



## Port of Esperance Survey of Lead and Nickel in Marine Sediments

Level (Stage) 2 – Bioavailability Investigation Report

January 2008





# **Port of Esperance Survey of Lead and Nickel in Marine Sediments**

## **Level (Stage) 2 – Bioavailability Investigation Report**

*Prepared for*

**Port of Esperance**

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**Oceanica Consulting Pty Ltd**

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## Executive Summary

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The Esperance Port Authority has developed a Sampling and Analysis Program (SAP) to examine the extent of lead and nickel contamination within the harbour in accordance with DEC guidelines. This was undertaken following detection of high lead and nickel in sediments near a discharge pipe at Berth 1 in Esperance Port in early 2007.

The SAP proposed a staged approach to investigation, in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure 1999's *Schedule B(5) Guideline on Ecological Risk Assessment* (NEPC 1999). This approach involves Stage 1 (Preliminary Screening Assessment), with further work potentially including Stage 2 (consideration of factors controlling bioavailability), Stage 3 (further sampling as required, and a full ecological risk assessment) and, if required, site management/remediation.

Results from Stage 1 (Preliminary Screening Assessment) were submitted to the Department of Environment and Conservation on 12 November 2007. During the Stage 1 investigations, several areas within the Esperance Port were classified as contaminated and therefore required further investigations to determine the bioavailability of the sediment metals. Lead and nickel contamination was highest adjacent to the discharge pipe at Berth 1, but was also elevated along the face of Berth 2. The spatial extent of lead contamination was far less than nickel, with the ISQG-High only exceeded at one site whereas for nickel it was exceeded at 10 sites. The lead contamination was also significantly attenuated within 50 m of the discharge pipe at Berth 1, and the berth pocket site at Berth 2. Nickel contamination was more widespread, exceeding National Sediment Quality Guidelines (ISQG-low) in an annular pattern around the edge of the harbour; concentrations within the central harbour sediment were below the National sediment quality guidelines (ISQG-low). Based on sites monitored as part of the Esperance Port Authority's routine sediment monitoring program, it appears that discharges from the pipe at Berth 1 have led to an increase in the level of lead and nickel contamination in sediments at Berth 1 sites since October 2006. However the level of lead and nickel contamination at Berth 2 has declined since October 2006.

In addition to identifying areas in which the bioavailable lead and/or nickel concentrations exceed the guidelines, the Stage 2 Bioavailability Investigation was designed to:

- Identify any sampling and analysis required for a Stage 3 investigation, including:
  - sites for which archived samples of deeper (2-6 and 6-10 cm) layers of sediment should be analysed;
  - any additional sampling needed to further delineate the extent of contamination; and
  - the need for further testing to determine the ecological and human health risks posed by the contamination.
- Revise the sites sampled in the Esperance Port Authority's routine sediment sampling programme.

The results of the Stage 1 study were used to identify those sites requiring further assessment for bioavailability of metals in sediments, for the Stage 2 risk assessment (consideration of factors controlling bioavailability). As a proportion of the metals in a sediment sample are likely to be present in biologically unavailable forms, a dilute acid extraction was performed on surface sediment (top 2 cm) samples collected in August 2007 and stored frozen, to extract the more readily available metals. Fifty one samples were analysed for bioavailable lead and nickel. The results were then compared against the National sediment quality guidelines (ISQG-Low and ISQG-High) (ANZECC/ARMCANZ 2000) and background concentrations. Results indicated that:

- Sediment lead concentrations at Esperance Port are more bioavailable than nickel with approximately 85% of the total lead being bioavailable compared to 6% for nickel.
- Bioavailable lead contamination was far more widespread than bioavailable nickel
- No sites exceeded the ISQG-Low or ISQG-High for bioavailable nickel
- Nine sites exceeded the ISQG-Low for lead
- No sites exceeded the ISQG-High for lead

The sampling and analyses required for a Stage 3 investigation—based on these Stage 2 results—are identified in this report.



# 1. Introduction

## 1.1. Background

The Port of Esperance is situated on the south coast of Western Australia (ca. 800 km south-east of Perth), on the north-eastern side of Dempster Head. The Port of Esperance is a regional port which services the south-east agricultural and the eastern and north-eastern Goldfields regions of Western Australia. The Port handles both bulk, solid and liquid cargoes; the main exports are grain, nickel concentrates and iron ore; and the main imports are petroleum and fertiliser products (Connell Wagner, 1997). Shipping of small amounts of lead concentrate commenced in July 2005.

The Port is sheltered from the south and east by a 1,200 metre breakwater. It has two adjacent land backed berths (Berths 1 and 2) and a third dolphin-type berth (Berth 3) located on the main breakwater (Figure 1.1). Berths 1 and 2 face north-east, and Berth 3 (constructed as part of a recent port upgrade and officially opened in 2002) faces north-west. Presently, the dredged entrance channel is approximately 350 m long and adjoins a swing basin with an approximate diameter of 550 m (Figure 1.2). The channel and turning basin for Berths 1 and 2 cover 27 ha and is dredged to 14.5 metres. No. 3 Berth and channel is dredged to 19.0 metres.



Figure 1.1 Esperance Port berths (red dots) and facilities (yellow dots)

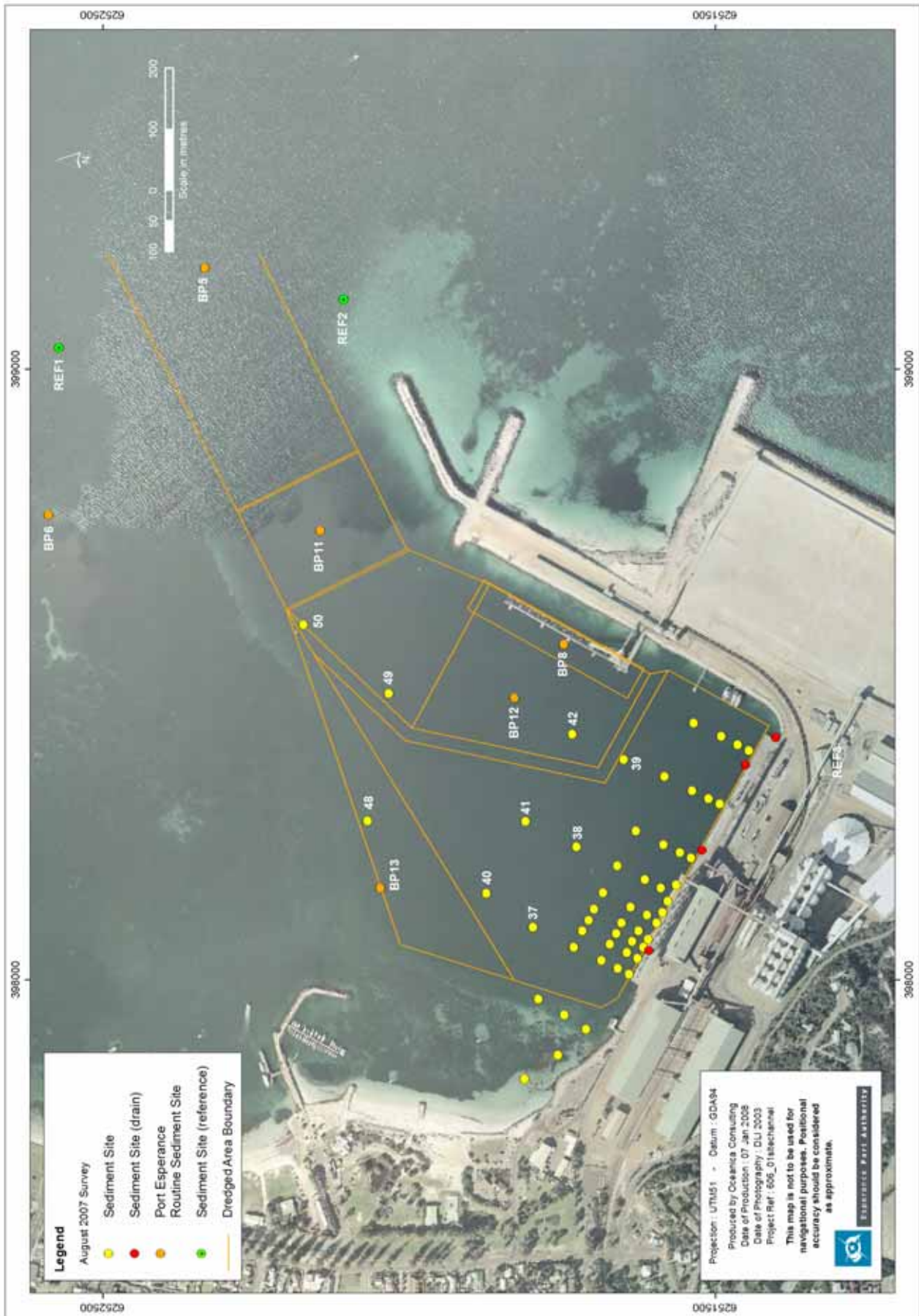


Figure 1.2 Shipping channel and turning basin at Esperance Port

In December 2006 and January 2007, more than 600 bird deaths occurred in and around Esperance. In the first two weeks of March 2007, a further 187 bird deaths were reported. Testing by the Department of Agriculture and Food of eight birds from the December 2006/January 2007 episode indicated lead poisoning as the likely cause of death. Results of testing on more recent bird samples received by the Department of Environment and Conservation (DEC) on 13 March also indicated the birds died of lead poisoning. All the birds affected were nectar-eating species, and a potential exposure route identified by the DEC was dust that falls onto the flowering plants that the birds feed on. A potential source of lead identified was lead dust from lead concentrate handled at the Port of Esperance.

The bird deaths created public concern, and shipping of lead concentrate from the Port of Esperance was suspended until the source of the lead responsible for the bird deaths was confirmed. The testing confirmed the source of lead to be from the port. The Department of Health has undertaken analysis of lead levels in blood samples from residents and water in rainwater tanks within the town: results to date indicate blood samples are below the current Australian blood level guideline for lead, but several rainwater tanks had lead levels in their water that were above Australian Drinking Water Guidelines. Sampling by the Department of Environment and Conservation (DEC) has also established that sediments from a small (five square metre) area under the Port of Esperance's discharge pipe (Berth 1) had lead readings of 3,600 to 29,000 mg/kg and nickel levels that were 3,300 to 6,600 mg/kg, orders of magnitude greater than national guidelines for ecosystem health (50–220 mg/kg for lead and 21–52 mg/kg for nickel), as provided in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000). The DEC tests were for total metals, that is, no analysis of bioavailable lead or nickel levels were undertaken.

As a result of the sediment contamination found near the Port of Esperance's discharge pipe, the DEC requested that the Esperance Port Authority develop a Sampling and Analysis Program (SAP) in accordance with DEC guidelines for Development of Sampling and Analysis Programs (DEP 2001), to examine the extent of lead and nickel contamination within the Port. The Esperance Port Authority subsequently commissioned Oceanica Consulting Pty Ltd (Oceanica) to prepare a SAP in accordance with the DEC's requirements, and Oceanica's final SAP was provided to DEC on 9<sup>th</sup> July 2007 (Oceanica 2007a, Report No. 606/1). This report was reviewed by an independent auditor and incorporated comments provided by Peter Skitmore, DEC, to Esperance Port Authority on 28 June 2007.

The objectives of the investigation were to examine the extent of lead and nickel contamination in the Port of Esperance, and (if necessary) any associated ecological risk. A staged approach to the investigation was also proposed, in accordance with the National Environmental Protection (Assessment of Site Contamination) Measure 1999's *Schedule B(5) Guideline on Ecological Risk Assessment* (NEPC 1999). For Stage 1, sampling locations were chosen to answer the following questions:

1. What is the spatial pattern (extent, magnitude) of lead and nickel contamination in sediments around the suspected point sources (discharge pipe running from the heavy metals handling area into the harbour along Berth 1, and berth face of Berth 2);
2. Has discharge from the suspected point and/or linear (berth face of Berth 2) sources been sufficient to increase the level of lead and nickel contamination in sediments at any sites monitored as part of the Esperance Port Authority's routine sediment monitoring program, since October 2006; and
3. Are the Esperance Port Authority's routine monitoring sites maintaining any spatial pattern of lead and nickel contamination in sediments since October 2006 that suggests sources of lead and nickel other than the discharge pipe or Berth 2.

The Stage 1 results for Berth 1 supported the theory that the high degree of contamination at this site has entered the harbour through the discharge pipe at Berth 1 due primarily to excessive stormwater runoff generated during the severe storm in December 2006. A decrease in lead and nickel contamination was found at Berth 2, which may be due to the Esperance Port Authority's recent installation of bunding along the wharf face at Berth 2, intended to significantly reduce the potential for entry of contaminants into the harbour during rain events. The decrease in lead and nickel levels at Berth 2 since October 2006 also indicated some redistribution of contaminants in sediments has occurred, presumably due to sediment re-suspension by propeller wash and boat movements.

Due to areas being classified as contaminated based on Stage 1 results, further work has been undertaken according to the National Environmental Protection (Assessment of Site Contamination) Measure 1999's Schedule B(5) Guideline on Ecological Risk Assessment (NEPC 1999). This report includes the findings of Stage 2 (consideration of factors controlling bioavailability), and consideration of any work needed for Stage 3 (further sampling as required, and a full ecological risk assessment) and, if required, site management/remediation.

Thus, in addition to identifying areas in which the bioavailable lead and/or nickel concentrations exceed the guidelines, The Level (Stage) 2 bioavailability investigation was designed to:

- Identify any sampling and analysis required for a Stage 3 investigation, including:
  - sites for which archived samples of deeper (2-6 and 6-10 cm) fractions of sediment cores should be analysed;
  - any additional sampling needed to further delineate the extent of contamination; and
  - the need for further testing to determine the ecological and human health risks posed by the contamination.
- Revise the sites sampled in the Esperance Port Authority's routine sediment sampling programme.

The triggers for subsequent stages of investigation, and details of the work to be undertaken within these stages, are given in Section 4.

## **1.2. Suspected contamination sources**

As noted previously, the results for Berth 1 support the theory that the high degree of contamination at this site has entered the harbour primarily through the discharge pipe at Berth 1 (which runs from the heavy metals handling area into the harbour), due to excessive stormwater runoff generated during the severe storm in December 2006. On 1<sup>st</sup> July 2007 a wastewater treatment system was commissioned at the heavy metals handling area which has significantly decreased the potential for lead and nickel contamination from the discharge pipe along Berth 1. The decrease in lead and nickel contamination at Berth 2 may be due to the Esperance Port Authority's recent installation of bunding along the wharf face at Berth 2, intended to significantly reduce the potential for entry of contaminants into the harbour during rain events. The decrease in lead and nickel levels at Berth 2 since October 2006 also indicates some redistribution of contaminants in sediments has occurred, presumably due to sediment re-suspension by propeller wash and boat movements.

The contamination centered on Berth 3 may be due to historic contamination or due to the settlement of contaminated 'fines' (silt and clay) within this area. Some redistribution of contaminants in sediments would occur due to sediment re-suspension by propeller wash and boat movements. There is no known current or recent contamination source within this area.

## 2. Methods

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### 2.1. Sampling locations – Stage 1

As described in the SAP (Oceanica 2007a), sampling locations for the strong acid extraction were chosen to determine the spatial pattern (extent, magnitude) of lead and nickel contamination in sediments surrounding the discharge pipe, and were positioned at increasing distances out from the berthing face (20 m, 50 m and 100 m) of Berth 1. In addition, sampling was undertaken at the following sites:

- along Berth 2 as well as Berth 1, and out further into the harbour (to determine if discharge from the suspected point source or run-off or dust from shiploading at Berth 2 was sufficient to increase the level of lead and nickel contamination in sediments at any sites monitored as part of the Esperance Port Authority's routine sediment monitoring program, or elsewhere within the port);
- leading out to the Esperance Port Authority's long-term monitoring sites, and the long-term monitoring sites themselves (BP5-7, BP11-13) (to further define the extent of contamination within port waters);
- west of Berth 1, to determine the extent of contamination moving towards the public beach; and
- Four new reference sites well removed from port operations.

The location of the sites sampled in the Stage 1 analysis is given in Figure 2.1. The site locations sampled were largely as described in the SAP, with some slight modifications. Due to initial lack of information on exactly where the discharge pipe was located, the location of some sites shown in Figure 2.1 of the SAP was shifted slightly (~15 m) to better cover the area adjacent to the pipe: sites 8 and 12 had already been sampled before the correct location of the discharge pipe was confirmed, and so re-sampling was required (shown as 8\_2 and 12\_2 in Figure 2.1). In addition, several other potential point source discharges were identified along Berth 1 and Berth 2, so some sites were re-aligned to better track contamination trends adjacent to these locations.

### 2.2. Samples for bioavailability analysis – Stage 2

In the SAP for this study (Oceanica 2007a), the original intention was for concentrations of total metals (lead and nickel) to be compared to ANZECC/ARMCANZ (2000) sediment quality guidelines (ISQG-Low and ISQG-High), with interpretation and reporting of results undertaken in the context of the Environment Protection Authority's Environmental Quality Criteria for Cockburn Sound (EPA 2005). This approach requires the median contaminant concentration from a defined sampling area (containing multiple sites) to be below the relevant EQG Value (equivalent to the ISQG-Low), and the median value for no single site to exceed the relevant EQG Re-sampling trigger (equivalent to the ISQG-High). This was to be accomplished by stratification of the sampling area, with sites exhibiting a similar degree of contamination grouped together.

The results for bioavailable lead and nickel are presented in Section 3. Further details of the Level (Stage) 1 – Screening Assessment may be found in Oceanica 2007b.

The areas were classified based on results presented in Oceanica 2007b and shown in Figure 3.3 and Figure 3.5 of this report. After the classification of the areas a dilute acid extraction was performed on 50% of the samples obtained from the contaminated areas, with those samples exhibiting total metal concentrations closest to the median selected for further analysis. The Marine and Freshwater Research Laboratory (MAFRL) undertook analysis of bioavailable nickel and lead from each of the sites identified as requiring either lead or nickel bioavailability investigation. As a result several samples were analysed for both lead and nickel, when the total metal concentration of one of these metals had been below the ISQG-low). Testing for bioavailable lead and nickel was undertaken on the following samples (see Figure 2.3):

- BP8 (3 replicates), BP14, BP13 (2 replicates);
- ZBP11 (3 replicates), ZBP12 (2 replicates); and

- 2, 3 (3 replicates), 4 (3 replicates), 8, 8\_2 (3 replicates), 10 (2 replicates), 12\_2 (3 replicates), 18 (3 replicates), 31, 32 (3 replicates), 33 (2 replicates), 34 (3 replicates), 43 (2 replicates), 44, 45 (3 replicates), 46 (3 replicates), 47, 48 (3 replicates).

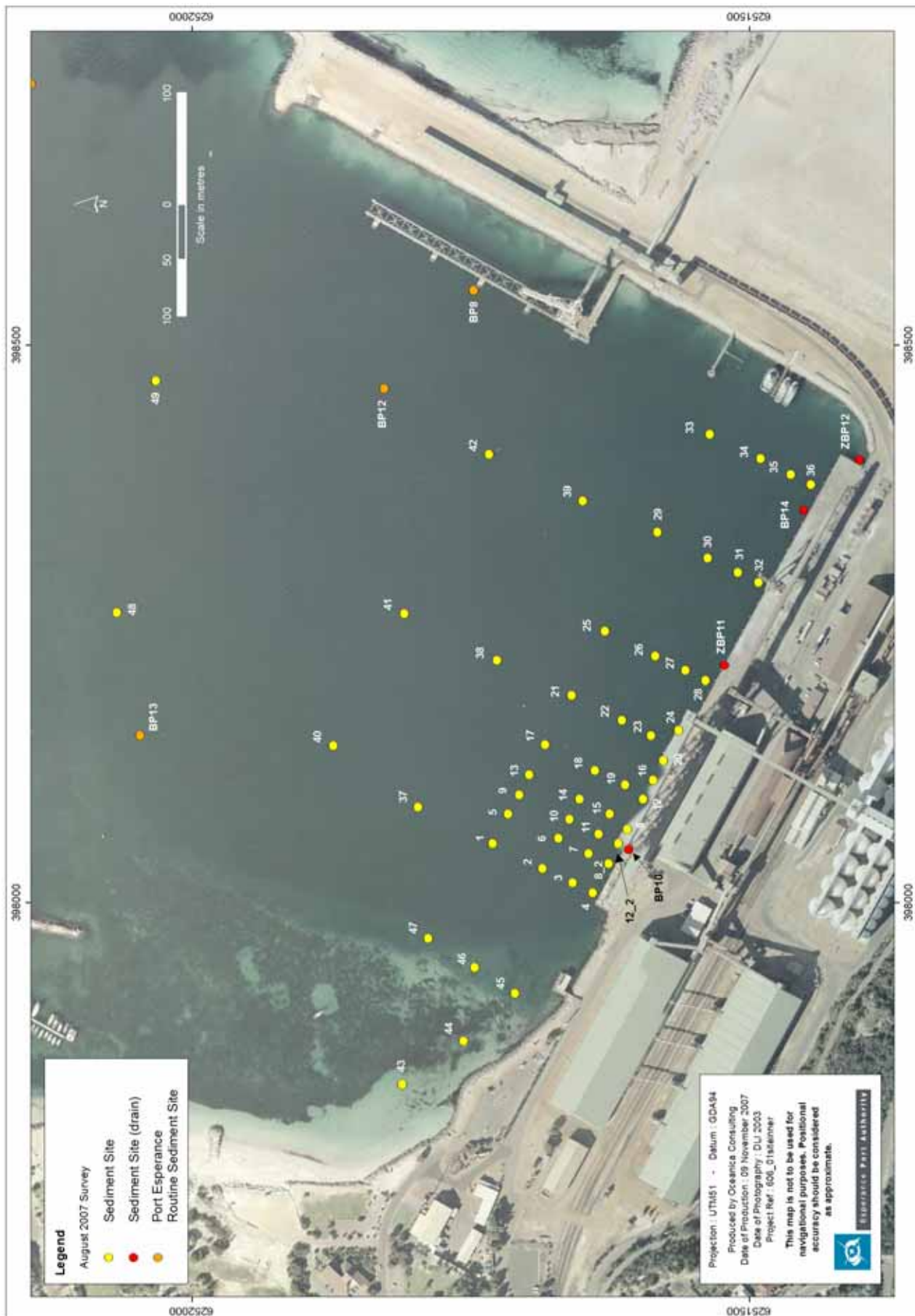
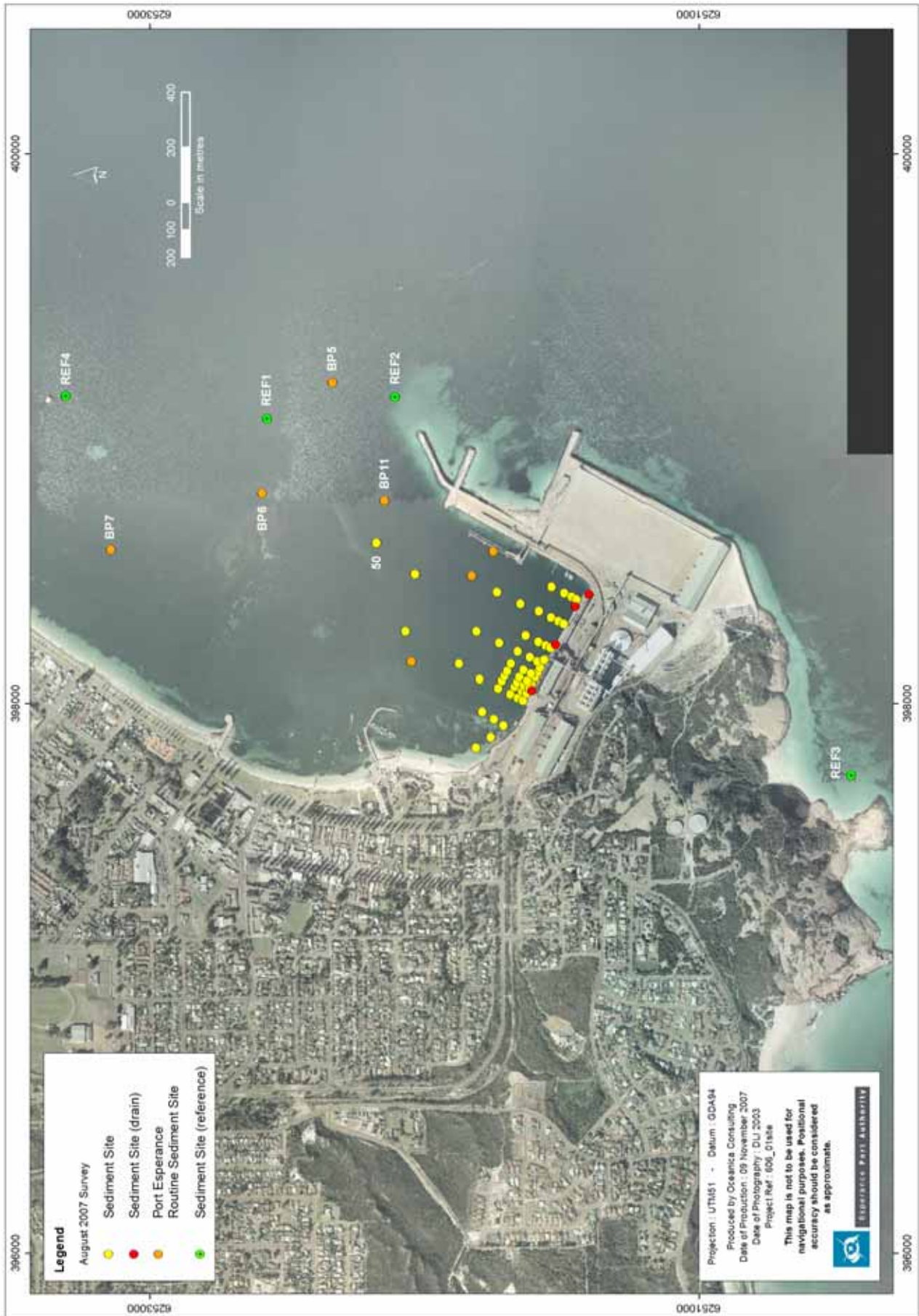
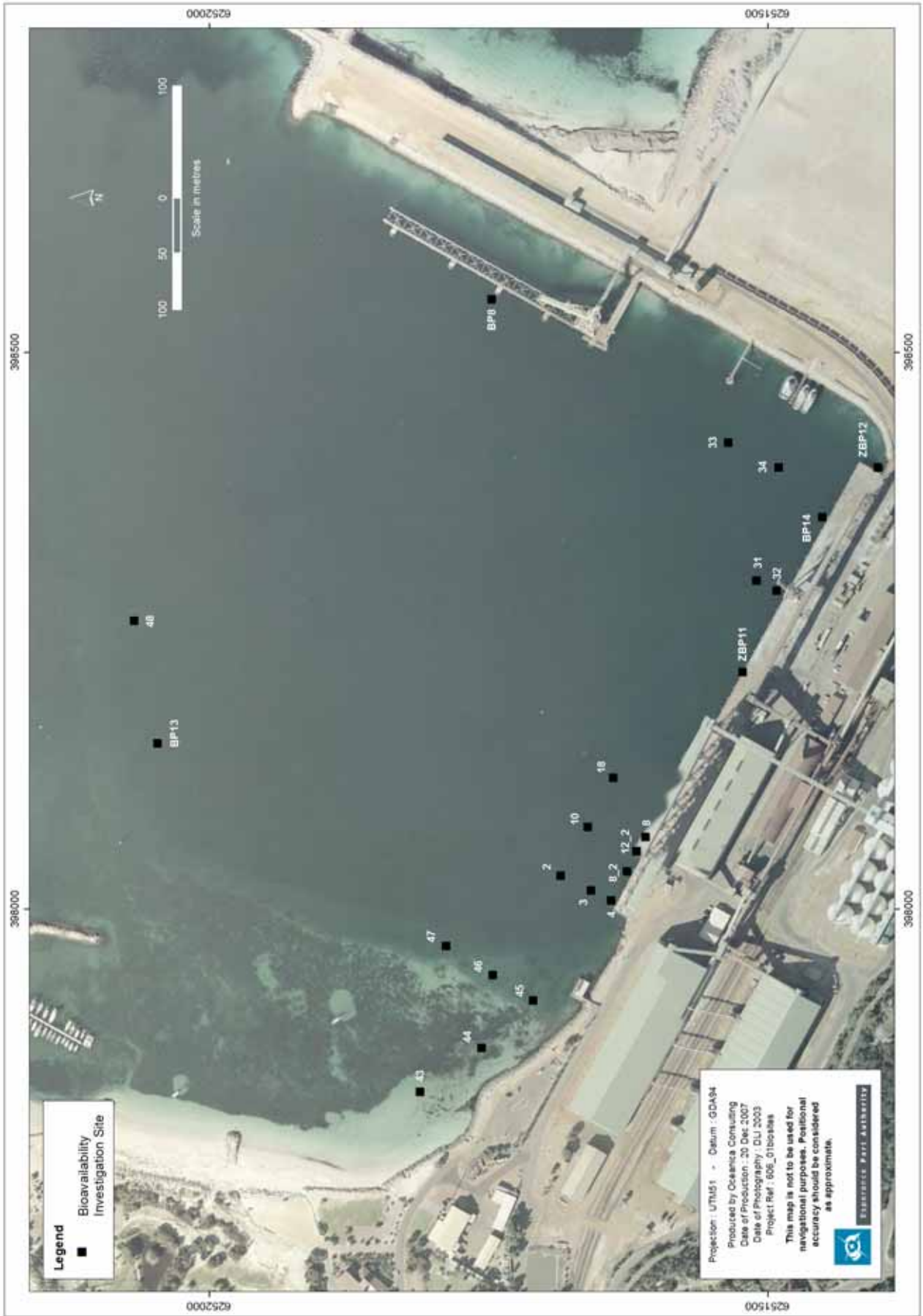


Figure 2.1 Detailed view of location of sediment sampling sites in Esperance Port (August 2007)



**Figure 2.2** Location of sediment sampling sites in Esperance Port and adjacent areas (August 2007)



**Figure 2.3** Location of samples for dilute acid extraction of bioavailable lead and nickel

### 2.3. Depth of sampling

Sediment cores were taken to a depth 10 cm, with the major focus of analysis on the top 2 cm. As noted in the SAP (Oceanica 2007a), this approach was taken because:

- given the relative stability of the harbour basin and entrance channel, and the recent nature of the contamination (December 2006), it was anticipated that any contamination would be largely confined to the surface sediments within the inner harbour;
- 10 cm is the depth typically associated with most biological activity; and
- the Esperance Port Authority's October 2006 sediment sampling included a ~40 cm deep core taken at berth pocket sites 8, 9 and 10 and approach channel site 11, and results for lead were much lower in these samples.

### 2.4. Sampling methods

Sampling took place between 20<sup>th</sup> and 28<sup>th</sup> August 2007, apart from sites REF4 and BP5, BP6 and BP7 which were sampled in the week of September 10<sup>th</sup>.

Three replicate samples were obtained from each site within 5 m of each other. Each replicate consisted of a composite of the top 2 cm of five cores taken from each corner and the centre of a 1 m<sup>2</sup> quadrat, according to the methods in EPA (2005b) (Figure 2.4). The composited material was thoroughly mixed before sub-sampling.



**Figure 2.4** Five cores within 1 m<sup>2</sup> quadrat to make one composite sample (Esperance Port, August 2007, Oceanica 2007)

Polycarbonate cores (internal diameter ~100 mm) were manually pushed into the sediment to a depth of 10 cm, with care taken to cause minimal disturbance to the sediment surface. Both ends of the core were then sealed using rubber bungs and the sample returned to the surface upright. The top 2 cm of material from each core (five to make each replicate, composite, sample) was combined and homogenised in the field, with sieving and further homogenisation completed at the laboratory. As sampling for metals took place, homogenisation was undertaken within a white plastic bucket, using a white plastic spoon (as coloured plastics often contain trace metals). Sediment samples were placed in pre-cleaned polyethylene containers supplied by the analytical laboratory (Australian Standard AS/NZS 5667.12:1999) and kept on ice while in transit to the analytical laboratory.

Notes were made on the characteristics of the samples (colour, sediment type, odour, apparent depth of redox zone, presence of foreign objects etc) and photographs were taken to record particular features (distinct redox layer etc).

The remaining 2-6 and 6-10 cm fractions of each core from one replicate at each site were collected separately, combined and homogenised, and stored frozen, to be analysed as

necessary following the initial results to determine whether the contamination extends beyond the top 2 cm.

## **2.5. Laboratory Analysis methods**

The Marine and Freshwater Research Laboratory (MAFRL) undertook the analysis of metal levels in sediment samples. MAFRL have previously undertaken sediment metals analysis for both Oceanica and the Port of Esperance. MAFRL's dilute acid digestion analysis methods are NATA accredited, and analyses meet the laboratory reporting limits (based in turn on analytical detection limits) specified in Table 3.1 of the SAP (Oceanica 2007a).

Dilute acid digestion extraction methods were used to obtain a measure of the bioavailable metal fraction in sediments, to allow comparison with historical data on nickel contamination collected by the Esperance Port Authority.

As noted within the SAP (Oceanica 2007a), ANZECC/ARMCANZ (2000), the Commonwealth of Australia (2002) and Simpson et al (2005) recommend a dilute acid extraction (1 M hydrochloric acid for one hour in a sediment ratio of 1:50) to better approximate the bioavailable fraction of metals. The Draft Assessment Levels for Soil, Sediment and Water (DEC 2003) similarly state that "when analysing for metals, the dilute-acid-soluble metal concentration is seen as a more meaningful measure than the total value". Therefore sufficient sediment was stored frozen to allow for the subsequent determination of the bioavailable fraction of metals in 50% of those samples where results for total metals exceeded guideline values.

Dilute acid extraction was performed on the ground sediment as this was consistent with the methods used for strong acid extraction and should provide a worst case scenario of contamination. Dilute acid extraction was also performed on 6 unground samples in order to allow comparison with results from ground material from the same sample. Strong acid extraction was carried out on 6 stored samples in order to determine if storage of samples affects total metal concentrations.

Samples were analysed for particle size distribution to ensure data interpretation was not confounded by sediments of different 'fines' content (i.e. the silt and clay fraction, typically sediment particles with diameters less than 62 microns [ $\mu\text{m}$ ]). This analysis was undertaken by CSIRO using sieving followed by laser diffraction (note this method is not NATA accredited, but CSIRO has appropriate QA/QC procedures in place).

### **2.5.1. QA/QC**

In line with the National *Ocean Disposal Guidelines for Dredged Material* (Commonwealth of Australia 2002), each batch (10-20 samples) of samples analysed for metals included one laboratory blank, one standard reference material and one spike. The laboratory reports (Appendix A) include these data.

## 3. Results and Discussion

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### 3.1. Particle size distribution

Full analysis reports and a summary of the surficial sediment particle size distributions at each site were included in Oceanica 2007b. The majority of sites were dominated by fine sands and to a lesser extent medium sands, with little or no 'fines' (silt+clay) content. Sites BP8 (the berth pocket at Berth 3) and BP10 (the berth pocket at Berth 1) had the highest fines content (7.38–9.15% fines), and sites along the western edge of the harbour (1, 2, 3, 4, 46, 47 and 48) or in deep waters (50 and REF1) had a fines content of more than 3%, but most sites had 0–1.5% fines. Sites BP5, 3, 26–28, 42, 43 and 49 were also unusual compared to the majority of sites in that they had a relatively high content of coarse sand and/or gravel: there was no apparent pattern to these results.

Figure 3.1 shows the percentage of sediment that was less than 62µm at all of the sampling sites. The 'fines' content of the sediments may help to explain some of patterns of contamination observed. The distribution of fines as shown in Figure 3.1 reflects the strong acid extraction nickel concentrations shown in Figure 3.5. Site 46, for example exhibits relatively high contamination by both lead and nickel (compared to neighbouring sites) and also exhibits a relatively high 'fines' content (5.97%). Contaminated 'fines' may be transported to this site from Berth 1 during periods of sediment resuspension. Similarly the lead and nickel contamination recorded at Berth 3 may be the result of contaminated 'fines' settling out in this area (sediment samples from BP8 had a median 'fines' content of 9.15%), or due to historic contamination. There is no known current or recent contamination source in the Berth 3 area.

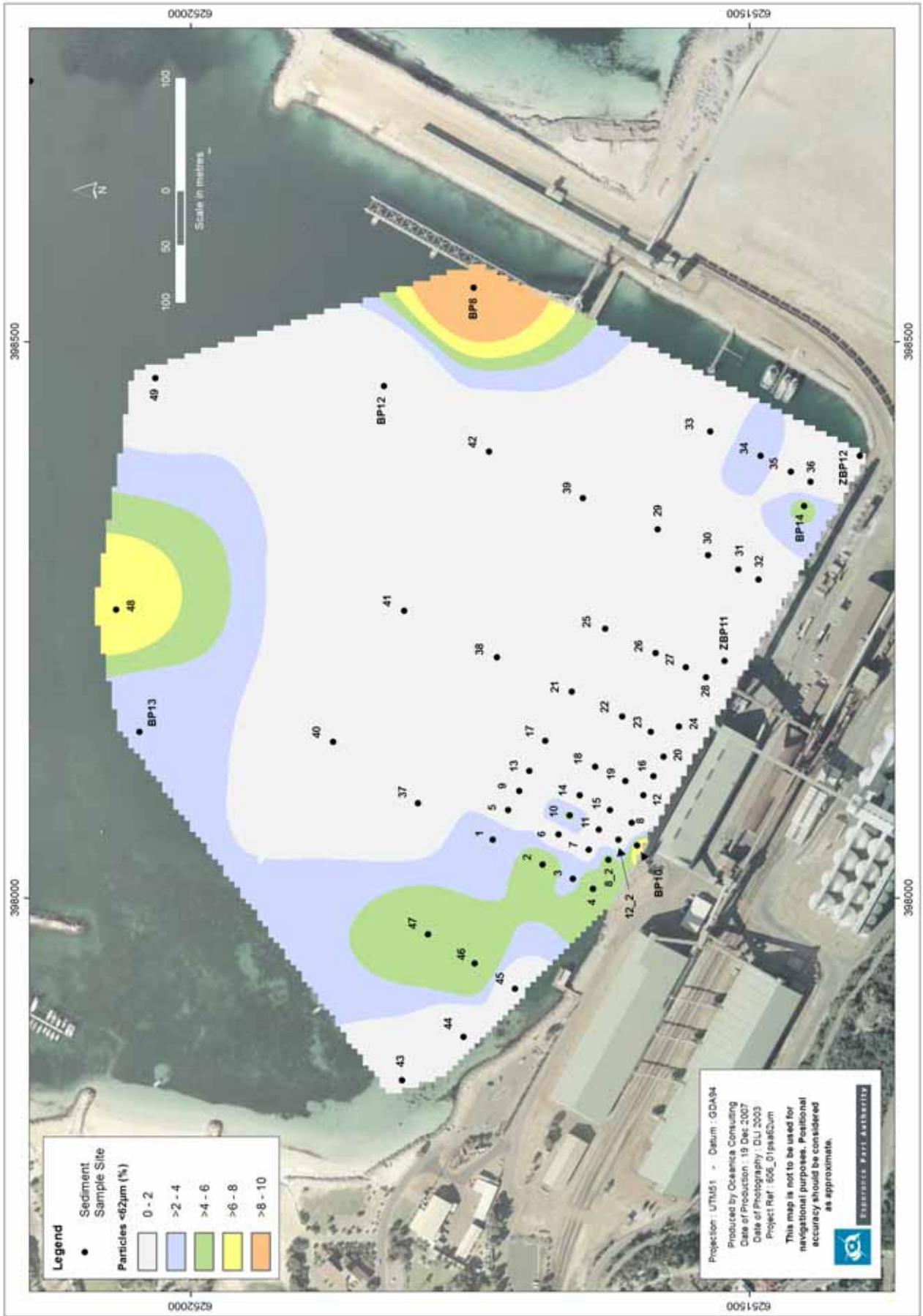


Figure 3.1 Percent of sediment <62µm

### 3.2. Lead and nickel

The strong acid extraction results for lead (see Figure 3.2) indicated a more spatially confined pattern of contamination than nickel, with a rapid decline in lead levels within 50 m of site BP10. The results for nickel (see Figure 3.4) were indicative of a roughly annular pattern of contamination, with the level of contamination decreasing towards the centre of the harbour. Accordingly, sites 49, BP12, 40–42, 37–39, 1, 5, 9, 13, 17, 21, 25, 29, 6, 10, 14, 18, 22, 26, 19, 23, 27, 16, 20, 24, and 28 comprise a ‘central harbour’ area for which the medians meet the EQG Values for lead and nickel, and no individual site exceeds the EQG Re-sampling trigger. The sites in the remainder of the harbour would not meet the criteria for nickel irrespective of how much they were subdivided into defined sampling areas, and therefore required further investigations to determine the bioavailability of sediment metals which was undertaken for this report. The berth pockets of Berths 1, 2 and 3 also required bioavailability investigation for lead (see Figure 2.3).

The median lead and nickel concentrations (dilute acid extractions) are presented in Table 3.1, with full analysis reports presented in Appendix A. No sites exceeded the ISQG-high or ISQG-low for nickel. Sites BP14, BP8, 12\_2, 31, 32, 4, 8\_2, ZBP11 and ZBP12 had lead concentrations greater than ISQG-low. No sites exceeded the ISQG-high for lead. The bioavailable fraction of nickel was approximately 6% of the total and the bioavailable lead fraction was approximately 85% of the total. Bioavailable lead contamination was greater than nickel contamination in both degree and spatial extent. , This was the opposite result to that for the total (strong acid extraction) concentrations determined for the Stage 1 analysis presented in Oceanica 2007b and shown in Figure 3.3 and Figure 3.5.

**Table 3.1 Median nickel and lead concentrations for dilute and strong acid extraction**

METHOD	Nickel Dilute Acid Ext	Nickel Strong Acid Ext	Lead Dilute Acid Ext	Lead Strong Acid Ext
Reporting Limit	<0.4	<0.4	<1	<1
ISQG-Low	<b>21</b>	<b>21</b>	<b>50</b>	<b>50</b>
ISQG-High	<b>52</b>	<b>52</b>	<b>220</b>	<b>220</b>
<b>Esperance Port Authority long-term monitoring sites</b>				
BP13	2.6	<b>25</b>	16	17
BP14	14	<b>250</b>	<b>92</b>	<b>140</b>
BP8	3.6	<b>65</b>	<b>52</b>	<b>68</b>
<b>New sites established for present study</b>				
10	1.55	<b>30</b>	26	28
12_2	2.3	<b>42</b>	<b>67</b>	<b>79</b>
18	1.5	<b>22</b>	24	27
2	1.6	<b>22</b>	26	25
3	1.7	<b>32</b>	23	29
31	2.4	<b>28</b>	<b>60</b>	<b>53</b>
32	3.7	<b>81</b>	<b>75</b>	<b>86</b>
33	4	<b>42</b>	39	38
34	7.2	<b>90</b>	43	48
4	5	<b>89</b>	<b>96</b>	<b>120</b>
43	2.05	<b>24</b>	18.5	22
44	2.7	<b>22</b>	14	15
45	3.1	<b>33</b>	39	48
46	3.3	<b>69</b>	42	<b>51</b>
47	2.7	<b>62</b>	30	39
48	2.2	<b>40</b>	16	20
8	2.5	<b>22</b>	46	35
8_2	2.8	<b>52</b>	<b>60</b>	<b>70</b>
ZBP11 (drain site)	6	<b>87</b>	<b>84</b>	<b>100</b>
ZBP12 (drain site)	20.5	<b>280</b>	<b>53.5</b>	<b>65</b>

Note: Results >ISQG-Low in bold text, results >ISQG-High also shaded grey.

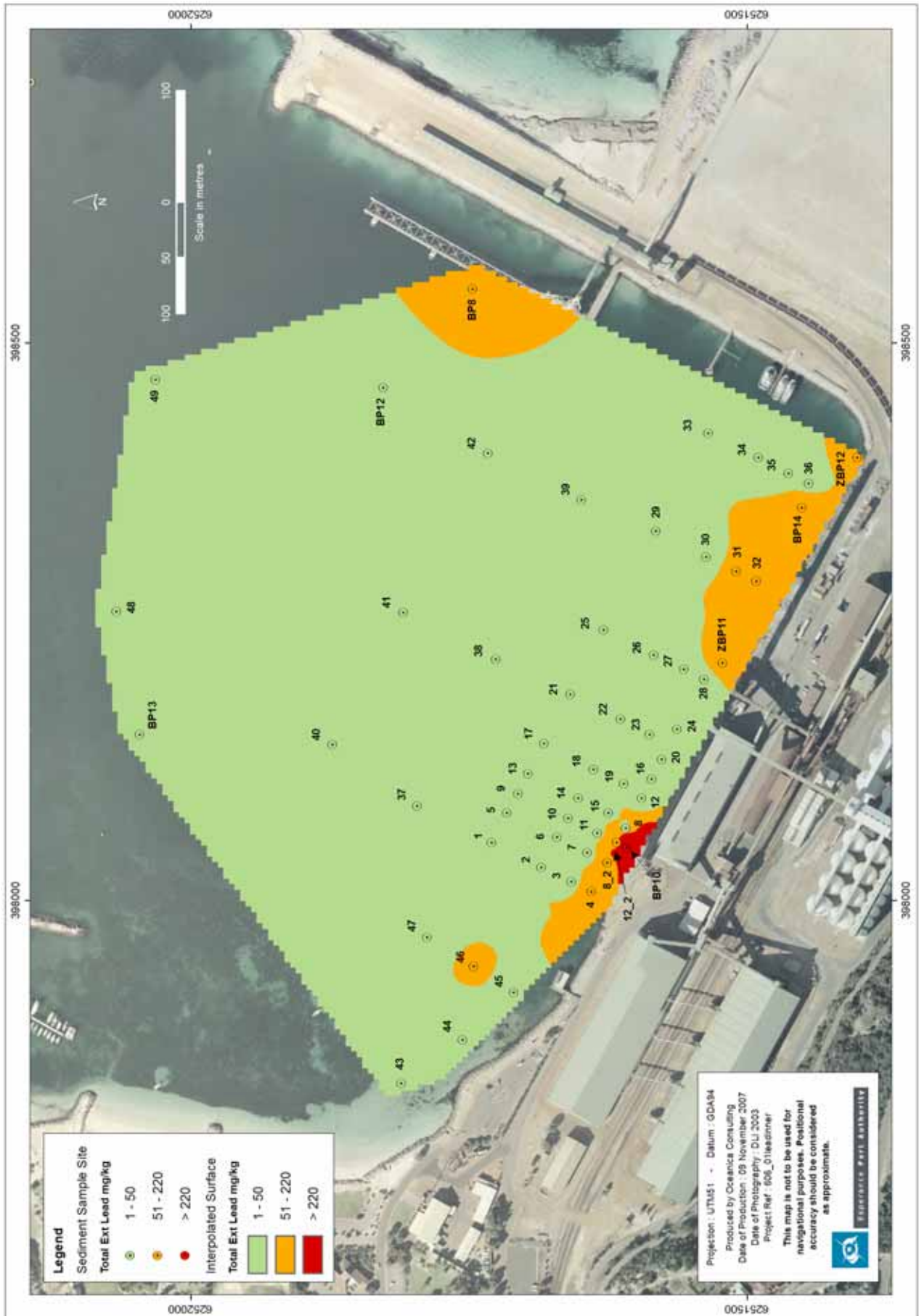
The reference sites sampled in this survey had fines contents similar to those of all harbour sites, except BP8 and BP10. The reference sites provide an indication of the natural levels of nickel and lead that could be expected in harbour sediments, and therefore the extent of contamination (Oceanica 2007a). The term 'contamination' is used in this context to denote the presence of a substance above natural background levels, but makes no inferences about the biological significance of the results.

Figure 3.2 and Figure 3.3 show the spatial extent of lead contamination for dilute and strong acid extraction, respectively. Figure 3.4 and Figure 3.5 shows the spatial extent of nickel contamination for dilute and strong acid extraction, respectively. In accordance with the SAP for this study (Oceanica 2007a), areas have been stratified based upon their contamination status: 'uncontaminated' (median lead and nickel concentrations equal to background, in this case taken as below laboratory reporting limit), 'slightly contaminated-low risk' (median lead and nickel concentrations below ISQG-Low values and no site exceeding ISQG-High values) and 'contaminated' (median value from a site exceeding the ISQG-Low, and/or an individual sample exceeding the ISQG-High).



**Figure 3.2 Detailed view of spatial pattern of lead contamination (dilute acid extraction) in the surficial sediments of Esperance Port**

Note: Central area unshaded because no dilute acid extractions done on these sediments (ISQG-Low not exceeded in strong acid extractions, see Figure 3.3)



**Figure 3.3 Detailed view of spatial pattern of lead contamination (strong acid extraction) in the surficial sediments of Esperance Port**



**Figure 3.4 Detailed view of spatial pattern of nickel contamination (dilute acid extraction) in the surficial sediments of Esperance Port**

Note: Central area unshaded because no dilute acid extractions done on these sediments (ISQG-Low not exceeded in strong acid extractions, see Figure 3.5)

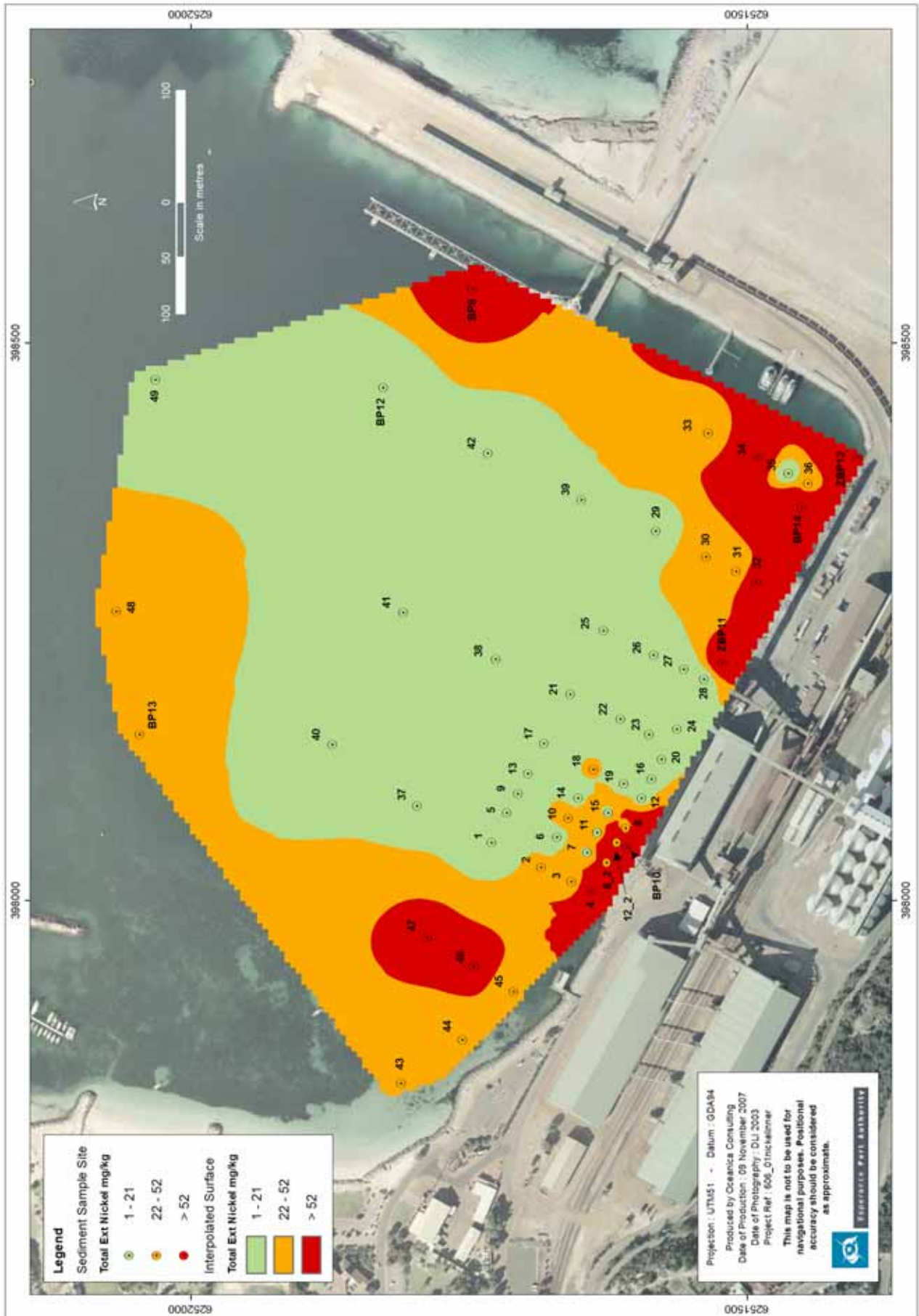


Figure 3.5 Detailed view of spatial pattern of nickel contamination (strong acid extraction) in the surficial sediments of Esperance Port

### 3.3. Sample storage and treatment QA

Dilute acid extraction was performed on both ground and unground sediment samples for nickel and lead (Table 3.2). Prior to the initial strong acid extraction, a portion of each sample was frozen, freeze-dried and then ground and stored at ambient temperature. The remaining portion was stored frozen, without being ground. A dilute acid extraction was performed on the freeze-dried and ground sediment as this was consistent with the methods used for strong acid extraction and should provide a worst case scenario of contamination. A dilute acid extraction was also performed on 6 unground samples in order to allow comparison with results from ground material from the same sample. There was very little difference in nickel and lead concentrations in the ground and unground samples. The small changes observed can be explained by the fact that the samples were split and so would be expected to show slight differences in metal concentrations.

**Table 3.2 Dilute acid extraction concentration of nickel and lead in ground and unground samples**

SITE	Ground Nickel Dilute Acid Ext	Unground Nickel Strong Acid Ext	% Unground of Ground	Ground Lead Dilute Acid Ext	Unground Lead Strong Acid Ext	% Unground of Ground
8C	2.5	2.1	119	46	46	100
12_2B	3.0	3.4	88	<b>89</b>	<b>120</b>	74
47B	2.7	2.8	96	30	35	86
BP13A	3.0	3.5	86	17	22	77
31C	2.4	2.1	114	<b>60</b>	<b>69</b>	87
34C	8.6	8.4	102	16	17	94

Note: Results >ISQG-Low in bold text, results >ISQG-High also shaded grey.

Due to concerns raised by DEC over the appropriate holding times for sediment samples for bioavailability analysis, a number of the samples which had been frozen, freeze dried then ground and stored at ambient temperature were analysed using both a dilute acid extraction and a strong acid digestion. Thus a strong acid extraction was performed in December on samples that had been stored since August to determine if the concentrations of total metals decreases following storage. The small variations in the metal concentrations between October and December may be explained by both minor sample variation (samples were split for the analysis) and laboratory variation: the small variations in concentration are within accepted QA limits for the analysis of duplicate samples (Table 3.3).

**Table 3.3 Strong acid extraction concentration of nickel and lead in fresh and stored samples**

SITE	October Strong Ext Ni	December Total Ext Ni	October % of December	October Strong Ext Pb	December Total Ext Pb	October % of December
2A	<b>24</b>	<b>28</b>	86	36	34	106
8_2B	<b>52</b>	<b>49</b>	106	<b>70</b>	<b>69</b>	101
45A	<b>43</b>	<b>48</b>	90	48	47	102
BP8A	<b>59</b>	<b>60</b>	98	<b>56</b>	<b>56</b>	100
BP14B	<b>250</b>	<b>260</b>	96	<b>100</b>	<b>110</b>	91
43A	<b>25</b>	<b>30</b>	83	24	26	92

Note: Results >ISQG-Low in bold text, results >ISQG-High also shaded grey.

### 3.4. Comparison of results with earlier surveys

Dilute acid extraction of nickel has been carried out by the Esperance Port Authority annually since 2003 at sites BP8 and BP9 and in 2005 and 2006 at BP10. The results shown in Table 3.4 demonstrate that site BP8 has consistently exhibited bioavailable nickel concentrations of <10 mg/kg. Historically site BP9 showed a spike in nickel concentration in May 2005 and the concentration has since decreased. No sites have exhibited bioavailable nickel concentrations greater than the ISQG-Low. As the National Ocean Disposal Guidelines (Commonwealth of Australia 2002) stipulate the need for samples for bioavailability testing to be representative of the overall sediment composition within an area, the samples exhibiting total metal concentrations closest to the median of the contaminated area were selected for

analysis as part of the Level (Stage) 2 Bioavailability Investigation. Site BP10 exhibited total nickel concentrations far greater than the median and as a result was not selected for bioavailability analysis. There have been no previous investigations into the bioavailability of lead within the Esperance Port.

**Table 3.4 Historical data on bioavailable (dilute acid extraction) nickel concentrations at Esperance Port's long term monitoring sites compared with those of the present (August 2007) study**

Site	March 2003	Nov 2004	May 2005	Sept 2005	Oct 2006	Aug 2007
BP8	1.2 1.6 1.6	5.4 6.3 8.8	5.5 7.4 10	3.0 4.2 4.6	3.0	3.6
Historic BP9 (Site 32 in present study)	12 12 14	19 21 23	66 72 79	16 18 23	7.7	3.7
BP10	-	-	5.7 7.5 7.5	-	3.0	-

Previous sampling was undertaken from 40 cm deep cores at sites BP8, BP9, BP10 and BP11 in October 2006. The results from these core samples indicated that the concentration of lead decreased with depth (Table 3.5). Samples were taken to 10 cm in August 2007 with the 2-6 and 6-10 cm fractions of the core stored for later analysis if required. Several of these deeper samples are now being analysed as outlined in Section **Error! Reference source not found.**

**Table 3.5 Total lead concentrations in surface 2 cm of sediment versus deeper sediments, measured in October 2006**

Total lead concentration in sediments, October 2006 (mg/kg)	Site 8	Site 9	Site 10	Site 11
Average ( $\pm$ standard deviation) of 5 replicates for surface 2 cm	80.8 (15.6)	2,270 (2,010)	164 (49)	4.4 (1.5)
Single measurement of 40 cm deep core	16.0	480	40	<1

## 4. Level (Stage)3 – Ecological Risk Assessment

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The Level (Stage) 3 investigation (Ecological Risk Assessment) will require further sampling and analysis as follows:

- Analysis of the deeper fraction of sediments from sites at which the bioavailable fraction of lead within surface samples exceeded the ISQG-Low;
- Further sampling to better spatially define the extent and severity of lead contamination around Berth 3 and adjacent to sites 33 to 36; and
- Based on results obtained in Stage 2, plus the additional sampling recommended above, whole sediment toxicity testing of sediments exhibiting a concentration of bioavailable lead exceeding the ISQG-Low.

Each of these sampling and analysis requirements are discussed below.

### 4.1. Analysis of deep sediment fractions

Deeper fractions of sediment will be analysed from all sites that exhibited a bioavailable (dilute acid extraction) lead concentration greater than the ISQG-Low. These sites are: 4, 8\_2, 12\_2, 31, 32, ZBP11, ZBP12, 31, 32 and BP8 (see Figure 3.2). These samples will be analysed using strong acid extraction and a dilute acid extraction to test for bioavailability within the deeper layers. As no sites exceeded the ISQG-Low for nickel no further analysis for nickel is required.

### 4.2. Extent of lead contamination in Esperance harbour

Further investigations are required in the area surrounding BP8 (Berth 3) in order to define the extent of contamination. These sites were not originally tested as there is no known lead source at Berth 3 and it was not believed that contamination would be found in this area. The sites sampled for the Level (Stage) 1 Assessment were chosen based on confirmed or suspected sources of nickel and lead and were centered around Berths 1 and 2. The new sites to be sampled (surface samples) and analysed for lead are shown in Figure 4.1. This analysis will consist of strong acid extraction and dilute acid extraction to test for bioavailability.

Further investigations are required adjacent to sites 33 to 36 to determine if lead contamination extends into this area. This area is close to the tug berth and would experience limited disturbance compared to those sites situated along the berth pockets. The new sites to be sampled (surface samples) and analysed for lead are shown in Figure 4.1. This analysis will consist of strong acid extraction and dilute acid extraction to test for bioavailability.

### 4.3. Whole sediment toxicity testing

Sediment toxicity testing is required when chemical parameters exceed guideline values and are present in bioavailable forms. As bioavailable lead was present in concentrations which exceeded the ISQG-low, whole sediment toxicity testing is now required. The purpose of whole sediment toxicity testing is to determine whether the contaminants within sediments are likely to result in acute or sublethal effects on biota. The amount of testing required has been based on guidelines within the National Ocean Disposal Guidelines (Commonwealth of Australia 2002). The minimum number of toxicity test samples for dredging is based on the volume of contaminated sediment. Contamination is not expected to occur below 0.5 m based on previous results from Esperance Port showing a lower concentration of total lead in 40 cm cores than in surface samples from the top 2 cm. The volume of contaminated sediment within Esperance Port, based on a depth of contamination of 50 cm, is 16,575 m<sup>3</sup>. This is made up of 2,250 m<sup>3</sup> off Berth 1, 11,500 m<sup>3</sup> off Berth 2 and, as an initial estimate prior to further sampling, ~2,825 m<sup>3</sup> off Berth 3. Commonwealth Australia (2002) states that the minimum number of samples for a volume of 0-50,000 m<sup>3</sup> is 3 and the samples must be representative of the overall spoil composition. The median concentration of bioavailable

lead in the area off Berth 1 is 73 mg/kg and off Berth 2 is 74 mg/kg so these areas exhibit very similar lead concentrations. As a result it is suggested that whole sediment toxicity testing should take place on 2 samples from each of the areas. Whole sediment toxicity testing will take place at the sites that have a dilute acid extracted lead concentration closest to the median for the area. These sites are 8\_2 and 12\_2 at Berth 1 and 32 and ZBP12 at Berth 2 (see Figure 3.2). The depth of material used for whole sediment toxicity testing will be determined following the receipt of results from the deeper fractions of sediment, and in consultation with the DEC. The types of toxicity tests will be determined in consultation with the laboratory, Ecotox Services Australia, and the DEC.

It is believed that whole sediment toxicity should not be carried out at this stage at Berth 3. This is because the spatial extent and severity of lead contamination in the area surrounding Berth 3 requires further investigation (see Section 4). In addition, the median for this area is 52 mg/kg which only exceeds the ISQG-Low of 50 mg/kg by 2 mg/kg. If the further investigation using dilute acid extraction around Berth 3 identifies that there is a greater extent of contamination and/or the whole sediment toxicity tests for Berths 1 and 2 suggest that the contamination does represent an ecological risk, then whole sediment toxicity testing may be triggered at Berth 3.

Should the Level 3 Ecological Risk Assessment indicate that the contamination is likely to be causing adverse ecological impacts, then a decision must be made whether to initiate a site management/remediation program, which may include monitoring, site management and site remediation.

#### **4.4. Revision of sites sampled in the Esperance Port Authority's routine sediment sampling programme.**

This Stage 2 investigation was also originally intended to revise the sites sampled in the Esperance Port Authority's routine sediment sampling programme. Due to the need to better spatially define the extent of contamination around Berth 3, it is recommended that this exercise would be better undertaken following the Stage 3 investigation.

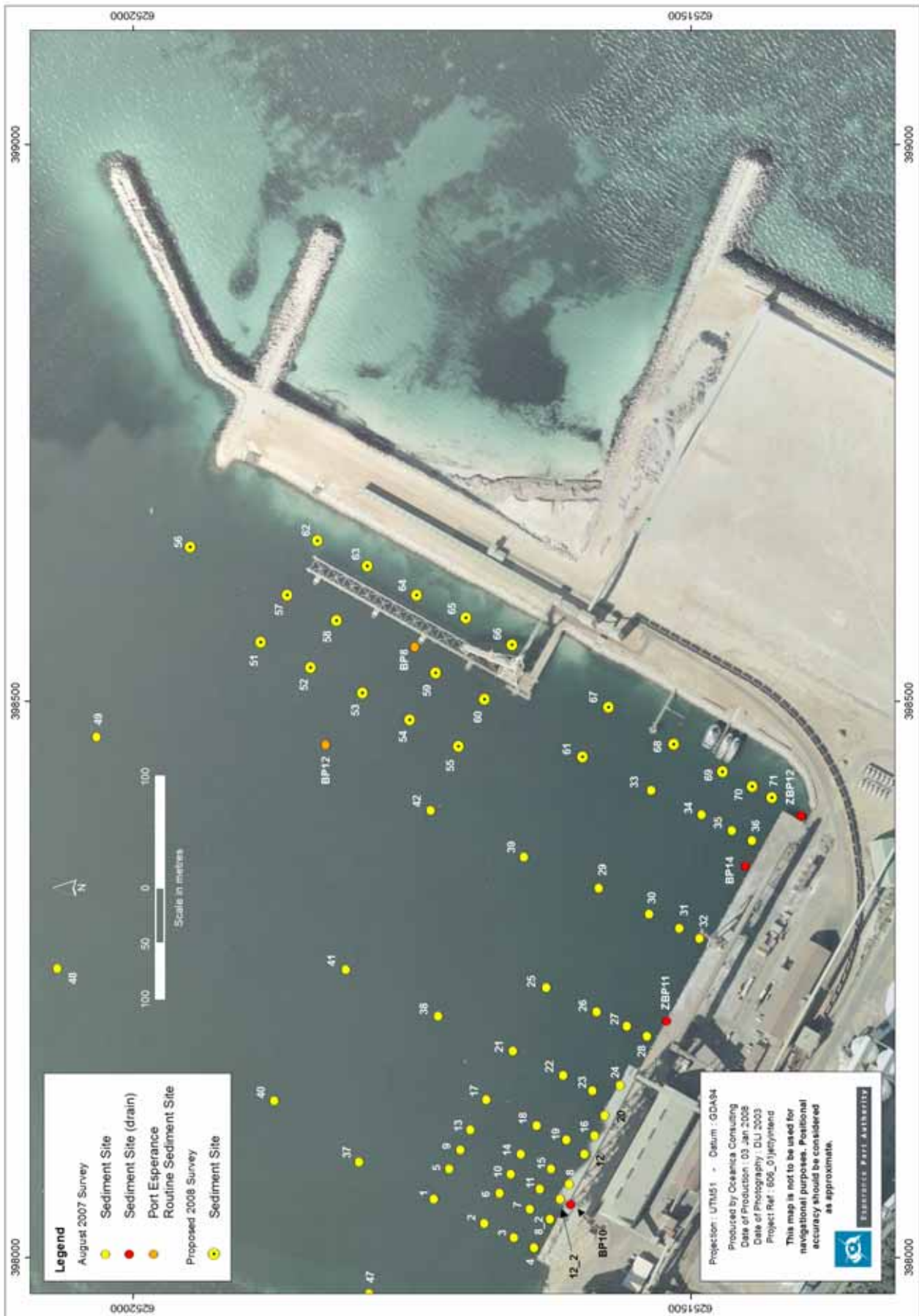


Figure 4.1 Proposed new sites for sampling and lead analysis

## **5. Acknowledgements**

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Sampling was undertaken by Spencer Shute (Oceanica Consulting), Lotte Horn and Marc Payne. Sediment metal analysis was performed by MAFRL and particle size analysis was undertaken by CSIRO. This report was prepared by Sarah Scott, Spencer Shute and Karen Hillman (Oceanica Consulting). The report was formatted by Hayley Perhavec.

## 6. References

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- ANZECC/ARMCANZ. 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand, National Water Quality Management Strategy No. 4.
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- Oceanica 2007a, *Port of Esperance Survey of Lead and Nickel in Marine Sediments, Sampling and Analysis Program (SAP)*, prepared for Esperance Port Authority by Oceanica Consulting Pty Ltd, Report No. 606/1.
- Oceanica 2007b, *Port of Esperance Survey of Lead and Nickel in Marine Sediments, Level (Stage) 1 Screening Assessment*, prepared for Esperance Port Authority by Oceanica Consulting Pty Ltd, Report No. 606/2.

## **Notes on site labelling**

CSIRO labelling of the following sites differs from those provided in Figure 2.1 as follows:

Sites EP1 to EP50 correspond to 1 to 50

Sites EP8NEW and EP12NEW correspond to 8\_2 and 12\_2



## **Appendix A**

**Laboratory reports, dilute acid extraction of lead and nickel**



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Contact: Spencer Shute  
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Date of Issue: 11/12/2007  
Our Reference: OCA07-70  
Your Reference: 606

**SEDIMENT DATA**

METHOD SAMPLE CODE	Sampling Date	Dilute Acid Ext Ni mg/kg <0.4	Dilute Acid Ext Pb mg/kg <1	ICP002 Total Ext Ni mg/kg <0.4	ICP002 Total Ext Pb mg/kg <1	File
EP2A	24/08/2007	1.6	26	28	34	07121001 07120701 07120701
EP3A	23/08/2007	1.6	23			
EP3B	23/08/2007	1.7	22			
EP3C	23/08/2007	2.5	34			
EP4A	23/08/2007	5.0	93			
EP4B	23/08/2007	4.9	96			
EP4C	23/08/2007	5.2	130			
EP8C	22/08/2007	2.5	46			
EP8ANEW	23/08/2007	2.4	47			
EP8BNEW	23/08/2007	2.8	60	49	69	
EP8CNEW	23/08/2007	3.5	73			
EP10A	23/08/2007	1.6	28			
EP10C	23/08/2007	1.5	24			
EP12ANEW	23/08/2007	2.0	59			
EP12BNEW	23/08/2007	3.0	89			
EP12CNEW	23/08/2007	2.3	67			
EP18A	24/08/2007	1.5	37			
EP18B	24/08/2007	1.0	21			
EP18C	24/08/2007	1.6	24			
EP45A	21/08/2007	3.1	39	48	47	
EP45B	21/08/2007	4.0	26			

All test items tested as received. Spare test items will be held for two months unless otherwise requested.

Signatory: *Spencer Shute*  
Date: 11/12/07

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Date of Issue: 11/12/2007  
Our Reference: OCA07-70  
Your Reference: 606

**SEDIMENT DATA**

METHOD SAMPLE CODE	Sampling Date	Dilute Acid Ext Ni mg/kg	Dilute Acid Ext Pb mg/kg	ICP002 Total Ext Ni mg/kg	ICP002 Total Ext Pb mg/kg	File
Reporting Limit		<0.4	<1	<0.4	<1	
		07121001	07121001	07120701	07120701	07120701
EP45C	21/08/2007	2.0	47			
EP46A	21/08/2007	3.3	42			
EP46B	21/08/2007	4.3	49			
EP46C	21/08/2007	3.2	39			
EP47B	21/08/2007	2.7	30			
EP48A	21/08/2007	2.5	16			
EP48B	21/08/2007	1.6	11			
EP48C	21/08/2007	2.2	16			
BP8A	21/08/2007	3.6	44	60	56	
BP8B	21/08/2007	3.0	52			
BP8C	21/08/2007	4.3	62			
ZBP11A	22/08/2007	6.0	66			
ZPB11B	22/08/2007	6.4	90			
ZPB11C	22/08/2007	4.7	84			
ZPB12A	23/08/2007	25	56			
ZPB12C	23/08/2007	16	51			
BP13A	26/08/2007	3.0	17			
BP13C	26/08/2007	2.2	15			
BP14B	27/08/2007	14	92	260	110	
EP31C	27/08/2007	2.4	60			
EP32A	27/08/2007	5.0	130			

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Date of Issue: 11/12/2007  
Our Reference: OCA07-70  
Your Reference: 606

**SEDIMENT DATA**

METHOD SAMPLE CODE	Sampling Date	Dilute Acid Ext Ni mg/kg	Dilute Acid Ext Pb mg/kg	ICP002 Total Ext Ni mg/kg	ICP002 Total Ext Pb mg/kg	File
Reporting Limit		<0.4	<1	<0.4	<1	
		07121001	07121001	07120701	07120701	07120701
EP32B	27/08/2007	3.6	73			
EP32C	27/08/2007	3.7	75			
EP33B	28/08/2007	4.8	45			
EP33C	28/08/2007	3.2	33			
EP34A	28/08/2007	6.1	87			
EP34B	28/08/2007	7.2	43			
EP34C	28/08/2007	8.6	16			
EP43A	26/08/2007	2.1	20	30	26	
EP43B	26/08/2007	2.0	17			
EP44C	28/08/2007	2.7	14			
UEP8C	22/08/2007	2.1	46			
UG_EP12B NEW	23/08/2007	3.4	120			
UG_EP47B	21/08/2007	2.8	35			
UG_BP13A	26/08/2007	3.5	22			
UG_EP31C	27/08/2007	2.1	69			
UG_EP34C	2/08/2007	8.4	17			

Note: UG samples are unground samples remaining samples are ground  
Dilute acid extraction is 1M hydrochloric acid in a sediment:acid ratio of 1:50 for 1 h.

Signatory: *Spencer Shute*  
Date: 11/12/07

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