



NSW Catchment and Lands- Crown Lands
Former Antimony Processing Plant- Urunga NSW
Detailed Investigation Report

December 2012

Executive summary

A Detailed Investigation of a former antimony processing facility located at Hillside Drive, Urunga, NSW was completed to provide a key input to achieve compliance with the Management Order 20111405. The investigation incorporated data from the Preliminary Investigation Report (GHD 2012) and a field investigation comprising sampling and analysis of soil, sediment and water from:

- 63 soil boreholes.
- 38 sediment boreholes.
- 9 surface water locations.
- 4 groundwater monitoring wells.
- 3 stockpiles and 2 loading ramps.
- Brick stockpiles.

The investigation was carried out in accordance with a Sampling Quality and Analysis Plan that was incorporated into the Preliminary Investigation Report (GHD 2012) and was reviewed and approved by the Environmental Protection Authority. Results were compared to adopted assessment criteria to provide:

- A comparison with historic concentrations and impact extent.
- Data to assess horizontal and vertical delineation.
- Data necessary for a remediation options assessment.
- An assessment of surface water and groundwater quality.
- Baseline data for assessing any future impact from site activities or remediation.

Findings of the investigation were used to update the Conceptual Site Model that was developed in the Preliminary Investigation Report (GHD 2012) and included:

- Antimony and arsenic were evident as the key contaminants of concern (COC)s.
- Other COCs included mercury, chromium, nickel, zinc, copper, lead and cyanide.
- In nearly all cases, where one of the COCs was present in significant concentrations, more significant concentrations of either antimony or arsenic were present. As a result, these analytes were deemed to be representative indicator analytes and the governing contaminants.
- Incidental contaminants may also be present on the Site including:
 - Total Petroleum Hydrocarbons;
 - Polynuclear Aromatic Hydrocarbons;
 - Organochlorine Pesticides;
 - Polychlorinated Biphenyls; and
 - Asbestos.
- Surface water and sediment (and to a lesser extent, groundwater) were noted as the main media for the transportation of COCs on the Site.

- Generally, contaminants exceeding relevant assessment criteria in surface water, groundwater and sediment correlated with those that exceeded assessment criteria in the soils.
- In most cases, the leachable concentrations of COCs in the soil and sediment were significantly less than total concentrations, suggesting the physical migration of contaminated soil or sediment has been the more important contaminant migration pathway.
- Notwithstanding the above, where there were significant concentrations of antimony and arsenic in soil or sediment samples, the corresponding leachable concentrations were well above ANZECC trigger values for protection of aquatic ecosystems.
- For “soil” samples (being those taken from “dry” areas of the site, including the tailings area, during GHD’s investigations) the degree of contamination generally reduces quite quickly so that the site can be divided into significantly impacted and relatively unimpacted areas. The exceptions to this are primarily adjacent to the ‘L’ shaped canal (where contamination is either within 10 times the assessment criteria, or covered by cleaner material), the south western corner of the site (which has insufficient sampling to define), and the area of disturbance at the north east corner of the site.
- For the majority of the COCs, dissolved concentrations were similar to total concentrations in the surface and groundwater samples, indicating the measured concentrations of contaminants are mobile in the water and not just bound to suspended particles.
- Concentrations of the main COCs in the soil recorded in this investigation were within a similar order of magnitude as those recorded in the historical investigations.
- Reduced total concentrations of COCs in the surface water were noted from the 1997 round of sampling to the present. This may be due to many factors and does not necessarily indicate an overall reduction in concentrations.
- The interpreted extent of the contamination in the soil can be summarised as:
 - Roughly correlating with the absence of vegetation.
 - Including the tailings deposit, former processing area and portions of the former unprocessed ore stockpiling area.
 - Extending into the south west corner of the site and likely across the property boundary near the wetland, however the extent of this impact has not been fully delineated.
 - Extending along the embankment in the vicinity of the ‘L’ shaped canal, at a depth of 1 m to 1.7m from the current ground surface (likely associated with the original soil surface prior to placement of spoil from excavation of the canal).
 - Not extending into the north east portion of the site with the exception of an area of unknown disturbance, to the north of the ‘L’ Shaped canal.
 - Not extending to the southern side of the wetland.
 - Varying in depth from approximately 0.5 metres below ground surface (mbgs) in the north west portion of the impact to 2.2 mbgs near the water’s edge and at some locations within the tailings deposit.
- The extent of the impact in the sediment can be summarised as:
 - Showing highest levels of impact adjacent to the tailings deposit, extending approximately 50 m downstream of the tailing deposit, extending across the wetland

- some 50 m to the south of the tailings deposit (roughly correlating with vegetation dieback), and within and adjacent to the north eastern portion of the 'L' shaped canal.
- Including the western and south eastern portions of the 'S' shaped canals.
 - Ranging from depths of about 1 mbgs near the tailings to 0.1 mbgs in the southern portion of the wetland.
 - Generally having greatest antimony and arsenic concentrations in the surface sediment (0-0.1 mbgs).
 - Generally corresponding with the visual presence of tailings sediment (grey silt).
 - Estimated volumes of impacted soil and sediment were:
 - 8,700 m³ of soil and 2,500 m³ of sediment exceeding 30 times the adopted assessment criteria.
 - 11,300 m³ of soil and 3,600 m³ of sediment (encompassing the volumes above) exceeding 10 times the adopted assessment criteria.
 - 26,500 m³ of soil and 6,700 m³ of sediment (encompassing the volumes above) exceeding the adopted assessment criteria.
 - The soils and sediment in the vicinity of the tailing deposit analysed and are considered to be Acid Sulfate soils. The preparation of a detailed Acid Sulfate Soils Management Plan (ASSMP) will be required for works that disturb the soil in that area.
 - The groundwater table onsite ranged from approximately 0.4 to 1.4 mbgs and groundwater is interpreted to discharge into the wetland. The tailings material and underlying peat are expected to be highly permeable and hence the contaminants are likely to have high groundwater connectivity to the wetland. Characteristics of deeper groundwater or groundwater flow into the site are not known.

This Executive Summary presents a brief summary of the information described in this report, and should be read in the context of the more detailed information presented in the body of this report, the scope of work and the limitations discussed in Section 9.

Abbreviations

ASSMAC	Acid Sulfate Soils Management Advisory Committee
As	Arsenic
CLM Act	Contaminated Land Management Act
CN	Cyanide
CSM	Conceptual Site Model
COC	Contaminant of Concern
Cr	Chromium
Cu	Copper
DECCW	NSW Department of Environment, Climate Change and Water (former, now the OEH)
DLWC	Department of Land and Water Conservation
DO	Dissolved Oxygen
DQO	Data Quality Objectives
EC	Electrical Conductivity
EIL	Environmental Investigation Level
EPA	NSW Environment Protection Authority
EQL	Estimated Quantitation Limit
GPS	Global Positioning System
Hg	Mercury
HIL	Health Investigation Level
ISQG	Interim Sediment Quality Guideline
LIDAR	Light Detection and Ranging
m	Metres
mbgs	Metres below ground surface
mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Litre (generally equivalent to parts per million)
mTOC	Metres below Top of Casing
µg/L	Micrograms per Litre (generally equivalent to parts per billion)
NATA	National Association of Testing Authorities
NEPM	National Environmental Protection Measure
NSW	New South Wales

OCP	Organochlorine Pesticides
OEH	Office of Environment and Heritage
OH&S or OHS	Occupational Health and Safety
PAHs	Polynuclear Aromatic hydrocarbons
PASS	Potential Acid Sulfate Soil
Pb	Lead
PBIL	Phytotoxicity Based Investigation Levels
PCBs	Polychlorinated Biphenyls
PMF	Probable Maximum Flood
PQL	Practical Quantitation Limit
PSA	Particle Size Analysis
Redox	Oxidation-reduction potential
RPD	Relative Percent Difference
SOP	Standard Operating Procedure
SPOCAS	Suspension Peroxide Oxidation Combined Acidity and Sulfur
QA	Quality Assurance
QC	Quality Control
RAP	Remediation Action Plan
Sb	Antimony
SCS	Soil Conservation Service
SWL	Standing Water Level
SEPP	State Environmental Planning Policy
SWMS	Safe Work Method Statement
TCLP	Toxicity Characteristic Leaching Procedure
TPH	Total petroleum hydrocarbons
UCL	Upper Confidence Limit
USCS	Unified Soil Classification System
WA	Weak Acid
XRF	X-Ray Fluorescence

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1. Introduction

The Soil Conservation Service (SCS) has been engaged by NSW Catchment & Lands - Crown Lands (Crown Lands) to project manage the rehabilitation of a former antimony processing facility located at Hillside Drive, Urunga, NSW (the Site). GHD has been engaged to undertake a series of tasks relating to that project including

- A Preliminary Investigation Report, which has previously been completed¹.
- This Detailed Investigation Report.
- A Remediation Action Plan which will be based on the findings of this report.

1.1 Background

The Site is located at Urunga, NSW, to the south east of the Pacific Highway and adjoining a SEPP 14 wetland as illustrated in Figure 1 and Figure 2. The proposed investigation area comprises part of Lot 1 and Lot 2 DP 874874 and Lot 253 DP 46013. Part of Lot 1 and Lot 2 was transferred to the Crown in 2012.

The site was a former antimony processing plant, which operated between 1969 and 1974, and was abandoned in 1974 without clean up or remedial work. Tailings and mill waste water were discharged onto the foreshore area during the plant operations. A tailings deposit approximately 1 ha in extent fans out into the adjoining wetland. The tailings and adjoining environment are contaminated by a range of heavy metals, particularly by arsenic, antimony and mercury. A belt of dead *Melaleuca* trees characterises the periphery of the tailings deposit. The tailings area is devoid of vegetation, and is periodically inundated by high tides and/or surface runoff.

A partial clean-up of surface debris and waste materials on the former antimony processing site has been carried out by Entech Industries (Entech), however no remediation or management of soil or tailings contamination has occurred.

A series of canals lies to the east of the tailings area, separating the contaminated area to some degree from the adjacent wetland and Station Creek, which runs through the wetland, discharging into Urunga Lagoon further to the east.

Under the provisions of the Contaminated Land Management Act 1997 (CLM Act), a Management Order (No. 20111405) applies to Lot 253, DP 46013 (Crown Land) (NSW EPA 2011). Following the land transfer from Tickner to Crown Lands (Notice to Amend Management Order 20124407) the Management Order also applies to Lot 1 and Lot 2, DP 874874. A portion of Lot 1, DP 874874 was removed from remediation area 1089 by means of a Notice to End Remediation Declaration (No. 22004) in November 2005 (NSW EPA 2005). This was reflected in a Notice to Amend Management Order (No. 20124407) issued on May 22, 2012 (NSW EPA 2012a). The dates for each milestone of the Management Order were revised in a further

¹ GHD 2012. Former Antimony Processing Plant- Urunga, NSW. Preliminary Investigation Report. Prepared for NSW Catchment and Lands- Crown Lands, July 2012.

Notice to Amend Management Order (No. 20124422) issued on September 9, 2012 (NSW EPA 2012b).

1.2 Objectives

The objectives of the overall remediation program are to:

- Achieve compliance with the Management Order 20111405 and Notices to Amend Management Order 20124407 and 20124422.
- Remediate the contamination at the Site so that any further impact on the adjacent wetland and receiving environment is minimised, and to allow the Site to be opened to public access without unacceptable risk to human health.

The specific objectives of the Detailed Investigation Report are to:

- Confirm, by field investigations, whether the present extent and degree of contamination is consistent with that indicated by previous studies.
- Provide more accurate delineation of the degree versus vertical and horizontal extent of contamination.
- Refine the Conceptual Site Model (CSM) developed in the Preliminary Investigation Report.
- Provide a more detailed assessment of potential acid sulfate soil impacts that may be associated with various remediation options.
- Liaise closely with the SCS and the Environmental Protection Authority (EPA) in determining the extent of required investigations, selecting the most appropriate remediation options for detailed review, and agreeing on the preferred remediation strategy for subsequent documentation in the Remedial Action Plan (RAP).
- Provide a Detailed Investigation Report to the EPA for review and approval.

This report will provide the foundation for the development the RAP.

1.3 Scope

The scope of the Detailed Assessment was set out in the Preliminary Investigation Report, which was reviewed and approved by the EPA and was to:

- Conduct field investigations to provide data to delineate the extent and degree of contamination.
- Assess the data in relation to previous studies.
- Develop an updated CSM.
- Present remediation options to form the basis for the RAP.



2. Location and Description

The Site is located on the southern side of Hillside Drive, adjacent to the Pacific Highway, approximately 1.5km from the town centre of Urunga, on the mid-north coast of NSW, as presented in Figure 1. Historic investigations have shown contamination to be located across several land parcels including:

- Lot 1 DP 874874.
- Lot 2 DP 874874.
- Lot 253 DP 46013.

Site features are presented in Figure 2. Photographs of the Site are presented in Appendix B. In general, the Site consists of:

- A disturbed area incorporating the various features associated with the former antimony processing facility, that is largely devoid of vegetation.
- A tailings area of approximately one hectare that is devoid of vegetation, extending from the former processing area into an adjacent, State Environmental Planning Policy (SEPP) 14 wetland (no. 354).
- A generally forested area adjacent to the SEPP 14 wetland in which 21 vulnerable and 3 endangered fauna species have previously been recorded (Redpath 2003).
- Surface material (within the disturbed areas) consisting of imported fill and tailings.
- Some remaining infrastructure consisting mainly of foundations of the former processing facility and loading ramps.
- Several remaining stockpiles of ore, rubbish and bricks.
- An 'L' shaped canal that has apparently been excavated from the wetland.
- A series of 'S' shaped canals (possibly constructed for use in tailings settling).
- Visually impacted *melaleuca* trees in the wetland area, adjacent to the tailings deposit.

Based on aerial photographs received from SCS following completion of the Preliminary Investigations (see Appendix D), the L shaped canal and S shaped canals were constructed about 1979, after operation of the processing facility had ceased (see Section 3.1.1).

The Site is located between the footslope of a small ridge to the north and west and the SEPP 14 wetland to the south and east. Several small drainage lines meander through the Site from the small catchment. Flood waters (data provided by BSC 2008) are shown to periodically inundate the Site (Figure 2) with the Probable Maximum Flood (PMF) level inundating the tailings, former gravel processing area (within the lower part of the former processing area) and the canal systems. The PMF does not cover the full extent of the former processing area.

The wetland drains into Station Creek which is partially tidal. No tidal influence was noted at the Site during the field investigation program; however tidal influences may periodically inundate portions of the tailings during different hydrological conditions. Station Creek discharges into Urunga Lagoon which forms part of the Bellinger-Kalang estuarine system.

The groundwater table onsite is approximately 1 metre below the ground surface (mbgs) and groundwater is interpreted to discharge into the wetland. Groundwater has only been investigated within the tailings area using existing shallow drive-point wells. Characteristics of deeper groundwater or groundwater flow into the site are not known.

Neighbouring land uses consist of:

- A SEPP 14 wetland and land owned by the Coffs Harbour and District Local Aboriginal Land Council, to the south and east.
- Hillside Drive and residential land to the north.
- Residential and commercial properties to the west followed by the Pacific Highway.



3. Preliminary Investigation

A summary of the Preliminary Investigation is outlined in the following subsections.

3.1 Desktop Review and Site Visit

3.1.1 Ore Processing and Site Development

The antimony processing plant was operated by 'Broken Hill Antimony Pty Ltd' and processed stibnite (antimony sulphide) ore mined from Wild Cattle Creek, Dorrigo from 1969 to 1974. The ore (containing impurities in the form of arsenic and mercury) was crushed and then passed through flotation cells to separate the precious metals from the rock waste. Reject material was dumped as tailings on the foreshore of the adjacent wetland. Chemicals used during the purification process included copper sulfate, sodium cyanide, lead nitrate, dextrin, sodium ethyl xanthate and cresylic acid. Water mill water was also contaminated with dissolved antimony and arsenic salts during treatment of the crushed ore. A gravel washery was also reported to be onsite, using water from the wetland.

In 1974, operations at the plant ceased due to the closure of mining production at Wild Cattle Creek. No clean-up operations or remedial work were undertaken when the site was abandoned.

In the late 1970s the property and processing plant were purchased by Mr R Tickner. In 1980, 'Australian Antimony N.L.' (owned by Mr Tickner) applied to the Bellingen Shire Council to restart operations. The application was refused.

A series of canals were constructed between 1979 and 1980. Since then, no further development has occurred.

In 1994 Mr Tickner approached the Bellingen Shire Council to seek Development Approval for residential use of Portions 169 and 138. Approval was not given (DLWC 1997a).

Crown Lands became aware of the contamination issues at the Site in 1995 when Mr Tickner reported the issue following the refusal of a development application. Crown Lands immediately took action to protect the public by erecting fencing and warning signs (SCS 2012).

3.1.2 Previous Investigations

More than twenty sources of relevant data including eight previous contaminant investigations were identified. An assessment of the reliability of the historic data was conducted with four sources of data deemed reliable for use in ongoing assessments. Those included data supplied from:

- The Department of Land and Water Conservation (DLWC) 1995.
- DLWC 1997.

- Coffey 2004.
- NSW Department of Environment Climate Change and Water (DECCW) 2008.

Historic photographs obtained from Urunga Museum and historical aerial photos were also reviewed to provide data used to provide and increased understanding of the Site.

Data gaps were also identified from an assessment of the data from previous investigations. These gaps provided the foundation for the Sampling Analysis and Quality Plan (SAQP) presented in the Preliminary Investigation Report (GHD 2012).

3.1.3 Site Visit and Interviews with Former Staff

A Site visit and inception meeting was held on May 9, 2012. It was attended by representatives from:

- GHD.
- EPA.
- Bellingen Shire Council.
- Crown Lands.
- SCS.

Interviews with former site staff were also conducted on May 17, 2012 that aided in the understanding of the sources of the contaminants.

Observations from the Site visit and information obtained from the interviews were used to aid in the development of the Preliminary Conceptual Site Model (CSM) and provide data for the development of SAQP.

3.1.4 Additional Data

Following the submission of the Preliminary Investigation Report, additional aerial photographs were obtained. A summary of findings from these photographs included:

- 1967: No activities or structures are evident on the site except for a small building (likely a house) in the north west corner.
- 1973: The area of the unprocessed ore stockpiling (as shown on Figure 2) is devoid of vegetation and the extent of the tailings deposit is limited to the immediate vicinity of the former processing area.
- 1979 (very poor resolution): The canals appear to be absent and the extent of the tailings deposit has increased to a similar extent to that noted in the current investigation. Disturbed areas extend across the northern portion of the site.
- 1980: The canals are evident and disturbance is apparent over much of the site. Other observations are provided in the Preliminary Investigation Report.
- 2009: Site features reflect those noted during the current investigation. A significant increase in water level between 1991 and 2009 were noted.



3.2 Preliminary Conceptual Site Model

The information obtained from the desktop review and Site visit was used to develop a Preliminary CSM identifying potential contaminant source areas, receptors and exposure pathways.

The CSM divided the area into Source, Impact and Receptor Zone, illustrated on Figure 15 and defined as follows:

- Source Zone, included the tailings deposits, ore stockpiles, former stockpiling area, former processing areas, incidental contaminants and fill material. The source zone potentially extends over the western boundary in the southern portion of the site. The Source Zone covers an area of approximately 16,000 m².
- Impact Zone, defined as the areas that are potentially directly impacted (secondary impact) by the contaminants, excluding the Source Zone. This area includes the eastern portion of the Site, the wetland immediately adjacent to the tailings, the 'L' shaped canal and the 'S' shaped canals. The Impact Zone covers an area of approximately 50,000 m².
- Receptor Zone, defined as the areas that may be indirectly affected by the contaminants. The area includes sensitive biota in the receiving wetland area including upstream and downstream aquatic fauna and peripheral vegetation. It also includes Lot 101, which has been validated in part by Coffey 2004 and is considered unlikely to have been significantly impacted by contamination from the Site. The Receptor Zone may also include the residential properties adjoining the Site to the west.

Information from the Preliminary CSM has been incorporated into the Updated CSM presented in Section 6.

3.3 Sampling Analysis and Quality Plan

A SAQP was developed entailing:

- 70 soil sampling locations.
- 30 sediment sampling locations.
- 9 surface water sampling locations.
- 5 groundwater sampling locations.

The SAQP also outlined:

- Data Quality Objectives (DQOs).
- An outline of proposed sampling methodology.
- An analytical schedule.
- Identified contaminant assessment criteria.

The DQOs identified in the SAQP in the Preliminary Investigation Report (GHD 2012) were based those defined in the NSW DEC *Guidelines for the NSW Site Auditor Scheme*

(2nd edition, 2006). The DQO process was applied to the investigation program, as described below, to ensure that data collection activities were appropriate and achieve the project objectives. The DQO process involves the following steps:

- **Step 1:** Stating the problem.
- **Step 2:** Identifying the decision.
- **Step 3:** Identifying inputs to the decision.
- **Step 4:** Defining the study boundaries.
- **Step 5:** Developing a decision rule.
- **Step 6:** Specifying limits on decision errors.
- **Step 7:** Optimising the design for obtaining data.

An assessment as to compliance with the steps is outlined in Section 5.7.



4. Detailed Investigation Methodology

The detailed investigation methodology was based on the SAQP outlined in the Preliminary Investigation Report, which was reviewed and approved by the EPA. A summary of the rationale and details of the sampling are provided in the following subsections.

4.1 Sampling Locations

4.1.1 Soil and Sediment

Sixty three soil and 38 sediment boreholes were advanced to enable an assessment of soil and sediment lithology and physical and chemical parameters. Sampling locations were based on those provided in the SAQP with modifications applied where required due to site features or as data became available from the field analysis. Locations were selected to provide adequate data to delineate the impacted areas and provide a sampling density suitable for calculating impacted soil and sediment volume data required for the RAP. Soil sampling locations are presented in Figure 3.

The sampling densities before and after the current investigation are presented in Table 1.

Table 1 Soil and Sediment Sampling Density

Zone	Approximate Area of Zone (m ²)	Number of reliable, historic soil and sediment sampling locations	Approximate Historic soil and sediment sampling density	Number of additional soil and sediment sampling locations provided in this assessment	Resulting Sampling Density
Source Zone	16,000	41	1: 400 m ²	32	1:220 m ²
Impact Zone	50,000	14	1:3,600 m ²	59	1:700 m ²
Receptor Zone	>120,000*	14	1:8,500 m ²	12	1:4,500 m ²

* The area of the receptor zone is difficult to define but was considered to encompass the area outlined in figure 5 and the wetland downstream to the railway for the purpose of this estimate.

The proposed sampling density was primarily based on a judgemental sampling plan, which is outlined in Section 2.3.1 of the 'NSW EPA Sampling Design Guidelines (1995)'. Given the known use and historical review undertaken for the site, the sampling program was designed to target and characterise the identified areas of impact, as well as to assess the distribution of contamination across the adjacent Impact Zone. The depth of the sampling locations at each area of the Site was based on the subsurface ground conditions encountered in that area. The final depths of the boreholes were determined during field works and when the depth of the target subsurface materials was achieved.

The rationale for the soil and sediment sampling locations is summarised below.

Source Zone

Historic results indicated that the Source Zone will likely require remediation or management. As substantial data was already available for this zone, sampling locations were limited to:

- Confirm historic concentrations and impact extent.
- Provide a correlation between field XRAY Fluorescence (XRF) and laboratory data.
- Fill data gaps in terms of horizontal and vertical delineation.
- Provide data necessary for a remediation options assessment (e.g. particle size, acid sulfate soil).

Impact Zone

The rationale for the sampling locations in the Impact Zone was to:

- Provide a correlation between field XRF and laboratory data.
- Fill data gaps in terms of horizontal and vertical delineation.
- Provide data necessary for a remediation options assessment (e.g. particle size, acid sulfate soil).

Soil sampling in the Impact Zone generally targeted:

- The vicinity of the 'S' and 'L' shaped canals.
- Potentially impacted areas to the northwest and northeast of the 'L' shaped canal.
- The vegetated areas in the northern portion of the Site (where the previous access was noted).
- Other areas surrounding the Source Zone.

Sediment sampling in the Impact Zone targeted the benthic layer of the wetland to the south of the tailings area and in or adjacent to the 'L shaped' and 'S' shaped canals. Sampling was undertaken at transects across these areas to assess the distribution of contamination at increasing distance from the source area and to guide decisions regarding the extent of the area requiring management or remediation.

Receptor Zone

Soil sampling in the Receptor Zone was conducted on the southern bank of the wetland.

Sediment sampling in the Receptor Zone was undertaken in areas to the south of the wetland and east of the 'L' shaped canal to assess contaminant concentrations beyond the Impact Zone. Sampling was conducted as part of the transects across these areas, to assess the distribution of contamination at increasing distance from the Impact Zone.

4.1.2 Bricks

Twenty five samples from 23 bricks, including at least one brick of each style or model were selected for XRF screening. Based on the XRF results, two samples were submitted



to the laboratory for crushing and analysis to verify the XRF results. The sampling was to assess the waste classification of the bricks to direct disposal options.

4.1.3 Stockpiles and Loading Ramps

Twenty two samples from three stockpiles and two loading ramps were selected for XRF screening. The results were used to assess the levels of impact within the stockpiles and govern the remediation options.

4.1.4 Surface Water

Nine surface water samples were collected during the program as shown in Figure 3. Sample locations were selected to:

- Provide an assessment of surface water quality from upstream to downstream of the Site.
- Provide a comparison with historic (DLWC 1997) data.
- Provide baseline data for assessing any future impact from site activities or remediation.

Surface water was sampled from the wetland and the 'S' shaped canals within the Impact Zone, in the wetland to the south and west of the tailings deposit and in the wetland to the east of the 'L' shaped canal within the Receptor Zone.

4.1.5 Groundwater

Five groundwater monitoring wells were installed by DLWC in 1997. Four of these wells were located and sampled as part of GHD's investigations, to assess groundwater quality. The purpose of the monitoring was to:

- Assess current groundwater quality.
- Provide a comparison with historic (DLWC 1997) data.
- Provide baseline data for assessing any future impact from site activities or remediation.

4.2 Sampling Methodology

4.2.1 Health Safety and Environment

All site investigations and visits were conducted in accordance with a site specific Safe Work Method Statement (SWMS) prepared by GHD that complied with relevant Occupational Health and Safety (OH&S) regulation and acts. The SWMS comprised a project outline, a summary of relevant Site activities and specific job-related tasks, a hazard register that identified all foreseeable hazards, a risk ranking system for the management of identified hazards, procedures for monitoring and/or implementing mitigating measures to manage all project based risks. This SWMS also included using appropriate Personal Protective Equipment, minimising contact with materials and cleaning down of equipment before leaving Site. A site specific OHS&E plan was prepared, incorporating these safety provisions and environmental management

measures required to minimise the potential impact from GHD's sampling activities on the environment and surrounding community.

All staff involved in the investigations were briefed on OHS&E requirements as well as other job specific information, such as site plans, sampling methodology, GHD proposal details, copies of relevant standard operating procedures etc.

All of GHD's field staff who operated the XRF units had completed a Radiation Safety and Operator Training course and were trained to use portable and hand-held Niton XRF units. In addition to this field staff were licensed for the use of ionising radiation apparatus and/or radioactive substances in accordance with s.6(45) Radiation Control Act 1990 (a NSW Radiation Control Act licence) with the NSW Office of Environment and Heritage (OEH).

4.2.2 Underground Service Location

Underground utilities and infrastructure were located using the 'dial before you dig' search facility and the services of a professional cable locating company (Cable and Pipe Locations Pty Ltd). Two 11kV cables were noted on the ground on the tailings area that were collapsed overhead lines. Essential Energy confirmed that the lines had been de-energised. A buried utility of unknown origin (but assumed to be an abandoned part of the former processing facility) was located to the east of the former processing building.

4.2.3 Location Data

Each site investigation location was located (easting, northings) using a hand held (Trimble) Global Positioning System (GPS), providing sub-metre horizontal accuracy. Elevation data sourced from Light Detection and Ranging (LIDAR) was used to establish a reference surface, and surface elevations to an order of magnitude suitable for the purposes of this investigation. Depths below ground surface were measured by tape measure during sampling.

Due to the limited results obtained from the groundwater wells (Section 5.4) no survey of the groundwater wells was conducted.

4.2.4 Field Documentation

Field Logbook and Sample Documentation

Written logs were maintained for all field activities. These logs covered general field observations and an account of daily works and events including:

- Works completed including start and end time.
- Weather conditions.
- Field observations.
- Results of field testing.
- Instrument calibration results.



- Sample details (e.g. time and date, sample, identification number and location, procedures used in sample collection, instrument readings, conditions surrounding the sampling location, observable characteristics).
- Decontamination procedures and health and safety monitoring.
- A register of all samples.

A copy of the field logbooks, sample registers and log sheets have been retained in the GHD job file in hard and electronic format.

Field Photography

Digital, colour photographs were taken of most sampling points, and surrounding areas, including photographs of sample cores from boreholes with any relevant site features.

Sample Labels

Samples were labelled with adhesive labels using indelible ink. The following information was included on the sample labels:

- Job number.
- Sample identification number.
- Date (and time, for water samples) of sampling.

The sample identification was also written with indelible ink on the cap of the sample bottle in case the sample label is lost or destroyed.

Each sample was assigned an individual sample identification number with the following format:

- The Sampling Code:
 - BH = Soil borehole
 - SE = Sediment
 - SW = Surface water
 - GW = Groundwater
- A unique identifier (e.g. 001-999).
- The sampling depth or interval at which the sample was taken below the surface to the nearest 0.1 m (in the case of soil or sediment).

Quality control sample labelling systems were used as follows:

- Field duplicate samples: BHDUP001, SEDUP002 etc.
- Inter laboratory duplicate sample: BHLABDUP001, SELABDUP002 etc.
- Trip blanks: TB001, TB002, etc.
- Rinsate blanks: RB001, RB002, etc.

Chain of Custody Forms

Chain of custody procedures were used to track samples and included:

- Site identification.
- Name of the sampler.
- Sample numbers.
- Nature of the sample.
- Collection date.
- Signature of sampler or field manager.
- Departure time from site.
- Dispatch courier(s).

Copies of the Chain of custody forms are provided in Appendix F.

4.3 Sampling and Field Analysis Procedures

All fieldwork was undertaken in general accordance with GHD's Standard Field Operating Procedures (SOP) including the following:

- New, disposable nitrile gloves were used for the collection of each sample.
- Samples were placed in laboratory-supplied bottles appropriate for the analysis required.
- Samples were stored in a dedicated container for transport to the project analytical laboratory with chain of custody documentation. Where required for appropriate preservation of samples prior to laboratory analysis, ice was used.
- All sampling equipment was thoroughly decontaminated (in accordance with written procedures) to mitigate cross contamination occurring between sampling locations. Sampling equipment was washed with Decon 90 and then rinsed in tap water and then deionised water prior to and after the collection of each individual sample.
- Quality Assurance/ Quality Control (QA/QC) sampling as outlined in Section 4.6.

4.3.1 Soil

Drilling

The majority of the soil boreholes were advanced using a hand auger. Boreholes offering too much resistance for hand augering were advanced with a Dingo fitted with an auger or a combination of the Dingo and hand auger.

Sampling was conducted as follows:

- Boreholes were advanced to the proposed investigation depth.
- Depending on the soil lithology encountered within the borehole, soil sampling was carried out at approximate depths of: surface to 0.1 mbgs, 0.2 to 0.3 mbgs, 0.5 mbgs, 1.0 mbgs and 0.5 metres thereafter within the soil profile until the desired depth was attained. Samples were collected from each discrete strata unit, without sampling across strata.



- Undertaking in-field XRF analysis for key metal contaminants including primarily Antimony (Sb) and Arsenic (As) and secondarily Copper (Cu) and Lead (Pb).

Soils were logged according to the Unified Soil Classification System (USCS), making observations of evidence of contamination (staining or odours), as appropriate.

Borehole logs were prepared for each soil borehole location showing geology, field screening, groundwater strikes, sampling depths and final depth. Borelogs are presented in Appendix E.

Upon completion of drilling, the boreholes were backfilled with soil cuttings, generally replaced in the same depth order as excavated. Care was taken to avoid backfilling uncontaminated portions of the borehole with any cuttings that were potentially contaminated.

XRF Procedures

XRF procedures were implemented to develop a relationship between the XRF and laboratory results. This allowed for the ability to rapidly delineate the presence and extent of contamination on site during the investigation such that the sampling regime could be altered without waiting for laboratory results.

The applicability of this technique was previously indicated by work conducted by the EPA in 2008.

A NITON XL3t XRF unit was used in accordance with procedures outlined in Appendix H of the Preliminary Investigation Report and generally involved:

- Setting the XRF for target analytes, appropriate excitation sources and parameters based on data quality objectives (DQOs).
- Calibration of the XRF using supplied blanks, verification samples and background samples.
- Preparation of the soil for sampling (ensuring the soil was not covered in standing water, did not contain any large, non-representative debris, could be contacted directly by the XRF, was covered with thin plastic (cling wrap) and contained a smooth, flat surface).
- Sample analysis. XRF measurement time for each sample was generally 30 seconds.
- Precision measurement checks.
- Submission of at least 5% of samples to a laboratory for confirmatory analysis.

4.3.2 Sediment

Sediment samples were collected using a specifically designed, sediment sampling, push tube device which was operated from a canoe or by foot (using waders). Sample cores were divided according to observable characteristics with depth, to allow separate analysis and assessment of shallower and deeper sediments and any underlying residual soils (if present). XRF analysis was not used on sediment samples due to limitations relating to XRF analysis of saturated samples.

4.3.3 Surface Water

Surface water was collected directly into laboratory-supplied bottles, from a canoe or by foot (using waders). Surface water field measurements including pH, electrical conductivity (EC), oxidation-reduction potential (redox), dissolved oxygen (DO) and temperature were recorded at each surface water sampling location. Water quality meters were calibrated at the beginning of each sampling round and periodically throughout the day.

Both unfiltered/ unpreserved and filtered/ preserved samples of surface water were collected, to allow comparison of total and dissolved metal concentrations. Samples for dissolved metals analysis were field-filtered using 0.45 µm membrane filters to remove colloidal matter before being transferred to sample containers of appropriate composition that were pre-treated in a manner appropriate for the laboratory analysis.

4.3.4 Ground Water

Following an assessment of their physical state, monitoring wells installed by DLWC (1997) were sampled as follows:

- The standing water level, at each monitoring well, was gauged using an electronic interface probe.
- Each well was redeveloped by bailer on August 17, 2012 to remove accumulated sediment. Development using a bailer allowed for a greater surging action and potentially a greater removal of sediment.
- Sampling was conducted on August 22, 2012, using a low flow pump in order to generate less disturbance of sediments that may remain present in the wells.
- The equipment requiring decontamination was cleaned using an appropriate detergent and rinsed with deionised water after each use.
- Field parameters, including pH, EC, redox, DO and temperature were measured during purging, along with observations of the presence of a sheen or odours.
- When field parameters reached equilibrium (i.e. consecutive measurements were within 10% of each other), groundwater samples were collected directly from the dedicated tubing attached to the sampling pump. Water samples were immediately placed into laboratory prepared bottles suitable for the required analyses.
- Where required for laboratory analysis, water samples were filtered in the field using 0.45 µm membrane filters to remove colloidal matter before being transferred to sample containers of appropriate composition that were pre-treated in a manner appropriate for the laboratory analysis.

4.3.5 Stockpiles and Loading Ramps

Three stockpiles and two loading ramps were analysed using XRF field analysis. Samples were taken from depths of approximately 0.1 to 0.2 m below the stockpile surface.



4.3.6 Bricks

Twenty three bricks were field screened with the XRF by taking a reading directly onto the surface of the bricks. Two samples were submitted to the laboratory for crushing and analysis to verify the XRF results.

4.4 Analytical Schedule

Based on the SAQP presented in the Preliminary Investigation report (GHD 2012) and data obtained from XRF analysis, an analytical schedule was implemented as outlined in Table 2. The implemented SAQP varied from the SAQP presented in the Preliminary Investigation report where field data provided evidence of contaminant extent that varied from that presented in the preliminary CSM. Laboratory analysis focused on the key parameters of concern, and parameters related to the mobility and toxicity of the contaminants.

Table 2 Completed Sampling and Analytical Quality Plan

Zone	Comments	Number of Sampling Locations	Laboratory Analysis																											
			Soil / Sediment										Surface Water and Ground Water																	
			Aluminium	Arsenic	Antimony	Iron	Mercury	Metals suite (x8) ¹	Cyanide	pH	TCLP for metals	Weak acid digest for metals	Moisture	TOC	Cation Exchange Capacity	Particle size / clay content	screening (pH _i and pH _{ox})	SPOCAS	Aluminium ²	Antimony ²	Metals suite (x8) ^{1,2}	Cyanide	Iron	Major Cations and Anions	TDS	TSS				
Source Zone	Soil	32 locations, 120 samples	11	21	21	6	18	15	8	8	13	-	21	4	4	4	9	6												
	Bricks	25 x brick samples	-	2	2	-	2	2	-	-	-	-	-	-	-	-	-	-												
	Groundwater	4 monitoring wells																	4	4	4	3	4	3	3	3				
Impact Zone	Soil	27 locations, 66 samples	7	18	18	3	18	8	14	14	9	-	18	4	4	-	-	-												
	Sediment	32 locations, 79 samples	18	46	46	5	48	46	34	34	8	20	49	10	10	8	4	3												
	Surface water	7 locations																	8	8	8	8	8	8	8	8	8	8	8	8
Receptor Zone	Soil	6 locations, 17 samples	2	3	3	1	3	2	2	2	3	-	3	1	1	1	-													
	Sediment	6 locations, 12 samples	1	4	4	1	5	4	3	3	2	3	6	-	-	2	1	-												
	Surface water	2 locations																	10	10	10	10	10	10	10	10	10	10	10	10
TOTAL Primary Samples			39	94	94	16	94	77	61	61	35	23	97	19	19	15	14	9	22	22	22	21	22	21	21	21	21	21	21	

¹ 8 Metals = As, Cd, Cu, Cr, Ni, Pb, Zn, Hg

² Metals in surface water = dissolved plus total



4.5 Assessment Criteria

Following additional data obtained during the detailed investigation (as outlined in Sections 5 and 6), updated assessment criteria are listed below.

4.5.1 Relevant Guidelines

The framework for contamination assessment is based on guidelines “made or approved”, by the NSW EPA under Section 105 of the *Contaminated Land Management Act, 1997*. These guidelines include, but are not limited to the following:

- NSW OEH, Contaminated Sites: Guidelines for Consultants Reporting on Contaminated Sites, 2011.
- DECC, Contaminated Sites: Guidelines on the Duty to Report Contamination under the Contaminated Land Management Act 1997, June 2009.
- DEC, Contaminated Sites: Guidelines for the Assessment and Management of Groundwater Contamination, 2007.
- DEC, Contaminated Sites: Guidelines for NSW Site Auditor Scheme. 2006.
- ANZECC, National Water Quality Management Strategy, Paper No. 4, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), 2000.
- NEPC, National Environment Protection (Assessment of Site Contamination) Measure (NEPM), 1999.
- NSW EPA, Contaminated Sites: Sampling Design Guidelines, 1995.
- ANZECC/NHMRC, Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites, 1992.
- ANZECC /ARMCANZ Interim Sediment Quality Guidelines (ISQG), 2000.

Additional regulatory guidelines used for classification of waste material for off-site disposal (including the bricks) include:

- DECCW 2009, Waste Classification Guidelines, December 2009.

Where relevant criteria were not contained in the above guidelines, reference was made to other guideline documents, including the following:

- MHSPE 1994, Environmental Quality Objectives in the Netherlands.
- USEPA 2004 Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual.

The assessment criteria against which the project analytical data has been compared are outlined in the following subsections.

4.5.2 Soil Assessment Criteria

The adopted soil assessment criteria are presented in Table 3. The rationale for the assessment criteria is provided in the Preliminary Investigation report and summarised as follows.

Health Based Criteria

Health-based soil Investigation Levels (HILs) are provided for a range of different exposure settings, which are based on the nature of the use(s) for which the site is currently used and/or it's approved use(s). As the future use of the Site is likely to be as a reserve, the most applicable exposure setting is considered to be **NEHF E- Parks, Recreational, Open space** as published in DEC (2006). This criterion corresponds with NEPM HIL (E) from NEPC (1999) and is herein referred to as HIL (E).

Ecological Investigation Levels

Interim Ecological Investigation Levels (EILs) are presented in NEPC (1999) for urban areas and are based on considerations of phytotoxicity, ANZECC B levels and soil survey data. Assessment criteria for regional areas are 'to be developed by jurisdictions as required' (NEPC 1999). The EILs have been included as assessment criteria for evaluation of potential phytotoxic impacts, however discussions of analyte concentrations in section 5 are in relation to HIL E criteria.

DEC 2006 includes Provisional Phytotoxicity Based Investigation Levels (PBILs) which relate to the potential uptake of contaminants that may result in adverse, phytotoxic impacts on sensitive plant species. These are generally equivalent to the NEPC (1999) EILs. DEC 2006 notes, however that the PBILs have significant limitations because phytotoxicity depends on soil and species parameters in ways that are not fully understood. They are intended for use as a screening guide only and may be assumed to apply to sandy loam soils, or soils of a similar texture, for pH 6-8.

Antimony

No criteria are given in NEPC 1999 for antimony. As outlined in the Preliminary Investigation Report, the following assessment criteria have been provided for an assessment of antimony concentrations:

- ANZECC/NH&MRC (1992) Environmental Investigation level - 20 mg/kg. and
- USEPA (2004) Residential - 310 mg/kg.

Acid Sulfate soils

Potential acid sulfate soils were assessed by criterion outlined in:

- *Acid Sulfate Soils Assessment (ASSMAC) Guidelines* (Ahern et al. 1998). and
- Queensland Acid Sulfate Soil Technical Manual- Soil Management Guidelines (Dear et al. 2002).



Table 3 Adopted Soil Assessment Criteria

Analyte	Units	NEPM 1999 HIL E	NEPM 1999 EIL
Antimony ⁽¹⁾	mg/kg	310	20
Arsenic	mg/kg	200	20
Cadmium	mg/kg	40	3
Chromium (III+VI) ⁽²⁾	mg/kg	200	50 ⁽²⁾
Cyanide Total ⁽³⁾	mg/kg	500	-
Copper	mg/kg	2000	100
Lead	mg/kg	600	600
Manganese	mg/kg	3000	500
Mercury	mg/kg	30	1
Nickel	mg/kg	600	60

- (1) Criteria for antimony will be 20 mg/kg (ANZECC/NH&MRC 1992) and 310 mg/kg (USEPA Res (2004)).
 (2) Chromium analysed as Total Chromium. Health-based Criteria for Cr (VI) used as a conservative screening measure, although Chromium is considered unlikely to be present in hexavalent form. ANZECC/NHMRC (1992) Environmental Investigation Threshold (EIT) adopted for total chromium, as Chromium is considered unlikely to be present in hexavalent form.
 (3) HIL for free cyanide used as a conservative measure.

4.5.3 Sediment Assessment Criteria

The adopted sediment assessment criteria for selected analytes are presented in Table 4. As outlined in the Preliminary Investigation Report, the assessment criteria for most analytes were from the ANZECC /ARMCANZ (2000) Interim Sediment Quality Guidelines (ISQG).

No criterion was available from ANZECC /ARMCANZ (2000) for cyanide. The Dutch intervention values (MHSPE 1994) for sediment of 20 mg/kg for free cyanide and 50 mg/kg for complex cyanides, have been adopted in this case.

The influence of site-specific conditions on contaminant bioavailability and toxicity to benthic invertebrates is a key consideration in the environmental risk assessment process. This is particularly relevant for contaminants with complex speciation chemistries such as arsenic (Irving et al 2008). However, Irving et al (2008) found sublethal toxicities of both arsenite (As(III)) and arsenate (As(V)) to be similar and not significantly affected by changes in DO.

In the consideration of guideline values for metals, total metals concentrations are used, however, acid-soluble metals, are more representative of a bioavailable fraction and it is envisaged that ultimately trigger value compliance will be based on this measurement (ANZECC 2000). Accordingly total concentrations were used for initial screening but where available, weak acid extractable concentrations were considered to be more appropriate in the assessment of risk.

Table 4 Adopted Sediment Assessment Criteria

Analyte	Units	ISQG- Low	ISQG- High
Antimony	mg/kg	2	25
Arsenic	mg/kg	20	70
Cadmium	mg/kg	1.5	10
Chromium	mg/kg	80	370
Copper	mg/kg	65	270
Cyanide	mg/kg	20	50
Lead	mg/kg	50	220
Mercury	mg/kg	0.15	1
Nickel	mg/kg	21	52
Zinc	mg/kg	200	410

4.5.4 Water Assessment Criteria

The adopted water assessment criteria for selected analytes are presented in Table 5. The rationale for the assessment criteria is provided in the Preliminary Investigation report.

For the purpose of this assessment, surface and groundwater quality will be compared to the assessment criteria outlined in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000). Electrical conductivity (EC) levels measured in the surface water by DLWC (1997) and during this investigation had a maximum value of 380 uS/cm. Although limited, the data indicates the receiving environment contains freshwater (brackish water is considered to have an EC of 800-1600 uS/cm (Environment Australia, 2002)), hence the guidelines for Freshwater were applied.

As the Site is deemed to be a 'slightly to moderately disturbed system', the 95% level of protection of species has been identified as being applicable in conjunction with the 99% level for selected analytes deemed to have a bioaccumulative effect.



Table 5 Adopted Water Assessment Criteria

Analyte	Units	ANZECC 2000 Fresh Water Slightly-moderate disturbed system
Aluminium	mg/L	0.05
Antimony	mg/L	0.009
Arsenic	mg/L	0.013
Cadmium	mg/L	0.0002
Chromium (III) ¹	mg/L	0.00331
Chromium (VI)	mg/L	0.001
Copper	mg/L	0.0014
Cyanide Total	mg/L	0.007
Lead	mg/L	0.0034
Mercury (inorganic) ²	mg/L	0.00006
Mercury (methyl)	Mg/L	ID2
Nickel	mg/L	0.011

¹ A moderate reliability trigger value for chromium (III) of 3.3 µg/L for freshwater was derived, using the statistical distribution method with 95% protection and an ACR of 77.6.

² There were Insufficient Data (ID) to derive trigger values for methyl mercury. The 99% protection levels for organic mercury are recommended for slightly-moderately disturbed systems as a precaution for bioaccumulation.

4.5.5 Exceedance Comparison Criteria

As presented in most of the data tables in Appendix C, a comparison of the magnitude of concentrations exceeding the assessment criteria has been facilitated with the following additional criteria:

- Ten times the assessment criteria.
- Thirty times the assessment criteria.

4.6 Quality Assurance/ Quality Control (QA/QC)

4.6.1 Field Programme QA/QC

All fieldwork was conducted in general accordance with GHD's SOP, which aim at collecting environmental samples using uniform and systematic methods, as required by GHD's QA system. Key requirements of these procedures were as follows:

- Appropriately trained and experienced staff conducting and documenting site activities using photographs and notes on standard field forms such as daily site records and sampling logs.
- Decontamination procedures including the use of new disposable gloves for the collection of each sample, decontamination of sampling equipment between each sampling location (using DECON 90) and the use of dedicated sampling containers provided by the laboratory.
- Logging procedures using a recognised system.

- Ensuring all field-monitoring equipment was appropriately calibrated.
- Using documentation and Chain of Custody procedures as outlined in the SAQP.
- Collection of duplicate and triplicate samples for QA/QC purposes as outlined in the SAQP which included 5% split duplicates and 5% blind replicate samples on the basis of sections 4.7 and 4.8 of the NEPM (1999) Schedule B(3) of the NEPM and the ANZECC / ARMCANZ 2000 *Australian Guidelines for Water Quality Monitoring and Reporting*.
- Collection of one rinsate blank per day.

QA/QC precision was assessed following assessment criteria outlined in the SAQP. Precision measures the reproducibility of measurements under a given set of conditions. The precision of the data is assessed by calculating the Relative Percent Difference (RPD) between duplicate sample pairs.

$$RPD(\%) = \frac{|C_o - C_d|}{C_o + C_d} \times 100$$

Where **Co =** **Analyte concentration of the original sample**

Cd = **Analyte concentration of the duplicate sample**

GHD generally adopts a nominal acceptance criterion of $\pm 30\%$ RPD for field duplicates and splits for inorganics and a nominal acceptance criterion of $\pm 50\%$ RPD for field duplicates and splits for organics. It is noted that this will not always be achieved, particularly in heterogeneous soil or fill materials, or at low analyte concentrations.

4.6.2 Laboratory Programme QA/QC

All analyses were carried out by ALS Laboratory (who are National Association of Testing Authorities (NATA) accredited), using analytical methodology consistent with the requirements of relevant guidelines. Where practical, analytical methodologies were selected to provide a Practical Quantitation Limit (PQL) low enough for comparison with the adopted assessment criteria.

The laboratories used their internal procedures and NATA accredited methods in accordance with their quality assurance system. Laboratory quality control procedures included:

- **Laboratory duplicate samples:** Duplicate sub samples were collected by the laboratory from one sample submitted for analytical testing at an overall rate of approximately 36%. A laboratory duplicate provides data on the analytical precision and reproducibility of the test result. Ideally laboratory duplicate samples should return RPDs within the NEPM acceptance criteria of $\pm 30\%$.
- **Spiked Samples:** An authentic field sample was spiked by adding an aliquot of known concentration of the target analyte(s) prior to sample extraction and analysis. A spike documents the effect of the sample matrix on the extraction and analytical techniques. Spiked samples were analysed at a rate of approximately 9%.



- **Certified Reference Standards:** A reference standard of known (certified) concentration was analysed along with a batch of samples. The Certified Reference Standard (CRS) or Laboratory Control Spike (LCS) provides an indication of the analytical accuracy and the precision of the test method and is used for inorganic analyses. LCS were analysed at a rate of approximately 12%.
- **Surrogate Standard/Spikes:** Are organic compounds which are similar to the analyte of interest in terms of chemical composition, extractability, and chromatographic conditions (retention time), but which are not normally found in environmental samples. These surrogate compounds are spiked into blanks, standards and samples submitted for organic analyses by gas-chromatographic techniques prior to sample extraction. Surrogate Standard/Spikes provide a means of checking that no gross errors have occurred during any stage of the test method leading to significant analyte loss. Although dependent on the type of analyte tested, concentrations of analytes and sample matrix should normally fall within the range of 70-130%.
- **Laboratory Blanks:** Are organic or aqueous solutions that are as free as possible of analytes of interest to which reagents are added, in the same volume, as used in the preparation and subsequent analysis of the samples. The reagent blank is carried through the complete sample preparation procedure and contains the same reagent concentrations in the final solution as in the sample solution used for analysis. The reagent blank is used to correct for possible contamination resulting from the preparation or processing of the sample. Laboratory blanks were analysed at a rate of approximately 12%. Laboratory blanks should return analyte concentrations as 'not detected'.

The individual testing laboratories conducted an assessment of the laboratory QC program internally, as discussed in Section 5.7.

5. Detailed Investigation Results

5.1 Soil

5.1.1 Lithology

Soil borehole logs are presented in Appendix E. Selected cross sections of the Site including lithological data are presented in Figures 4 to 6. A summary of soil lithology noted across the site is presented in Table 6.

In general, the lithology in the vicinity of the tailings consists of silty sand to approximately 1.5 m overlaying approximately 1 m of clayey silt (described by DLWC 1997 as peat), and then silty clay at depths greater than approximately 2.5 m.



Table 6 Soil Lithology Summary

Area	Boreholes (BH#)	Zone	Lithology Summary	Approximate depth to groundwater
Tailings deposit	23,24,30,31,32,41,42,43,50,51,52,53,54	Source	0-1.5 m silty SAND, grey, moist 1.5-2.5 m clayey SILT, brown, wet 2.5->4.0 m silty CLAY, grey/orange, moist	0.3-0.8 m
Former Unprocessed Ore Stockpiling	1,20,21,28,29,40,46,47	Source	0-0.3 m silty GRAVEL, brown, dry 0.3-0.7 m sandy SILT, brown, moist 0.7->1.5 m silty CLAY, orange, moist	>1.5 m
Former Processing Area	2,3,4,5,6,10,11,22,39,100,101	Source	0-0.8 m sandy SILT, brown, dry 0.8-1.5 m clayey SILT, dark brown, moist 1.5->2.2 silty CLAY, orange/grey, wet	1.2 m
NE portion of Site	56,57,61,61,62,63,64,65,66,67,68,70,71,72,73	Impact	0-0.5 m sandy SILT, brown, moist 0.5->1.2 m silty CLAY	>1.2 m
Vicinity of 'L' and 'S' Shaped Canals	69,74,75,76,77,78,79,80,81,82,83,84	Impact	0-1.0 m sandy SILT, brown, moist 1.0->1.7 m silty CLAY, orange/grey, moist/wet	1.5 m
South of Wetland	12,14,27,34,91,93	Receptor	0-0.3 m sandy SILT, brown, moist 0.3->1.0 m silty CLAY, orange/grey, moist	0.8 m

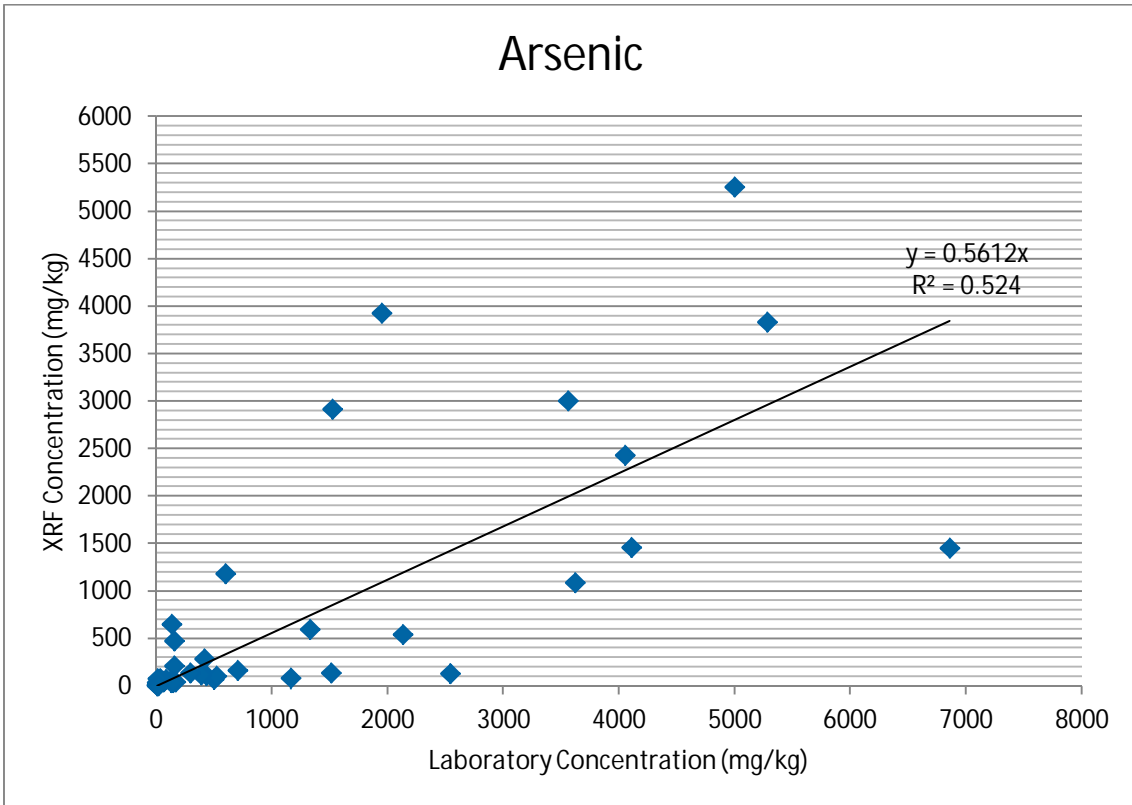
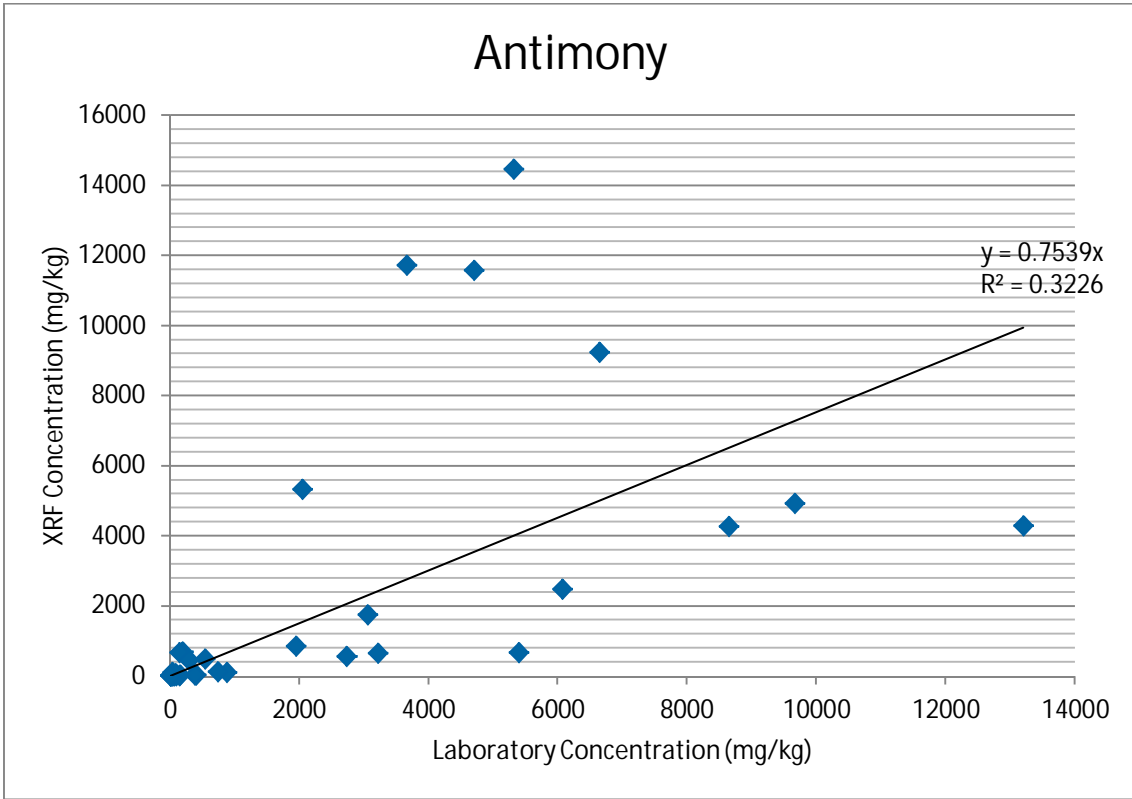
5.1.2 Field Analysis

As discussed in Section 4.3.1, an XRF unit was used for field analysis of metal concentrations in soil. Results are presented in Table C1, Appendix C. A comparison of XRF data with chemical data is presented in Table 3, Appendix C and graphically in Graph 1.

In summary, a comparison of XRF data with chemical data includes:

- RPDs were generally within 150%.
- The XRF results were, on average 75% of the laboratory concentrations for antimony and 56% of the laboratory concentrations for arsenic.
- Non-detects and low values were generally reported consistently by both the laboratory and XRF.
- Inaccuracies increased when high antimony and arsenic concentrations were encountered.
- Possible rationale for the differences include:
 - A high degree of variability in the concentrations of analytes within a given sample as indicated by relatively high RPDs found in field and interlaboratory duplicate samples (as shown in Section 5.7).
 - The non-homogenous nature of the soil.
 - Differences in the sample portion analysed. The depth of x-ray penetration is less than approximately 0.17mm.
 - Moisture content of a sample, when in excess of 20% can have a negative impact on sample precision. The cause of the error is that the XRF gives wet weight results whereas the laboratory gives dry weight results. These are not directly comparable as the dry weight results will return higher concentrations of contaminants present (as supported by this data). XRF analysis is considered less reliable if soils are identified to have a likely moisture content close to saturation.

In general, the XRF results did not correlate well with the laboratory results, however the XRF data is deemed accurate enough to give an indication of the presence/absence of the target analyte and is generally accurate enough to indicate analyte concentrations within the orders of magnitude required to classify the concentrations within the parameters used in this investigation (being exceeding assessment criteria, exceeding 10 times the assessment criteria and exceeding 30 times the assessment criteria).



Graph 1 XRF/ Chemical Data Comparison Graphs

5.1.3 Chemical Analysis

Chemical analysis results for historic and current samples are presented in Table C1, Appendix C. Soil antimony and arsenic concentrations are also presented in Figures 7 to 9. (Table C1 and Figures 7 to 9 also show XRF data). Discussions regarding comparison of analyte concentrations with 'assessment criteria' refer to HIL E criteria, as outlined in section 4.5.

A summary of soil analyte concentrations is presented in Table 7. Note that this table is based solely on laboratory analytical data, due to relatively poor correlation with XRF data. The summarised laboratory results are considered to provide a representative indication of the degree of contamination at the site, while the more extensive XRF data has been used primarily to provide further detail on the extent of contamination.

The interpreted impact extent is presented in Figures 1, 7, 8 and 9 and estimated volumes of impacted soil are presented in Figure 10a.

In summary, results show that:

- The data was deemed adequate for the development of a CSM sufficient for the purposes of planning remediation.
- Assessment criteria exceedances were noted for antimony, arsenic, chromium, cobalt, copper, lead, mercury and cyanide. This is consistent with the COCs noted in historic investigations.
- Antimony and arsenic concentrations exceeded the assessment criteria most frequently and by the largest percentage (up to 40 times the criteria).
- Concentrations of the main COC recorded in this investigation were within a similar order of magnitude (given differences in sampling and analysis methods) as those recorded in the historical investigations. This implies concentrations have remained relatively constant over the 1995 to 2012 sampling period, and current methodology is comparable with that used in the previous investigations. (Although as indicated in Table 7, historic concentrations of some parameters such as chromium and copper were significantly higher in historic results, possibly due to different laboratory methodology at the time).
- Observations regarding the horizontal impact include:
 - The extent of significant arsenic and antimony contamination roughly follows the extent of areas without vegetation as shown in figures 7 to 9 and verified during the field investigation.
 - The impact in the south west corner of the site, near the wetland has not been delineated due to site access constraints. Delineation would entail further sampling in the neighbouring property.
 - Soil on the southern side of the wetland was free of contaminants.
 - Soil in the north east portion of the site is relatively free of contaminants with the exception of an area of unknown disturbance, to the north west of the 'L' Shaped canal. This area showed elevated antimony, arsenic and lead concentrations to a depth of approximately 1 mbgs (sample location BH073).



Elevated concentrations were also noted for mercury, zinc and copper. Zinc exceeds the EIL but not the HIL, however the concentration at this location is ten times greater than any other result, except for a location in the south west corner of the site (DLWC95-S3), sampled during the DLWC (1995) investigation.

- The soil within the embankment immediately to the north of the 'L' shaped canal showed elevated antimony and arsenic concentrations mainly from between 1 mbgs to 1.7 mbgs (current ground surface). No major change in lithology was noted at that depth, however the depths roughly correlate with the presence of groundwater. It is possible that impacted sediment and soil was excavated from the location of the 'L' shaped canal during canal and embankment construction. Relatively clean soil from deeper within the profile beneath the 'L' shaped canal would then have been placed over the impacted/ excavated sediment. Alternatively, the contaminated interval may represent the original soil surface impacted by contaminant migration from the antimony processing area prior to the canal and embankment construction (historic aerial photographs indicate the original alignment of a drainage course through the site was approximately in this area).
- Adequate data has been presented to enable vertical delineation of the contaminants in the tailings. Approximate depths of impact are shown in Figure 10a. Depths exceeding the adopted assessment criteria varied from approximately 0.5 mbgs in the north west portion of the impact to approximately 2.2 mbgs near the water's edge and some locations within the tailings deposit.
- For "soil" samples (being those take from "dry" areas of the site, including the tailings area, during GHD's investigations) the degree of contamination generally reduces quite quickly so that the site can be divided into significantly impacted and relatively unimpacted areas. The exceptions to this are primarily adjacent to the 'L' shaped canal (where contamination is either within 10 times the assessment criteria, or covered by cleaner material), the south western corner of the site (which has insufficient sampling to define), and the area of disturbance at the north east corner of the site.
- Contaminant concentrations in the relatively unimpacted areas are generally less than EILs as well as less than HIL E.
- In most cases, the leachable concentrations of COCs in the soil and sediment were significantly less than total concentrations, suggesting the physical migration of contaminated soil or sediment has been the more important contaminant migration pathway.
- Notwithstanding the above, where there were significant concentrations of antimony and arsenic in soil or sediment samples, the corresponding leachable concentrations were well above ANZECC trigger values for protection of aquatic ecosystems. This is discussed further in section 5.3.

Table 7 Laboratory Analysed Soil Chemistry Summary

Potential Contaminant/indicator	Source Zone (mg/kg)				Impact Zone (mg/kg)				Receptor Zone (mg/kg)				Comment
	Current (Max)	Current (Min)	Historic (Max)	Historic (Min)	Current (Max)	Current (Min)	Historic (Max)	Historic (Min)	Current (Max)	Current (Min)	Historic (Max)	Historic (Min)	
Al	17,300	410	-	-	16,100	5,440	-	-	13,100	4,660	-	-	Limited data. Elevated throughout site. No assessment criteria used. Likely to be commensurate with natural soil concentrations.
Sb	13,200	<5	17,160	<1	3,220	<5	2,010	360	7	<5	39	3	COC. Assessment criteria = 310 mg/kg.
Leachable Sb (mg/L)	10.5	<0.1	-	-	10.6	<0.1	-	-	-	-	-	-	Surface water assessment criteria = 0.27 mg/L.
As	69,000	<5	9,820	<0.5	2,130	<5	309	197	16	5	84	12	COC. Assessment criteria = 200 mg/kg.
Leachable As (mg/L)	16.2	<0.1	-	-	1.1	<0.1	-	-	-	-	-	-	Surface water assessment criteria = 0.0045 mg/L.
Cd	11	<1	25.5	<0.5	3	<1	1.6	<0.5	<1	<1	0	<0.5	All laboratory results below assessment criteria of 40 mg/kg.
Cr	34	3	1,540	1.4	20	4	363	10	15	5	16	7	All current laboratory results below assessment criteria of 200 mg/kg.
Cu	724	<5	3,448	2.4	120	<5	2,716	33	12	<5	76	7.2	All current laboratory results below assessment criteria of 2000 mg/kg.
Fe	27,400	11,000	-	-	8,020	2,720	-	-	25,400	25,400	-	-	Limited data. Elevated throughout site. No assessment criteria used. Likely to be commensurate with natural soil concentrations.



Potential Contaminant/ indicator	Source Zone (mg/kg)				Impact Zone (mg/kg)				Receptor Zone (mg/kg)				Comment
	Current (Max)	Current (Min)	Historic (Max)	Historic (Min)	Current (Max)	Current (Min)	Historic (Max)	Historic (Min)	Current (Max)	Current (Min)	Historic (Max)	Historic (Min)	
Pb	996	6	3,550	5	518	8	500	33	12	8	98	6.9	All current laboratory results below assessment criteria of 600 mg/kg except 1 sample (BH032_0.3-0.5)
Hg	343	<0.1	81	<0.05	57.8	<0.1	7.9	7.9	0.1	<0.1	0.33	<0.05	Assessment criteria = 30 mg/kg. Potential COC.
Ni	9	<2	2	<1	18	<2	-	-	5	<2	-	-	All laboratory results below assessment criteria of 600 mg/kg.
Zn	695	<5	7,477	2	305	8	294	24	8	<5	128	17	All levels below assessment criteria of 14,000 mg/kg.
CN	39	<1	18	<0.1	83	<1	0.6	0.6	3	2	0.1	<0.1	All levels significantly below assessment criteria of 1,000 mg/kg.
TOC	9.46	0.2	34	0.1	17.6	0.3	4.2	4.2	2.88	2.88	31	3.6	Highly variable TOC. Similar range to historic results.
pH (units)	7.5	3	6.7	2.9	5.6	3.2	5.8	5.8	5.1	4.7	6.9	4.8	Generally acidic

Notes: Table 7 does not include XRF results. Refer to Table C1 for all results, including XRF and laboratory analysed results.
Units in mg/kg unless otherwise noted.

5.1.4 Physical Analysis

Results for soil and sediment physical characteristics are presented in Table C4, Appendix C. A summary of results includes:

- Sixteen (5 soil and 11 sediment) samples were analysed for particle size analysis (PSA).
- Lithology noted on the borehole logs closely matched the laboratory results for soil, with the classification matching in three cases and having the same key constituent for the remaining two.
- Sediment logging was generally less accurate due to the difficulties associated with the field classification of saturated sediments. In summary:
 - Laboratory results matched the field classification in two cases.
 - Laboratory results had the same key constituents as the field classification in five cases.
 - Laboratory results poorly matched field classification in four cases. This was generally in cases where a laboratory result of silty CLAY was field classified as SILT.
- The data indicates that the soil logging used by GHD is within a sufficient degree of accuracy for assessing remediation options. Sediment analysis should generally be considered to have higher clay content than the lithology presented in the borehole logs for this investigation.

5.1.5 Acid Sulfate Soil

Results for soil and sediment acid sulfate potential are presented in Table C5 Appendix C. A summary of results includes:

- Eighteen samples from 11 locations (in the tailings (including the underlying soils at a depth of 2.0 mbgs), the sediment adjacent to the tailings and the vicinity of the canals) were analysed for field analysis of potential acid sulfate soils (PASS) with all samples indicating a high likelihood of acid sulphate generation potential for all these materials.
- Based on the field analysis, nine samples from five locations (in the tailings and in the sediment adjacent to the tailings) were analysed for Suspension Peroxide Oxidation Combined Acidity and Sulfur (SPOCAS) analysis.
- Based on the percentage of oxidisable sulfur (net acidity-sulphur) and a comparison with the Action Criteria in Table 4.4 of the Acid Sulfate Soils Management Advisory Committee (ASSMAC) guidelines (Ahern et al. 1998), the preparation of a detailed management plan and development consent will be required for works that disturb the soil.
- Surface soils in the vicinity of the tailings deposit were noted to have lower pH and net acidity. This is interpreted to be a result of the soil in that area having been



exposed to oxygen and hence having already completed an acid generating reaction.

- Net acidity generally increased with depth to the maximum depth analysed (1.8-2.0m).

5.2 Sediment

5.2.1 Lithology

Sediment borehole logs are presented in Appendix E. A cross section of the wetland area including sediment lithological data is presented in Figure 6. A summary of sediment lithology noted across the site is presented in Table 8.

Table 8 Sediment Lithology Summary

Area	Boreholes (SE#)	Zone	Lithology Summary
Adjacent and West of Tailings	1,2,3,4,5,6,10,11,12,13,14,20,21,22,102	Impact	0-0.3 m clayey SILT, dark brown 0.3->1.1 m silty CLAY, grey
Within 'S' Shaped Canals	50,51,52,53,54,56	Impact	0->0.6 m silty CLAY, grey
Adjacent to 'L' Shaped Canal	30,31,32,33,40,41,42,43,55,57,60,61,62	Impact	0->0.7 silty CLAY, dark brown/grey
East of 'L' Shaped Canal	63,64,65,66,67,68	Receptor	0-0.2 m SILT, organic matter, black 0.2-0.3 m sandy CLAY, dark grey 0.3->0.6 m SILT, organic matter, black

5.2.2 Field Observations

A summary of the environment from which the sediment was sampled is as follows:

- Upstream (west) of tailings deposit: Swampland consisting of reeds, grass, *melaleuca* trees and ferns (as shown in Photo 16, Appendix B). Vegetation showed little physical evidence of impact.
- Vicinity of tailings deposit: An area of dead *melaleuca* trees which was relatively devoid of other vegetation (as shown in Photos 14 and 15, Appendix B). Impact from former site activities was highly evident.
- Adjacent to and east of the 'L' shaped canal: Lilies, reeds and *melaleuca* trees (as shown in Photos 11 and 12, Appendix B) showing little physical evidence of impact.

- Neither discernible flow nor tidal influence was noted during the investigation.
- The water level was noted to be significantly lower by SCS staff in late October 2012. This was following a relatively low rainfall period.
- An old fenceline in the tailings area is buried in sediment, with only approximately 0.3 m of each post exposed, indicating the water level and sediment have risen since the installation of the fence (although water levels may be seasonally variable, as noted above).

5.2.3 Chemical Analysis

Chemical analysis for sediment samples are presented in Table C2, Appendix C. Antimony and arsenic concentrations with interpreted impact extent are presented in Figures 11 and 12. Estimated volumes of impacted sediment are presented in 10b. A summary of sediment analyte concentrations is presented in Table 9.

Discussions regarding comparison of analyte concentrations with 'assessment criteria' refer to the ANZECC /ARMCANZ (2000) Interim Sediment Quality Guidelines as outlined in Section 4.5.3.

In summary, results show that:

- The data was deemed adequate for the development of a CSM sufficient for the purposes of planning remediation.
- As outlined in section 4.5.3, a comparison with weak acid extractable metal concentrations with the assessment criteria was deemed more applicable than total concentrations in assessing the bioavailability of the analytes.
- The weak acid extractable antimony, arsenic, copper, lead and zinc concentrations exceeded the relevant assessment criteria most frequently. A comparison of total with weak acid extractable concentrations for antimony and arsenic are presented in Graph 2. For a conservative approach, it is noted with some confidence that the weak acid extractable concentrations are unlikely to exceed 40% and 25% of the total metal concentrations for antimony and arsenic respectively.
- Although total concentrations of antimony, arsenic, copper, lead, mercury (and to a lesser extent, zinc and chromium) were either elevated or noted to exceed the assessment criteria at most locations, the weak acid extractable concentrations indicate lower bioavailability of those analytes. Applying the comparative ratios of 40% and 25% for antimony and arsenic, respectively to the total metals concentrations results in approximately 20% of the samples analysed reduced to a lower assessment category (being exceeding, exceeding 10 times or exceeding 30 times the assessment criteria).
- In most cases, the leachable concentrations of COCs in the sediment were significantly less than total concentrations, suggesting the physical migration of contaminated sediment has been the more important contaminant migration pathway.



- Notwithstanding the above, where there were significant concentrations of antimony and arsenic in sediment samples, the corresponding leachable concentrations were well above ANZECC trigger values for protection of aquatic ecosystems. This is discussed further in section 5.3.
- Regarding the horizontal extent of the impacted sediment:
 - The interpreted impact extent of antimony and arsenic were similar. The antimony concentrations were generally higher than arsenic in comparison with their respective adopted assessment criteria.
 - Showing highest levels of impact adjacent to the tailings deposit, extending approximately 50 m downstream of the tailing deposit, extending across the wetland some 50 m to the south of the tailings deposit (roughly correlating with vegetation dieback), and within and adjacent to the north eastern portion of the 'L' shaped canal.
 - The impacted sediments adjacent to the eastern portion of the 'L' shaped canal may be as a result of deposition in an 'eddy' that would be present during high flow events. The other possible source of this impact would be from discharge from the north eastern end of the 'S' shaped canals; however relatively low concentrations of COC in sediment samples from the 'S' shaped canals indicate this is the less likely source.
 - The western portion of the 'S' shaped canals was impacted at concentrations exceeding 30 times the adopted assessment criteria. Topography in that area and proximity to the tailings area indicates the likelihood for surface run-off from the tailings deposit to directly enter the western-most portion of the 'S' Shaped canals. Limited connectivity was noted from this portion of the canal to the eastern (remaining) portion of the 'S' shaped canal system. This was supported by the lack of significant impact from COCs in the eastern area.
 - The south eastern portion of the 'S' Shaped canal (Sample SE054) was impacted. This may be associated with potential impact relating to placement of spoil from excavation of the canal.
 - Insufficient data was available to delineate the full extent of sediment impact to the south east of the site, adjacent to the southern shore of the wetland. Similarly, sediment data to the north east of the 'L' shaped canal is limited. The importance of these data gaps will depend on decisions regarding the extent of remediation across the wetland areas.
- Regarding the vertical extent of the impacted sediment:
 - Depths of impact ranges from about 0.5 mbgs near the tailings to 0.1 mbgs in the southern portion of the wetland.
 - The greatest concentrations were generally noted in the surface sediment (0-0.1 m).
 - In several cases (where organic matter was noted to overlay the sediment), the highest concentrations were noted in the second lithological layer (eg 0.2-0.4m).

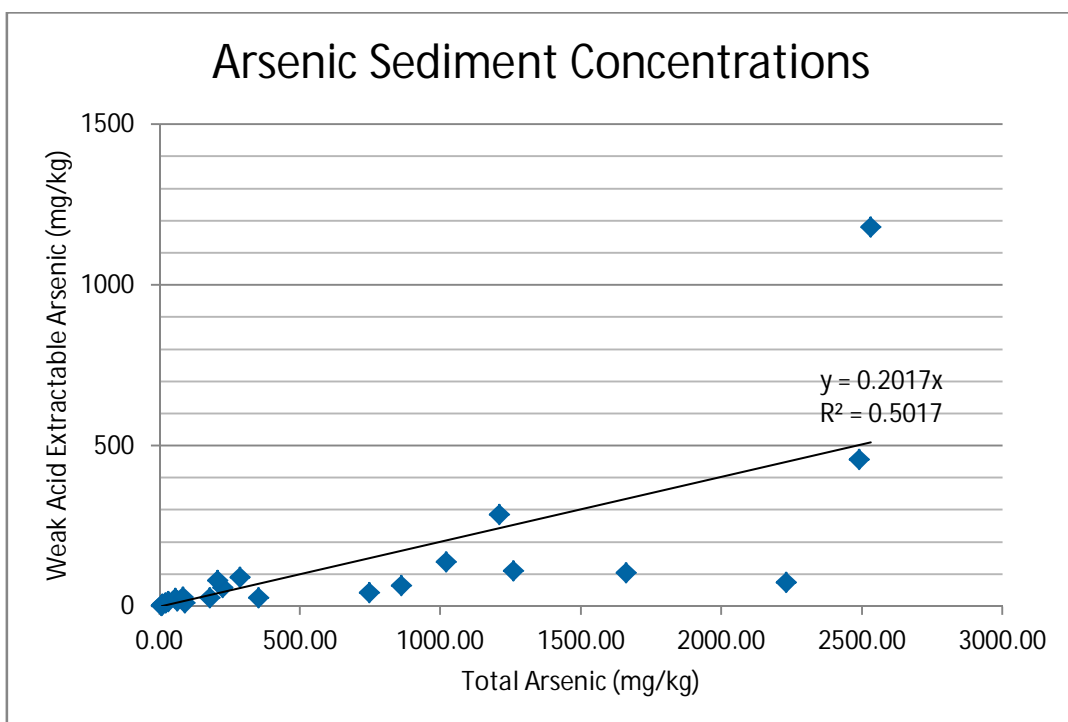
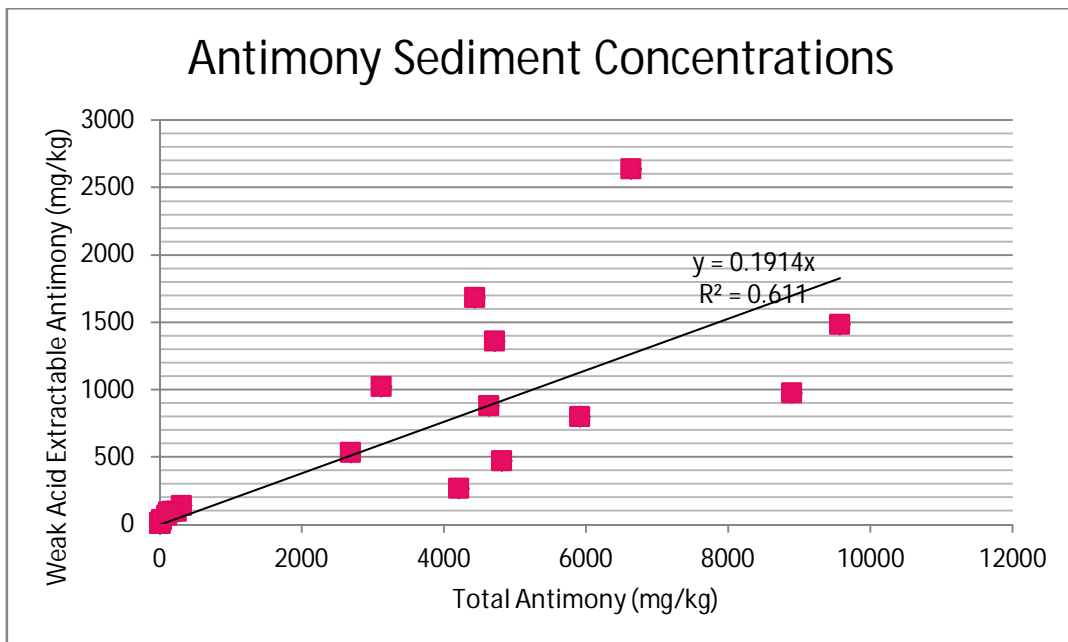
Table 9 Sediment Chemistry Summary

Potential Contaminant	Impact Zone (mg/kg)		Receptor Zone (mg/kg)		Comment
	Max	Min	Max	Min	
Al	18,400	990	7,700	7,700	No defined assessment criteria. Likely to be commensurate with natural soil concentrations.
Sb- Total	11,900	<5	242	130	COC- Elevated levels, likely at least 2.5 times higher than the more applicable weak acid (W.A.) extractable concentrations.
Sb- W.A. Extractable	2,640	2.9	96	90.9	COC- reduced from total levels but significantly exceeding assessment criteria of 25 mg/kg in vicinity of tailing deposit.
Sb- Leachable (mg/L)	8.8	<0.1	1.1	0.6	COC- Limited data. Surface water assessment criteria = 0.27 mg/L.
As- Total	5,410	6	286	22	COC- Elevated levels, likely at least 4 times higher than the more applicable W.A. extractable concentrations..
As- W. A. Extractable	1,180	2.3	91.4	11.7	COC- Significantly reduced from total levels but still significantly exceeding assessment criteria of 70 mg/kg in vicinity of tailing deposit.
As- Leachable (mg/L)	3.8	<0.1	0.3	0.1	COC- Limited data. Surface water assessment criteria = 0.0045 mg/L.
Cd	8	<1	4	<1	All values less than assessment criteria of 10 mg/kg.
Cr	1,450	3	15	10	All values except 1 (SE002_0.0-0.1) less than assessment criteria of 370 mg/kg.
Cu	1,900	6	310	73	Approx. half samples exceed assessment criteria of 270 mg/kg, W.A. extractable values reduced but some still exceed assessment criteria. Limited data on leachable concentrations.
Fe	11,600	2,870	6,610	6,610	No defined assessment criteria. Likely to be commensurate with natural soil concentrations.
Pb	3,280	<5	54	21	Possible COC- Elevated levels exceed assessment criteria of 220 mg/kg, W.A. extractable values reduced but some still exceed assessment criteria. Limited data on leachable concentrations.
Hg	151	<0.1	0.9	0.1	COC- Elevated levels exceed assessment criteria of 1 mg/kg. Leachable concentrations below LOR of 0.001 mg/L (surface water assessment criteria 0.00006 mg/L) except for SE032 (0.0082 mg/L).



Potential Contaminant	Impact Zone (mg/kg)		Receptor Zone (mg/kg)		Comment
	Max	Min	Max	Min	
Ni	26	<2	10	6	All values less than assessment criteria of 52 mg/kg.
Zn	2,150	<5	1,130	74	Possible COC- Elevated levels exceed assessment criteria of 410 mg/kg, W.A. extractable values not significantly reduced. Leachable levels range from 0.9 to 9.1 mg/L. Surface water assessment criteria 0.008 mg/L.
CN	235	<2	4	<1	Possible COC- 5 samples exceed assessment criteria of 50 mg/kg.

Notes: Table 9 does not include XRF results (only limited XRF data for sediment, and not considered reliable due to high moisture content). Refer to Table C1 for all results, including XRF and laboratory analysed results.
Units in mg/kg unless otherwise noted.



Graph 2 Comparison of Total Versus Weak Acid Extractable Concentrations in Sediment.



5.2.4 Physical Analysis

Results for soil and sediment physical analysis are discussed in section 5.1.4.

5.2.5 Acid Sulfate Soil

Results for soil and sediment acid sulfate testing are discussed in section 5.1.5.

5.3 Surface Water

5.3.1 Field Observations

A summary of the environment from which the surface water was sampled is as follows:

- Upstream (west) of tailings deposit: Swampland consisting of reeds, grass, *melaleuca* trees and ferns. Vegetation showed little physical evidence of impact.
- Vicinity of tailings deposit: An area of dead *melaleuca* trees which is relatively devoid of other vegetation (as shown in Photos 14 and 15, Appendix B). Impact from former site activities was highly evident.
- Adjacent to and east of the 'L' shaped canal: Lilies, reeds and *melaleuca* trees (as shown in Photos 11 and 12, Appendix B) showing little physical evidence of impact.
- Neither discernible flow nor tidal influence was noted during the investigation.
- The water level was noted to be significantly lower by SCS staff in late October 2012. This was following a relatively low rainfall period.

5.3.2 Field Analysis

Field analytical results are presented in Table C6, Appendix C.

pH values were between 4.9 and 6.9 which indicates a slightly acidic environment. Values were consistent with DLWC 1997 data and not considered acidic enough to assist in the large scale mobilisation of heavy metals. The pH values may indicate limited impact from potential oxidisation of acid sulfate soils.

EC levels measured in the surface water by DLWC (1997) and during this investigation had a maximum value of 320 $\mu\text{S}/\text{cm}$. Although limited, the data indicates the wetland contains freshwater. Brackish water is considered to have an EC of 800-1600 $\mu\text{S}/\text{cm}$ (Environment Australia, 2002).

DO values were relatively low and may be attributable to the relatively stagnant nature of the water within the wetland.

5.3.3 Chemical Analysis

Chemical analysis for historic and current surface water samples are presented in Table C6, Appendix C. Aluminium, antimony, arsenic, copper, lead and zinc concentrations are also presented in Figure 13.

A summary of current surface water analyte concentrations is presented in Table 10. A graphical representation of antimony and arsenic results is presented in Graph 3.

Discussions regarding comparison of analyte concentrations with 'assessment criteria' refer to the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000) for freshwater in a 'slightly to moderately disturbed system', as outlined in Section 4.5.4.

In summary, results show that:

- The data was deemed adequate for the development of a CSM sufficient for the purposes of planning remediation.
- Aluminium, antimony, arsenic and copper concentrations for most samples exceeded the assessment criteria.
- Cadmium and zinc concentrations were elevated in several samples, but except as follows were within an order of magnitude of the assessment criteria. Zinc concentrations from two locations (SW008 and SW009) in the 'S' Shaped canal were particularly elevated (up to 30 times the assessment criteria).
- Total lead concentrations exceeded the assessment criteria in most cases, however no dissolved concentrations exceeded the criteria.
- During the current investigation, the elevated aluminium concentrations were reasonably consistent at all sites, with the greatest concentration recorded upstream of the tailings area. Aluminium concentrations were not elevated in the soils. This suggests that these concentrations are representative of natural levels.
- Copper concentrations were significantly lower than those measured in previous investigations, and were within an order of magnitude of the assessment criteria.
- In relation to antimony and arsenic concentrations, Graph 3 shows:
 - Relatively low antimony and arsenic concentrations upstream of the Site.
 - A rapid increase in the concentrations within the proximity of the tailings.
 - Maximum concentrations within 50m downstream of the tailings.
 - A relatively linear decrease in concentrations with increasing distance, downstream of the tailings.
 - Reduced total concentrations from the 1997 round of sampling to the present. This may be due to many factors (e.g. recent rainfall events, sampling methodology) and does not necessarily indicate an overall reduction in concentrations.
- Dissolved antimony concentrations were, on average, about 75% of the total concentrations, indicating the majority of the antimony is present in soluble form.
- Dissolved arsenic concentrations were, on average, 40% of the total concentrations, indicating a greater proportion of the arsenic was bound to suspended particles.



- DLWC results showed cyanide exceedances. GHD found all cyanide concentrations to be below the Estimated Quantitation Limit (EQL) and the assessment criteria.

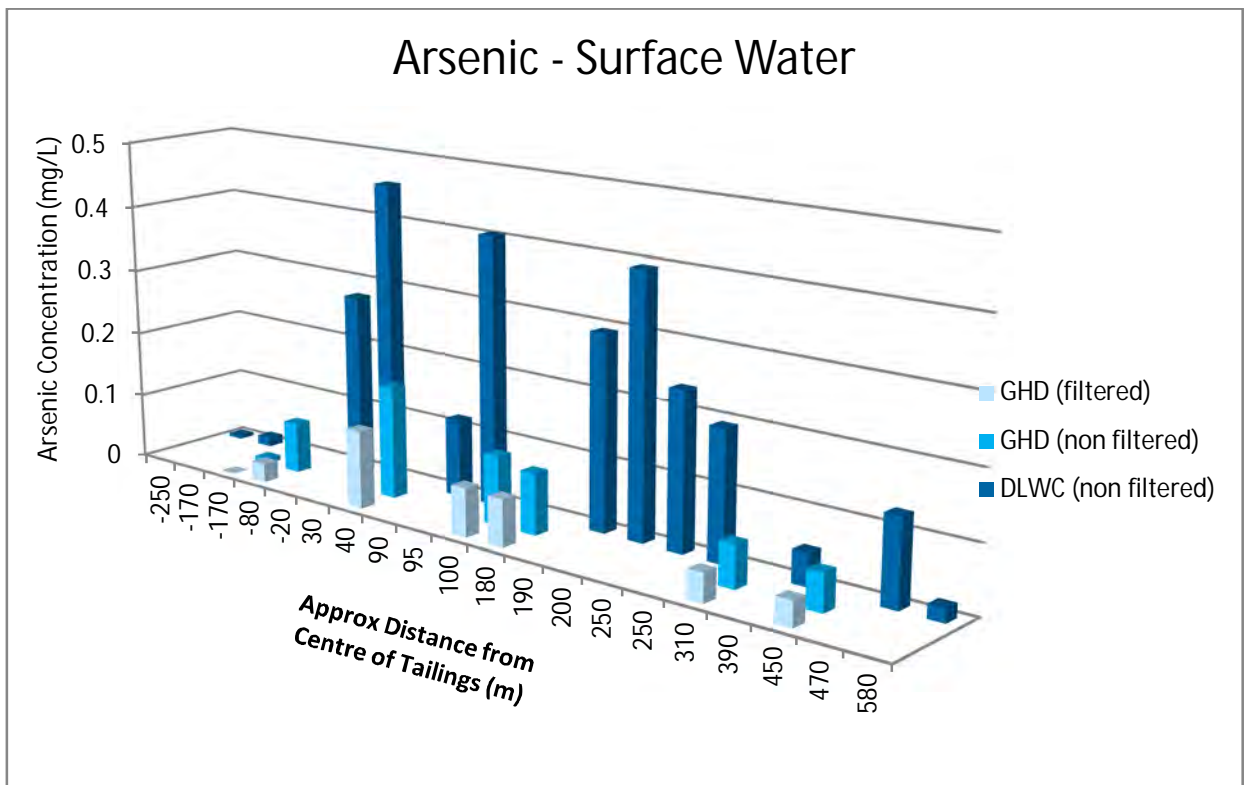
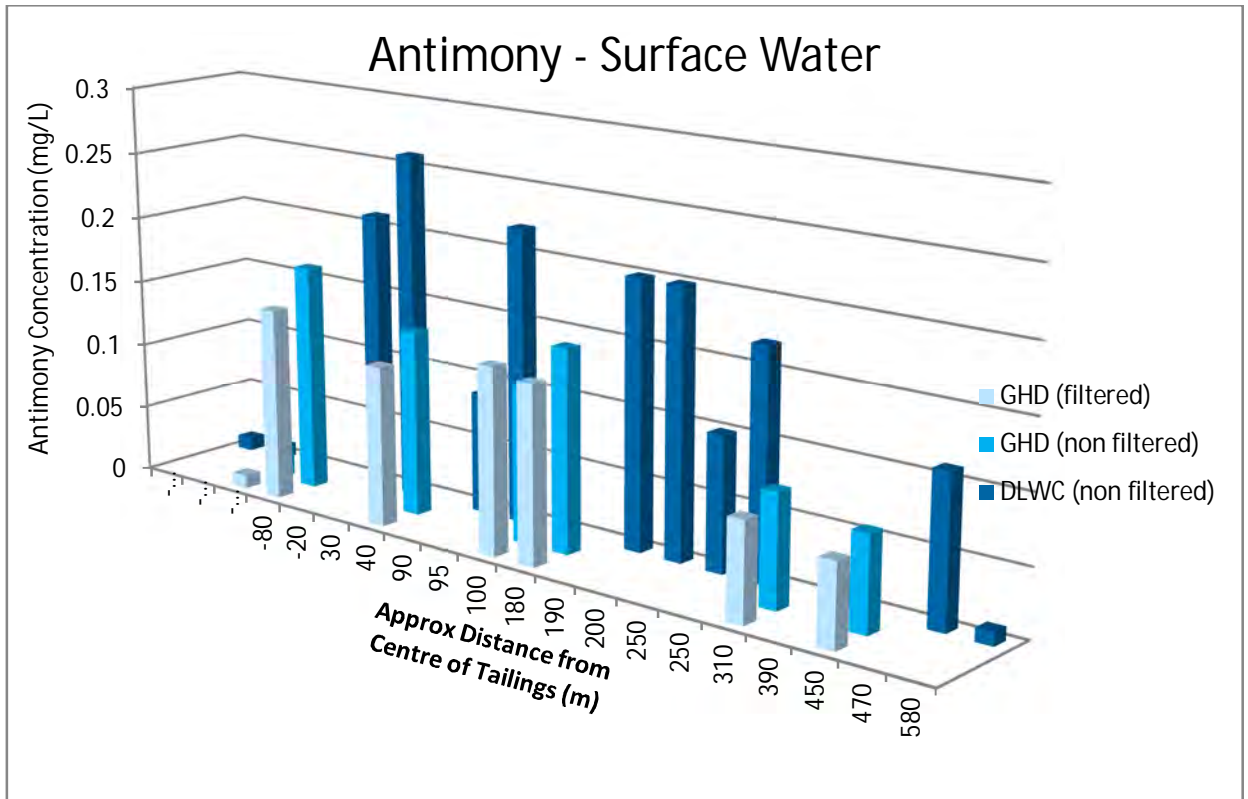
Table 10 Surface Water Chemistry Summary

Potential Contaminant	Impact Zone (mg/L)		Receptor Zone (mg/L)		Comment
	Max	Min	Max	Min	
Total Al	0.25	0.05	0.36	0.24	Most results exceed assessment criteria of 0.055 mg/L. Upstream sample highest concentration. Historic data relatively consistent with current.
Dissolved Al	0.21	0.03	0.018	0.09	Most exceed assessment criteria of 0.055 mg/L. Dissolved levels 0-25% less than total values.
Total Sb	0.244	0.018	0.083	0.022	COC- All results exceed assessment criteria of 0.009 mg/L. Most exceed 10 x assessment criteria. Relatively minor reduction from historic results noted.
Dissolved Sb	0.155	0.012	0.073	0.01	COC- All exceed assessment criteria of 0.009. Dissolved levels 0-25% less than total values.
Total As	0.171	0.016	0.063	0.008	COC- All results but 1 exceed assessment criteria of 0.013 mg/L. Significant reduction from historic results noted.
Dissolved As	0.118	0.002	0.043	<0.001	COC- Most exceed assessment criteria of 0.013 mg/L. Dissolved levels approx. 30% less than total values.
Total Cd	0.0006	<0.0001	<0.0001	<0.0001	All values except 1 (SW09 in 'S' shaped canal) less than assessment criteria of 0.0002 mg/L.
Dissolved Cd	0.0005	<0.0001	<0.0001	<0.0001	All values except 1 less than assessment criteria of 0.0002 mg/L. Consistent with total Cd values.
Total Cr	0.001	<0.001	0.001	<0.001	All values less than assessment criteria of 0.001 mg/L.
Dissolved Cr	<0.001	<0.001	<0.001	<0.001	All values less than assessment criteria of 0.001 mg/L.
Total Cu	0.017	0.007	0.021	0.013	Possible COC- All values except 1 (SW01 upstream sample) exceed assessment criteria of 0.0014 mg/L, but by less than ten times. Significant reduction from historic results noted.
Dissolved Cu	0.012	0.008	0.01	0.001	All values except 1 greater than assessment criteria of 0.0014 mg/L. Dissolved levels 0-25% less than total values.



Potential Contaminant	Impact Zone (mg/L)		Receptor Zone (mg/L)		Comment
	Max	Min	Max	Min	
Total Fe	2.94	0.54	5.38	1.74	No assessment criteria identified. Results slightly reduced from historic data.
Dissolved Fe	1.21	0.13	1.05	0.54	No assessment criteria identified.
Total Pb	0.005	<0.001	0.006	0.001	Exceeded assessment criteria of 0.0034 mg/L at approximately half of the locations. Consistent with historic data.
Dissolved Pb	0.003	<0.001	0.003	<0.001	Less than assessment criteria of 0.0034 mg/L at all locations.
Total Hg	-	-	<0.001	<0.001	<EQL (0.0001 mg/L) in all cases. EQL>assessment criteria of 0.00006 mg/L.
Dissolved Hg	<0.0001	<0.0001	-	-	<EQL in all cases. EQL>assessment criteria of 0.00006 mg/L.
Total Ni	0.003	<0.001	<0.001	<0.001	All values less than assessment criteria of 0.011 mg/L.
Dissolved Ni	0.003	<0.001	<0.001	<0.001	All values less than assessment criteria of 0.011 mg/L. Consistent with total values.
Total Zn	0.848	0.016	0.048	0.016	All values except exceeded assessment criteria of 0.008 mg/L.
Dissolved Zn	0.82	0.018	0.047	0.018	All values except exceeded assessment criteria of 0.008 mg/L. Consistent with total values.
CN	<0.004	<0.004	0.044	<0.005	All current values less than assessment criteria of 0.007 mg/L. Significant reduction from historic data.
TDS	194	104	129	105	Indicates freshwater, tolerable to most environmental receptors. Limited potential transportation of contaminants.
TSS	15	<5	43	8	Low turbidity. Limited potential transportation of contaminants via suspended particles.

Notes: Table 10 only includes current analytical results. See Table C6 for historic results.
Units in mg/L unless otherwise noted.



Graph 3 Surface Water Chemistry Graphs



5.4 Groundwater

5.4.1 Field Observations

Five groundwater monitoring wells were installed by DLWC in 1997. Four of these wells were located and sampled to assess groundwater quality. Monitoring well DLW97-GW13 (in the tailings area) could not be located.

In general, the water was slightly turbid with a brown tinge. Recharge rates were very slow indicating a possible blockage of the screen of the wells as soil lithology surrounding the monitoring wells would indicate high permeability rates.

Standing groundwater levels (SWL) measured from top of casing (TOC) are presented in Table 11. Due to limited data, groundwater contours were not calculated, however groundwater was interpreted to discharge into the wetland. Although the data from the wells cannot be considered to be reliable, a comparison with the DLWC 1997 data indicates a similar standing water level.

Table 11 Standing Groundwater Levels

Monitoring Well	SWL (mTOC) - 2012	TOC elevation (arbitrary, from DLWC 1997) (m)	SWL (m above arbitrary datum)- 2012	SWL (m above arbitrary datum)- DWLC 1997
GW004	1.445	99.63	98.185	Dry
GW006	0.425	98.78	98.355	98.02
GW007	0.585	98.74	98.155	97.77
GW012	0.585 (very slow recharge rate)	98.65	98.065	97.96

5.4.2 Field Analysis

Field analytical results are presented in Table C7, Appendix C.

pH values in the order of 4.4-6.6 indicated a slightly acidic environment. Values were relatively consistent with DLWC 1997 data and similar to the pH of surface water in the adjacent wetland.

EC levels were slightly more elevated than in the surface water with a maximum value of 1144 $\mu\text{S}/\text{cm}$ and an average value of 768 $\mu\text{S}/\text{cm}$. Although limited, the data indicates the groundwater is relatively fresh.

5.4.3 Chemical Analysis

Chemical analysis for historic and current groundwater samples are presented in Table C7, Appendix C. Select metal concentrations are also presented in Figure 14.

A summary of current groundwater analyte concentrations is presented in Table 12. A graphical representation of antimony and arsenic results is presented in Graph 4.

Discussions regarding comparison of analyte concentrations with 'assessment criteria' refer to the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000) for freshwater in a 'slightly to moderately disturbed system', as outlined in Section 4.5.4.

In summary:

- The amount and quality of the data was deemed inadequate for the development of a detailed CSM. Depending on the requirements of the RAP, further investigations of groundwater may be required.
- Due to low monitoring well recharge rates, insufficient sample volumes were available for analysis of both total and dissolved metal concentrations. Only dissolved concentrations were analysed in these investigations.
- Insufficient data was available to compare current with historic data due to a difference in the analysis completed (i.e. no total concentrations analysed).
- Antimony and arsenic concentrations for all samples exceed 30 times the assessment criteria. Antimony concentrations in groundwater were approximately an order of magnitude higher than surface water concentrations. Arsenic concentrations in groundwater were approximately three orders of magnitude higher than surface water concentrations.
- Antimony and arsenic concentrations in groundwater were generally consistent across the Site.
- Assessment criteria exceedances were also noted for aluminium, chromium, copper, lead, mercury, nickel and zinc. Copper and zinc concentrations were of similar magnitude to those in surface water, with the concentrations of the other metals generally at least an order of magnitude higher than in surface water.

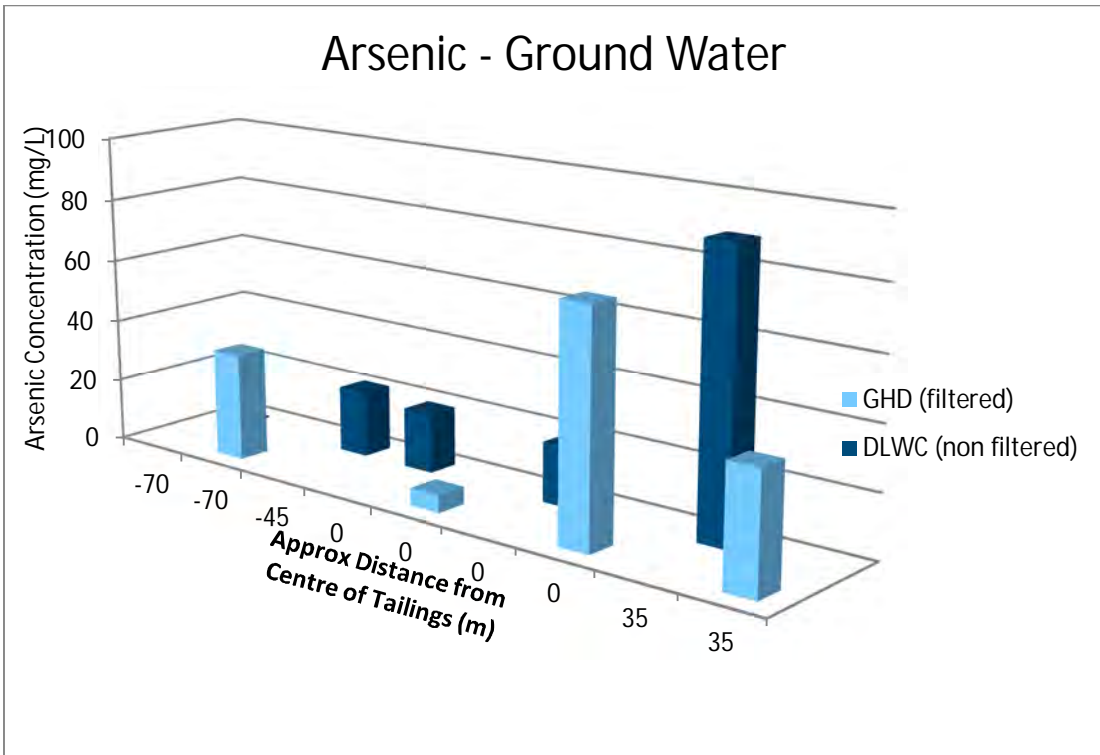
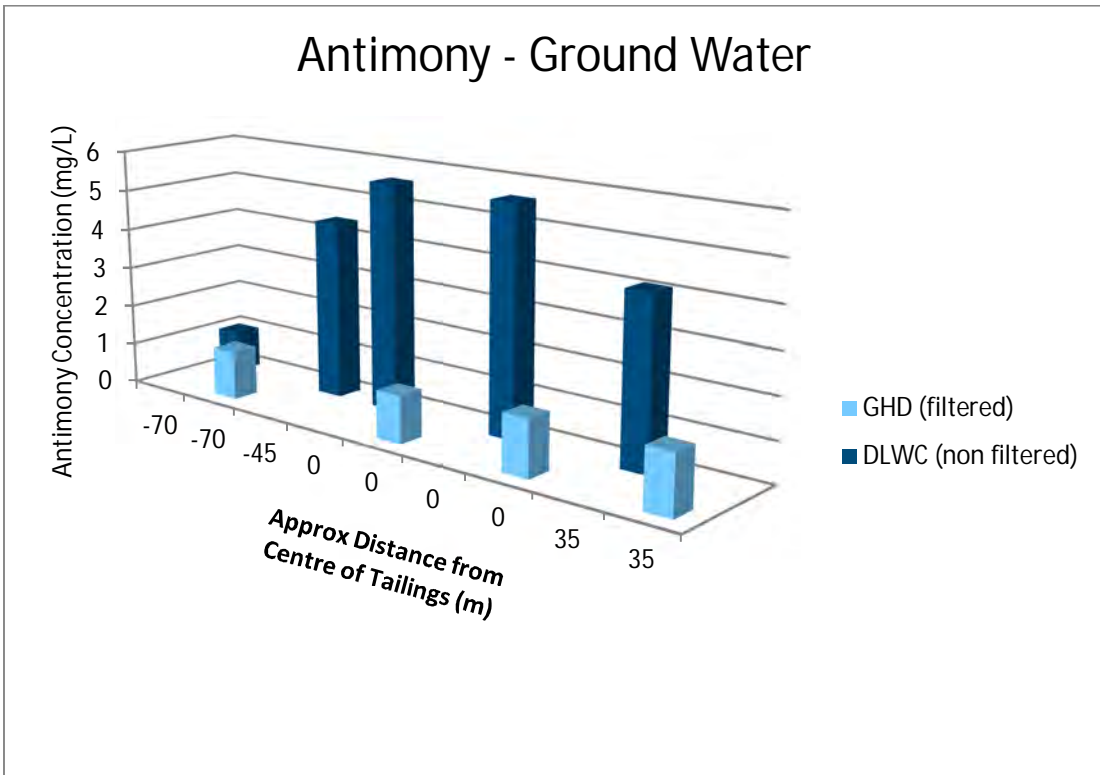
Further groundwater investigations may be required to gain greater certainty regarding the shallow aquifer and obtain data regarding groundwater at greater depths. This would enable an analysis of the flow characteristics, conductivity and migration pathways, particularly if contamination is to be left onsite or contained in-situ.



Table 12 Ground Water Chemistry Summary

Potential Contaminant	Source Zone (mg/L)		Comment
	Max	Min	
Dissolved Al	2.19	0.05	All locations except GW12 exceed assessment criteria of 0.055 mg/L. Generally an order of magnitude higher than surface water concentrations.
Dissolved Sb	1.45	1.17	All locations exceed 30 x assessment criteria of 0.009 mg/L.
Dissolved As	72.6	5.56	All locations exceed 30 x assessment criteria of 0.013 mg/L.
Dissolved Cd	0.0001	<0.0001	All values less than assessment criteria of 0.0002 mg/L.
Dissolved Cr	0.132	0.006	All locations except GW07 exceed 10 x assessment criteria of 0.001 mg/L. GW07 exceeds assessment criteria.
Dissolved Cu	0.027	0.001	All locations exceed assessment criteria of 0.0014 mg/L. One location (GW004) exceeds 10 x assessment criteria.
Dissolved Fe	90.5	9.05	No identified assessment criteria. Concentrations approximately two orders of magnitude higher than surface water concentrations.
Dissolved Pb	0.125	0.002	All locations except GW12 exceed assessment criteria of 0.0034 mg/L.
Dissolved Hg	0.0026	<0.0001	All locations exceed assessment criteria of 0.00006 mg/L.
Dissolved Ni	4.07	0.013	All locations exceed assessment criteria of 0.011 mg/L.
Dissolved Zn	0.208	0.051	All locations exceed assessment criteria of 0.008 mg/L.
CN	0.597	<0.004	Exceeded assessment criteria of 0.007 mg/L at GW06 and GW07. GW06 has a higher concentration than historic data.
TDS	970	412	Indicates freshwater, comparable to receiving surface water environment.
TSS	1,190	356	Low turbidity. Indicates sampling methodology has not resulted in significant entrainment of suspected solids.

Notes: Only includes current analytical results. See Table C7 for historic results.
Units in mg/L unless otherwise noted.



Graph 4 Groundwater Chemistry Graphs



5.5 Stockpiles

Three stockpiles and two abandoned loading ramps were analysed for metals concentrations using XRF analysis only.

5.5.1 Field Observations

The stockpiles consisted mainly of ore material and soil with some debris including metal and possible asbestos containing material. Photographs of the stockpiles are shown as Photos 3 and 4, Appendix B.

5.5.2 Field Analysis

Results of the XRF analysis are presented in Table C1, Appendix C. In summary:

- Antimony and arsenic concentrations within the stockpiles and the small loading ramp were of a similar magnitude to that of the tailings deposit (exceeding 10 x the assessment criteria, with many samples exceeding 30 x the assessment criteria).
- The antimony and arsenic concentrations in stockpiles 1 and 3 were higher than those in stockpile 2.
- The large loading ramp (only one sample taken) did not appear to be contaminated.

5.6 Bricks

Twenty three bricks including at least one of each type were analysed for metal concentrations using XRF analysis. Additionally, two of the bricks were submitted for laboratory analysis. Analysis was to assess whether the bricks had been manufactured from impacted soil material and to provide a waste classification for disposal.

5.6.1 Field Observations

The bricks appeared structurally sound and showed no signs of impact from site activities.

5.6.2 Field and Chemical Analysis

Field and chemical analysis is presented in Table C8, Appendix C. Results indicate:

- The bricks do not contain metal concentrations beyond background levels, and do not appear to have been manufactured from site materials.
- Exceedances of the General Solid Waste assessment criteria were noted for chromium and mercury, however in most cases the EQL of the XRF exceed the assessment criteria and hence does not necessarily indicate an exceedance.
- One laboratory concentration of mercury (6 mg/kg) exceeded the General Solid Waste (non leachable) assessment criteria of 4 mg/kg. The leachable mercury concentration could be analysed for further comparison with the General Solid Waste TCLP criteria, however given the bricks do not appear to have been

manufactured from site materials, they should be able to be pre-classified as General Solid Waste.

- All analyte concentrations were less than the Restricted Waste assessment criteria.

5.7 Data Quality Analysis

5.7.1 Field QA/QC Programme

All fieldwork was conducted in general accordance with standard FOP including decontamination procedures, sample identification procedures, information requirements for soil bore logs, chain of custody information, sample duplicate frequency and field equipment calibration requirements.

Two soil trip blanks were analysed for antimony and arsenic. Results are summarised in Table C9, Appendix C. Both had results less than the EQL.

Rinsate samples were collected for soil sampling equipment on each of the five days of sampling and analysed for antimony and arsenic. Results are summarised in Table C9, Appendix C. Results showed concentrations ranging from 0.01 to 1.64 mg/L for antimony and from 0.004 to 3.59 mg/L for arsenic. This shows minor levels of cross contamination between samples that are deemed insignificant given the assessment criteria concentrations of 310 and 200 mg/kg respectively.

Rinsate samples were not taken for surface water or groundwater due to a lack of significant potential for cross contamination.

One soil sampling location (BH023) was incorrectly labelled in the field (as BH034). This was noted in the field notes but the data is presented as BH034 in the laboratory results.

5.7.2 Precision

Results for RPDs between duplicate samples are presented in Table C9, Appendix C.

RPDs for approximately half of the field and interlab duplicate soil samples were greater than 50% indicating a high degree of variability in concentrations of all analytes present. This is likely due to the non-homogenous nature of the soil, especially in the tailings deposit.

Given the non-homogenous nature of the soil; however, the duplicate data indicates that the field QA/QC is of an acceptable quality for the assessment of the soil in relation to impacts from the historic site activities and the development of remediation options.

5.7.3 Accuracy

The NATA certified laboratory QA/QC sheets, as presented in Appendix F, refer to a QC program comprising the analysis of spikes, method blanks, surrogates, holding times and duplicate samples.

Non QA/QC compliances noted in the laboratory reports includes:



- Holding time exceedances for all soil samples for cyanide and pH. The impacts of these exceedances are not deemed to have a significant impact on the data due to consistency with historic data.
- Holding time exceedances for 24 soil samples for mercury (second round of analysis). Similarly, the impacts of these exceedances are not deemed to have a significant impact on the data.
- Regarding duplicates, method Blanks, laboratory control samples and matrix spikes:
 - For all matrices, no method blank value outliers occurred.
 - For all matrices, no duplicate outliers occurred.
 - For all matrices, no laboratory control outliers occurred.
 - For all matrices, no matrix spike outliers occurred.
- For all regular sample matrices, no surrogate recovery outliers occurred.
- No quality control sample frequency outliers existed.

Based on a review of the laboratory QA / QC data, it is considered that the analytical results are reasonably representative of analyte concentrations at the time of the investigation.

Compliance with the seven DQO steps as outlined in the SAQP are outlined as follows:

Step 1: Stating the Problem

The 'problem' as it stands is consistent with that outlined in the SAQP in that the Site has been significantly impacted by previous use as an antimony processing plant. The Site also contains a significant SEPP 14 wetland which has been affected by contamination from the processing plant.

Contamination has been identified as having adverse impacts on the Site's suitability for various uses and environmental receptors, as described in the CSM in Section 6.

A management order has been placed on the site requiring preparation and implementation of a RAP to address the contamination.

Step 2: Identifying the Decisions

Sufficient data was required to allow development and implementation of a RAP to address the identified contamination impacts from past Site uses that have resulted in unacceptable risks to human health or the environment. The specific study questions have been addressed in the following sections:

- What is the extent of the contamination and has it changed from the previous investigations? Sections 5 and 6.
- To what point in the "Impact Zone" should remediation extend? Section 7.
- How significant is the migration of contamination in groundwater? Sections 5.4 and 6.

- What is the significance and risk of ecological effects beyond the immediate area of source contamination? Section 6.
- Is there sufficient data to assess remediation options? Sections 5, 6 and 7.
- If the immediate source area is adequately contained / managed / remediated, will ecological impacts in the surrounding area recover in a reasonable time frame? This is a factor to be considered in the selection of remediation options and extent of remediation undertaken (Section 7). Further studies may be required.

Step 3: Identifying Inputs to the Decision

The Detailed Investigation sampling program was designed to provide sufficient information to allow a sound scientific and statistical evaluation of the questions set out in Step 2. This was achieved by:

- Collection of soil, sediment, surface and groundwater samples to provide sound site coverage and statistically valid data sets upon which to base subsequent decisions. This included limited sampling in areas of previous testing to verify previous results, with more extensive sampling to address data gaps identified in the Preliminary Investigation Report. At this stage, comprehensive hydrogeological characterisation of the site was not undertaken. Areas of likely “incidental contamination” were noted for remediation or management requirements, but assessment focused on contamination associated with the former antimony processing plant.
- Comparing the analytical data to applicable guidelines to evaluate the potential for contamination to adversely impact upon human health and / or environmental receptors. A site-specific risk assessment has not been completed.
- Qualitative evaluation of Step 5 was undertaken by means of the comparison above, and considered further in evaluation of the identified remediation options outlined in section 7.

The significance of assessment criteria exceedances in terms of ‘risk’ that the measured concentrations may present to human health or the environment have been assessed in Section 6. The client may determine what level of risk it is prepared to accept and what degree of management of that risk is possible and acceptable. These decisions will be discussed with the relevant stakeholders and taken into account in evaluation of remediation or management options.

Step 4: Defining the Study Boundaries

With respect to physical boundaries, the lateral boundaries of the investigation areas were defined as follows:

- The northern property boundary adjoining Hillside Drive, excluding the subdivided portion of Lot 1.
- The western property boundary.
- The southern edge of the wetland.
- The wetland immediately east of the eastern edge of the ‘L’ shaped canal.



The vertical soil boundary was the underlying natural clay soils or identified maximum depth of contaminant impact.

Step 5: Developing a Decision Rule

In order to decide whether the data obtained was sufficiently precise, accurate, reliable and reproducible for the Site at the time of the investigation, field and laboratory QA/QC procedures were utilised throughout the sampling programmes and all sampling work was carried out in accordance with GHD's Standard Field Operating Procedures, which are based on relevant guidelines and current industry practices. QA/QC results were compared to nominal acceptance limits and are discussed in Section 5.7.

Project analytical data has been compared to EPA approved guidelines. The nominated assessment criteria are presented in Section 4.5. On the basis of this comparison, a decision has been made as to whether or not the contamination poses a potential risk (environmental or health based), warranting further assessment.

Step 6: Specifying Limits on Decision Errors

With regard to the Detailed Site Investigation, two primary decision error-types had potential to occur due to uncertainties or limitations in the project data set:

- A sample/area may be deemed to pass the nominated assessment criteria, when in fact it does not. This may occur if contamination is 'missed' due to limitations in the sampling plan, or if the project analytical data set is unreliable.
- A sample/area may be deemed to fail the nominated assessment criteria, when in fact it does not. This may occur if the project analytical data set is unreliable, due to inappropriate sampling, sample handling, or analytical procedures.

To minimise the potential for decision errors, data quality indicators (DQIs) were established, for completeness, comparability, representativeness, precision and accuracy.

The SAQP outlined DQIs for sampling techniques and laboratory analysis of collected samples identifying the acceptable level of error for this investigation. The DQOs were assessed by reference to data quality indicators as follows:

- **Data Representativeness** - expresses the degree with which sample data accurately and precisely represents a characteristic of a population or an environmental condition. Representativeness has been achieved by collecting samples in an appropriate pattern across the site, and by using an adequate number of sample locations to characterise the site. Consistent and repeatable sampling techniques and methods were utilised throughout the sampling.
- **Completeness** - defined as the percentage of measurements made which are judged to be valid measurements. The completeness goal was set at there being sufficient valid data generated during the study.
- **Comparability** - is a qualitative parameter expressing the confidence with which one data set can be compared with another. This was achieved through maintaining a level of consistency in techniques used to collect samples and

ensuring analysing laboratories use consistent analysis techniques and reporting methods. Comparability had particular relevance when using XRF as a field screening tool. Details regarding XRF comparability are provided in Section 5.1.2.

- **Precision** - measures the reproducibility of measurements under a given set of conditions. Precision of the data is assessed in Section 5.7.2.
- **Accuracy** - measures the bias in a measurement system. Accuracy can be undermined by such factors as field contamination of samples, poor preservation of samples, poor sample preparation techniques and poor selection of analytical techniques by the analysing laboratory. Accuracy was assessed by reference to the analytical results of laboratory control samples, laboratory spikes, laboratory blanks and analyses against reference standards. Compliance with the “acceptance limits” on laboratory control samples were assessed in Section 5.7.3.
- Accuracy of the field works was assessed by examining the level of contamination detected in field and equipment blanks as also outlined in Section 5.7.3.

Step 7: Optimise the Design for Obtaining Data

The investigations were undertaken in accordance with the SAQP (incorporated as part of the Preliminary Investigation Report) which was reviewed and approved by the EPA, giving consideration to the DQOs and to the financial and time constraints of the project. Works was completed in accordance with NSW OEH guidelines and accepted industry standards.



6. Updated Conceptual Site Model

The following Updated CSM has been developed, based on information obtained from the Preliminary CSM and data obtained from the results presented in Section 5.

6.1 Site Description

6.1.1 General

Site features are presented in Figure 1 and Figure 2. In general, the Site consists of:

- A disturbed area incorporating the various features associated with the former antimony processing facility that is largely devoid of vegetation.
- A tailings area of approximately one hectare that is devoid of vegetation, extending from the former processing area into an adjacent, State Environmental Planning Policy (SEPP) 14 wetland (no. 354).
- A generally forested area adjacent to the SEPP 14 wetland in which 21 vulnerable and 3 endangered fauna species have previously been recorded (Redpath 2003).
- Surface material (within the disturbed areas) consisting of imported fill and tailings.
- Some remaining infrastructure consisting mainly of foundations of the former processing facility and loading ramps.
- Several remaining stockpiles of ore, rubbish and bricks.
- An 'L' shaped canal that has apparently been excavated from the wetland.
- A series of 'S' shaped canals (possibly constructed for use in tailings settling).
- Visually impacted *melaleuca* trees in the wetland area, adjacent to the tailings deposit.

Based on aerial photographs received from SCS following completion of the Preliminary Investigations (see Appendix D), the L shaped canal and S shaped canals were constructed about 1979, after operation of the processing facility had ceased (see Section 3.1.1).

The Site is located between the footslope of a small ridge to the north and west and the SEPP 14 wetland to the south and east. Several small drainage lines meander through the Site from the small catchment. Flood waters (data provided by BSC 2008) are shown to periodically inundate the Site (Figure 2) with the Probable Maximum Flood (PMF) level inundating the tailings, former gravel processing area (within the lower part of the former processing area) and the canal systems. The PMF does not cover the full extent of the former processing area.

The wetland drains into Station Creek which is partially tidal. No tidal influence was noted at the Site during the field investigation program; however tidal influences may periodically inundate portions of the tailings during different hydrological conditions.

Station Creek discharges into Urunga Lagoon which forms part of the Bellinger-Kalang estuarine system.

The groundwater table onsite is approximately 1 metre below the ground surface (mbgs) and groundwater is interpreted to discharge into the wetland. Groundwater has only been investigated within the tailings area using existing shallow drive-point wells.

Characteristics of deeper groundwater or groundwater flow into the site are not known.

Neighbouring land uses consist of:

- A SEPP 14 wetland and land owned by the Coffs Harbour and District Local Aboriginal Land Council, to the south and east.
- Hillside Drive and residential land to the north.
- Residential and commercial properties to the west followed by the Pacific Highway.

6.1.2 Soils

Reference to the Macksville Nambucca 1:100,000 Soil Landscape Map indicates the bedrock slopes above the mill at the site are in the Pine Creek (pn) landscape being gravelly red kurosols. The low footslopes above the tailings area are mottled grey red clays of the Bowra Creek (ba) soil landscape. The wetland area below the tailings is predominantly permeable acid peats and impermeable grey humic clays of the Charlmont (ch) soil landscape group (typically wetlands). This soil type contains high sulphide content presumably in both organic and inorganic forms (SCS 2012).

As outlined in Section 5.1.5 the soils in the vicinity of the tailing deposit are considered to be Acid Sulfate soils. The preparation of a detailed Acid Sulfate Soil Management Plan (ASSMP) will be required for works that disturb the soil in that area. This is to be provided as part of the RAP. Acid sulfate soils generate acid where pyritic material is exposed to oxygen. Increased acidity may, in turn exacerbate the mobilisation of metal contaminants.

In general, the lithology in the vicinity of the tailings consists of silty Sand to approximately 1.5 mbgs overlaying approximately 1 m of clayey Silt (described by DLWC as peat) and then silty Clay from approximately 2.5 mbgs.

6.1.3 Hydrology

The Site sits between the footslope of a small ridge to the north and west and the SEPP 14 wetland to the south and east. Several small drainage lines meander through the site from the small catchment. Flood waters (BSC 2008) are shown to periodically inundate the Site (Figure 2) with the PMF level inundating the tailings, former gravel processing area and the canal systems. The PMF level does not cover the full extent of the former processing area. The wetland drains into Station Creek which is partially tidal. No tidal influence was noted during the field investigation program; however tidal influences may periodically inundates portions of the tailings during different hydrological conditions. Aerial photographs and anecdotal evidence from different times of the year indicate a significant fluctuation in the water level in the wetland, with the wetland in the vicinity of the tailings deposit apparently being dry at some times. Station Creek discharges into Urunga Lagoon which forms part of the Bellinger-Kalang estuarine system.



6.1.4 Hydrogeology

The groundwater table onsite ranged from approximately 0.4 to 1.4 mbgs and is interpreted to discharge into the wetland. The standing water level was noted to be relatively consistent between the 1997 and 2012 sampling events. Groundwater has only been investigated within the tailings area. Recharge rates within the monitoring wells were very slow indicating a possible blockage of the screen of the wells as soil lithology surrounding the monitoring wells would indicate high permeability rates. Characteristics of deeper groundwater or groundwater flow into the site are not known.

6.2 Source, Impact and Receptor Zones

For the purposes of the CSM, the Site has been divided into the following zones, as presented in Figure 15:

- Source Zone, including the tailings deposits, ore stockpiles, former stockpiling area, former processing areas, incidental contaminants and fill material. The Source Zone covers an area of approximately 16,000 m². It is anticipated that remediation will be required across most, if not all of the Source Zone.
- Impact Zone, defined as the areas that are potentially, directly impacted (secondary impact) by the contaminants, excluding the Source Zone. This area includes the eastern portion of the Site, the wetland immediately adjacent to the tailings, the potentially impacted areas to the northwest and northeast of the 'L' shaped canal and the benthic layer within the 'S' shaped canals. The Impact Zone covers an area of approximately 50,000 m². GHD's investigations indicate that some areas of the impact zone have not been significantly impacted by contamination and are unlikely to require remediation, whereas other areas have been more significantly impacted, but remediation may be difficult due to accessibility or potential impacts from the remediation works. This is discussed further in Section 7.
- Receptor Zone, defined as the area that is considered unlikely to have been significantly impacted by contamination from the Site but may be indirectly affected by the contaminants. The area includes sensitive biota in the receiving wetland area including upstream and downstream aquatic fauna and peripheral vegetation to the south of the wetland and east of the 'L' shaped canal beyond the Impact Zone. It also includes Lot 101, which has been validated in part by Coffey 2004 and may also include the residential properties adjoining the Site to the west. It is not anticipated that any remediation will be required in the receptor zone.

6.3 Contaminant Characterisation

6.3.1 Contaminants of Concern (COC)

Several potential contaminant sources have been identified at the site including the tailings deposits, ore stockpiles, incidental contaminants, fill material, excavated sediments (from the creation of the canals) and any exposed, acid sulfate soils.

Chemicals used during the purification process included copper sulfate, sodium cyanide, lead nitrate, dextrin, sodium ethyl xanthate and cresylic acid. Mill water was also contaminated with dissolved antimony and arsenic salts during treatment of the crushed ore (DLWC 1997). All steps within the flotation method used to concentrate the stibnite were performed at an alkaline pH (up to 11.5). To obtain this pH, large amounts of caustic soda (sodium hydroxide) and soda ash (sodium carbonate) were used (DLWC 1997).

Based on an assessment of the known chemicals used in the processing, the possible contaminants would include As, Sb, Pb, Cu, Cr, Al, Hg, CN, S, Na and nitrates. Sodium hydroxide and sodium carbonate are expected to have ameliorating effects on preventing acidity of the tailings, and are not considered to be potential contaminants.

Based on a comparison of the historic results (in the Preliminary Investigation Report) and current analyte concentrations with the adopted assessment criteria:

- Antimony and arsenic were evident as the key COCs.
- In nearly all cases, where one of the other possible COCs was present in significant concentrations, more significant concentrations of either antimony or arsenic were present. As a result, these analytes (antimony and arsenic) were deemed to be representative indicator analytes and the governing contaminants.
- Aluminum and iron concentrations throughout the site appeared similar to background samples, and are considered likely to be commensurate with concentrations in uncontaminated media. These analytes are not considered COCs in this investigation.
- Chromium and nickel concentrations in the groundwater exceeded the adopted assessment criteria at most groundwater sampling locations. However chromium and nickel concentrations in the soil, sediment and surface water were generally less than the relevant assessment criteria and are not deemed to be COCs in this investigation.
- Zinc concentrations were significantly less than the adopted health-based assessment criteria in soil and sediment and generally less than the EILs for soil, but exceeded sediment criteria at some locations (primarily in the eastern portion of the site) which may indicate a different source of contamination. Zinc exceeded the assessment criteria for most of the groundwater and surface water sampling locations, but for the aforementioned reasons are not considered a COC associated with the antimony tailings, and are unlikely to govern remediation.
- Copper and lead concentrations were noted to exceed the adopted assessment criteria in the sediment, surface water and groundwater. Concentrations of copper and lead in a limited number of soil samples also exceeded the relevant HIL assessment criteria, but except in rare cases, always in association with higher levels of arsenic or antimony contamination. Copper and lead are deemed to be COCs in this investigation but are deemed unlikely to govern remediation.
- Mercury concentrations exceeding the assessment criteria were noted in all media (except surface water, where the LOR was higher than the criterion) and were noted to generally correlate with antimony and arsenic concentrations. Mercury is



considered to be a COC in this investigation but is unlikely to govern remediation (apart from one location (SE032) where mercury only was analysed).

- Cyanide was noted to be relatively low in soil, slightly elevated in some sediments but recent surface water results were all below surface water assessment criteria. Most groundwater samples exceeded the relevant assessment criteria. Cyanide is hence considered a minor COC in this investigation but is deemed unlikely to govern remediation.
- Incidental contaminants may also be present on the Site, (especially in the residual stockpiles) including:
 - Total Petroleum Hydrocarbons (TPH);
 - Polynuclear, Aromatic Hydrocarbons (PAH);
 - Organochlorine Pesticides (OCP);
 - Polychlorinated Biphenyls (PCB); and
 - Asbestos.

6.3.2 Key Contaminant Properties

Antimony

Antimony is a non-essential element in humans, animals and plants and antimony compounds show toxic properties similar to those of arsenic. Adverse health impacts, if inhaled or ingested may include eye and lung irritation and heart and lung problems, stomach pain, diarrhea, vomiting, and stomach ulcers (SEWPaC 2012).

Little information is available on the transformations and transport of antimony in various environmental media (e.g. air, water, soil) and the mobility of antimony in soils is not clearly understood. Some studies indicate that antimony is highly mobile, while others conclude that it strongly adsorbs to soil. In water, it usually adheres to sediments.

ANZECC (2000) reports that two forms of antimony are found in natural water: antimony (III) occurs under moderately oxidising conditions, whereas antimony (V) predominates in highly oxidising environments. Most of the toxicological studies have been completed on antimony (III). ANZECC (2000) states that bioconcentration factors of 40 for freshwater fish and 16,000 for freshwater invertebrates have been reported. Freshwater algae are the most sensitive of the organisms tested with a concentration of 760 µg/L resulting in a 50% decrease in growth over a 96 hour exposure. This is in contrast to freshwater fish which showed 50% mortalities at concentrations of 9,000 to 12,000 µg/L and daphnia showing immobilisation at 12,100 to 423,450 µg/L (ANZECC 2000).

This assessment was supported by an investigation on the Macleay River where Ashley et al (2007) demonstrated that antimony and, to a lesser extent arsenic, are bioavailable, with uptake into common riparian vegetation and aquatic alga species, especially in reducing, organic-rich conditions in backswamps and oxidising acidic conditions.

In contrast, SEWPaC (2012), reports that most antimony compounds show little or no tendency to accumulate in aquatic life

Antimony is more soluble at neutral pH than at low pH (University of Otago 2012).

Arsenic

Arsenic has a high acute (short-term) toxicity to aquatic life, birds and land animals. Where soil arsenic content is high, plant growth may be reduced. Arsenic has a high chronic (long-term) toxicity to aquatic life, and moderate chronic toxicity to birds and land animals. Organic arsenic compounds are very persistent in the environment and are expected to bioaccumulate in fish and shellfish (SEWPaC 2012).

Several forms of arsenic occur in natural waters, depending upon the redox potential and pH, the two most common being arsenic (III) and arsenic (V). Both arsenic (III) and arsenic (V) form stable bonds with carbon, resulting in numerous organo-arsenic compounds, some of which are very toxic (e.g. methylarsine) (NSW EPA 2000).

In their study on the Macleay River, Ashley et al (2007) demonstrated that arsenic is bioavailable, with uptake into common riparian vegetation and aquatic alga species, especially in reducing, organic-rich conditions in backswamps and oxidising acidic conditions.

Arsenic is also more soluble at neutral pH than at low pH (University of Otago 2012).

Mercury

Both mercury and its compounds have high acute (short-term) and high chronic (long-term) toxicity on aquatic life. Ingestion of fish contaminated with mercury has potential to cause poisoning in humans, birds and land animals exposed in the same manner. Mercury and its compounds are highly persistent in water and the environment and will have the potential to bioaccumulate or concentrate in the tissues of fish. These concentrations will be considerably higher than the water from which the fish is taken (SEWPaC 2012).

Of particular concern to the aquatic environment is the fact that inorganic forms of mercury (of relatively low toxicity and availability to bioconcentrate) may be converted by bacteria in-situ into organomercury complexes (particularly methylmercury), which are more toxic and tend to bioaccumulate (ANZECC 2000).

There are insufficient data to derive a trigger value for methyl mercury for either fresh or marine water (ANZECC 2000). Methyl mercury analysis was hence not completed as part of this assessment due to the limited additional value that this data would provide to the development of the RAP.

6.3.3 Contaminant Media and Fate

Based on the CSM, the main pathways for transport of contaminants identified in the soil/tailings (the Source Zone) would be through surface water runoff, groundwater discharge or mobilisation of sediments. Airborne dust would also be a migration pathway for transport of contaminants from exposed areas of the site.

COC distribution

Generally, contaminants exceeding relevant assessment criteria in surface water, groundwater and sediment were the same as those that exceeded assessment criteria for soils (including tailings and remaining ore stockpiles).



In nearly all cases, where one of the COCs was present in significant concentrations, more significant concentrations of either antimony or arsenic were present. As a result, these analytes were deemed to be representative indicator analytes and the governing contaminants.

Soil

Soils in the source zone (including tailings and remaining ore stockpiles) represent the main mass of contaminants on the site, with concentrations of arsenic and antimony in most samples exceeding the soil assessment criteria by several orders of magnitude. In most cases, the leachable concentrations of COCs were significantly less than total concentrations indicating that although total concentrations often exceed the adopted soil assessment criteria by several orders of magnitude, the percentage of COCs available for transportation into the groundwater or surface water is significantly reduced.

Notwithstanding this, where there were significant concentrations of antimony and arsenic in soil or sediment samples, the corresponding leachable concentrations were well above ANZECC trigger values for protection of aquatic ecosystems and hence migration through surface water and groundwater is considered to be a significant pathway.

Sediment

Data from GHD's investigations indicate concentrations of the main COCs in sediment are generally 60 to 80% of those found in the soil.

The transportation of contaminants through the mobilisation of sediment from the source area (which may include historic discharges from the operation of the antimony processing facility, as well as contaminant transport subsequent to its closure) is supported by contaminant distribution in the sediment with the most elevated concentrations noted adjacent to the tailings deposit, extending approximately 50 m south and east of the tailing deposit and adjacent to the north eastern portion of the 'L' shaped canal. This is interpreted to reflect the distribution of sediment that would be expected from flood events transporting sediment downstream. The impacted sediments to the north east of the 'L' shaped canal may be as a result of deposition in an 'eddy' that would be present during high flow events. The other possible source of this impact would be from discharge from the north eastern end of the 'S' shaped canals; however relatively low concentrations of COC in sediment samples from the 'S' shaped canals indicate this is the less likely source.

Elevated concentrations of COCs were also noted to correspond with the visual presence of tailings sediment (grey silt) and were generally confined to the surface layer of sediment.

A comparison with weak acid extractable metal concentrations with the assessment criteria was deemed more applicable than total concentrations in assessing the bioavailability of the analytes. It is noted that the weak acid extractable concentrations are unlikely to exceed 40% and 25% of the total metal concentrations for antimony and arsenic respectively. Applying these ratios results in approximately 20% of the samples analysed reduced to a lower assessment category (being exceeding, exceeding 10 times or exceeding 30 times the assessment criteria).

Limited data regarding the leachable concentrations of COCs in the sediment indicated that leachable concentrations were significantly less than total concentrations. This suggests the physical migration of contaminated sediment has been the more important contaminant migration pathway.

A study of antimony and arsenic concentrations in the Macleay River Valley (Ashley et al 2007) indicates that antimony and arsenic are absorbed by riparian vegetation and aquatic algae growing in impacted sediment, that antimony uptake is greater than that of arsenic and that there are large variations in the relative uptakes between species.

Surface Water

As well as being a primary receptor of contamination at the site, surface water is one of the main media for the transportation of COCs from the Site. This is evident by the contaminant distribution in the surface water including:

- Relatively low COC concentrations upstream of the Site.
- A rapid increase in the concentrations within the proximity of the tailings.
- Maximum concentrations approximately 50m downstream of the tailings.
- A relatively linear decrease in concentrations with increasing distance downstream of the tailings.

Dissolved COC concentrations were generally 45-75% of the total COC concentrations in surface water indicating that the majority of the COCs are present in a dissolved form and not just bound to suspended particles. This relates both to the bioavailability and mobility of the contaminants in surface water.

Under oxidising, near-neutral pH conditions, antimony and arsenic have significant solubilities, with stream waters passing through contaminated sediments continuing to leach metalloids and allowing bio-availability (Ashley et al 2007). Reducing organic conditions and oxidising acid sulfate soil conditions in backswamp regions can also contribute to mobility and bio-availability (Ashley et al 2007).

Groundwater

Concentrations of arsenic in groundwater were in some cases an order of magnitude higher than leachable concentrations of arsenic in soils, and generally concentrations of antimony in groundwater were similar to leachable concentrations of antimony in soils. Concentrations of antimony and arsenic in groundwater were generally one to three orders of magnitude higher than their respective concentrations in surface water.

The potential transportation of contaminants through the migration of groundwater is supported by the elevated concentrations of COCs in the groundwater within the vicinity of the tailings deposit and the expected permeable characteristics of the tailings. Analysis in GHD's investigations was for dissolved metals, so the reported concentrations can be expected to be mobile in the groundwater.

Groundwater investigations have not been sufficient to assess the significance of this migration pathway. Any remediation options that do not involve removal of the



contaminant source would need to further investigate groundwater characteristics (including flow).

6.3.4 Contaminant Delineation

Horizontal Extent

The interpreted extent of the contamination in the soil and sediment is presented in Figures 3, 7, 8, 9, 10a and 10b. The extent of impact in the surface water and groundwater are presented in Figures 13 and 14, respectively. The data indicates considerable impact in the tailings, sediments and groundwater (given limited data), and a lesser extent of impact on the surface water quality, further decreasing with distance from the site.

Observations regarding the horizontal impact in the soil include:

- Roughly following the extent of areas without vegetation.
- The impact in the south west corner of the site, near the wetland has not been delineated due to site access constraints. Delineation would entail further sampling in the neighbouring property.
- Soil on the southern side of the wetland was free of contaminants.
- Soil in the north east portion of the site is relatively free of contaminants with the exception of an area of unknown disturbance, to the north west of the 'L' Shaped canal.
- The soil within the embankment immediately to the north of the 'L' shaped canal showed elevated antimony and arsenic concentrations mainly from between 1 mbgs to 1.7 mbgs (current ground surface). It is possible that impacted sediment and soil was excavated from the location of the 'L' shaped canal during canal and embankment construction. Alternatively, the contaminated interval may represent the original soil surface impacted by contaminant migration from the antimony processing area prior to the canal and embankment construction (historic aerial photographs indicate the original alignment of a drainage course through the site was approximately in this area).

Observations regarding the horizontal extent of the impacted sediment include:

- The interpreted impact extent of antimony and arsenic were similar. The antimony concentrations were generally higher than arsenic in comparison with their respective adopted assessment criteria.
- Showing highest levels of impact adjacent to the tailings deposit, extending approximately 50 m downstream of the tailing deposit, extending across the wetland some 50 m to the south of the tailings deposit (roughly correlating with vegetation dieback), and within and adjacent to the north eastern portion of the 'L' shaped canal.
- The impacted sediments adjacent to the eastern portion of the 'L' shaped canal may be as a result of deposition in an 'eddy' that would be present during high flow events. The other possible source of this impact would be from discharge from the

north eastern end of the 'S' shaped canals; however relatively low concentrations of COC in sediment samples from the 'S' shaped canals indicate this is the less likely source.

- The western portion of the 'S' shaped canals was impacted at concentrations exceeding 30 times the adopted assessment criteria. Topography in that area and proximity to the tailings area indicates the likelihood for surface run-off from the tailings deposit to directly enter the western-most portion of the 'S' Shaped canals. Limited connectivity was noted from this portion of the canal to the eastern (remaining) portion of the 'S' shaped canal system. This was supported by the lack of significant impact from COCs in the eastern area.
- The south eastern portion of the 'S' Shaped canal was impacted. This may be associated with potential impact relating to placement of spoil from excavation of the canal.
- Insufficient data was available to delineate the full extent of sediment impact to the south east of the site, adjacent to the southern shore of the wetland. Similarly, sediment data to the north east of the 'L' shaped canal is limited. The importance of these data gaps will depend on decisions regarding the extent of remediation across the wetland areas.

Vertical Extent

The interpreted, vertical extent of the impact in the soil is presented in Figures 10a and 10b. Depths vary from approximately 0.5m in the north west portion of the impact to 2.2 m near the water's edge and at some locations within the tailings deposit.

Impacts in the sediment ranged in depth from about 1m near the tailings to 0.1m on the south of the wetland. The greatest antimony and arsenic concentrations were generally noted in the surface sediment (0-0.1 m).

6.3.5 Estimated Volume of Impacted Soil and Sediment

Estimated volumes of impacted soil and sediment are shown in Figures 10a and 10b. The rationale for the estimated horizontal extent is outlined in Sections 5.1.3 and 5.2.3 and as follows. The interpreted vertical extent of the impacted soil was based on the interpolated concentrations of antimony and arsenic noted during the investigation as well as an assessment of the lithology in each borehole. The vertical extent of the impact was based on limited data (being samples that were advanced to a depth where no impact was identified) hence a high degree of interpretation was required.

Volumes were conservatively based on an assumption that contaminant impacts at the perimeter of an impacted area were at the same depth of impact noted at locations within and adjacent to that perimeter, rather than tapering up to the surface from those locations.

6.3.6 Contaminant Concentration/Time Relationship

Concentrations of COCs in the soil recorded in this investigation were within a similar order of magnitude (given differences in sampling and analysis methods) as those



recorded in the historical investigations. This implies concentrations have remained relatively constant over time.

Reduced total concentrations of COCs in the surface water were noted from the 1997 round of sampling to the present. This may be due to many factors (e.g. recent rainfall events, sampling methodology) and does not necessarily indicate an overall reduction in concentrations. Further rounds of sampling and analysis would be required to assess changes to COC concentrations over time.

Data from sediment and groundwater was insufficient for historic comparisons due to lack of historic data and/or differences in sampling methodology.

6.4 Contaminant Receptors

There are a number of potential human and environmental receptors of the contamination, provided an exposure pathway is present. The receptors have been classified as being present in the 'Source Zone', the 'Impact Zone', and the 'Receptor Zone' as outlined in the following subsections.

6.4.1 Source Zone and Impact Zone

Human health and environmental receptors identified in the Source Zone and Impact Zone include:

- On site personnel that are involved in site works including remediation.
- Future recreational users, depending on the future land use.
- The SEPP 14 Wetland adjacent to the Site.
- Terrestrial flora and fauna that inhabit or visit the site.
- Aquatic and benthic flora and fauna inhabiting the wetland and canals.

6.4.2 Receptor Zone

Receptors identified in the Receptor Zone include:

- Recreational users of the lower portions of the wetland, Station Creek or Urunga Lagoon.
- Residents/workers on adjacent properties.
- Terrestrial flora and fauna on adjacent land.
- Aquatic and benthic flora and fauna inhabiting the lower portions of the wetland, Station Creek and Urunga Lagoon.

The exposure pathways by which these receptors may be impacted by potential contamination are discussed below.

6.5 Exposure Pathways

Based on the identified receptors and the release, fate and transport characteristics of the contaminants, pathways through which receptors may become exposed to contamination

include inhalation, ingestion and dermal absorption of the contaminated material or affected sediments, surface water, groundwater or air. A summary of the potential contamination risks and risk to receptors are presented in Table 13. These are discussed briefly below in the context of the site setting:

- **Ingestion Exposure Pathway:** Ingestion of COCs by site occupants may occur through day-to-day activities and contact with contaminated soil. This pathway is important as COCs in sediments, groundwater (as pore water close to discharge interfaces) or surface water are ingested by benthic and aquatic fauna and many COCs have the potential to bioaccumulate. Recreational users of surface water also are at risk of ingesting contaminated water or eating aquatic organisms (yabbies, prawns or fish) caught by recreational fishermen. This pathway is also of concern to terrestrial fauna and birds where the contaminated water is used for drinking and aquatic organisms are a food source.
- **Dermal Exposure Pathway:** The contaminants may enter via sorption through biological membranes such as skin or gills. Exposure to the contaminants in the soil via this pathway could be of concern to human and ecological health in the vicinity of the Site. However, dermal exposure could also be a major concern where contaminated sediments, groundwater or surface water come into direct contact with benthic and aquatic flora and fauna, adding to the bioaccumulation occurring through ingestion. Recreational users of surface water are also at risk of dermal exposure to COCs.
- **Inhalation Exposure Pathway:** There is the potential for a range of contaminants (especially antimony and arsenic) at the site's surface to be mobilised by wind and to be inhaled by receptors in the form of dust, however, the amount of exposure is dependent on particle size.
- There is no indication in the site history or previous investigations that volatile contaminants are likely to be present on the site. Although both cyanide and mercury can occur in vapour form, both have relatively low vapour pressures and no enclosed spaces are present or proposed at the site where vapours are likely to accumulate. Based on this, vapour phase contamination is not considered a significant exposure pathway.

6.6 Other Site Features

6.6.1 Stockpiles

The stockpiles consisted mainly of ore material and soil with some debris including metal and possible asbestos containing material. The metal concentrations and COCs in the stockpiles were similar to those found in the tailings deposit. The potential asbestos containing material may present a significant health risk to sensitive receptors, especially if disturbed.



6.6.2 Bricks

Anecdotal evidence suggests the bricks contained onsite were manufactured off-site and are unlikely to be impacted by site activities (GHD 2012). One laboratory concentration of mercury (6 mg/kg) exceeded the General Solid Waste (non leachable) assessment criteria of 4 mg/kg. The leachable mercury concentration could be analysed for further comparison with the General Solid Waste TCLP criteria, however given the bricks do not appear to have been manufactured from site materials, they should be able to be pre-classified as General Solid Waste.

6.7 Further Investigation Requirements

The quantity and quality of data obtained from the current and historic investigations is deemed adequate for the formulation of this CSM and for a preliminary assessment of remediation options. Depending on the selected remediation option and the extent of remediation proposed, further investigations may be required including the following:

- Aquatic ecotoxicology assessment to better assess the impacts of contaminated sediments and the implications of leaving some or all of these materials in situ.
- Infill sampling to better delineate the extent and degree of sediment impacts, particularly in the wetland to the south east of the tailings area, and to the south and east of the 'L' shaped canal.
- Sampling on adjacent properties to the west of the southern portion of the former processing area to delineate the extent of off-site impact in this direction.
- More detailed investigations of groundwater, to assess groundwater flow characteristics and on-going migration pathways, particularly if contamination is to be left or contained in-situ.
- Geotechnical properties of the site and tailings if on-site containment is proposed.
- Treatment trials to assess effectiveness of treatment to reduce the mobility of contaminants in the tailings and contaminated soils and sediments.
- Ecological study of the wetland areas proposed for remediation, to assess the impacts of remediation and assist in design of rehabilitation requirements.

6.8 CSM Summary

A summary of the potential contamination risk and risk to receptors are depicted in Figures 16 and 17 and Table 13.

Table 13: Conceptual Site Contamination Model

Source	Identified Contaminant of Concern	Contaminant Release Mechanism(s)		Potential for Contamination	Significant Pathway(s)						Potential Receptors of Concern									
		Primary	Secondary		Surface Water (SW)	Sediment (SED)	Groundwater (GW)	Direct Contact (D)	Aeolian (A)- Dust	Vapour (V)	Source Zone and Impact Zone				Receptor Zone					
											Health		Ecological		Health		Ecological			
											Site visitors/ Recreational users	SEPP 14 Wetland	L' Shaped Canal	Terrestrial Flora and Fauna	Aquatic/Benthic Flora and Fauna	Recreational users of adjacent land, waterways and lagoon	Residential users of adjacent land to the west of the Site	Off-site SEPP 14 Wetland	Terrestrial flora and fauna on adjacent land to the west of the Site	Aquatic / Benthic flora and fauna inhabiting off-site waterways and lagoon
Tailings Deposits, former processing area and former unprocessed ore stockpile area	Heavy Metals (As, Sb, Pb, Cu, Hg), Cn	Migration of contaminants as sediment and dissolved / suspended in surface water via overland flow; leaching of contaminants to groundwater. Dermal contact, ingestion and inhalation (dust during dry conditions) of contaminants.	Discharge of contaminated groundwater to surface water. Leaching of contaminants and direct contact with contaminants in sediments that have migrated from source area.	High	✓	✓	✓	✓	✓		D, A	SW, SED, GW, D	SW, SED, GW, D	D, SW, GW	SW, GW, D	SW	D, A	SW, SED, GW, D	D, A	SW, SED
Stockpiles	Heavy Metals (As, Sb, Pb, Cu, Cr, Al, Hg), CN	Migration of contaminants as sediment and dissolved / suspended in surface water via overland flow; leaching of contaminants to groundwater. Dermal contact, ingestion and inhalation (dust during dry conditions) of contaminants.	Discharge of contaminated groundwater to surface water. Leaching of contaminants and direct contact with contaminants in sediments that have migrated from source area.	High	✓	✓	✓	✓	✓		D, A	SW, SED, GW, D	SW, SED, GW, D	D, SW, GW	SW, GW	SW	A	SW, SED, GW, D	A	SW, SED
Incidental Contamination (not assessed in this investigation)	Asbestos, TPH, PAH, OCPs and PCBs	Migration of contaminants as dissolved / suspended in surface water via overland flow; leaching of contaminants to groundwater. Dermal contact, ingestion and inhalation (dust during dry conditions) of contaminants.	Discharge of surface water runoff and groundwater to environmental receptors.	Medium	✓		✓	✓	✓		D, A	SW, GW	SW, GW	D, SW, GW	SW, GW	SW	A	SW, GW	A	SW
Fill Material	Heavy Metals (As, Sb, Pb, Cu, Al, Hg), Cn	Migration of contaminants as dissolved / suspended in surface water via overland flow; leaching of contaminants to groundwater. Dermal contact, ingestion and inhalation (dust during dry conditions) of contaminants.	Discharge of surface water runoff and groundwater to environmental receptors.	Low	✓		✓	✓	✓		D, A	SW, GW	SW, GW	D, SW, GW	SW, GW	SW	A	SW, GW	A	SW
Embankment adjacent to 'L' shaped canal. Possibly excavated sediments from the canals	Heavy Metals (As, Sb, Pb, Cu, Hg), Cn	Migration of contaminants as sediment.	Discharge of contaminated groundwater to surface water.	Low		✓	✓						SED, GW	SED, GW						
Area of unknown disturbance to NE of 'L' shaped canal	Heavy Metals (As, Sb, Pb, Cu, Hg, Zn)	Migration of contaminants as sediment and dissolved / suspended in surface water via overland flow; leaching of contaminants to groundwater. Dermal contact, ingestion and inhalation (dust during dry conditions) of contaminants.	Discharge of contaminated groundwater to surface water. Leaching of contaminants and direct contact with contaminants in sediments that have migrated from source area.	Medium	✓	✓	✓	✓	✓		D, A	SW, SED, GW, D	SW, SED, GW, D	D, SW, GW	SW, GW, D	SW	D, A	SW, SED, GW, D	D, A	SW, SED
Acid Sulphate Soils	Sulphuric acid and resulting, mobilised metals	Excavation and exposure leading to generation of acids and greater mobility of heavy metal contaminants.	Migration of contaminants to surface water via overland flow and leaching of contaminants to groundwater and potential discharge to surface water.	Medium	✓	✓					D	SW, GW	SW, GW	D, SW, GW	SW, GW	SW		SW, GW		SW

Estimated sensitivity to impact from potential contamination source

	NA or minimal potential for impact to receptor
	Potential for Impact to receptor
	High potential for impact to receptor

7. Remediation Considerations

7.1 Remediation Requirements

It is evident from previous investigations and the additional data obtained by GHD that significant contaminant impact is present in soils (including tailings and waste stockpiles) on the site, sediment in adjoining areas, groundwater on the site and surface water on and adjoining the site. Section 6 summarises the pathways and impacts relevant to the identified contamination. In addition to the evident impacts and risks to human health and the environment, there is a regulatory requirement to address contamination on the site, by way of the Management Orders discussed in Section 1.1. The questions remaining to be resolved are the extent and means of remediation or management that will be applied.

Remediation requirements and options have been discussed previously in:

- DLWC 1997.
- A Site visit and inception meeting that was held on May 9, 2012 and attended by representatives from:
 - GHD.
 - NSW Environmental Protection Authority (EPA).
 - Bellingen Shire Council.
 - Crown Lands. and
 - Soil Conservation Service.
- Urunga Antimony Processing Plant Contaminated Site - Project Application & Preliminary Environmental Assessment (SCS 2012)

7.2 Remediation Objectives

The intention of Crown Lands is to use the site as Public Open Space. Considering this proposed land use and the location of the site (adjoining a SEPP 14 wetland and upstream of Urunga Lagoon), the following remediation objectives should be met:

- Remediation should enable the site to be safely opened to public access, without unacceptable risk to health from contamination.
- Remediation should result in final landforms that facilitate beneficial use of the site as public open space, and satisfy relevant stakeholders to the maximum practical extent.
- Remaining contamination should not present any unacceptable risks to the environment.
- Remediation works should not cause greater environmental or health impacts than would occur if the contamination is left in place.
- Concentrations of contaminants should be below appropriate health-based assessment criteria in surface soils and soils likely to be disturbed during use of the site (taking into account potential regrading of the site during redevelopment works).
- Concentrations of contaminants exceeding ecological investigation levels must not be placed in a location or manner that could reasonably be expected to exacerbate existing risks of potential impact to ecological receptors.
- Remediation must be able to be completed within the funding available for the work.
- Remediation must meet the requirements of EPA Management Order.

The adopted remediation activity must also:

- Be cost effective to ensure maximum reduction in bio-available contaminants over the long term.
- Consider the latest approaches to stabilisation of the key contaminants of concern.
- Allow for the impact of periodic flooding and tidal influence at the site.
- Favour solutions that separate contaminated material from water within the hydrological zones.
- Consider the management of acid sulfate soils (ASS).
- Be in compliance with all relevant Commonwealth, State and Local legislation.

The decision process governing remediation should also consider the final land form and land use. For instance, management measures or institutional controls may be an effective means of controlling risks in some areas, if these are compatible with long-term beneficial use of the area. These considerations are likely to be specific to each particular area of the site. GHD considers that effective planning and a clear vision of the final land form and use will result in the most cost effective remediation as well as the best outcome for rehabilitation of the site. The involvement of key stakeholders at the remediation planning stage will be essential to this outcome.

7.3 Identified Remediation Options

Four broad options for remediating the site have currently been identified. These are briefly outlined as follows:

- Off-site Reprocessing: Removal of source material, long haul transport, and off-site reprocessing at an appropriate ore processing facility.
- Off-site Disposal: Removal of source material, possible treatment on-site or off-site, long haul transport, and disposal to a licensed facility with possible containment cell.
- On-site Disposal: Removal of source material, possible treatment on-site, short haul transport for disposal to a possible containment cell on-site.
- In-situ Containment: Leave source material in place, possible stabilisation or treatment, and construct containment system in-situ to prevent direct exposure or mobilisation and separate contaminated material from surface and ground waters.

While a single remediation strategy may be selected for the overall works, it is likely that a combination of strategies may be applicable to some areas of the site (i.e. outside the main remediation area), particularly in areas where a management rather than intrusive remediation approach is considered to be more appropriate (following the considerations described elsewhere in this report).

The option of 'Do Nothing' was not considered appropriate due to the identified, current impact resulting in a lack of vegetation in the vicinity of the tailings deposit and potential risk associated with further, potential mobilisation of impacted soil, sediment and water. However, this may apply to "fringe" areas of the site, as noted above.

7.4 Remediation Action Plan

Evaluation, selection and implementation of the preferred remediation option will require the development of a RAP which would be prepared in accordance with the OEH (2011) *Guidelines for Consultants Reporting on Contaminated Sites*. The RAP will:

- Provide a detailed consideration of the remedial options nominated by the EPA from those outlined in the Investigation Report or other options put forward in writing by the EPA.
- Outline requirements for the protection of the Environment and Community.
- Nominate the preferred remedial option and provide reasoning.
- Provide sufficient detail in the RAP to enable it to be implemented by a remediation contractor. This will include, but not be limited to:
 - Assessment / Remediation Criteria and Clean up Goals.
 - Detailed characterisation of the nature of the material requiring remediation.
 - Figures, maps and/or plans showing with precision the location of the material requiring remediation.
 - The methods and design of the preferred remedial system.
 - Descriptions of any remedial technologies to be utilised.
 - Basis of validation of the remediation works.
 - Quality Assurance/Quality Control Plan.
 - Outline of Health and Safety requirements.
- Provide a contingency plan, should the nominated remedial method fail.

The RAP will require sufficient detail to enable the preferred method to be costed and implemented by a remediation contractor, but will not include detailed methodology for implementation. This will enable the remediation contractor the flexibility to propose their preferred methodology.

The RAP will be provided to SCS for submission to the EPA for review and approval.

8. Conclusion

A Detailed Investigation of a former antimony processing facility located at Hillside Drive, Urunga, NSW was completed to provide a key input to achieve compliance with the Management Order 20111405. The investigation incorporated data from the Preliminary Investigation Report (GHD 2012) and a field investigation comprising sampling and analysis of soil, sediment and water from:

- 63 soil boreholes.
- 38 sediment boreholes.
- 9 surface water locations.
- 4 groundwater monitoring wells.
- 3 stockpiles and 2 loading ramps.
- Brick stockpiles.

The investigation was carried out in accordance with a Sampling Quality and Analysis Plan that was incorporated into the Preliminary Investigation Report (GHD 2012) and was reviewed and approved by the Environmental Protection Authority. Results were compared to adopted assessment criteria to provide:

- A comparison with historic concentrations and impact extent.
- Data to assess horizontal and vertical delineation.
- Data necessary for a remediation options assessment.
- An assessment of surface water and groundwater quality.
- Baseline data for assessing any future impact from site activities or remediation.

Findings of the investigation were used to update the Conceptual Site Model that was developed in the Preliminary Investigation Report (GHD 2012) and included:

- Antimony and arsenic were evident as the key COCs.
- Other COCs included mercury, chromium, nickel, zinc, copper, lead and cyanide.
- In nearly all cases, where one of the COCs was present in significant concentrations, more significant concentrations of either antimony or arsenic were present. As a result, these analytes were deemed to be representative indicator analytes and the governing contaminants.
- Incidental contaminants may also be present on the Site including:
 - Total Petroleum Hydrocarbons;
 - Polynuclear Aromatic Hydrocarbons;
 - Organochlorine Pesticides;
 - Polychlorinated Biphenyls; and
 - Asbestos.
- Surface water and sediment (and to a lesser extent, groundwater) were noted as the main media for the transportation of COCs on the Site.
- Generally, contaminants exceeding relevant assessment criteria in surface water, groundwater and sediment correlated with those that exceeded assessment criteria in the soils.

- In most cases, the leachable concentrations of COCs in the soil and sediment were significantly less than total concentrations, suggesting the physical migration of contaminated soil or sediment has been the more important contaminant migration pathway.
- Notwithstanding the above, where there were significant concentrations of antimony and arsenic in soil or sediment samples, the corresponding leachable concentrations were well above ANZECC trigger values for protection of aquatic ecosystems.
- For “soil” samples (being those take from “dry” areas of the site, including the tailings area, during GHD’s investigations) the degree of contamination generally reduces quite quickly so that the site can be divided into significantly impacted and relatively unimpacted areas. The exceptions to this are primarily adjacent to the ‘L’ shaped canal (where contamination is either within 10 times the assessment criteria, or covered by cleaner material), the south western corner of the site (which has insufficient sampling to define), and the area of disturbance at the north east corner of the site.
- For the majority of the COCs, dissolved concentrations were similar to total concentrations in the surface and groundwater samples, indicating the measured concentrations of contaminants are mobile in the water and not just bound to suspended particles.
- Concentrations of the main COCs in the soil recorded in this investigation were within a similar order of magnitude as those recorded in the historical investigations.
- Reduced total concentrations of COCs in the surface water were noted from the 1997 round of sampling to the present. This may be due to many factors and does not necessarily indicate an overall reduction in concentrations.
- The interpreted extent of the contamination in the soil can be summarised as:
 - Roughly correlating with the absence of vegetation.
 - Including the tailings deposit, former processing area and portions of the former unprocessed ore stockpiling area.
 - Extending into the south west corner of the site and likely across the property boundary near the wetland, however the extent of this impact has not been fully delineated.
 - Extending along the embankment in the vicinity of the ‘L’ shaped canal, at a depth of 1 m to 1.7m from the current ground surface (likely associated with the original soil surface prior to placement of spoil from excavation of the canal).
 - Not extending into the north east portion of the site with the exception of an area of unknown disturbance, to the north of the ‘L’ Shaped canal.
 - Not extending to the southern side of the wetland.
 - Varying in depth from approximately 0.5 metres below ground surface (mbgs) in the north west portion of the impact to 2.2 mbgs near the water’s edge and at some locations within the tailings deposit.
- The extent of the impact in the sediment can be summarised as:
 - Showing highest levels of impact adjacent to the tailings deposit, extending approximately 50 m downstream of the tailing deposit, extending across the wetland some 50 m to the south of the tailings deposit (roughly correlating with vegetation dieback), and within and adjacent to the north eastern portion of the ‘L’ shaped canal.
 - Including the western and south eastern portions of the ‘S’ shaped canals.

- Ranging from depths of about 0.5 mbgs near the tailings to 0.1 mbgs in the southern portion of the wetland.
- Generally having greatest antimony and arsenic concentrations in the surface sediment (0-0.1 mbgs).
- Generally corresponding with the visual presence of tailings sediment (grey silt).
- Estimated volumes of impacted soil and sediment were:
 - 8,700 m³ of soil and 2,500 m³ of sediment exceeding 30 times the adopted assessment criteria.
 - 11,300 m³ of soil and 3,600 m³ of sediment (encompassing the volumes above) exceeding 10 times the adopted assessment criteria.
 - 26,500 m³ of soil and 6,700 m³ of sediment (encompassing the volumes above) exceeding the adopted assessment criteria.
- The soils and sediment in the vicinity of the tailing deposit analysed and are considered to be Acid Sulfate soils. The preparation of a detailed Acid Sulfate Soils Management Plan (ASSMP) will be required for works that disturb the soil in that area.
- The groundwater table onsite ranged from approximately 0.4 to 1.4 mbgs and groundwater is interpreted to discharge into the wetland. The tailings material and underlying peat are expected to be highly permeable and hence the contaminants are likely to have high groundwater connectivity to the wetland. Characteristics of deeper groundwater or groundwater flow into the site are not known.

9. Limitations

This report: has been prepared by GHD for NSW Catchment and Lands- Crown Lands and may only be used and relied on by NSW Catchment and Lands- Crown Lands for the purpose agreed between GHD and the NSW Catchment and Lands- Crown Lands as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than NSW Catchment and Lands- Crown Lands arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by various third parties. GHD has not independently verified or checked beyond the agreed scope of work and does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

This Report should be read in full and no excerpts are taken to be representative of the findings of this Report.

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

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	B. Cork	I. Gregson	<i>I. Gregson</i>	I. Gregson	<i>I. Gregson</i>	9/11/12
1	B. Cork	I. Gregson		I. Gregson		10/12/12

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