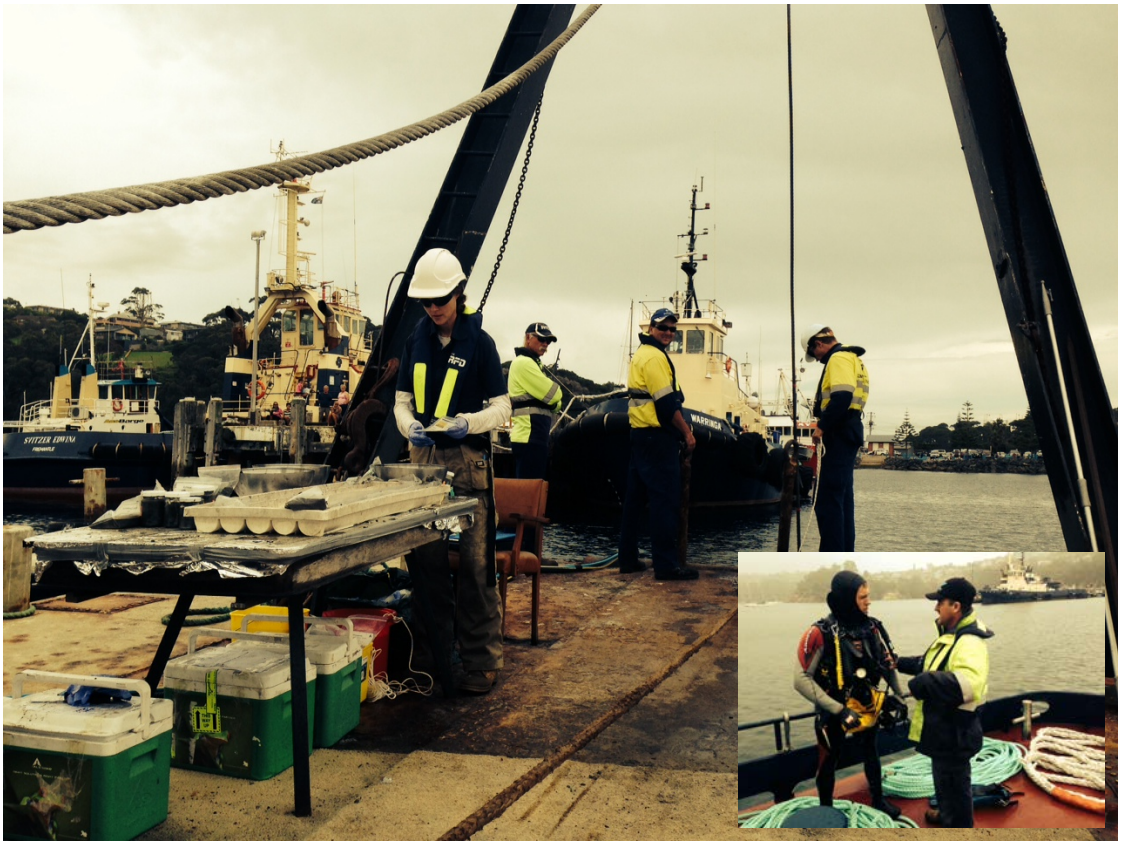
Australasian Marine Associates

NSW GOVERNMENT Department of Industry

# SEDIMENT SAMPLING AND ANALYSIS PLAN IMPLEMENTATION REPORT

## Eden Breakwater Wharf Extension



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Front cover: Photographs of Snug Cove, Eden and AMA sediment sampling.

# EXECUTIVE SUMMARY

NSW Department of Industry - Lands has identified the need to extend the Eden Breakwater Wharf and dredge the approach channel and berth pocket to -10.5m Chart Datum (CD) to accommodate cruise ships greater than 300 m in length. This document presents the outcomes of the approved Sediment Sampling and Analysis Plan (SAP).

The physical sediment analysis and field observations confirmed that the sediments within the proposed dredging area were dominated by the sand fraction, with minor components of silt, clay and in some instances, a relatively high percentage of gravel (i.e. up to 32 %). These analyses confirmed only a small fraction of fine-grained material present in the proposed dredge material (maximum of 11% silt and clay at Site 3). This is an important finding, as during the dredging works, it is the fine-grained fraction that has the greatest potential to remain in suspension and contribute to the intensity and extent of dredging plumes.

The 95% UCL calculated for each of the inorganic (i.e. metals) analyses performed were all below the NAGD Screening Levels and NEPM HIL A Levels. There was one individual observation of silver exceeding the NADG Screening Level. This observation occurred at Site 9 in the surface sediment (i.e. 2.7 mg/kg, NADG Screening Level = 1 mg/kg) and the 95% UCL was below the NADG Screening Level. There is a paucity of sediment quality data to facilitate historical comparisons; however some surficial sediment characterisation in nearby Cattle Bay provided additional insight, with all sediment analytes returning metal concentrations below sediment quality guideline values (ANZECC, 2000).

Tributyl Tin (TBT), a contaminant sourced from historical use as an anti-fouling agent on vessel hulls, returned a 95% UCL above the NADG Screening Level. This result was influenced by several TBT concentrations found in the surface sediments at Sites 4, 5, 8 and 13. The highest concentration of 113.5 µg/kg was detected at Site 5, located approximately 100 m from the existing multipurpose jetty and 400 m from the slipway. The other sites were located closer to the existing multipurpose jetty, but >100 m from the slipway. Given the distance to the slipway, the TBT concentrations reported were likely resultant from historic vessel movement and berthing activities, rather than from boat maintenance activities associates with the slipway.

Consistent with the NADG (2009) approach, further sediment sampling and analysis to assess the solubility of the TBT in surface (0-0.5m) samples at Sites 4, 5, 8 and 13 was completed. The results from this work confirmed that TBT concentrations in aqueous phase (i.e. biologically available) were below the analytical detection limits (i.e. 2 ng/L). The TBT is therefore likely to be tightly bound to the organic phase in the sediment and no further testing was required.

The potential for acid generation from potential acid sulphate soils (PASS) was assessed using the SPOCAS technique. All results confirmed that PASS sediments were not present in the proposed dredging area. Therefore, PASS is not considered a risk to the environment.

Considering the results of this SAP, the sediments proposed for capital dredging works in Eden are considered suitable for unconfined offshore disposal. All of the samples tested had concentrations below the NEPM Health-based Investigation Levels for Residential Land use (HIL-A). Therefore, on-shore disposal of dredge material is also considered a suitable option.

# Contents

# 1.0 INTRODUCTION

NSW Department of Industry - Lands (DoI – Lands) is responsible for the management of approximately half of the land in NSW, encompassing the dry and submerged lands, up to 5.5 km offshore from the NSW coastline. DoI - Lands manage a range of built maritime assets, including 25 coastal harbours and 21 river entrances, and where appropriate maintains access to these assets.

Recently, the Port of Eden has seen increased activity from the cruise industry, however restricted by draft and length, cruise ships are currently unable to berth alongside land-based infrastructure (i.e. berth at the Breakwater Wharf). Consultation with the cruise industry and Port Authority NSW indicates that, while ships in the 220-260 m size range (and smaller) will continue to be used for over 30 years, there will likely be an increasing number of longer vessels (greater than 300 m) within 5-10 years.

DoI - Lands has identified the need to extend the Eden Breakwater Wharf to accommodate cruise ships in excess of 300m in length and dredge the approach channel and berth pocket to -10.5m Chart Datum (CD).

This sediment sampling and analysis (SAP) implementation report has been prepared in accordance with the approved SAP (AMA, 2016), which describes the approach for collection and analysis of the sediments to be dredged. The primary aims of this SAP implementation report were to investigate the suitability of the dredge material for offshore dredge spoil disposal and also aid the regulatory approval process in accordance with the National Assessment Guidelines for Dredging (NAGD) (Commonwealth of Australia, 2009).

The objectives of this investigation included:

- Implementation of the approved SAP;
- Characterisation of sediment suitability for disposal on land/ and or at sea; and
- Preparation of a SAP implementation report to inform dredging and disposal activities.

## 1.1 Description of the Study Area

The Eden Breakwater Wharf is located in Snug Cove, Eden. The first wharf built for shipping was in 1860. Snug Cove consists of three wharfs, namely the Mooring Jetty, Multi-Purpose Jetty and Breakwater Wharf (see **Figure 1**). The first stage of construction of the Breakwater Wharf was in the late 1970's, with construction completed in 1978. The second stage of the Breakwater Wharf was then completed in the late 1980's.

The current bathymetry north of the Breakwater Wharf is between -4 m to -10 m Australian Height Datum (AHD) (GBG Australia, 2014). To ensure the safe navigation of cruise ships into the Eden Breakwater Wharf, capital dredging is proposed along the northern edge of the Breakwater.


**Figure 1 The location of the Breakwater Wharf in Snug Cove, Eden (referenced from Crown Lands, 2014.**

# 2.0 METHODS

## Approved SAP Implementation

The dredge volume documented in the approved Sediment Sampling Analysis document (July 2015) is 170,000 $m^3$ of dredge material (including over-dredge). This estimate was based on preliminary channel designs (WoreleyParsons, 2015) and since then, a number of factors have contributed to an increase in the dredge area and volume. These include:

- Bring the proposed dredge area closer to the existing port infrastructure, in a north easterly direction. This decision was made to maximise safe berthing of the cruise ships, by reducing expose to prevailing waves beyond the existing breakwater structure;
- The dredge area has also been extended to a north westerly direction to ensure sufficient, and safe, movement of the cruise ships during berthing operations.

To accommodate these changes, the spatial area of the dredge footprint has increased, which has resulted in a maximum dredge volume of 231,500 $m^3$, including an allowance for over-dredging.

Given the change in dredge volume, the SAP fieldwork was executed during two separate sampling campaigns. The sampling and analysis approach was executed in accordance with the approved Eden Breakwater Wharf Extension SAP (AMA, 2015).

Sediment samples were collected from across the full extent of the designated dredge area. The first sampling campaign occurred in the dredge area adjacent to the existing Breakwater Wharf facility

and a vibrocorer was used to extract the intact sediment cores from the deeper dredge cut at each location. The second sampling campaign occurred in the broader dredge area seaward of the existing Breakwater Wharf facility. This area is naturally deeper and the maximum core depth of 1 m was achieved using a piston corer. Sediment cores were recovered to the maximum dredge depth (-10.5 m CD). The core samples retained were initially assessed for the following:

- Retention of surficial sediments;
- Vertical core has been obtained;
- An intact sample has been obtained through the core with minimal disturbance;
- Core is taken to the required depth, or core refusal in stiff in-situ material is encountered.

The volume of sediment retained satisfied the analysis requirements at all locations.

For the first sampling campaign, Abyss Commercial Diving operated and positioned the vessel at each pre-determined location. At each location:

- A field sheet was completed which described the field conditions (for example, weather, tides, currents), sample locations, sampling methods and handling and storage methods, field numbers, date, time and the identity of sampler.
- A field sediment core log was completed, which provided a field description of the sediments characteristics, including but not limited to the physical appearance and properties, colour, odour, presence of foreign material, presence of shell fragments and/or biota. A digital image was also taken of each core.
- The core was extruded from the vibrocorer into core socks and then into core trays;
- The core was then split open and samples collected from the following sampling intervals: 0–0.5 m, 0.5–1.0 m; and the remainder of the core below 1 m composited into a single sample.
- Each discrete sample collected was homogenised and stored in clean pre-labelled sample containers, as provided by the laboratory.

Triplicate samples were collected at two random sample locations (Locations 3 and 6) and a duplicate split at one random sample location (Location 8)[1], as prescribed in the SAP. **Table 1** below provides details of the total number of samples, including subsamples, primary, duplicate splits and triplicate samples.

**Table 1 Sediment Sampling and Analysis Program**

| Dredge Areas | Eden Breakwater Wharf |
|---|---|
| 0–0.5 m | 15 |
| 0.5–1.0 m | 15 |
| >1.0 m | 15 |

[1] Sample Locations 15 and 16 were outside of the proposed dredge area, following refinement of the dredge footprint and have been included in this report only to provide additional background data on the contamination status of nearby sediments and also to provide complementary QA/QC data, including random split samples, collected at Location 8.

| | |
|---|---|
| Duplicate Splits* | 2 |
| Triplicate Samples** | 4 |
| **Total Samples** | **51** |

*A single core (that is, approximately 5% of the total number of dredge sampling locations) was homogenised, split into three containers, uniquely labelled and separately analysed, with one of the three samples sent to a secondary laboratory for analysis.
** Triplicate core samples were taken at two pre-determined locations (10% of the total number of sample locations). In each case a triplicate core sample was collected (one primary, as well as a duplicate and triplicate core) and treated as separate samples.

For the second sampling campaign, Australasian Marine Associates operated and positioned the vessel at each pre-determined location. At each location:

- A field sheet was completed which described the field conditions (for example, weather, tides, currents), sample locations, sampling methods and handling and storage methods, field numbers, date, time and the identity of sampler.
- A field sediment core log was completed, which provided a field description of the sediments characteristics, including but not limited to the physical appearance and properties, colour, odour, presence of foreign material, presence of shell fragments and/or biota. A digital image was also taken of each core sample.
- The sediment was extruded from the piston corer into separate stainless steel bowls for each of the sediment profile strata (0–0.5 m and 0.5–1 m);
- Each discrete sample collected was homogenised and sub samples were taken, stored in clean pre-labelled sample containers, as provided by the laboratory.

Triplicate samples were collected at one random sample location (Location 21) and a duplicate split at one random sample location (Location 22), as prescribed in the SAP. **Table 2** below provides details of the total number of samples, including subsamples, primary, duplicate splits and triplicate samples.

**Table 2 Sediment Sampling and Analysis Program**

| **Dredge Areas** | **Eden Breakwater Wharf** |
|---|---|
| 0–0.5 m | 11 |
| 0.5–1.0 m | 2 |
| Duplicate Splits* | 2 |
| Triplicate Samples** | 2 |
| **Total Samples** | **17** |

*A single core (that is, approximately 5% of the total number of dredge sampling locations) was homogenised, split into three containers, uniquely labelled and separately analysed.
** Triplicate core samples were taken at one pre-determined locations (10% of the total number of sample locations). In each case a triplicate core sample was collected (one primary, as well as a duplicate and triplicate core) and treated as separate samples.

A total of 68 samples were collected across the two sampling campaigns at a total of 26 locations. The number of locations sampled during this program exceed the number of sample locations specified in NAGD (2009) for a dredge column of 231,500 $m^3$. Given that two locations (i.e. Locations 15 and 16) fell outside of the revised dredge footprint, only the sediment samples collected from 24 of the 26 locations were used as part of sample analyses and dredge material characterisation. These locations were included in the report only to provide additional background data on the contamination status of nearby sediments and also to provide complementary QA/QC data.

All samples were collected using disposable nitrile gloves, and placed into laboratory supplied sample containers and kept chilled in the dark prior to transport to the NATA accredited analytical laboratory, under chain of custody procedures for the broad suite of analysis as described in the next section.

### TBT Bioavailability

Further surface coring (0-0.5m) at Sites 4, 5, 8 and 13 was completed on 9 April 2015. The primary purpose of this extra coring was to capture additional sediment volume for TBT pore water analysis. The need for this work and discussion of the results, are presented in Section 3.

## 2.1 Laboratory Analysis

The sediment samples collected were analysed for a range of organic and inorganic analytes and compounds, plus particle size distribution (PSD) and acid sulphate soils (ASS). The sediment samples collected from the dredge area were tested in accordance with analyses identified in **Table 3**. The NAGD suite of analyses is presented in **Table 4**. All primary samples were tested for PSD (2–2000 µm) by wet sieving and hydrometer and acid sulphate soils using the SPOCAS suite.

**Table 3 Sample Analyses**

| | Analyses | | | | | |
|---|---|---|---|---|---|---|
| | **Organics** | **Particle Size*** | **TOC** | **Metals** | **Organotins** | **Acid Sulphate Soils*** |
| Total | 68 | 58 | 68 | 68 | 68 | 58 |

* Particle size distribution and acid sulphate soils was not performed on splits and triplicate samples.

**Table 4 NAGD suite of analyses.**

| **ANALYTE** | **Limit of Reporting** |
|---|---|
| **METALS** | **mg/kg** |
| As, Cr, Cu, Pb, Ni, Zn | 1.0 |
| Hg | 0.01 |
| Cd and Ag | 0.1 |
| Co | 0.5 |
| **Total Organic Carbon** | **0.02%** |
| **ORGANOTINS** | **ugSn/kg** |
| Tributyltin | 0.5 |
| **ORGANICS** | **mg/kg** |
| Benzene, Ethylbenzene, Toluene and Xylene (BTEX) | 0.2 mg/kg |
| **Polycarbonated biphenyls (PCBs)** | **5.0 µg/kg** |
| **Polycyclic aromatic hydrocarbons (PAHs)** | **5.0 µg/kg** |
| **Total recoverable hydrocarbons (TRH) (C10-C40)** | **10–50 mg/kg** |
| **Organochlorine pesticides (OCPs)** | **µg/kg** |
| Aldrin, DDT, DDE, DDD, Dieldrin, Endosulfan, Endrin, Heptaclor, Hexachlorobenzene, Methoxychlor | 0.5 |
| Lindane (Gamma (BHC)) and Chlordane | 0.25 |

## 2.2 Quality Assessment and Quality Control

All laboratories used for sediment analyses were NATA accredited for the methods used and were experienced in the analysis of marine sediments. Australian Laboratory Services (ALS) was the primary laboratory and Advanced Analytical Australia (AAA) the secondary service provider.

**Table 5** provides a summary of the details regarding the laboratory method information for the suite of total tests to be undertaken on sediment samples.

**Table 5 Method information for sediment analysis**

| Test | Method Reference | Practical Quantitation Limit |
|---|---|---|
| Moisture Content | Gravimetric | 0.1% |
| Particle size distribution | Sieve and hydrometer | 2-2000 µm |
| Total organic carbon | Handbook of soil and water | 0.01% |
| Organotins | In-house (Abalos et al 1997, Attaar, 1996) | 0.5 µgSn/kg |
| Benzene, Ethylbenzene, Toluene and Xylene (BTEX) | USEPA 5030/8260 | 0.2 mg/kg |
| Polycarbonated biphenyls (PCBs) | USEPA 3640/3620 USEPA8081/8082 | 5.0 µg/kg |
| Polycyclic aromatic hydrocarbons (PAHs) | USEPA 3640/8270 | 5.0 µg/kg |
| Total recoverable hydrocarbons (TRH) | USEPA 3510 | 10–50 mg/kg |
| Organochlorine pesticides (OCPs) | USEPA 3640/3620 USEPA8081/8082 | 0.25 –0.5 µg/kg |
| Trace Metals | USEPA 3050/ 200.7 ICP/AES | 0.1 mg/kg |
| Mercury | USEPA 3050/ 7471A CVAAS | 0.01 mg/kg |

The field based QA/QC data quality objectives adopted for this investigation are presented in **Table 6**, and the outcomes are presented in the Results section of this report.

**Table 6 Field-based QA/QC Data Quality Objectives**

| Objectives | Frequency | Data Quality Objectives |
|---|---|---|
| **Field Data Quality Objectives** | | |
| Field Splits | 5% of locations | <+/- 50% RSD |

| | | |
|---|---|---|
| Field Triplicates | 10% of locations | <+/- 50% RSD |
| Trip Blanks (volatiles only) | 1 per sampling event | </= LOR |
| **Laboratory Data Quality Objectives** | | |
| Matrix Spikes | 1 per batch or 20 samples | 75-125% |
| Surrogate Spikes | All organics | 75-125% |
| Laboratory Control Spike | 1 per batch or 20 samples | 80-120% |
| Laboratory Duplicate | 1 per batch or 20 samples | 65-135% |
| Lab Blanks | 1 per batch | < method LOR |
| Holding times | All samples | All sample analysed within HT's |
| **Comparability** | | |
| SOP's for sample collection, subsampling and handling | All samples | All sampling done in accordance with SOP |
| Standard analysis methods | All samples | All samples analysed according to standard analysis methods |
| LOR met SAP requirements | All Samples | All samples |
| **Completeness** | | |
| Chain of custody, sample description, site observations, location logged | All samples | All samples |
| Samples received at Lab specified on CoC | All samples | All samples received unbroken |
| QC samples sufficient and acceptable results | All QA/QC | Meet NAGD requirements |
| Completeness objectives met (~95%) | All data | Minimum 95% |

With specific consideration to the NADG (2009) QA/QC recommendations, all quality control procedures were adhered to. In summary, these included measures such as:

- Sample containers were provided by the laboratory, and included glass containers for organics and inorganics and plastic bags for PSD and acid sulphate soils samples.
- Use of powder free nitrile gloves.
- Decontamination of equipment between samples.
- Population of a field log noting weather, tide, current, sampling methods, field sample numbers, date, time, and identity of sampler.
- Field descriptions of sediment collected; appearance, colour, constituents, biota, smell, texture.
- COC forms listing all samples collected and tests required were prepared for each batch and submitted to the laboratory.
- Three field triplicates (spatial variation), two split samples (laboratory variation) and two trip blanks.
- Samples were submitted to a NATA accredited laboratory, accredited for the analyses requested.
- Laboratory QA/QC Laboratory QA/QC procedures included laboratory blank, standard reference material analysis, matrix spike, surrogates, and replicate analysis was undertaken and reported.

- Sample holding times were within the prescribed limits as per Appendix 7 of the NAGD.
- The Laboratory was instructed to analyse one sample from a previous batch if a new batch of samples is processed.

## 2.4 Analysis and Interpretation

The analysis included standardisation of all organic compounds to 1% TOC and calculation of the 95% UCL of the mean for comparison with screening levels. ProUCL Version 5 was used to examine the distribution of the data and the data transformed where required, prior to calculation of the 95% UCL.

Tables have been prepared for PSD and the NAGD Suite, which include the analyte/ compound names, laboratory detection limits, results and the relevant screening levels/ criteria. Further assessment of the dredge material suitability for ocean disposal, can be performed by undertaking elutriate testing and pore-water analyses and the concentrations of contaminants compared to water quality guidelines in ANZECC/ARMCANZ (2000). These tests are dependent on the concentrations in whole sediments reported.

The suitability of the dredge material was defined by comparing the environmental test results with the NAGD (2009) guidelines for offshore disposal suitability and the soil Human Investigation Levels (HILs), as defined in the National Environment Protection (Assessment of Site Contamination) Measure 1999 (NEPC, 1999) and the EPA Waste Classification Guidelines (EPA, 2014) for onshore disposal. This information will be used to support the statutory approval process, including obtaining a Sea Dumping Permit.

For sediments containing TBT above the Screening Level, standard toxicity tests fail to respond at TBT concentrations below the Maximum level specified in NADG (2009). Further discussion of TBT concentrations found in the sediments at the Breakwater Wharf Extension is presented in Section 3.

# 3.0 RESULTS AND DISCUSSION

This section presents the results obtained for the Sediment Sampling and Analysis program. The field and core logs completed during fieldwork are presented in **Appendix B**. Analytical summary data tables (**Appendix C**) and laboratory certificates, including quality control (**Appendix D**), are included in this report for future reference.

The data for core Locations 15 and 16 (located outside of the dredge area), have been excluded from any analysis presented in this section of the report. These data have been included for future reference in **Appendix C**. Results of chemical and physical analysis are presented here, together with a summary of the quality assurance/ quality control, which examines data quality and aids in the verification of the analytical data obtained.

## 3.1 Field Observations

The first field-based sampling campaign was completed between 20th and 23rd April 2015, and the second occurred between 8th and 9th July 2015. The target core depth of 10.5 m CD, as specified in the approved SAP (AMA, 2015) was achieved (see **Appendix B**). Images of cores extracted are provided in **Appendix E**.

During the field investigation, the sediments were largely reported as sandy gravel, with minor contribution of finer grained material. This observation is not surprising considering the physical location of Snug Cove, which is adjacent to high-energy marine waters. The high energy marine environment tends to reduce the likelihood of finer grained material settling out of solution and being deposited on the seabed. The associated particle size distribution data is further discussed in Section 3.3 of this report.

## 3.2 Individual Sample Results & NAGD/NEPM Assessment

A summary of the sediment analyte data is provided in **Table 7**. The majority of the 95% UCLs for the parameters of interest were reported below their respective NAGD Screening Levels, HILs and EPA Waste Classification Guidelines (**Appendix C**). All sediment samples returned organochlorine pesticide concentrations below the Limit of Reporting (LOR) specified in the SAP (AMA, 2015) (**Appendix C**).

Tributyl Tin (TBT), a contaminant that originates from historical uses of anti-fouling agents on vessel hulls, reported a 95% UCL above the NADG Screening Level (see **Table 7**). This result was attributed to several high TBT concentrations in the surface sediments at Sites 4, 5, 8 and 13. The highest concentration of 113.5 µg/kg was detected at Site 5, located approximately 100 m from the existing multipurpose jetty and 400 m from the slipway. The other sites were located closer to the existing multipurpose jetty, but > 100m from the slipway.

**Table 7. Summary of Analytical Results and assessment against NADG screening levels (24 Core locations).**

| Analytical Parameters | | Units | Detection Limit | NEPM HIL A | General solid Waste CT1 | NAGD (2009) Screening Levels | NAGD (2009) Sediment Quality High Values | 95% UCL 0-0.5 | 95% UCL 0.5-1 | 95% UCL >1 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Metals** | | | | | | | | | | |
| | Antimony | mg/kg | 0.5 | | | 2 | 25 | - | 0.376 | 0.30 |
| | Arsenic | mg/kg | 1 | 100 | 100 | 20 | 70 | 9.153 | 10.02 | 8.86 |
| | Cadmium | mg/kg | 0.1 | 20 | 20 | 1.5 | 10 | - | 0.083 | - |
| | Chromium | mg/kg | 1 | 100 | | 80 | 370 | 7.39 | 6.135 | 4.99 |
| | Copper | mg/kg | 1 | 1000 | | 65 | 270 | 13.82 | 5.048 | 3.61 |
| | Cobalt | mg/kg | 0.5 | | | | | 1.687 | 2.186 | 1.76 |
| | Lead | mg/kg | 1 | 300 | 100 | 50 | 220 | 10.99 | 4.969 | 4.33 |
| | Nickel | mg/kg | 1 | 600 | 40 | 21 | 52 | 3.915 | 5.135 | 4.32 |
| | Silver | mg/kg | 0.1 | | 100 | 1 | 3.7 | 0.643 | 0.229 | 0.08 |
| | Zinc | mg/kg | 1 | 7000 | | 200 | 410 | 56.87 | 18.46 | 14.43 |
| | Mercury | mg/kg | 0.01 | 15 | 4 | 0.15 | 1 | 0.0566 | 0.0161 | 0.01 |
| **Organo Tins** | | | | | | | | | | |
| | Normalised Tributyltin as Sn | µgSn/kg | 0.5 | | | 9 | 70 | 28.87 | 6.75 | 2.32 |
| **TPH** | | | | | | | | | | |
| | Total TPH (Normalised to 1% TOC | mg/kg | 3 | | 10000 | 550 | | 99.34 | 29.3 | 53.93 |
| **PAH** | | | | | | | | | | |
| | Total PAH (Normalised to 1% TOC | µg/kg | 4 | 20000 | 200000 | 10000 | 50000 | 480 | 734.8 | 26.29 |

The Environmental Protection Authority of NSW, under the Environmentally Hazardous Chemicals ACT 1985, has a Chemical Control Order (CCO) in relations to organotin wastes. The CCO sets controls on the disposal of all solid or liquid organotin wastes generated during the application or removal of antifouling paint. The CCO only applies to dredged sediments contaminated with organotin, where these are clearly associated with facilities used to apply or remove organotin products (this is likely to include, for example, sediments immediately adjacent to slipways). The sediment proposed for dredging as part of the Eden Breakwater Wharf Extension are not directly adjacent to the local slipway. Therefore, the assessment of sediment quality and suitability of disposal options was addressed using NADG (2009).

NADG (2009) state that in sediments containing TBT above the Screening Level, standard toxicity tests will fail to respond at TBT levels below the maximum level specified, because the guidelines are based on imposex effects on gastropods. Furthermore, there is no point in doing pore water toxicity tests, as these are also only responsive at high TBT levels. The appropriate procedure is to obtain sediment pore water analyse for TBT and compare to the TBT ANZECC/ARMCANZ 2000 marine water quality guideline values.

In some circumstances, it may not be possible to obtain sufficient pore water for testing (300–500 ml required) even from large sediment cores (NADG, 2009). In this case, it is acceptable to carry out a seawater elutriate test, analyse for TBT and compare data to the ANZECC/ARMCANZ 2000 marine water quality guideline value.

The samples collected (~1000 g, maximum NADG recommend) from the cores during 9 April 2015, did not contain enough pore water and therefore, elutriate analysis was adopted. All elutriate tests for Sites 4, 5, 8 and 13 returned TBT concentrations below the detection limit of the analytical equipment (< 2 ng/L). These results confirm that the bioavailability of TBT is very low and that the TBT is likely to be tightly bound to the organic material present in the sediment.

There was one individual observation of silver exceeding the NADG Screening Level. This observation occurred at Site 9 in the surface sediment (i.e. 2.7 mg/kg, NADG Screening Level = 1 mg/kg) and the 95% UCL was below the NADG Screening Level.

There is a paucity of data to compare the current sediment investigation too; however some surface sediment sampling and analysis was undertaken in the adjacent bay (Cattle Bay) in Snug Cove. The investigation found that all organic and inorganic contaminants were below the ANZECC (2000) ISQG Low values (**Table 8**).

**Table 8. Sediment contaminant concentrations found in Cattle Bay Sediments (Source: Marine Pollution Research, 2013).**

**Table 2 Cattle Bay Sediment Contamination**

| Analyte | units | PQL | ANZECC ISQG low | ANZECC ISQG high | Min | Median | Mean | SE of Mean | Max |
|---|---|---|---|---|---|---|---|---|---|
| Moisture | content % | 1 | - | - | 24.8 | 27.1 | 26.8 | 0.6 | 27.9 |
| TOC | % | 0.02 | - | - | 0.46 | 0.50 | 0.50 | 0.01 | 0.55 |
| Aluminium | mg/kg | 50 | - | - | 2120 | 2670 | 2730 | 218 | 3310 |
| Iron | mg/kg | 50 | - | - | 5840 | 7285 | 7743 | 941 | 11700 |
| Antimony | mg/kg | 0.5 | 2 | 25 | | | <0.5 | | |
| Arsenic | mg/kg | 1 | 20 | - | 5.02 | 5.29 | 6.63 | 1.07 | 10.70 |
| Cadmium | mg/kg | 0.1 | 1.5 | 10 | | | <0.1 | | |
| Chromium | mg/kg | 1 | 80 | 370 | 7.1 | 7.7 | 8.1 | 0.6 | 10.4 |
| Copper | mg/kg | 1 | - | - | 3.2 | 4.4 | 4.5 | 0.5 | 6.2 |
| Cobalt | mg/kg | 0.5 | 65 | 270 | 1.2 | 1.5 | 1.5 | 0.1 | 1.9 |
| Lead | mg/kg | 1 | 50 | 220 | 4.0 | 4.8 | 5.3 | 0.6 | 7.5 |
| Manganese | mg/kg | 10 | - | - | 19 | 23.5 | 24.0 | 1.8 | 31 |
| Nickel | mg/kg | 1 | 21 | 52 | 3.1 | 3.8 | 3.9 | 0.3 | 5.1 |
| Selenium | mg/kg | 0.1 | - | - | | | <0.1 | | |
| Silver | mg/kg | 0.1 | 1 | 3.7 | | | <0.1 | | |
| Vanadium | mg/kg | 2 | - | - | 11.8 | 14.2 | 15.3 | 2.0 | 23.4 |
| Zinc | mg/kg | 1 | 200 | 410 | 13.7 | 16.4 | 18.2 | 2.2 | 25.2 |
| Mercury | mg/kg | 0.01 | 0.15 | 1 | 0.01 | 0.010 | 0.016 | 0.004 | 0.03 |
| TPHs | mg/kg | 3 | 550 | - | | | <3 | | |
| TBT* | µgSn/kg | 0.5 | 9 | 70 | <0.5 | <0.5 | 0.7 | 0.3 | 2.0 |
| PAHs* | µg/kg | 4 | 10,000 | 50,000 | 7.7 | 130.2 | 97.9 | 30.1 | 152.9 |

Note* Values for TBT and PAH were normalised for TOC prior to calculations

Considering the sediment concentrations reported and the information provided in Section 3.2 of this report, the sediments within the proposed dredge area for the Eden Breakwater Wharf Extension are considered suitable for dredging and unconfined offshore disposal or onshore disposal.

## 3.3 Physical Characteristics

The percentage gravel, sand, silt and clay, as determined from the PSD analyses, is provided in T**able 9** (see **Appendix C** for detailed clay/silt fractionations). Laboratory analytical reports (including PSD analyses) are provided in **Appendix D**.

The composition of the sediment samples collected from the proposed dredge area for the Breakwater Wharf Extension Project were dominated by the sand fraction, with minor components of silt, clay and in some instances relatively large proportions of gravel (i.e. up to 32 %). These data confirm that there is only a small fraction of fine-grained material present in the proposed dredge material (maximum of 11% silt and clay at site 3). On average the proposed dredge material is 93.5 % sand and gravel.

**Table 9 Particle Size Distributions percentages in the dredge area sediments.**

| Core | Strata | Clay (<2 µm) | Silt (2-60 µm) | Sand (0.06-2.00 mm) | Gravel (>2mm) | Cobbles (>6cm) |
|---|---|---|---|---|---|---|
| **VC01-0.5** | 0-0.5 | 2 | 1 | 82 | 15 | <1 |
| **VC01-1.0** | 0.5-1 | 4 | 2 | 91 | 3 | <1 |
| **VC01>1.0** | >1 | 5 | 2 | 88 | 5 | <1 |
| **VC02-0.5** | 0-0.5 | 6 | <1 | 89 | 5 | <1 |
| **VC02-1.0** | 0.5-1 | 1 | <1 | 93 | 6 | <1 |
| **VC02>1.0** | >1 | 4 | <1 | 93 | 3 | <1 |
| **VC03-0.5** | 0-0.5 | 8 | 3 | 81 | 8 | <1 |
| **VC03-1.0** | 0.5-1 | 7 | 3 | 75 | 15 | <1 |
| **VC03>1.0** | >1 | 6 | 4 | 76 | 14 | <1 |
| **VC04-0.5** | 0-0.5 | 6 | 3 | 90 | 1 | <1 |
| **VC04-1.0** | 0.5-1 | 6 | 2 | 78 | 14 | <1 |
| **VC04>1.0** | >1 | 6 | 3 | 88 | 3 | <1 |
| **VC05-0.5** | 0-0.5 | 4 | 1 | 94 | 1 | <1 |
| **VC05-1.0** | 0.5-1 | 5 | 2 | 82 | 11 | <1 |
| **VC05>1.0** | >1 | 5 | 3 | 89 | 3 | <1 |
| **VC06-0.5** | 0-0.5 | 4 | 3 | 76 | 17 | <1 |
| **VC06-1.0** | 0.5-1 | 5 | <1 | 90 | 5 | <1 |
| **VC06>1** | >1 | 3 | 1 | 92 | 4 | <1 |
| **VC07-0.5** | 0-0.5 | 3 | 1 | 80 | 16 | <1 |
| **VC07-1.0** | 0.5-1 | 2 | <1 | 85 | 13 | <1 |
| **VC07>1.0** | >1 | 3 | 1 | 91 | 5 | <1 |
| **VC08-0.5** | 0-0.5 | 7 | 4 | 81 | 8 | <1 |
| **VC08-1.0** | 0.5-1 | 7 | 1 | 73 | 19 | <1 |
| **VC08>10** | >1 | 5 | 2 | 61 | 32 | <1 |
| **VC09-0.5** | 0-0.5 | 8 | 2 | 61 | 29 | <1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **VC09-1.0** | 0.5-1 | 7 | 3 | 84 | 6 | <1 |
| **VC09>1.0** | >1 | 5 | <1 | 92 | 3 | <1 |
| **VC10-0.5** | 0-0.5 | 6 | <1 | 93 | 1 | <1 |
| **VC10-1.0** | 0.5-1 | 4 | <1 | 94 | 2 | <1 |
| **VC10>1.0** | >1 | 6 | 1 | 70 | 23 | <1 |
| **VC11-0.5** | 0-0.5 | 5 | <1 | 91 | 4 | <1 |
| **VC11-1.0** | 0.5-1 | 5 | 2 | 91 | 2 | <1 |
| **VC11>1.0** | >1 | 6 | 1 | 87 | 6 | <1 |
| **VC12-0.5** | 0-0.5 | 6 | 3 | 87 | 4 | <1 |
| **VC12-1.0** | 0.5-1 | 5 | 1 | 88 | 6 | <1 |
| **VC12>1.0** | >1 | 3 | <1 | 96 | 1 | <1 |
| **VC13-0.5** | 0-0.5 | 5 | 1 | 68 | 26 | <1 |
| **VC13-1.0** | 0.5-1 | 5 | 3 | 61 | 31 | <1 |
| **VC13>1.0** | >1 | 3 | 1 | 85 | 11 | <1 |
| **VC14-0.5** | 0-0.5 | 5 | 3 | 67 | 25 | <1 |
| **VC14-0.7** | >1 | 2 | 2 | 90 | 6 | <1 |
| **VC14-1.0** | 0.5-1 | 4 | 2 | 89 | 5 | <1 |
| **VC17-0.5** | 0-0.5 | 3 | 2 | 94 | 1 | <1 |
| **VC17-1.0** | 0.5-1 | 5 | 1 | 93 | 1 | <1 |
| **VC18-0.5** | 0-0.5 | 7 | 4 | 88 | 1 | <1 |
| **VC19-0.5** | 0-0.5 | 4 | 4 | 90 | 2 | <1 |
| **VC20-0.5** | 0-0.5 | 3 | 3 | 91 | 3 | <1 |
| **VC20-1.0** | 0.5-1 | 3 | 1 | 81 | 15 | <1 |
| **VC21-0.5** | 0-0.5 | ---- | ---- | ---- | ---- | ---- |
| **VC22-0.5** | 0-0.5 | 5 | 4 | 88 | 3 | <1 |
| **VC23-0.5** | 0-0.5 | 4 | 4 | 90 | 2 | <1 |
| **VC24-0.5** | 0-0.5 | 5 | 1 | 91 | 3 | <1 |
| **VC25-0.5** | 0-0.5 | 4 | <1 | 91 | 5 | <1 |
| **S26-0.5** | 0-0.5 | 4 | 1 | 92 | 3 | <1 |

## 3.4 Potential Acid Sulphate Soils

The Potential Acid Sulfate Soils (PASS) test results are summaries in **Table 10** and the full screening laboratory certificates are in **Appendix D**. The SPOCAS suite is the acid sulphate soil assessment method recommended by Dear *et al*. (2002).

All of the sediment results returned a net acidity of <0.02 %S. These results confirm that the acid production potential of the sediments targeted for dredging to facilitate the Eden Breakwater Wharf Extension is low.

**Table 10. SPOCAS laboratory results for the marina sediments.**

| Analytical Parameters | pH KCl (23A) | ANC Fineness Factor | Net Acidity (sulfur units) | Net Acidity (acidity units) | Liming Rate |
|---|---|---|---|---|---|
| **Units** | **pH unit** | **-** | **(%S)** | **mole H+ / t** | **(Kg CaCO3/ t)** |
| **LOR** | **0.1** | **0.5** | **0.02** | **10** | **1** |
| **VC01-0.5** | 9.6 | 1.5 | <0.02 | <10 | <1 |
| **VC01-1.0** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC01>1.0** | 9.6 | 1.5 | <0.02 | <10 | <1 |
| **VC02-0.5** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC02-1.0** | 9.2 | 1.5 | <0.02 | <10 | <1 |
| **VC02>1.0** | 9.4 | 1.5 | <0.02 | <10 | <1 |
| **VC03-0.5** | 9.4 | 1.5 | <0.02 | <10 | <1 |
| **VC03-1.0** | 9.4 | 1.5 | <0.02 | <10 | <1 |
| **VC03>1.0** | 9.4 | 1.5 | <0.02 | <10 | <1 |
| **VC04-0.5** | 9.3 | 1.5 | <0.02 | <10 | <1 |
| **VC04-1.0** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC04>1.0** | 9.4 | 1.5 | <0.02 | <10 | <1 |
| **VC05-0.5** | 9.6 | 1.5 | <0.02 | <10 | <1 |
| **VC05-1.0** | 9.6 | 1.5 | <0.02 | <10 | <1 |
| **VC05>1.0** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC06-0.5** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC06-1.0** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC06>1** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC07-0.5** | 9.6 | 1.5 | <0.02 | <10 | <1 |
| **VC07-1.0** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC07>1.0** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC08-0.5** | 9.4 | 1.5 | <0.02 | <10 | <1 |
| **VC08-1.0** | 9.3 | 1.5 | <0.02 | <10 | <1 |
| **VC08>10** | 9.4 | 1.5 | <0.02 | <10 | <1 |
| **VC09-0.5** | 9.4 | 1.5 | <0.02 | <10 | <1 |
| **VC09-1.0** | 9.4 | 1.5 | <0.02 | <10 | <1 |
| **VC09>1.0** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC10-0.5** | 9.4 | 1.5 | <0.02 | <10 | <1 |
| **VC10-1.0** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC10>1.0** | 9.6 | 1.5 | <0.02 | <10 | <1 |
| **VC11-0.5** | 9.6 | 1.5 | <0.02 | <10 | <1 |
| **VC11-0.6** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC11>1.0** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC12-0.5** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC12-1.0** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC12>1.0** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC13-0.5** | 9.6 | 1.5 | <0.02 | <10 | <1 |

| | | | | | |
|---|---|---|---|---|---|
| **VC13-1.0** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC13>1.0** | 9.6 | 1.5 | <0.02 | <10 | <1 |
| **VC14-0.5** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC14-0.6** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC14-0.7** | 9.6 | 1.5 | <0.02 | <10 | <1 |
| **VC17-0.5** | 8.9 | 1.5 | <0.02 | <10 | <1 |
| **VC17-1.0** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC18-0.5** | 9.4 | 1.5 | <0.02 | <10 | <1 |
| **VC19-0.5** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC20-0.5** | 9.6 | 1.5 | <0.02 | <10 | <1 |
| **VC20-1.0** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC21-0.5** | 9.4 | 1.5 | <0.02 | <10 | <1 |
| **VC22-0.5** | 9.6 | 1.5 | <0.02 | <10 | <1 |
| **VC23-0.5** | 9.6 | 1.5 | <0.02 | <10 | <1 |
| **VC24-0.5** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **VC25-0.5** | 9.5 | 1.5 | <0.02 | <10 | <1 |
| **S26-0.5** | 9.5 | 1.5 | <0.02 | <10 | <1 |

## 3.5 Data Validation

### 3.5.1 Field Duplicate Split and Triplicates

The NAGD stipulates the analysis of quality assurance field duplicate splits and triplicate samples to determine the precision of the analysis. Field duplicate splits and triplicate samples were analysed to determine the variation associated with sub sample handling and within location variation (by relative standard deviation (RSD) of primary, secondary and triplicate cores). The level of acceptability is ±50% (see **Appendix C**). None of the RSDs exceeded the nominated acceptance criteria and data quality objective (DQO) of 95% compliance. **Table 11** and **Table 12** summarises the RSD results for each sampling campaign.

**Table 11 Summary of RSD Results Exceeding Acceptable Range**

| Sampling location | QC samples | | Inorganics | Organics | TOC | Moisture Content |
|---|---|---|---|---|---|---|
| | Duplicate | Triplicate | | | | |
| VC03_0.5 | T1 | T2 | 48 | 270 | 3 | 3 |
| VC06_0.5 | T3 | T4 | 48 | 270 | 3 | 3 |
| VC08_0.5 | Split 1 | Split 2 | 48 | 270 | 3 | 3 |
| Total QA analysis | | | 144 | 810 | 9 | 9 |
| Total Outside Limit | | | 0 | 8 | 0 | 0 |
| % Compliance | | | 100% | 99% | 100% | 100% |

**Table 12 Summary of RSD Results Exceeding Acceptable Range**

| Sampling location | QC samples | | Inorganics | Organics | TOC | Moisture Content |
|---|---|---|---|---|---|---|
| | Duplicate | Triplicate | | | | |
| VC20_0.5 | T1 | T2 | 33 | 270 | 3 | 3 |
| VC21_0.5 | T3 | T4 | 33 | 270 | 3 | 3 |
| Total QA analysis | | | 66 | 540 | 6 | 6 |

| Sampling location | QC samples | | Inorganics | Organics | TOC | Moisture Content |
|---|---|---|---|---|---|---|
| | Duplicate | Triplicate | | | | |
| Total Outside Limit | | | 0 | 4 | 0 | 0 |
| % Compliance | | | 100% | 99.3% | 100% | 100% |

Based on the observed summary of duplicate split and triplicate sample RSD results presented in **Table 6**, organics, inorganics, TOC and moisture content RSD results returned a total percentage compliance above the 95% compliance objective.

### 3.5.1 Field Trip Blanks

Two field trip blank samples (jars containing chromatographic sand) were taken into the field to comply with the NAGD recommendation for analysis for volatile compounds and was submitted with the batch of samples to the primary laboratory.

Returned concentrations of TPH/BTEX compounds were below the analysing laboratory Limit of Reporting (LOR). Returned concentrations of BTEX compounds below the analysing laboratory LOR indicate zero cross contamination between samples during collection, interim storage and final transport to the analysing laboratory. Reporting of results is considered acceptable and potentially free of cross contamination from volatile sources.

# 4.0 CONCLUSIONS AND RECOMMENDATIONS

Sediments were sampled within the proposed dredging area in accordance with the approved SAP (AMA, 2016). Samples were collected from discrete horizons at each of the 26 locations down to the maximum dredge cut depth of 10.5 m (i.e. surface (0-0.5 m), mid profile (0.5-1 m) and where required deep (>1 m).

The physical sediment analysis and field observations confirmed that the sediments within the proposed dredging area were dominated by the sand fraction, with minor components of silt, clay and in some instances, a relatively high percentage of gravel (i.e. up to 32 %). These analyses confirmed only a small fraction of fine-grained material present in the proposed dredge material (maximum of 11% silt and clay at Site 3). This is an important finding, as during the dredging works, it is the fine-grained fraction that has the greatest potential to remain in suspension and contribute to the intensity and extent of dredging plumes.

The 95% UCL calculated for each of the inorganic (i.e. metals) analyses performed were all below the NAGD Screening Levels and NEPM HIL A Levels. There was one individual observation of silver exceeding the NADG Screening Level. This observation occurred at Site 9 in the surface sediment (i.e. 2.7 mg/kg, NADG Screening Level = 1 mg/kg) and the 95% UCL was below the NADG Screening Level. There is a paucity of sediment quality data to facilitate historical comparisons; however some surficial sediment characterisation in nearby Cattle Bay provided additional insight, with all sediment analytes returning metal concentrations below sediment quality guideline values (ANZECC, 2000).

Tributyl Tin (TBT), a contaminant sourced from historical use as an anti-fouling agent on vessel hulls, returned a 95% UCL above the NADG Screening Level. This result was influenced by several TBT concentrations found in the surface sediments at Sites 4, 5, 8 and 13. The highest concentration of 113.5 µg/kg was detected at Site 5, located approximately 100 m from the existing multipurpose jetty and 400 m from the slipway. The other sites were located closer to the existing multipurpose jetty, but >100 m from the slipway. Given the distance to the slipway, the TBT concentrations reported were likely resultant from historic vessel movement and berthing activities, rather than from boat maintenance activities associates with the slipway.

Consistent with the NADG (2009) approach, further sediment sampling and analysis to assess the solubility of the TBT in surface (0-0.5m) samples at Sites 4, 5, 8 and 13 was completed. The results from this work confirmed that TBT concentrations in aqueous phase (i.e. biologically available) were below the analytical detection limits (i.e. 2 ng/L). The TBT is therefore likely to be tightly bound to the organic phase in the sediment and no further testing was required.

The potential for acid generation from potential acid sulphate soils (PASS) was assessed using the SPOCAS technique. All results confirmed that PASS sediments were not present in the proposed dredging area. Therefore, PASS is not considered a risk to the environment.

Considering the results of this SAP, the sediments proposed for capital dredging works in Eden are considered suitable for unconfined offshore disposal. All of the samples tested had concentrations

below the NEPM Health-based Investigation Levels for Residential Landuse (HIL-A). Therefore, on-shore disposal of dredge material is also considered a suitable option.

# 5.0 REFERENCES

AMA (2015) Sediment Sampling and Analysis Plan. Eden Breakwater Wharf Extension Project. Prepared by Australasian Marine Associates for NSW Crown Lands.

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