



**Cardno
Ecology Lab**

Shaping the Future

Marine and Freshwater Studies



Ex HMAS Adelaide Artificial Reef Sediment Quality Monitoring Survey 2

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Catchments and Lands**

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Executive Summary

The Ex-HMAS Adelaide was gifted from the Australian to the NSW Government for the specific purpose of scuttling the ship as an artificial dive reef off the Central Coast of NSW. In accordance with the Artificial Reef (Sea dumping) permit, the Department of Primary Industries - Catchments and Lands, must implement a Long Term Monitoring and Management Plan (LTMMP) prepared by Worley Parsons in March 2011.

The LTMMP covers environmental and structural monitoring for the first five years post-scuttling and forms the basis for ongoing monitoring and maintenance over the operational life of the vessel as a dive site, which is estimated to be 40 years. Part of the LTMMP involves the monitoring of marine sediments in and around the ship to examine how metal corrosion and degradation of protective paint layers over time may impact on the surrounding marine environment and benthic biota.

Sediments were collected by a benthic ponar grab deployed from a vessel at reference and monitoring locations. As per the requirements of the LTMMP, sediment samples were tested for aluminium, iron, chromium, copper, lead, nickel and zinc. Sediments collected from the hull of the ship were tested for lead only.

The survey found that concentrations of metals in sediment samples at monitoring and reference sites were well below the Australian and New Zealand Fresh and Marine Water Quality Guidelines (ANZECC/ARMCANZ 2000) ISQG (Interim Sediment Quality Guideline) lower trigger values (for metals which guidelines are established). Metal concentrations at monitoring sites were very similar to those at reference sites. Comparison of metal concentrations from the current survey (21 months post-scuttling) with earlier surveys, also showed that metal concentrations were generally lower than at the time of the baseline survey and similar to results one month and six months post-scuttling.

The results of the sediment quality survey indicated that 21 months on from the scuttling of the Ex-HMAS Adelaide, there has been no appreciable increase in the concentrations of the metals tested in marine sediments adjacent to the ship. Rather, for many of the metals analysed (aluminium, chromium, iron, nickel and zinc), concentrations were similar to that of the previous survey. Concentrations of copper and lead were similar for all surveys.

Based on these findings, impact to the marine environment and associated benthic biota as a result of metal corrosion and/or degradation of paint layers from the Ex-HMAS is considered unlikely.

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Glossary

Artificial Reef	A structure or formation placed on the seabed for the purpose of increasing or concentrating populations of marine plants and animals or for the purpose of being used in human recreational activities.
ANZECC/ARMCANZ	Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.
Bioaccumulation	The accumulation of substances, such as pesticides or heavy metals in an organism. Bioaccumulation occurs when an organism absorbs a toxic substance at a rate greater than that at which the substance is eliminated.
Biomagnification	Where animals feeding on bioaccumulators have a diet enriched with these substances. If unable to excrete them they acquire an even greater body burden of the substance.
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities.
EP&A Act	Environmental Planning & Assessment Act 1979.
LAT	Lowest Astronomical Tide.
LTMMP	Long Term Management and Monitoring Plan.

1 Introduction

1.1 Background and Aims

Cardno (NSW/ACT) trading as Cardno Ecology Lab Pty Ltd was commissioned by the NSW Department of Primary Industries – Catchments and Lands (DPI Catchments and lands), to undertake the post-scuttling environmental monitoring for the Ex-HMAS Adelaide artificial reef and dive site.

The Ex-HMAS Adelaide was gifted from the Australian to the NSW Government for the specific purpose of scuttling the ship as an artificial reef off the Central Coast of NSW. A comprehensive environmental assessment was undertaken for the project in accordance with state and federal environmental legislation. This included approval under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) and obtaining an Artificial Reef (or Sea Dumping) Permit issued under the *Environment Protection (Sea Dumping) Act 1981* from the federal Department of Sustainability, Environment, Water, Population and Communities (DSEWP&C).

Sea Dumping Permits ensure that appropriate sites are selected, materials are suitable and appropriately prepared, that there are no significant adverse impacts on the marine environment and that the reef does not pose a danger to marine users. A condition of the Permit is that DPI Catchments and Lands must implement the proposed Long Term Monitoring and Management Plan (LTMMP) prepared by Worley Parsons in March 2011.

The LTMMP covers environmental and structural monitoring for the first five years post-scuttling and forms the basis for ongoing monitoring and maintenance over the operational life of the vessel as a dive site, which is estimated to be 40 years. The frequency of monitoring and the methodologies used will be reviewed periodically during the life of the Plan. The scope of work to be carried out by Cardno Ecology Lab is for a two year period post-scuttling, which follows on from initial baseline investigations carried out by Worley Parsons in April/May 2011. It includes the following environmental monitoring components:

- Reef communities;
- Sediment quality; and
- Bioaccumulation studies.

This Progress Report outlines the methodology and findings for the second of two sediment quality surveys. These surveys are to be carried out six and 18 months post-scuttling. Due to inclement weather the second survey was post-poned to 21 months post-scuttling. Sediment quality will then be analysed again at 60 months post-scuttling. Annual sampling and analysis is not proposed.

The aim of the sediment quality monitoring survey, as outlined in the LTMMP, is to gain an understanding of how metal corrosion and degradation of paint layers is influencing/impacting on the marine environment and whether benthic organisms are likely to be affected by metal enrichment. The LTMMP stipulates that sediment testing is carried out for the following metals:

- Aluminium;
- Iron;
- Chromium;
- Copper;
- Lead;
- Nickel; and
- Zinc.

Sediment quality results are to be compared with ANZECC/ARMCANZ (2000) Guidelines and previous results for reference sites. As required by the monitoring condition set by the Administrative Appeals Tribunal, sediment from two sites within the hull is also to be sampled and analysed for lead to measure any changes in sediment lead concentrations over time. The location of the monitoring sites shall be in the bottom centre of the Laundry (compartment number 4-140-0-Q); and Auxiliary Machinery Room Number 3 (compartment number 5-292-0-L). This component of the study was not however, carried out at this time.

This progress report outlines the following:

- Description of sampling dates, times, weather conditions and tidal height;
- Description of the methods used to retrieve sediment samples;

- Results and interpretation of laboratory analyses;
- Discussion of findings; and
- Reports of any condition or occurrence that may influence results of the study.

1.2 Study Site and Nature of Contaminants

The Ex-HMAS Adelaide artificial reef and dive site is located within Bulbararing Bay, approximately 1.87 km offshore from Avoca Beach. The ship lies at a depth of approximately 32 m to 34 m of water at Lowest Astronomical Tide (LAT) on top of a relatively flat, sandy substratum. There is a minimum of 6 m of sand overlying bedrock. The vessel is orientated with the bow facing into the prevailing ESE swell direction (**Figure 1**).

The ship is 138.1 m in length, with a beam of 14.3 m and an original displacement of 4,200 tonnes. The hull is made of steel and the superstructure of aluminium alloy. Heights are approximately 12 m to the main deck, 18 m to the bridge, 24 m to the top of the foremast (the mast closest to the bow), and 39 m to the top of the mainmast (NSW Government 2011). The ship was prepared for scuttling by McMahon's Services. This involved the removal of the main mast structures for safety and navigation reasons and stripping of machinery, hatches and any items that could pose a risk to divers or the environment. Potential contaminants such as fuels, oils, heavy metals, batteries and electrical items containing polychlorinated biphenols (PCBs) were removed. Diver access holes have been cut into the sides of the hull, floors and ceilings to allow extra vertical access between decks and also to allow light to penetrate. Further holes were also made to allow air to escape during the scuttling process (NSW Government 2011).

The Ex-HMAS Adelaide was prepared to meet DSEWPaC standards which were specified during the months of preparation prior to scuttling. DSEWPaC had conducted a series of inspections to confirm that its detailed requirements were achieved. The original clean-up process included removing loose or flaking paint in accordance with DSEWPaC's requirements. A total of 110 paint locations were then tested from representative locations across the ship, confirming the presence of lead primer at some locations on the steel lower decks of the ship. The paint at other locations tested had yellow primer, red oxide, white topcoat and grey topcoat which did not contain lead. The use of lead-based primer is only relevant to the internal steel hull and lower decks of the ship where it was used for corrosion protection, as the superstructure is constructed of aluminium.

Environmental risk experts concluded that the risks to the environment and human health from the presence of lead-based primer are negligible because the lead primer used is in the form of lead tetroxide, which is very insoluble so there would be minimal leaching. The lead is also in a form that has low bioavailability, little potential for bioaccumulation, and does not biomagnify. Risks due to copper in the anti-fouling paint are not a significant concern because the coating is designed to leach as part of its protective process and the leaching rate declines after the first six months. Because of this declining rate, the Navy's standard practice is to apply a new coating every five years and the last coating was applied to the Adelaide seven years ago, so it is therefore near the end of its useful life, thus reducing the amount of copper remaining that could be released into the marine environment.

1.3 Previous Studies

Prior to the current study, sediment was collected and analysed for metal contaminants before the scuttling of the Ex-HMAS (baseline survey) and also one month post-scuttling.

During the baseline survey (Worley Parsons 2009) marine sediments were collected from three sites in the approximate location in which the Ex-HMAS Adelaide would be scuttled. Concentrations of all metals in the baseline survey were less than their respective ANZECC / ARMCANZ (2000) ISQG-Low values (where these had been established). One month post-scuttling, the concentrations of metals in sediment at all reference and impact sites were below the ISQG-Low values, indicating that there is a low risk that any adverse biological effects will occur to marine organisms living within the sediments surrounding the Ex-HMAS Adelaide (Worley Parsons 2011). Mean metal concentrations in sediments obtained during the previous two surveys were very similar.

A further investigation was carried out 6 months post-scuttling (Cardno Ecology Lab 2011). Results of that investigation indicated that six months on from the scuttling of the Ex-HMAS Adelaide, no appreciable increase in the concentrations of the metals tested in marine sediments adjacent to the ship and that for many of the metals

analysed (aluminium, chromium, iron, nickel and zinc), concentrations were lower than in previous surveys. Sediments tested from within the hull of the ship did not indicate any significant lead contamination.



Boundary of Dive Site	Easting (MGA 94)	Northing (MGA 94)
A	356428.713	6296117.693
B	356538.438	6296341.142
C	356850.615	6296188.618
D	356742.410	6295963.310

Figure 1: Location of Ex-HMAS Adelaide Artificial Reef and Dive Site. The approximate location and orientation of the ship is indicated by the yellow line.

2 Study Methods

2.1 Sampling Sites

Samples were collected from the same sites as those pre-determined by Worley Parsons in the earlier (one month post-scuttling survey) and subsequent monitoring surveys. These included a total of nine samples with three reference locations (S2, S3 and S6) and six monitoring locations (I1, I2, I3, I4, I5 and I6). For continuity, the same location ID's as previous surveys were used. Locations and GPS positions of the nine sampling locations are given in Table 1 and Figure 2.

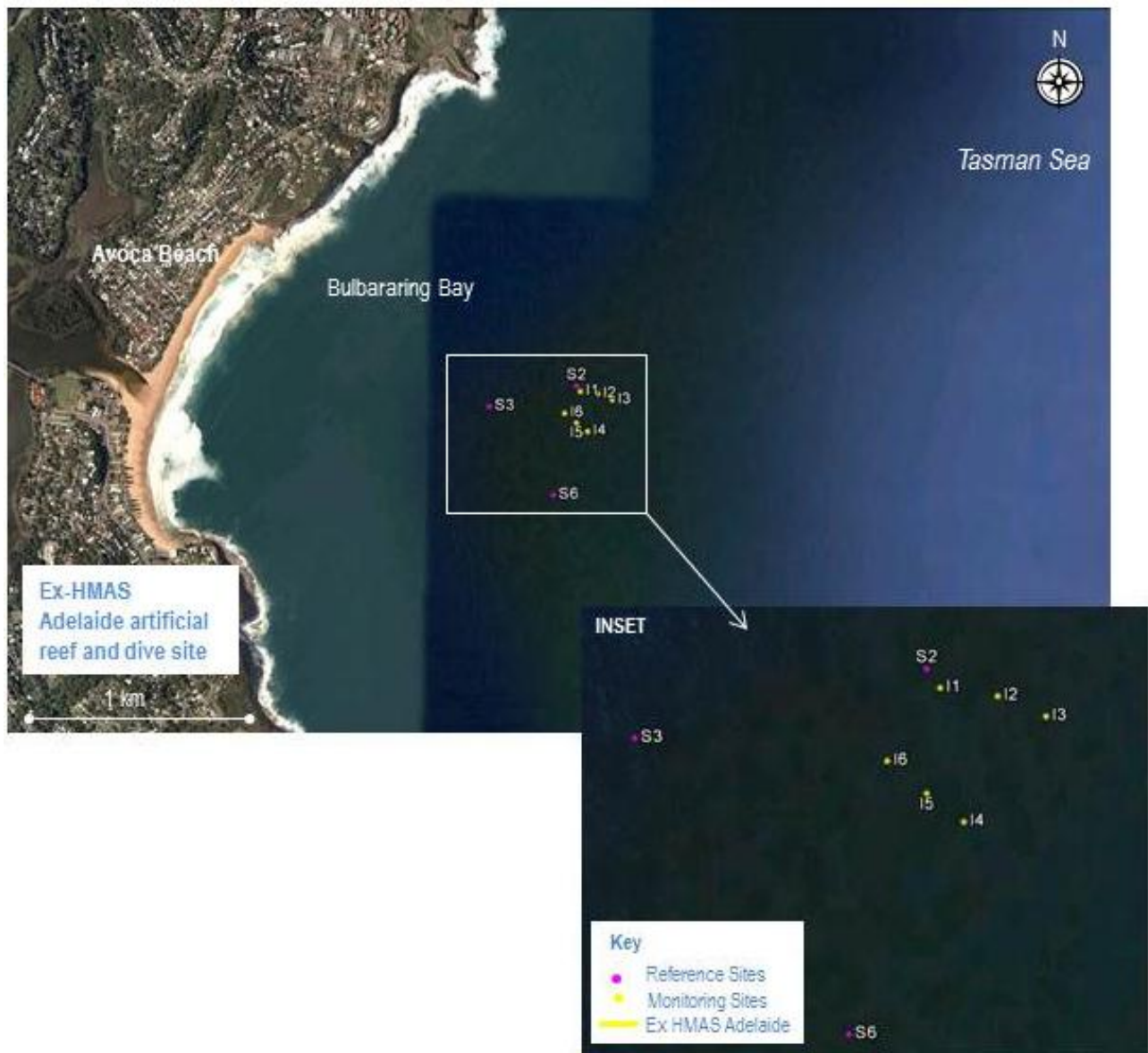


Figure 2: Locations of Marine Sediment Quality Sampling Sites.

Table 1: GPS Positions of Marine Sediment Quality Sampling Sites (Coordinates are in MGA 94).

Sample Point	Latitude (S)	Longitude (E)
Control Site - S2	33°27.829'	151°27.416'
Control Site - S3	33°27.880'	151°27.157'
Control Site - S6	33°28.099'	151°27.347'
Monitoring Site - I1	33°27.843'	151°27.428'
Monitoring Site- I2	33°27.849'	151°27.479'
Monitoring Site - I3	33°27.864'	151°27.522'
Monitoring Site - I4	33°27.942'	151°27.449'
Monitoring Site - I5	33°27.921'	151°27.416'
Monitoring Site - I6	33°27.897'	151°27.381'

2.2 Sampling Methodology

2.2.1 Adjacent Sediments

Sediment samples were collected by deploying a Ponar benthic grab from a boat. The sampler collects approximately 2 L of sediment. At each site, co-ordinates were recorded using GPS (accurate to < 5 m). Approximately 500 g of sediment was extracted from each grab, transferred into a polyurethane zip-lock bag and chilled in an esky. After each sample was collected, the sieve was inverted and rinsed with a jet of water to avoid cross-contamination of samples. Each sample was clearly labelled internally and externally, with the project details, time, date, location, site and replicate number. Samples were refrigerated at 4°C overnight then sent by courier to ALS laboratories (an NATA accredited laboratory), Sydney for processing.

2.2.2 Laboratory Methods

Sediment samples were tested for trace metals aluminium (Al), iron (Fe), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni) and zinc (Zn) against NODG (National Ocean Disposal Guideline for Dredged Material 2002) and ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines.

Sediment samples were prepared by 'Hot Block Digest' for metals in soils, sediments and sludges and tumbler extraction of solids/sample clean up. Moisture content was calculated by a gravimetric procedure based on weight loss over a 12 hour drying period at 103 – 105°C. Total metals in sediments were calculated by the ICPMS (Inductively Coupled Plasma Mass Spectrometry) technique which uses argon plasma to ionise selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector. 1g of sample is leached at room temperature for 1 hour in 10% hydrochloric acid. The resultant extract is filtered and bulked for analysis of extracted metals.

2.3 Analyses

Sediment concentrations were reported as means with standard deviations from the mean. Concentrations of heavy metals found within sediment samples at all sites were compared to Australian and New Zealand Fresh and Marine Water Quality Guidelines (ANZECC/ARMCANZ 2000). The recommended guideline values are tabulated as Interim Sediment Quality Guidelines (ISQG) where low and high ISQG values correspond to low and medium effects ranges (ANZECC and ARMCANZ 2000).

Metal concentrations at monitoring sites (I1 – I6) were compared with concentrations at reference locations (S2, S3 and S6) and also compared among survey times: baseline, one month post-scuttling, 6 months post-scuttling and the current survey (21 months post-scuttling).

2.4 Assumptions and Limitations

Location S2 is not considered to be appropriate as a reference location due to its close proximity to the ship and other monitoring locations. This should therefore be treated with caution when considering the overall results.

3 Results

Sediment samples from monitoring locations in the vicinity of the Ex-HMAS Adelaide and at reference locations were collected on 11 January 2013. Sea conditions were choppy with a NNE WIND in the morning changing to a ENE breeze in the afternoon (BOM 2013). The tide was high (1.98 m) in the morning falling to a low of 0.13 m in the afternoon (14:12).

Concentrations of metals in sediment samples at monitoring and reference sites were well below the ANZECC/ARMCANZ ISQG lower trigger values (for metals which guidelines are established). Metal concentrations at monitoring sites were also very similar to those at control sites (**Table 2**).

Comparison of metal concentrations from the current survey (21 months post-scuttling) with the previous (six month post-scuttling) survey show that metal concentrations in the current survey were very similar (**Table 3**).

Table 2: Heavy Metal Concentrations Recorded in Sediment Samples Collected from Monitoring and Control Locations during May 2011 (one month post-scuttling), October 2011 (six months post-scuttling) and January 2013 (21 months post-scuttling).

		Aluminium			Chromium			Copper			Iron			Nickel			Lead			Zinc			
		(mg/kg)			(mg/kg)			(mg/kg)			(mg/kg)			(mg/kg)			(mg/kg)						
low - high trigger values		n/a			80 - 370			65 - 270			n/a			21 - 52			50 - 220			200 - 410			
	Sample ID	Month 1 (May 2011)	Month 6 (Oct 2011)	Month 21 (Jan 2013)	Month 1 (May 2011)	Month 6 (Oct 2011)	Month 21 (Jan 2013)	Month 1 (May 2011)	Month 6 (Oct 2011)	Month 21 (Jan 2013)	Month 1 (May 2011)	Month 6 (Oct 2011)	Month 21 (Jan 2013)	Month 1 (May 2011)	Month 6 (Oct 2011)	Month 21 (Jan 2013)	Month 1 (May 2011)	Month 6 (Oct 2011)	Month 21 (Jan 2013)	Month 1 (May 2011)	Month 6 (Oct 2011)	Month 21 (Jan 2013)	
Reference Sites	S2	1200	180	230	7.4	1.5	1.9	1.8	2.3	<1.0	10000	1290	1350	2.6	<1.0	<1.0	3.3	2.3	2.2	11	3.2	4.4	
	S3	1100	160	200	6.9	1.3	1.6	1.7	<1.0	<1.0	10000	1080	1280	2.5	<1.0	<1.0	3.1	2.2	2.9	10	2.3	3.4	
	S6	740	110	100	6	1	1	0.8	<1.0	<1.0	7300	960	770	1.5	<1.0	<1.0	3.1	2.3	2.2	6.5	1.9	2.3	
	Mean	1013	150	177	6.8	1.3	1.5	1.4	2.3	<1.0	<1.0	9100	1110	1133.3	2.2	<1.0	<1.0	3.2	2.3	2.4	9.2	2.5	3.4
	S.D.	241.9	36.1	68.1	0.7	0.3	0.5	0.6	1.3	0.0	1558.8	167.0	316.6	0.6	0.0	0.0	0.1	0.1	0.4	2.4	0.7	1.1	
Monitoring Sites	I1	1300	180	270	8.2	1.5	1.8	3.4	1.8	1.8	10000	1000	1270	2.9	<1.0	<1.0	3.3	1.4	1.4	12	2.3	5	
	I2	1300	240	250	7.5	1.8	1.8	2.6	2.4	1.1	10000	1470	1380	2.7	<1.0	<1.0	3.2	2.0	1.8	11	3.1	4	
	I3	1100	160	170	6.8	1.4	1.6	1.4	<1.0	<1.0	8900	1160	1070	2.3	<1.0	<1.0	3.8	2.0	2.2	9.7	2.7	3.6	
	I4	1100	150	170	6.9	1.3	1.6	1.3	<1.0	<1.0	9400	1120	1070	2.2	<1.0	<1.0	3.2	2.2	2.3	9.7	2.6	4.2	
	I5	1200	190	180	6.5	1.6	1.5	1.5	<1.0	<1.0	9900	1300	1250	2.3	<1.0	<1.0	3.1	2.2	2.2	9.5	2.8	3.4	
	I6	1100	160	210	6.5	1.4	1.7	1.5	<1.0	<1.0	9200	1180	1320	2.2	<1.0	<1.0	3.1	2.0	2.5	9.7	2.6	4.2	
	Mean	1183	180	208	7.1	1.5	2	2.0	2.1	1	9567	1205	1227	2.4	<1.0	<1.0	3.3	2.0	2	10.3	2.7	4	
	S.D.	98.3	32.9	43.1	0.7	0.2	0.1	0.9	1.1	0.8	467.6	162.0	129.4	0.3	0.0	0.0	0.3	0.3	0.4	1.0	0.3	0.6	

Table 3: Mean Metal Concentrations (mg/kg) in Marine Sediments Collected during Baseline and Monitoring Surveys One , Six and 21 Months Post-Scuttling of the Ex-HMAS Adelaide.

	Baseline	Monitoring Sites		
	Baseline Mean (mg/kg)	1 Month Post-Scuttling Mean (mg/kg)	6 Months Post-scuttling Mean (mg/kg)	21 Months Post-scuttling Mean (mg/kg)
Aluminium	1183	1183	180	208
Chromium	7.6	7.1	1.5	1.7
Copper	1.4	2.0	2.1	1.5
Iron	9603	9567	1205	1227
Nickel	2.5	2.4	<1.0	<1.0
Lead	3.5	3.3	2.0	2.1
Zinc	10.2	10.3	2.7	4.1

4 Discussion

The results of the sediment quality survey indicate that 21 months post-scuttling of the Ex-HMAS Adelaide there has been no appreciable increase in the concentrations of the metals tested (aluminium, chromium, copper, iron, nickel, lead and zinc) in marine sediments adjacent to the ship. For many of the metals analysed (aluminium, chromium, Iron, lead and zinc, mean concentrations were marginally higher than in previous surveys, while mean concentrations of copper had decreased and concentrations of nickel remained the same.

Based on these findings, impact to the marine environment and associated benthic biota as a result of metal corrosion and/or degradation of paint layers from the Ex-HMAS is considered unlikely.

5 Acknowledgements

This report was written by Kate Reeds and reviewed by Rick Johnson. Field Work was done by Kate Reeds and Chris Roberts. Laboratory work was done by ALS Laboratories, Sydney. Thanks to David and Tom Lindfield for assisting in fieldwork.

6 References

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7 Appendices

Appendix 1: Laboratory Results



General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.

LOR = Limit of reporting

^ = This result is computed from individual analyte detections at or above the level of reporting



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Client sample ID

				S2 - CONTROL	S3 - CONTROL	S6 - CONTROL	I1 - MONITORING	I2 - MONITORING
				11-JAN-2013 09:30	11-JAN-2013 09:30	11-JAN-2013 09:30	11-JAN-2013 09:30	11-JAN-2013 09:30
				ES1300738-001	ES1300738-002	ES1300738-003	ES1300738-004	ES1300738-005
Compound	CAS Number	LOR	Unit					
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	24.4	24.4	24.0	25.7	23.8
EG005-SDH: 1M HCl-Extractable Metals by ICPAES								
Aluminium	7429-90-5	50	mg/kg	230	200	100	270	250
Chromium	7440-47-3	1.0	mg/kg	1.9	1.6	1.0	1.8	1.8
Copper	7440-50-8	1.0	mg/kg	<1.0	<1.0	<1.0	1.8	1.1
Iron	7439-89-6	50	mg/kg	1350	1280	770	1270	1380
Lead	7439-92-1	1.0	mg/kg	2.2	2.9	2.2	1.4	1.8
Nickel	7440-02-0	1.0	mg/kg	<1.0	<1.0	<1.0	<1.0	<1.0
Zinc	7440-66-6	1.0	mg/kg	4.4	3.4	2.3	5.0	4.0



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Client sample ID

Client sampling date / time

				I3 - MONITORING	I4 - MONITORING	I5 - MONITORING	I6 - MONITORING	QA
				11-JAN-2013 09:30	11-JAN-2013 09:30	11-JAN-2013 09:30	11-JAN-2013 09:30	11-JAN-2013 09:30
Compound	CAS Number	LOR	Unit	ES1300738-006	ES1300738-007	ES1300738-008	ES1300738-009	ES1300738-010
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	22.9	24.6	23.9	24.9	21.0
EG005-SDH: 1M HCl-Extractable Metals by ICPAES								
Aluminium	7429-90-5	50	mg/kg	170	170	180	210	160
Chromium	7440-47-3	1.0	mg/kg	1.6	1.6	1.5	1.7	1.4
Copper	7440-50-8	1.0	mg/kg	<1.0	<1.0	<1.0	<1.0	<1.0
Iron	7439-89-6	50	mg/kg	1070	1070	1250	1320	1070
Lead	7439-92-1	1.0	mg/kg	2.2	2.3	2.2	2.5	2.6
Nickel	7440-02-0	1.0	mg/kg	<1.0	<1.0	<1.0	<1.0	<1.0
Zinc	7440-66-6	1.0	mg/kg	3.6	4.2	3.4	4.2	2.9