1			4	
		Pseudagrion sp2					4		14						8	4					
		Pseudagrion sp2							2						7	7					
		Undetermined sp		1	1																
Trichoptera	Hydropsychidae	Orthopsyche		2										4	2						
	Philopotamidae	Chimarra						1													
		Undetermined sp									2										
		TOTAL	**30**	**23**	**59**	**72**	**14**	**17**	**53**	**19**	**28**	**37**	**34**	**39**	**74**	**56**	**31**	**62**	**37**	**39**	**68**

In addition to the macroinvertebrate sampling and microscopic identification provided in Table 19 above, opportunistic observations of larger Macrobranchium individuals were also made at each site. A total of four larger Macrobranchium species were identified in the field. These four species are common and widely distributed in streams in Guadalcanal and Solomon Islands (Table 20).

Table 20:Species of freshwater crustacean identified

		Chovohio				TSF/Kwara						Tinahulu					Metapona	
Family names	**Species names**	**0**	**1**	**2**	**17**	**3**	**4**	**5**	**6**	**9**	**11**	**7**	**8**	**18**	**10**	**12**	**13**	**14**
Palaemonidae	*Macrobrachium australe*																	
	M. lar																	
	M. latidactylus																	
	M. latimanus																	
	Total species	3	3	3	3	2	3	3	3	4	2	3	3	4	3	3	3	3

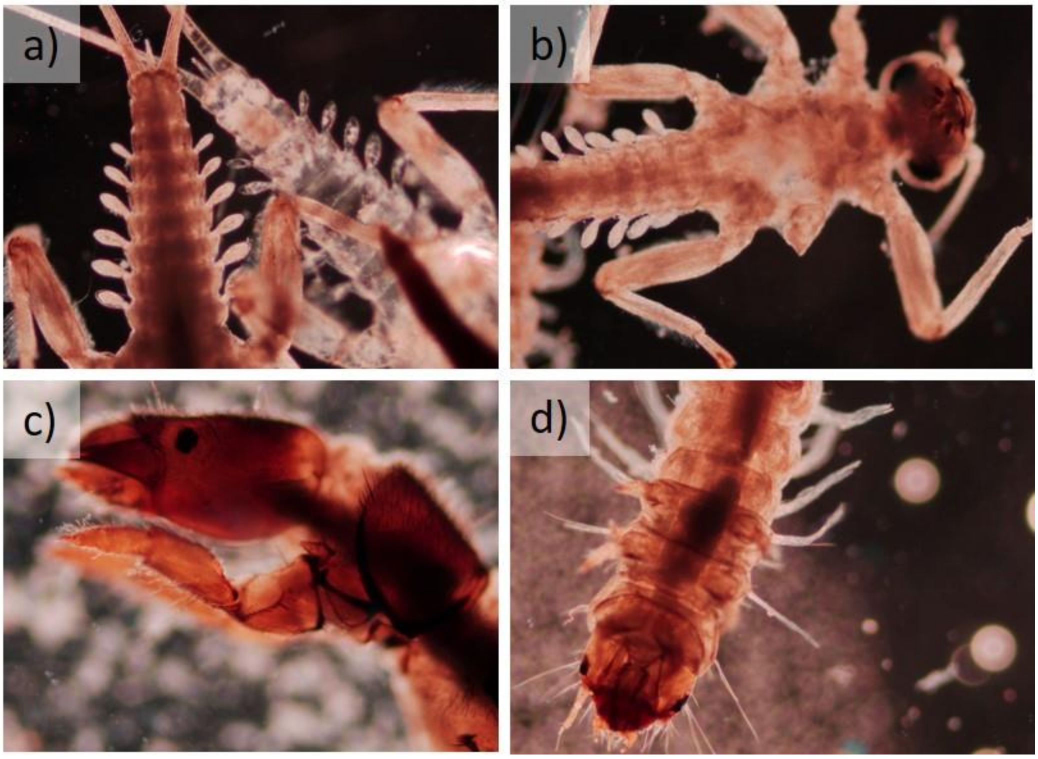

Figure 25: Microscopic images of macroinvertebrate species identified during surveys a) and b) *Acentrella sp.*, c) *Hydropsychidae sp.* d) *Crambidae sp.*

Fish

A total of 36 fish species from 23 genus and 14 families were recorded during this survey (Table 21). Due to the poor weather conditions experienced during fish surveys as a result of the close proximity of cyclonic weather conditions to field site at the time of survey it is anticipated that the fish diversity and abundance could be higher than that recorded during the survey. . However, the fish recorded is representative of any island streams. The family Gobiidae dominated the fish records with a total of 13 species (38 %). This is followed by Eleotridae with a total of 7 species (20 %). These two families alone have comprised 58% of the total fish species recorded. The fish from the families Gobiidae and Eleotridae are two common species that can dominate the fish species in the tropical island streams (Boseto et al. 2007, Jenkins and Boseto 2008, Jenkins et al 2010). Species from these two families are also widely distributed in Solomon Islands and throughout many island nations (Polhemus et al 2008, Jenkins and Jupiter 2011; Copeland et al 2015).

A total of 34 fish species recorded are native to Solomon Islands and two species are introduced species. During the fish surveys native species were commonly recorded within streams, whereas introduced species Mossambicus Tilapia (*Oreochromis mossambicus*) and Eastern Mosquito fish (*Gambusia holbrooki*) dominated within the tailings dam (SIG 3, SIG 4, and SIG 5) and in the pool below the tailings dam (SIG 6) and a stream on site SIG 9. The introduced species can live and survive in a broad range of environmental conditions including degraded habitats.

It was observed during the survey that *Aguilla leptocephalus* and the goby fry were migrating from the ocean into the Metapona River mouth at site (SIG 16). Goby fry migration was also observed on sites SIG 7 to SIG 18 upstream of the Metapona River mouth. The upstream migration of the *Aguilla leptocephalus* and goby fry is a clear indication that the physical and chemical conditions within these streams is able to support fish reproduction. However, any further land-based development could alter the stream condition enough to limit the life cycle of these fish species.

None of the fish species recorded are locally or regionally threatened. Most of the fish recorded from the Metapona River and Tinahulu River are also recorded from other nearby streams on Guadalcanal and other islands in the Solomon Islands and the Pacific (Gehrke et al 2011).

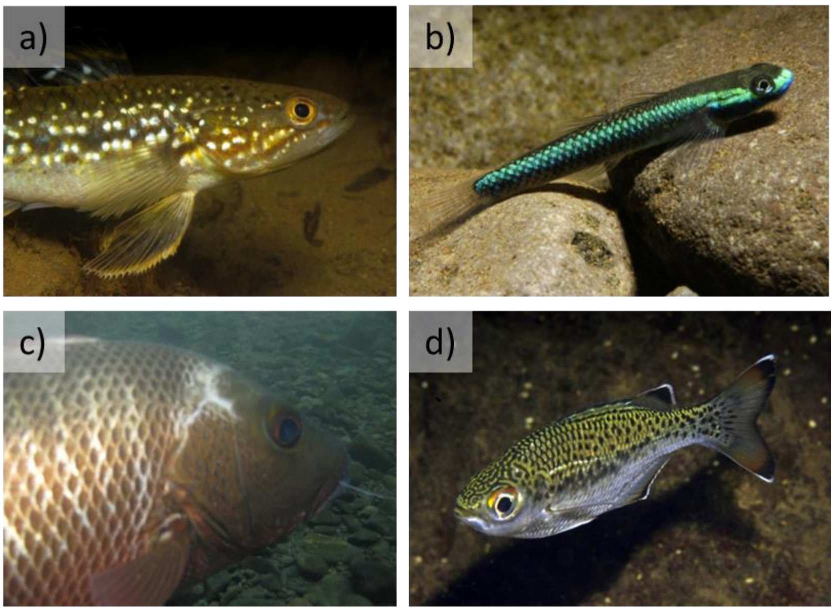

Figure 26: Fish species observed during surveys a) *Giuris margaritacea*, b) *Stiphodon semoni* c) *Lutjanus* argentimaculatus d) *Kuhlia marginata*

Table 21: Presence (green highlight) of fish species at each site

		Chovohio				TSF/Kwara						Tinahulu					Metapona		
Family names	**Species names**	**0**	**1**	**2**	**17**	**3**	**4**	**5**	**6**	**9**	**11**	**7**	**8**	**18**	**10**	**12**	**13**	**14**	**16**
Ambassidae	*Ambassis interrupta*				X												X	X	
	Ambassis miops				X					X							X	X	X
Angullidae	*Anguilla marmorata*			X	X					X	X			X	X	X		X	
	Anguilla leptocephalus													X					X
Cichlidae	*Oreochromis mossambicus*	X				X	X	X	X	X									
Eleotridae	*Belobranchus segura*			X						X		X		X	X	X	X		
	Belobranchus sp									X									
	Bunaka grinoides				X									X					
	Butis butis				X														X
	Eleotris fusca	X	X							X	X	X	X	X	X	X		X	
	Giuris hoedti				X					X						X		X	
	Giuris margaritacea																	X	
Gobiidae	*Awaous guamensis*															X	X		
	Awaous ocellaris				X														
	Glossogobius illimis									X			X		X	X	X		
	Periophthalmus argentilineatus																		X
	Sicyopterus cynocephalus	X	X	X						X		X	X	X					
	Sicyopterus lagocephalus	X	X	X						X			X				X		
	Sicyopterus stiphonoides											X		X					
	Sicyopterus sp 1	X	X	X															
	Sicyopterus sp 2		X																
	Stenogobius sp				X										X	X			
	Stiphodon pelewensis									X									
	Stiphodon rutilaureus	X	X		X							X	X						
	Stiphodon semoni	X	X	X	X					X		X	X						
	Goby Fry				X					X	X	X	X	X	X	X	X	X	X
Kuhliidae	*Kuhlia marginata*				X					X		X						X	
	Kuhlia repestris																	X	
Lutjanidae	*Lutjanus argentimaculatus*																		X
Ophichthidae	*Lamnostoma kampeni*				X									X	X	X	X	X	
Poeciliidae	*Gambusia holbrooki*					X	X	X	X	X									
Rhyacicthyidae	*Rhyacichthys guilberti*	X	X	X	X							X							
Scatophagidae	*Scatophagus argus*																		X
Sphyraenidae	*Sphyraena* sp																		X
Syngnathidae	*Microphis retzii*												X						X
Tetrarogidae	*Tetraroge niger*				X														
	Total fish species recorded	8	8	7	15	2	2	2	3	15	3	9	8	9	7	9	8	10	9

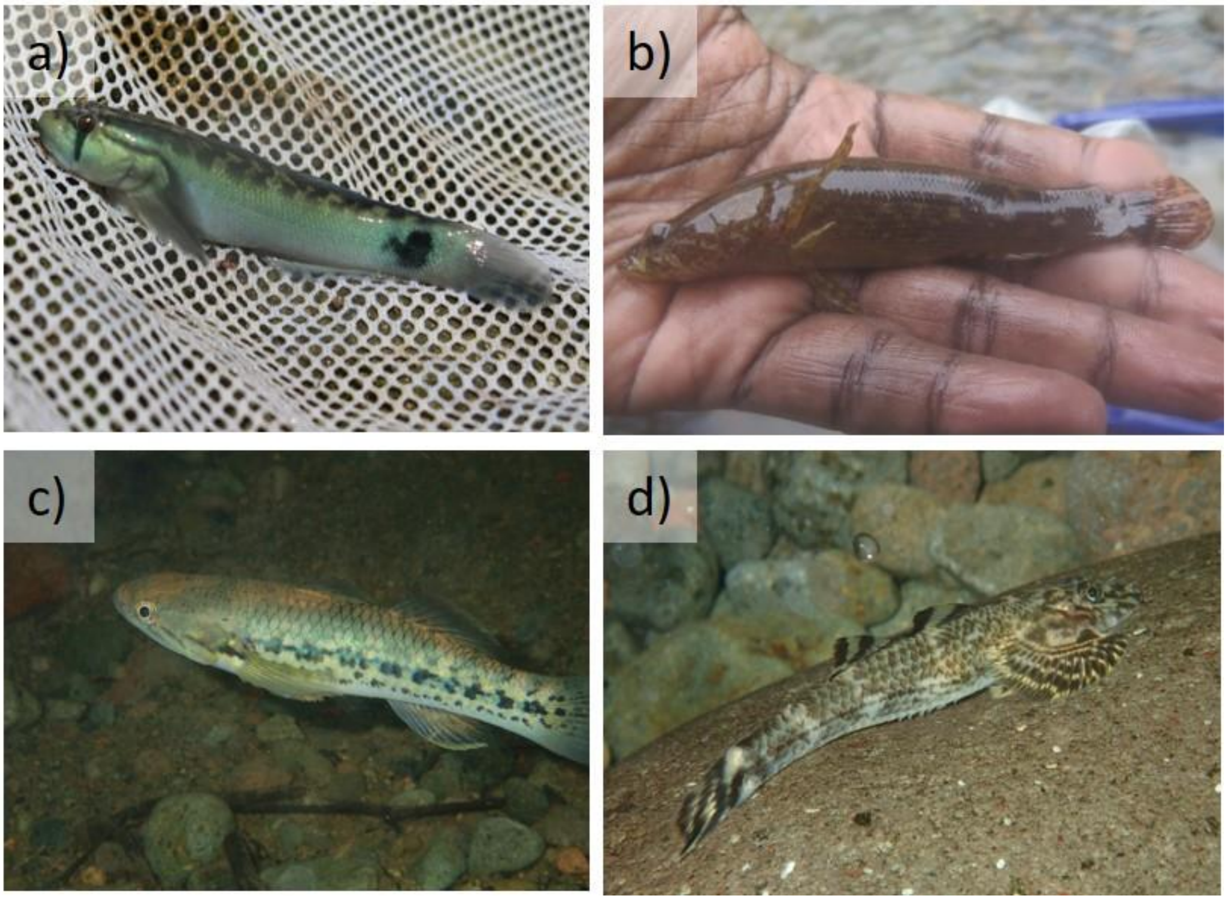

Figure 27: Fish species observed during surveys a) *Sicyopterus sp* 1, b) *Bunaka grinoides*, c) *Giuris hoedti*, d) *Rhyacichthys guilberti*

A total of 19 species were regarded as least concern, which means that they are widely distributed and have a healthy population (Table 22). A total of four species are listed as data deficient that requires more studies on their distribution and population status and a total of seven species were yet to be assessed by taxonomic experts. This means that there are no real threats on the fish species or population recorded from this survey in terms of conservation status. However, a detailed assessment of the incorporation of elevated Arsenic levels into the food chain could be considered in future work. It was observed during this survey that people who resided close to the rivers fished for eel, gobies, gudgeons, jungle perch and other invertebrates (prawns) for food.

The two introduced species (Mossambicus Tilapia and Eastern Mosquito fish) were most abundant species observed during this survey. This is not surprising as introduced species such as tilapia and mosquito fishes have been noted to have the ability to dominate streams in which they inhabit (Boseto 2006). From our survey four species were recorded as rare (where single individuals were recorded persite), six species were recorded as uncommon and nine species were recorded as common.

Table 22: Fish status, conservation and relative abundance across all sites

Scientific Name	Common Name	Status (Endemic, Native, Introduced)	Conservation Status (IUCN)	Relative abundance
Abassidae				
Ambassis interrupta	Long-spined Glassfish	Native	Least Concern	Common
Ambassis miops	Flag-tailed glass perchlet	Native	Least Concern	Common
Anguillidae				
Anguilla marmorata	Marbled Eel	Native	Least Concern	Uncommon
Cichlidae				
Oreochromis mossambicus	Mossambicus Tilapia	Introduced	Least Concern	Abundant
Eleotridae				
Belobranchus Segura		Native	Data Deficient	Common
Belobranchus sp				
Bunaka gyrinoides	Greenback gauvina	Native	Least Concern	Rare
Butis butis	Duckbill sleeper	Native	Least Concern	Uncommon
Eleotris fusca	Dusky sleeper	Native	Least Concern	Uncommon
Giuris hoedti		Native	Not yet Assessed	Common
Giuris margaritacea	Snakehead gudgeon	Native	Least Concern	Common
Gobiidae				
Awaous guamensis	Scribbled goby	Native	Least Concern	Uncommon
Awaous oceallaris		Native	Least Concern	Uncommon
Glossogobius illimis		Native	Not yet Assessed	Rare
Periophthalmus argentilineatus	Barred mudskipper	Native	Not yet Assessed	Common
Sicyopterus cyanocephalus		Native	Not yet Assessed	Common
Sicyopterus lagocephalus	Red-tailed goby	Native	Least Concern	Common
Sicyopterus stiphonoides		Native	Not yet Assessed	Uncommon
Sicyopterus sp 1				Abundant
Sicyopterus sp 2				Common
Stenogobius sp				Uncommon
Stiphodon pelewensis		Native	Data Deficient	Uncommon
Stiphodon rutilaureus	Golden-red stiphodon	Native	Least Concern	Common
Stiphodon semoni		Native	Data Deficient	Common
Kuhliidae				
Kuhlia marginata	Silver flagtail	Native	Least Concern	Common
Kuhlia rupestris	Rock flagtail	Native	Least Concern	Common
Lutjanidae				
Lutjanus argentimaculatus	Mangrove red snapper	Native	Least Concern	Uncommon
Ophichthidae				
Lamnostoma kampeni		Native	Least Concern	Rare
Poeciliidae				
Gambusia holbrooki	Eastern Mosquito fish	Introduced	Least Concern	Abundant
Rhyacicthyidae				
Rhyacichthys guilberti		Native	Data Deficient	Common
Scatophagidae				
Scatophagus argus	Spotted Scars	Native	Least Concern	Rare
Sphyraenidae				
Sphraena sp		Native		Uncommon
Syngnathidae				
Microphis retzii	Ragged-tail pipefish	Native	Not yet Assessed	Uncommon
Tetrarogidae				
Tetraroge niger		Native	Least Concern	Uncommon

Land use mapping

The habitats down stream of Gold Ridge Mine are composed of mostly oil palm (37%), degraded forest habitats (28.3 %), forest (14.8%) and gardens (14.6%). Grasslands (3.2%), villages (1.1%) and coconut plantations (1%) make up the remainder. Coastal fringes are dominated by villages, small holder cocoa plantations, and gardens (Figure 28). Degraded forests are dominated by the invasive trees, paper mulberry (*Broussonetia papyrifera*, Rain trees (*Albizia saman*), and coconuts (*Cocos nucifera*). A mixture of secondary growth, grassland, and gardens have replaced riparian vegetation along the rivers. Grasslands of north Guadalcanal are also habitat to some unique species, such as the Solomon Islands Spotted Button-quail (Red-backed Button-quail) *Turnix maculosa solomonis*. This was not seen or heard during the surveys.

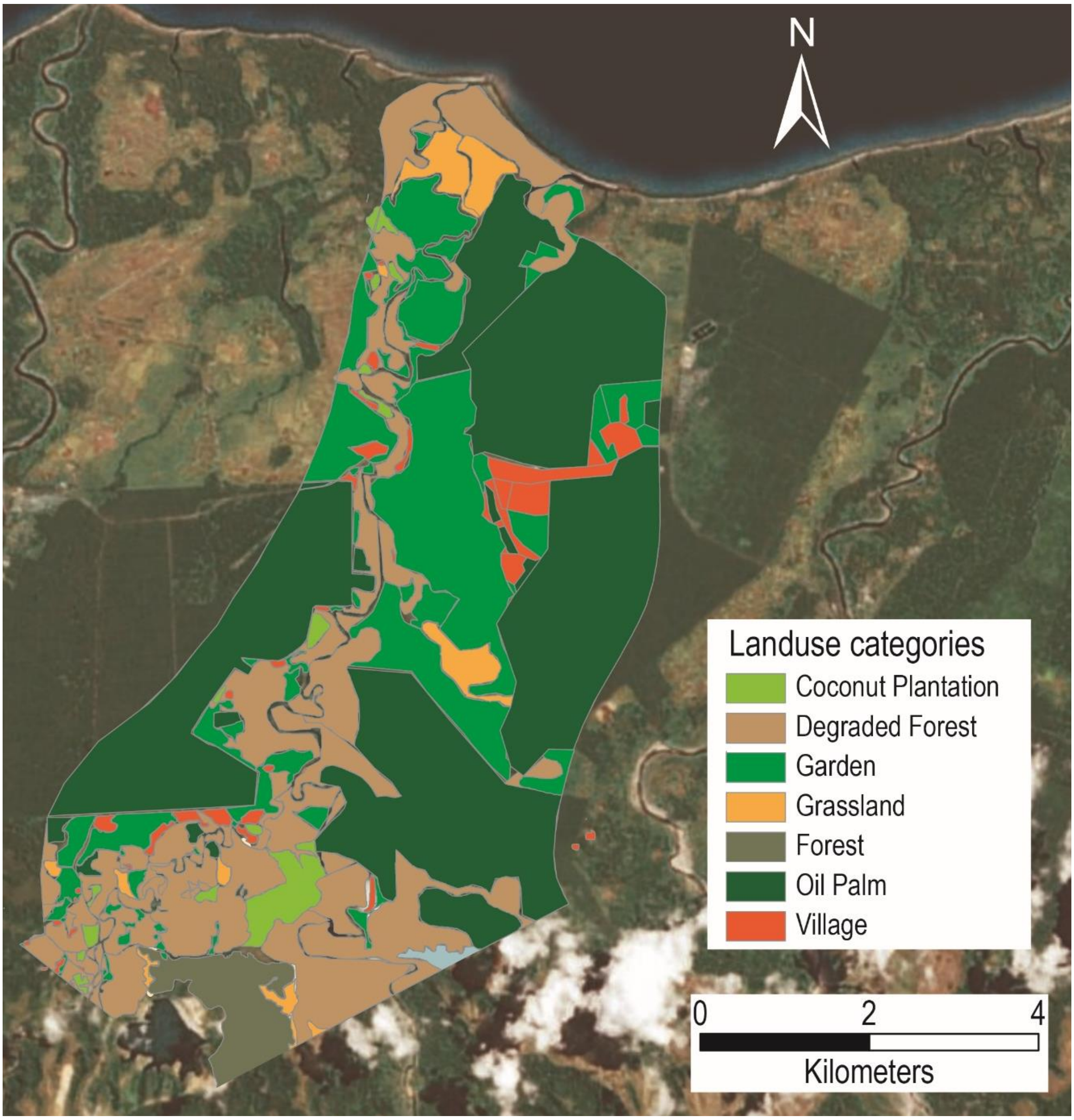

Figure 28: Landuse of areas downstream of the Gold Ridge Tailings Storage Facility

Future work

This baseline assessment of water and sediment quality and ecology of the aquatic ecosystems downstream of Gold Ridge Mine has provided an important overview against which future comparisons can be made. The sampling sites have been well structured to capture the key components of the system and should be maintained in future monitoring efforts. Likewise, the majority of parameters measured are deemed appropriate, in particular taking into account both total and dissolved fractions of metals. Given the difficulty in achieving accurate results due to logistical constraints analysis of Biochemical Oxygen Demand and Microbiology could be removed from future monitoring programs unless a specific issue requires it. During dewatering a subset of these sampling sites could be assessed on a weekly and daily basis.

Possible sampling strategy during dewatering:

Monthly-All sites for dissolved/total metals, Cyanide, Flow and turbidity.

Weekly-SIG3-10, SIG 18 and SIG 14 for dissolved/total metals, Cyanide, Flow and turbidity.

Daily – SIG 3-5, SIG7-8, SIG 18 and SIG 14 for dissolved/total metals, Cyanide, Flow and turbidity.

Hourly – Turbidity at SIG 4, SIG 5, SIG 7 and SIG 8.

The best approach would be to install a real-time continuous turbidity logging station at SIG 5, SIG 8 and SIG 14. This system could be designed to upload data through the GSM mobile network and send automated alerts if turbidity levels exceed a certain threshold.

The five key findings of this report that require further assessment are:

High suspended sediments and total arsenic entering the system from the Charivunga catchment from both artisanal mining activities and the exposed ore body. A more detailed assessment of the artisanal mining activities would provide information on human health issues, sources of sediment and arsenic and possible mitigation strategies.

Threefold increase in Arsenic concentrations in TSF since previous sampling in July 2015-Previous assessments of TSF water quality over the past two years have indicated a slow reduction in Arsenic concentrations in the water column down to <0.03 mg/l in July 2015. However sampling in February 2016 indicated a substantial increase in dissolved Arsenic to 0.087 mg/l. It is likely this sudden increase in Arsenic is a result of release from tailings sediment that may have been triggered by low dissolved oxygen conditions. Three approaches are recommended to further understand this important finding:

-Collation and analysis of all previous water quality data from the TSF

-Installation of water quality instruments to monitor changes in temperature, pH, dissolved oxygen and Arsenic over time and through the water column

-Collection of tailings sediment cores and laboratory incubation of cores to quantify Arsenic flux rates under variable temperature and dissolved oxygen

The loads of Arsenic, suspended sediments and Copper into the environment from Gold Ridge are largely driven by episodic flood events. Time lapse photography has indicated the rapid changes in water flow that can occur over 12-24 hour periods. These dynamic events and their relative importance in loads of contaminants can be quantified by installing long-term water quality monitoring stations within the Metapona River system. This station would provide real-time continuous water quality data uploaded through the GSM mobile network to a central government server. It could include a pressure transducer to act as a flood warning system. SIG 14 at the Metapona bridge is likely the safest location for this station.

Moderate levels of Cyanide are present downstream of the TSF embankment within the sump despite no detectable levels of Cyanide being measured within the TSF itself. This indicates Cyanide is leaching from the tailings sediments into the shallow groundwater system and into the sump. As the TSF water level is currently at unprecedented levels it is likely the flow rates of this groundwater into the sump is also higher than previous assessments. A more detailed assessment of flow rates, concentrations and fate of the Cyanide within the TSF sump is important to ensure there is no threat to the communities living in the immediate vicinity of the TSF.

Assessment of water quality in adjacent catchments will help to provide context to the results from the Chovohio, Tinahulu and Metapona catchments. In the longer term, improving the spatial and temporal understanding of water quality parameters will help to build a database on which to develop Solomon Islands specific water quality guidelines. Currently a significant focus of water quality assessments in Solomon Islands is to compare results to international guidelines (often Australian ANZECC guidelines). However, the applicability of these guidelines to the Solomon Islands context is questionable. The relatively new volcanic geology of Solomon Islands is distinctly different from the large ancient continents where the majority of guidelines have been developed. Thus it can be expected that several water quality parameters that are deemed to “exceed guideline levels” may be a natural feature of the aquatic environments of Solomon Islands.

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