

ANTIFOULANT AND TRACE METAL CONTAMINATION OF SEDIMENTS FROM THE NAPIER INNER HARBOUR



A commercial slipway, Napier

REPORT PREPARED FOR:
HAWKE'S BAY REGIONAL COUNCIL

BY:
JASON STRONG MSc (Hons)
ENVIRONMENTAL ASSESSMENTS &
MONITORING LIMITED.

JULY 2005

EMI0511
HBRC Plan Number: 3687

TABLE OF CONTENTS

1.0 INTRODUCTION	1
2.0 METHODOLOGY	3
2.1 Sample Collection	3
2.2 Laboratory Methods	3
3.0 RESULTS & DISCUSSION	5
3.1 Antifoulants	5
3.1.1 Irgarol & Diuron.....	5
3.1.1.1 Summary of results	5
3.1.1.2 Comparisons with other studies.....	5
3.1.1.3 Comparison with Standards and Guidelines.....	7
3.1.2 Organotin	8
3.1.2.1 Summary of Results.....	8
3.1.2.2 Comparisons with other studies.....	9
3.1.2.3 Comparisons with standards and guidelines	9
3.1.3 Chlorothalonil	11
3.1.3.1 Summary of results	11
3.1.3.2 Comparisons with other studies.....	11
3.1.3.3 Comparisons with standards and guidelines	11
3.1.4 DDT.....	11
3.1.4.1 Summary of results	11
3.1.4.2 Comparisons with other studies.....	12
3.1.4.3 Comparisons with standards and guidelines	13
3.2 Trace Metals	14
3.2.1 Summary of Results.....	14
3.2.2 Comparisons with other studies	15
3.2.3 Comparison with Standards and Guidelines.....	16
4.0 CONCLUSIONS	18
5.0 RECOMMENDATIONS	22
6.0 REFERENCES	23
APPENDIX 1: SITE PHOTOS	26
APPENDIX 2: LABORATORY RESULTS	30

1.0 INTRODUCTION

The growth of fouling organisms such as barnacles, mussels, calcareous tubeworms and algae on the hulls of vessels and other submerged structures increases friction and subsequent fuel consumption; speeds the degradation of materials and increases maintenance and repair costs. Copper rosin-based antifoulants were introduced to the shipping industry nearly a century ago and have remained in use since then. Copper (primarily as Cu_2O or CuSCN) is highly toxic to fouling organisms such as barnacles, mussels and tubeworms, however some algal species (i.e. *Enteromorpha* and *Ectocarpus*) show tolerance to the mode of action of copper (Stewart, 2003).

In the 1950's 'booster' agents such as DDT, organomercurial, organolead and arsenical compounds were used in conjunction with copper rosins as they offered a broad spectrum of toxicity to antifouling organisms. Unfortunately, the broad toxicity that made these antifoulant compounds so effective also posed significant risks to the ongoing health of marine ecosystems due to their toxicity to non-target species. These 'booster' agents were subsequently withdrawn from use in the early 1960's (Stewart, 2003).

During the latter 1960's tributyltin (TBT) was found to be a highly effective replacement to these 'booster' agents as it had a broad spectrum of toxicity against most fouling biota. However, as with the likes of DDT, the toxicity and persistence of TBT on the marine environment was greatly underestimated. Research indicated that concentrations as low as $0.1 \mu\text{g}$ per litre (0.1 parts per billion) could cause sub-lethal growth effects and mortality in marine organisms, reduce the growth rates in juvenile mussels (Salazar and Salazar, 1991), and cause shell thickening in oysters (King et al, 1989). Growing evidence of imposex (the development of male reproductive appendages in female gastropods causing infertility) also triggered concern for the reproductive success of these marine organisms (MfE, 1998). These findings led to the International community deciding to deregulate the use of this antifoulant and as such it hasn't been sold or applied in NZ since 1993 on large boats and since 1989/90 on small boats (Stewart, pers.comm. 2005). However, the complete phasing out of Tributyltin based antifoulants does not legally occur until 2008 in New Zealand and as such it is possible that there are stockpiles currently being used. In response to environmental concerns and the subsequent ban on the sale of TBT, co-biocides (copper plus the addition of a biocide) were developed in the late 1980's to replace TBT based antifoulants.

Again however, co-biocide compounds such as the herbicides Irgarol 1051, Diuron, and the fungicide Chlorothalonil were introduced with little known about their fate and toxicity in the marine environment and recently there has been growing concern that they may have the same adverse environmental effects as presented by TBT (Stewart, 2003; Voulvoulis et al., 1999a).

To this end, the United Kingdom has revoked the use of Diuron on all vessels and Irgarol and Chlorothalonil for all vessels <25m long (Stewart, 2003). Currently these three co-biocides are approved for use in antifoulants products in the New Zealand marine industry.

Where wastewater management practices are lacking or poorly implemented, areas associated with the repair and maintenance of boat hulls can be significant point source contributors of contaminants (particularly organic herbicides/fungicides and trace metals from antifouling paints and fuel oils) to aquatic environments, (e.g. Stewart, 2003; Thomas et al., 2003; and Coomber et al. 2002b).

The aim of this study is to provide a brief overview of the toxicity characteristics of sediments within the Napier Inner Harbour, with specific reference to contaminants associated with boat maintenance and repair (in particular antifoulant compounds and associated trace metals). Study sites have been selected to align with these aims. These characteristics will then be assessed to determine whether contaminants associated with boat repair and maintenance activities (antifouling and trace metal contaminants) have accumulated within the inner harbour to levels that may pose a threat to marine health.

Environmental Assessments and Monitoring Limited have been engaged by the Hawke's Bay Regional Council to carry out the above brief. The above brief was formulated and supplied by Hawke's Bay Regional Council Coastal and Marine Scientist Anna Madarasz.

2.0 METHODOLOGY

2.1 Sample Collection

Samples of between 500-1000g of sediment were collected from each site (see Figure 1 for site locations and Appendix 1 for site photos) with each sample being a composite of ten sub-samples. By collecting samples in this manner a greater representation of the study site is obtained and the likelihood of highly variable results due to sampling are reduced. Sediment samples were collected to a maximum depth of 5cm with a Teflon spatula (for sites with exposed intertidal flats - Site 1: Marine Club Slipway, Site 2: Commercial Slipway, and Site 3: Marine Club Slipway) or Ponar® dredge (for sites permanently covered with water – Site 4: Boat Ramp and Site 5: Iron Pot) and placed into acid washed glass containers. Samples were immediately stored in an iced chilly bin to inhibit degradation and couriered the same day to Hill Laboratories Limited in Hamilton.

At each sampling site the following additional information was collected: date and time of sampling, GPS coordinates, sediment texture, tidal state relative to low tide, foreign objects such as paint flakes in sediment and the proximity to hull washing/maintenance facilities. A summary of these details is provided in Table 1 below.

Table 1: Location and descriptions of sampling sites in this survey

Site	Date/time	Tidal state relative to low tide	Location	Sediment description	Distance from hull washing facility
Site 1: Marine Club Slipway	22/06/05 @ 1056	-22 minutes	2844550 E 6184090 N	Mix of sand/gravel and silt. Paint chips evident in sediment (see Appendix 1 for photo)	5m
Site 2: Commercial Slipway	22/06/05 @ 1020	-58 minutes	2844610 E 6184095 N	Mix of sand/gravel and silt. Paint chips evident in sediment. Large amounts of red particulates from hull washing noticed in sediments (see Appendix 1 for photo)	5m
Site 3: Marine Club Slipway	22/06/05 @ 1127	+9 minutes	2844680 E 6183940 N	Mix of sand/gravel and silt. Paint chips and paint over-spray evident in sediment (see Appendix 1 for photo)	5m
Site 4: Boat Ramp	22/06/05 @ 1222	+64 minutes	2844760 E 6183780 N	Fine mud/silt with anoxic black colouration	300m
Site 5: Iron Pot	22/06/05 @ 1306	+108 minutes	2845155 E 6184140 N	Fine mud/silt with anoxic black colouration	~600m

2.2 Laboratory Methods

Methodologies for sample analyses are attached with Hill Laboratory Reports of Analysis as Appendix 2.

Figure 1: Location of sampling sites for this survey



Site One: Marine Club Slipway

Site Two: Commercial Slipway

Site Three: Marine Club Slipway and Maintenance Berth

Site Four: Boat ramp

Site Five: Iron Pot

3.0 RESULTS & DISCUSSION

3.1 Antifoulants

Concentrations of antifouling compounds in sediment samples collected for this survey are presented in Table 2 and discussed further below. Full reports of analysis from Hill Laboratories are attached as Appendix 2.

Table 2: Antifoulant concentrations in sediments from this survey (all results expressed on a dry weight basis)

Contaminant	Site 1: Marine Club Slipway	Site 2: Commercial Slipway	Site 3: Marine Club Slipway	Site 4: Boat Ramp	Site 5: Iron Pot
Irgarol (ng/g)	7	90	5	<5	<5
Diuron (ng/g)	630	2350	34	<5	<5
Chlorothalonil (ng/g)	6550	19500	920	<5	<5
Monobutyltin (ng/g as Sn)	36	90	62	<3	<2
Dibutyltin (ng/g as Sn)	139	250	210	5	<5
Triphenyltin (ng/g as Sn)	<1	70	8	<1	<1
Tributyltin (ng/g as Sn)	534	1130	276	11	<5
2,4'-DDE (ng/g)	<5	9	36	<5	<5
2,4'-DDD (ng/g)	<5	237	<5	<5	<5
2,4'-DDT (ng/g)	<5	186	6	<5	<5
4,4'-DDE (ng/g)	<5	205	5	<5	<5
4,4'-DDD (ng/g)	8	883	10	<5	<5
4,4'-DDT (ng/g)	15	844	5	<5	10
Total DDT Isomers (ng/g)	30	2360	60	<30	<30

3.1.1 Irgarol & Diuron

3.1.1.1 Summary of results

Of the five sites sampled in this survey, only three (the commercial and club slipways; sites 1-3) recorded detectable amounts of Irgarol and Diuron in sediment. The highest concentrations were found at Site 2 (90 ng/g Irgarol and 2350 ng/g Diuron) followed by Site 1 (7 ng/g Irgarol and 630 ng/g Diuron) and Site 3 (5 ng/g Irgarol and 34 ng/g Diuron) sites. No detectable concentrations of Irgarol and Diuron were found at the Boat Ramp or Iron Pot sites.

3.1.1.2 Comparisons with other studies

Until quite recently there has been little data collected on the levels of Diuron and Irgarol in New Zealand marine ecosystems. The only significant study has been by Stewart (2003) where sediments and seawater from 28 sites around New Zealand (from Northland to Nelson) were collected and analysed. The data given by Stewart (2003) compared well to other international data and it was generally accepted that the highest levels of Diuron & Irgarol are associated with point source discharges from areas of boat hull maintenance and repair (refer to Table 4 below).

The results from this survey follow the same spatial trend to that illustrated by Stewart (2003) with sediment concentrations of Irgarol and Diuron being greatest adjacent to maintenance slipways (refer Table 4 below). Similarly, the data from Stewart (2003) compared well with this survey for sites not directly influenced by point sources in that the lowest concentrations of Diuron & Irgarol were found around areas used primarily for mooring boats (Iron Pot and Boat Ramp). The range of sediment Irgarol (<5-90 ng/g) and Diuron (<5-2350) concentrations in this survey suggest that sediment contamination is similar if not slightly lower to other areas in New Zealand with Stewart (2003) reporting a range of <5-1450 ng/g Irgarol and <5-9410 ng/g for Diuron.

It was proposed by Stewart (2003) that the reason for the high sediment concentrations of Irgarol and Diuron around boat maintenance areas was due to discrete paint particles being present and this is likely to be the case in this study as paint particles were visible in collected sediment samples from the commercial and marine club slipway sites (refer Section 2.1 and Appendix 1). The significance of paint particle-bound contaminants in marine sediments is that it has been shown that when bound to these particles, Diuron and more so Irgarol are more persistent than when as free forms in the water column. As such these sediment-bound compounds can be slowly released through degradation and thus continue to pollute sediment pore waters and the overlying water column for long periods. Thomas (2003) illustrates the longevity of these compounds when after 42 days Irgarol and Diuron showed no noticeable degradation when associated with paint particles in sediment. The lower results found around the areas used primarily for boat mooring (Iron Pot and Boat ramp) indicates that there is little contamination of these sediments and that the likely source in these areas is through leaching from boat hulls to seawater and ultimately partitioning to bottom sediments.

Table 4: Comparison of sediment Diuron and Irgarol concentrations for sites in this survey, to national & international data.

Location	Diuron (ng/g)	Irgarol (ng/g)
Data from this survey		
Site 1: Marine Club Slipway	630	7
Site 2: Commercial Slipway	2350	90
Site 3: Marine Club Slipway	34	5
Site 4: Boat Ramp	<5	<5
Site 5: Iron Pot	<5	<5
Other New Zealand Data (Stewart, 2003)		
Northland		
Tutukaka Marina	<5	<5
Whangarei Town Basin Marina	<5	<5
Auckland		
Gulf Harbour Marina inner site	5	<5

Table 4: Continued

Westhaven Marina haulout grid	7	<5
Coromandel		
Whitianga Marina	<5	<5
Whitianga Estuary	<5	<5
Whangamata Estuary	<5	<5
Tauranga		
Sulphur Point Marina slipway	9410	114
Malborough Sounds		
Waikawa Marina slipway 0-5 cm	1060	745
Waikawa Marina slipway 5-10 cm	1260	537
Picton boat repainting yard 0-5 cm	4140	155
Picton boat repainting yard 5-10 cm	3240	1450
Picton Marina	<5	<5
Havelock Marina	<5	<5
Nelson		
Nelson main slipway 1	146	8
Nelson main slipway 2	20	<5
Nelson Marina outer jetties	6	<5
Nelson Marina inner jetties	8	<5
Iron Pot	<5	<5
International Data (in Stewart, 2003)		
Orwell Estuary (United Kingdom) Slipway Base (from Comber <i>et al.</i> , 2002b)	1680	-
United Kingdom Marina Sediments not influenced by point sources (from Thomas <i>et al.</i> , 2002)	1-15	-
Greek Marine Sediments (from Albanis <i>et al.</i> , 2002) – results from non-point source sites	-	3-690
United Kingdom Sediments (from Comber <i>et al.</i> , 2002b) –results from sites directly (highest) and non-directly (lowest) influenced by point sources	-	10-5006
North Sea & Baltic Sea Sediments (from Biselli <i>et al.</i> , 2000) – results from sites not influenced by point sources	-	3-220

3.1.1.3 Comparison with Standards and Guidelines

At present there are no guidelines for Diuron in sediment either nationally or internationally, as most studies appear to have focussed on seawater contamination rather than sediments. However, if we consider that the ANZECC (2000) water quality guideline for Diuron in marine waters is only 1.8 µg/L it is likely that the high levels of Diuron found in sediments at the commercial and marine club slipway sites may potentially be having an adverse affect on the local ecosystem.

Sediment quality guidelines with regards to Irgarol toxicity are also rather scarce and the only guideline given by Stewart (2003) was 1.4 ng/g. This figure was proposed as an Environmental Exposure Limit (EEL) in relation to an application to ERMA New Zealand (Application HSR02005) for the import/manufacture of new co-biocide antifoulants. This value is based around the Netherlands Maximum Permissible Concentrations (Van Wezel *et al.*, 2001), which are widely used in literature for assessing co-biocide levels (Stewart, 2003).

Applying this EEL, biological effects from Irgarol contamination are likely to be occurring frequently at the commercial and marine club slipway sites. The high limits of detection for both Irgarol and Diuron methodologies make any significant conclusions for the Boat ramp and Iron Pot sites difficult.

3.1.2 Organotin

3.1.2.1 Summary of Results

Sediment concentrations of Organotin compounds (Triphenyltin (TphT) and Tributyltin (TBT) along with associated degradation products Dibutyltin (DBT) and Monobutyltin (MBT)) show a similar pattern to Irgarol and Diuron contamination with the greatest levels found around sites utilised for boat maintenance activities. Once again site 2, the commercial slipway indicates greatest sediment contamination, with TphT, TBT, DBT and MBT concentrations of 70 ng/g, 1130 ng/g, 250 ng/g and 90 ng/g respectively. Sites 1 (marine club slipway – 534 ng/g TBT, 139 ng/g DBT and 36 ng/g MBT) and 3 (marine club slipway - 276 ng/g TBT, 210 ng/g DBT, 62 ng/g MBT and 8 ng/g TphT) also contained appreciable concentrations of organotin. Small traces of TBT (11 ng/g) and DBT (5 ng/g) were detected around the Boat Ramp site while no detectable concentrations of organotin were found at the Iron Pot site.

Ratios of DBT:TBT can be used to assess TBT degradation in the environment allowing an insight as to the age of the latest inputs (Michel *et al.*, 2001). Low ratios of DBT:TBT are usually associated with recent or 'fresh' inputs, or, of very slow processes of degradation (Stewart, 2002). The sampling sites in this study indicate low ratios of TBT to its degradation product DBT of 0.26, 0.22, 0.76 and 0.45 for site 1 (marine club slipway), 2 (commercial slipway), 3 (marine club slipway), and site 4 (Boat Ramp) respectively suggesting that there has been quite recent contamination by TBT to aquatic sediments. However, as TBT has supposedly not been sold or applied in New Zealand since 1993 on large boats and since 1989/1990 on smaller boats, historic persistent contamination due to an association with paint particulates is the more likely scenario. Generally speaking, when high levels of TBT are identified in sediments it is expected that there will be slow rates of degradation as it is usually associated with the presence of paint particulates and also because at high concentrations, TBT has an autoinhibitive effect on its own degradation (Stewart, pers. comm., 2005).

3.1.2.2 Comparisons with other studies

Table 5 compares the data of this survey to that of other studies carried out nationally and internationally. It should be noted that data from other studies was generally recorded from sites not directly influenced by point source areas such as marine slipways while in contrast this study used a ‘targeted’ strategy aimed at assessing the contribution of point source areas. By comparing these two differing sample sets it becomes obvious that areas of boat maintenance are major sources of TBT in the inner harbour.

Concentrations found at the Boat Ramp and Iron Pot sites were similar to data from other studies indicating that there is only low-level contamination in areas not directly affected by point sources.

Table 5: Comparison of sediment Tributyltin concentrations for sites in this survey to national & international data.

Location	Tributyltin (ng/g)
<i>Data from this survey</i>	
Site 1: Marine Club Slipway	534
Site 2: Commercial Slipway	1130
Site 3: Marine Club Slipway	276
Site 4: Boat Ramp	11
Site 5: Iron Pot	<5
<i>Other New Zealand Data</i>	
Tamaki Estuary – typically non-point source sites (King <i>et al.</i> , 1989)	1 - 240
Opuia Inlet – typically non-point source sites (King <i>et al.</i> , 1989)	1 - 2
Tutukaka – typically non-point source sites (King <i>et al.</i> , 1989)	1 - 12
Waikawa Bay (Nelson) – (Stewart, 2002) – from sites not directly affected by point sources	19 - 39
<i>International Data</i>	
Portugal (Diez <i>et al.</i> , 2005) – typically non-point source sites	<3.8 - 489
Vietnam (Nhan <i>et al.</i> , 2005) – typically non-point source sites	8.3 – 50.5
Brazil (Almeida <i>et al.</i> , 2004) – typically non-point source sites	<1 - 82

3.1.2.3 Comparisons with standards and guidelines

The ANZECC (2000) sediment guidelines have been derived from the best available overseas data, and refined with knowledge of existing baseline concentrations and local effects data from Australia and New Zealand (ANZECC, 2000). The ANZECC guidelines are largely formulated from one large biological effects based dataset (Morgan and Long, 1991; Long *et al.* 1995) used to rank North American sediments. This effects based system provides two sediment quality guidance values, the ‘effects range low level (ER-L) and the ‘effects range median level (ER-M),’ which represent a statistical probability of effects from contaminants, to biological systems.

The ER-L values are equal to the 10th percentile of the dataset, above which adverse effects to sensitive life stages/species may occur, while the ER-M concentration values are equal to the 50th percentile, and above these contaminant levels, biological effects frequently occur (ANZECC, 2000).

ANZECC (2000) utilise similar effects based guideline values, the Interim Sediment Quality Guideline-low (ISQG-low) and the (ISQG-high) values, for contaminants. If the contaminant concentration is < ISQG-low value, then adverse biological effects are unlikely. If the concentration of a contaminant is >ISQG-low value, but <ISQG-high value, biological effects are expected occasionally, and if the concentration is >ISQG-high value, then effects are expected frequently. These ISQG values are set as trigger values, and form part of a decision tree process that is used when applying the sediment guidelines (ANZECC, 2000). Should the ISQG-low value be exceeded then the decision tree defines what type of action is required, and this is usually remedial action, or the initiation of further site-specific studies to determine the actual risk to the ecosystem in question.

When the results from this survey are compared to ANZECC (2000) interim sediment quality guidelines (Table 6) it can be seen that the marine club slipway at site 1 (534 ng/g), commercial slipway (1130 ng/g) and marine club slipway at site 3 (276 ng/g) far exceed both the ISQG-Low and ISQG-High guideline concentrations. However, while it is likely that these concentrations will be having an adverse affect on the local ecosystem it is difficult to determine to what extent due to the unknown of how much is being released at any time from degradation of the paint matrix to sediment pore waters.

Sediments from Boat Ramp site (11 ng/g) exceeded the ISQG-Low guideline limit suggesting further investigation may be warranted while the Iron Pot sediments indicated concentrations below guideline limits.

Table 6: Comparison of sediment Tributyltin concentrations for sites in this survey to ANZECC (2000) Sediment Quality Guideline

Contaminant	ISQG-Low (ng/g) (Trigger value)	ISQG-High (ng/g)
Tributyltin	5	70

3.1.3 Chlorothalonil

3.1.3.1 Summary of results

High concentrations of Chlorothalonil were found in sediment samples collected from the commercial slipway at site 2 (19500 ng/g), the marine club slipways at sites 1 (6550 ng/g) and 3 (920 ng/g). There were no detectable amounts of Chlorothalonil in sediments collected from around the Boat Ramp or Iron Pot sites. It is most probable that the high sediment concentrations of Chlorothalonil are also due to the presence of discrete particles particularly as it only has a half-life of 2.8 days in its free form in seawater. This scenario is supported when comparing these results with those from areas of no direct point sources (Boat Ramp and Iron Pot) that did not indicate Chlorothalonil contamination.

3.1.3.2 Comparisons with other studies

There is very little data available for Chlorothalonil in sediments in New Zealand. Overseas studies have reported the occurrence of Chlorothalonil in sediments e.g. Albanis *et al.* (2002) where sediments from Greek marinas and ports contained maximum levels of 165 ng/g Chlorothalonil. Voulvoulis *et al.*, (2002b) reports on Chlorothalonil in sediments of the Blackwater Estuary, Essex, UK but this contamination was attributed to agricultural runoff.

The results from this study when compared to other data indicate that there is considerable contamination around the areas of boat hull washing activities.

3.1.3.3 Comparisons with standards and guidelines

At present there aren't any sediment quality standards or guidelines for Chlorothalonil either nationally or internationally (Stewart, pers. comm., 2005). Canadian Environmental Quality Guidelines (EQG's) for the protection of aquatic life do however provide a guideline value of 0.36 µg/L Chlorothalonil in marine waters and when compared to the high sediment concentrations found in this study it is likely that environmental effects will be occurring around areas of boat maintenance.

3.1.4 DDT

3.1.4.1 Summary of results

DDT and associated degradation compounds (DDD and DDE isomers) continued the trend of above with the greatest contamination being around the areas of boat maintenance activities.

The commercial slipway at site 2 again indicates the highest level of contamination (2360 ng/g total DDT isomers) followed by the marine club slipways at site 1 (30 ng/g total DDT), and site 3 (60 ng/g total DDT isomers) sites while only small traces of DDT (10 ng/g total DDT isomers) were detected at the Iron Pot site. Sediments from the Boat Ramp site were non detectable for DDT.

3.1.4.2 Comparisons with other studies

Table 7 below presents both national and international data from other sediment quality surveys with respect to DDT contamination.

Table 7: Comparison of sediment Total DDT concentrations for sites in this survey, to national & international data

Location	Total DDT
<i>This Study</i>	
Site 1: Marine Club Slipway	30
Site 2: Commercial Slipway	2360
Site 3: Marine Club Slipway	60
Site 4: Boat Ramp	<30
Site 5: Iron Pot	<30
<i>Other New Zealand Data</i>	
Tauranga Harbour (Burggraaf <i>et al.</i> , 1994)	<0.1 – 5.36
Manakau Harbour (Holland <i>et al.</i> , 1993)	0.07 – 22
<i>International Data</i>	
Kyeonggi Bay, Korea (Lee <i>et al.</i> , 2000)	<0.046 – 32
Namyang Bay, Korea (Lee <i>et al.</i> , 2000)	0.088 – 0.38
San Francisco Bay, USA (Pereira <i>et al.</i> , 1994)	<0.1 – 9
Osaka Bay, Japan (Tanabe <i>et al.</i> , 1991)	0.16 – 12
Lake Baikal, Russia (Iwata <i>et al.</i> , 1995)	0.014 – 2.7

Note: Data from other studies were not associated with direct point sources as was the case in this survey.

The striking feature of this comparison is that the total DDT concentrations found at the commercial slipway at site 2 and to a far lesser extent at sites 3 and 1 far exceed the highest concentrations sourced from polluted aquatic environments in countries such as Japan (12 ng/g) and the USA (9 ng/g). As for TBT described above, the reason for this is due to the different sampling strategies employed in each survey i.e. this study employed a ‘targeted’ approach aimed at direct point sources while the other studies were based on typical non-point source related sediments. Interestingly, the nearest comparison is the data from the Manakau Harbour (22 ng/g) in Auckland, New Zealand. It is expected that the high levels of DDT found in this survey are attributable to persistent discrete paint chips in sediments.

Although results from the other sites in this study (Boat Ramp and Iron Pot) are difficult to compare due to the method limit of detection, it is clear that these sites have not been affected by historical point source contamination, as is the case above.

3.1.4.3 Comparisons with standards and guidelines

ANZECC (2000) Interim Sediment Quality Guidelines (ISQG's) for DDT and its degradation products (DDD and DDE) are shown in Table 8 below.

Table 8: Comparison of sediment DDT, DDE and DDD concentrations for sites in this survey to ANZECC (2000) Sediment Quality Guidelines

Contaminant	ISQG-Low (ng/g) (Trigger value)	ISQG-High (ng/g)
Total DDT	1.6	46
p.p'-DDE	2.2	27
o.p'-+ p.p-DDD	2	20

From this table the following was observed:

Total DDT: Both the ISQG-Low (1.6 ng/g) and ISQG-High (46 ng/g) guideline values were exceeded at the commercial slipway site 2 (2360 ng/g), and the marine club slipway at site 3 - 60 ng/g)). Only the ISQG-Low value was exceeded at the Iron Pot (10 ng/g) and the marine club slipway at site 1 (30 ng/g) sites.

No detectable concentrations were found at the Boat Ramp site, however due to the guideline value being somewhat lower than the detection limits of this study it can't be known whether the ISQG-Low value has been exceeded or not.

p.p'-DDE (4, 4 -DDE): Both the ISQG-Low (2.2 ng/g) and ISQG-High (27 ng/g) guideline values were exceeded at the commercial slipway at site 2 (205 ng/g) while only the ISQG-Low value was exceeded at the marine club slipway site 3 (5 ng/g) site. No detectable concentrations were found at the Boat Ramp, the marine club slipway at site 1 or Iron Pot sites, however as above, due to the guideline value being somewhat lower than the detection limits of this study it can't be known whether the ISQG-Low value has been exceeded or not at these sites.

o.p'-+ p.p-DDD: Both the ISQG-Low (2 ng/g) and ISQG-High (20 ng/g) guideline values were exceeded at the commercial slipway at site 2 (1120 ng/g) while only the ISQG-Low value was exceeded at the marine club slipways at sites 1(8 ng/g) and 3 (10 ng/g). No detectable concentrations were found at the Boat Ramp, or Iron Pot sites, however as above, due to the guideline value being somewhat lower than the detection limits of this study it can't be known whether the ISQG-Low value has been exceeded or not at these sites.

The summary above indicates that there is substantial contamination of DDT and its degradation products around the areas of boat maintenance and in particular the commercial slipway at site 2 and the marine club slipway at site 3. It is expected that at these two sites biological effects may occur frequently from DDT contamination.

3.2 Trace Metals

Concentrations of trace metals in sediment samples collected for this survey are presented in Table 9 and discussed further below.

Table 9: Comparison of sediment trace metal concentrations for study sites in this survey and ANZECC (2000) Sediment Quality Guidelines (all results mg/kg dry wt)

Site	Cu mg/kg	Pb mg/kg	As mg/kg	Hg mg/kg	Zn mg/kg	
Results from this survey						
Site 1: Marine Club Slipway	435	40.8	4.7	0.11	227	
Site 2: Commercial Slipway	1070	230	13.3	4.02	689	
Site 3: Marine Club Slipway	301	70.7	5.1	0.12	129	
Site 4: Boat Ramp	33	61.6	7	0.16	116	
Site 5: Iron Pot	31.2	26.1	5.9	0.08	184	
ANZECC	ISQG-Low	65	50	20	0.15	200
	ISQG-High	270	220	70	1	410

3.2.1 Summary of Results

Arsenic (As)

Concentrations of arsenic in sediment indicate similar levels at all sites with the exception of the commercial slipway at site 2 where the concentration (13.3 mg/kg) was around 2-3 times greater than from the marine club slipways at sites 1 (4.7 mg/kg), and 3 (5.1 mg/kg), and sites 4 (Boat Ramp 7.0 mg/kg) and 5 (Iron Pot 5.9 mg/kg). It is probable that the higher levels of arsenic are attributable to contamination from paint chips and/or marine timbers treated with arsenical compounds.

Copper (Cu)

Sediment copper concentrations illustrate striking differences between sites located around areas of boat maintenance to those that are primarily associated with boat launching and berthing. The marine club slipways at sites 1 (435 mg/kg) and 3 (301 mg/kg), and the commercial slipway at site 2 (1070 mg/kg) sediments are significantly higher in copper (up to 35 times) than sediments taken from the Boat Ramp (33.0 mg/kg)

and Iron Pot (31.2 mg/kg). The contamination of these sediments is likely to be largely due to copper based antifoulant products.

Mercury (Hg)

Sediments adjacent to the commercial slipway at site 2 were shown to have extremely high concentrations of mercury (4.02 mg/kg) in comparison to all other sites sampled in this survey. Concentrations of mercury in sediment samples from sites 1, 3, 4 and 5 are similar with lower concentrations of 0.11, 0.12, 0.16 and 0.08 mg/kg Hg found respectively. Mercury contamination of these sediments is likely to be from historic antifoulant paints treated with mercurial compounds and/or from fuel oil/hydrocarbon discharges.

Lead (Pb)

As for other trace metals, the sediment lead concentration (230 mg/kg) found at the commercial slipway at site 2 was far greater than at other sites. Sediment lead concentrations from the other sites in this survey were in the range of 3-9 times lower with recorded values from site 1, 3, 4 and 5 of 40.8, 70.7, 61.6 and 26.1 mg/kg Lead respectively. It is possible that lead contamination is due to historic organolead paint applications but more likely it is as a result of contamination from leaded fuels. The presence of high lead concentrations at the Boat Ramp (site 4) site would tend to support this suggestion.

Zinc (Zn)

The commercial slipway at site 2 again indicated the highest metal contamination with 689 mg/kg Zinc being recorded. This result was approximately 3 times higher than at the marine club slipway at site 1 (227 mg/kg), 5 times higher than the marine club slipway at site 3 (129 mg/kg), 6 times higher than the Boat Ramp (site 4-116 mg/kg) and almost 4 times higher than at the Iron Pot (site 5;184 mg/kg). High sediment zinc concentrations are possibly due to antifoulant co-biocides such as Zinc pyrithine (ZPT) and/or discharges from fuels and oils.

3.2.2 Comparisons with other studies

Table 10 compares trace metal concentrations from sites studied as part of this survey, to mean concentrations from other estuaries/lagoons in Hawke's Bay as described by Strong (2005).

From this comparison, it can be seen that recorded metal concentrations in sediments in this survey, and in particular those sites situated near boat maintenance activities, were generally far greater than the mean concentrations calculated from other estuaries (including the Ahuriri Estuary) in Hawke's Bay and the calculated regional mean.

Table 10: Comparison of sediment trace metal concentrations for study sites in this research, and for other Hawke's Bay sites (all results mg/kg dry wt)

Site	Cu mg/kg	Pb mg/kg	As mg/kg	Hg mg/kg	Zn mg/kg
Results from this survey					
Site 1: Marine Club Slipway	435	40.8	4.7	0.11	227
Site 2: Commercial Slipway	1070	230	13.3	4.02	689
Site 3: Marine Club Slipway	301	70.7	5.1	0.12	129
Site 4: Boat Ramp	33.0	61.6	7.0	0.16	116
Site 5: Iron Pot	31.2	26.1	5.9	0.08	184
Results for other Hawke's Bay sites (Strong, 2005). Figures are mean results for each site					
Ahuriri Estuary	19.2	17.0	3.54	<0.05	84.9
Maungawhio Estuary	5.67	6.58	4.00	<0.05	34.0
Whangawehi Estuary	10.1	7.27	2.56	<0.05	56.3
Waikokopu Estuary	5.17	6.72	4.04	<0.05	47.6
Whakaki Lagoon	7.23	10.8	3.03	<0.05	46.4
Te Paeroa Lagoon	12.2	27.3	6.83	<0.05	54.6
Ohuia Lagoon	10.8	9.4	2.27	<0.05	55.6
Wairau Lagoon	11.9	18.1	4.26	<0.05	67.2
Wairoa Estuary	8.22	7.68	3.10	<0.05	50.5
Pakuratahi Estuary	4.91	6.84	3.11	<0.05	34.4
Esk Estuary	5.12	6.90	2.88	<0.05	45.1
Waitangi Estuary	10.3	12.8	3.58	<0.05	79.0
Tukituki Estuary	11.9	11.1	3.29	<0.05	54.5
Kairakau Lagoon	21.1	11.4	3.73	<0.05	57.5
Porangahau Estuary	15.4	8.61	2.73	<0.05	48.8
Mean concentration for Hawke's Bay Estuaries/lagoons (Strong, 2005)	9.08	9.08	3.23	<0.05	50.9

3.2.3 Comparison with Standards and Guidelines

Comparing the results from this survey to ANZECC (2000) interim sediment quality guidelines (Table 11) the following is observed:

- Both the ISQG-low and ISQG-high copper guidelines are exceeded at the marine club slipways at sites 1 (435 mg/kg) and 3 (301 mg/kg), and at the commercial slipway at site 2 (1070 mg/kg). The samples collected at the Boat Ramp and Iron Pot sites were below the copper ISQG-low guideline of 65 mg/kg.
- Both the ISQG-low and ISQG-high lead guidelines are exceeded at the commercial slipway at site 2 (230 mg/kg), while only the ISQG-low was exceeded at site 3 - Marine Club Slipway (70.7 mg/kg), and Site 4 - Boat Ramp (61.6 mg/kg) site.

The marine club slipway at site 1 and Iron Pot sites were below the lead ISQG-low guideline of 50 mg/kg.

- Arsenic concentrations at all sites were below the ISQG-low guideline value of 20 mg/kg.
- Both the ISQG-low and ISQG-high mercury guidelines are exceeded at the commercial slipway at site 2 (4.02 mg/kg). Of the remaining sites only the Boat Ramp sediments exceeded the ISQG-low guideline of 0.015 mg/kg.
- Both the ISQG-low and ISQG-high zinc guidelines were exceeded at Site 2 – commercial slipway (689 mg/kg) while only the ISQG-low was exceeded at Site 1 - marine club slipway (227 mg/kg). All other sites were below the zinc ISQG-low guideline of 200 mg/kg.

4.0 CONCLUSIONS

The conclusions reached as a result of this assessment, are as follows:

- Three of the five sites sampled in this survey contained detectable levels of Diuron and Irgarol in sediments. The highest concentrations were found at the commercial slipway at site 2 (90 ng/g Irgarol and 2350 ng/g Diuron) followed by the marine club slipway (site 1) (7 ng/g Irgarol and 630 ng/g Diuron) and the marine club slipway at site 3 (5 ng/g Irgarol and 34 ng/g Diuron). The reason for the high levels of Diuron and Irgarol at these sites is most likely due to the presence of discrete paint particulates in sediments. No detectable concentrations of Irgarol and Diuron were found at the Boat Ramp or Iron Pot sites.
- Diuron and Irgarol results from this survey compared well with national and international data suggesting that most contamination of the Inner Harbour sediments is as a result of point source discharges from boat maintenance activities.
- Sediment concentrations of TBT illustrated a similar pattern to Irgarol and Diuron contamination with the greatest levels found around sites utilised for boat maintenance activities (commercial slipway at site 2 (1130 ng/g), marine club slipways at sites 1 (534 ng/g) and 3 (276 ng/g) sites). Only traces of TBT (11 ng/g) were detected around the Napier Boat Ramp site while no detectable concentrations were found at the Iron Pot site. It is postulated that the high levels found at sites near the boat maintenance facilities are due to organotin-rich paint particulates in sediments.
- The marine club slipways at sites 1 (534 ng/g), and 3 (276 ng/g), and the commercial slipway at site 2 (1130 ng/g) far exceed both the ISQG-Low and ISQG-High guideline concentrations for TBT. It could be expected that these concentrations may be having an adverse affect on the local ecosystem but is difficult to determine to what extent due to the unknown of how much is being released at any time from degradation of the paint matrix to sediment pore waters.

- Sediments from Boat Ramp site (11 ng/g) exceeded the ISQG-Low guideline limit suggesting further investigation may be warranted while the Iron Pot sediments indicated concentrations below guideline limits.
- High concentrations of Chlorothalonil were found in sediment samples collected from the commercial slipway at site 2 (19500 ng/g), and the marine club slipways at sites 1 (6550 ng/g) and 3 (920 ng/g) sites. There were no detectable amounts of Chlorothalonil in sediments collected from around the Boat Ramp or Iron Pot sites.
- The commercial slipway at site 2 had the highest level of DDT contamination (2360 ng/g total DDT isomers) followed by the marine club slipways at sites 3 (60 ng/g total DDT) and 1 (30 ng/g total DDT isomers). Only traces of DDT (10 ng/g total DDT isomers) were detected at the Iron Pot site. Sediments from the Boat Ramp site were non detectable for DDT. The high levels of DDT continued the trend of other contaminants above with the greatest contamination being around the areas of boat maintenance activities. It is likely that the DDT found in this survey is from persistent historic discharges of paint particulates.
- For total DDT, both the ISQG-Low (1.6 ng/g) and ISQG-High (46 ng/g) guideline values were exceeded at the commercial slipway at site 2 (2360 ng/g), and the marine club slipway at site 3 (60 ng/g) sites. Only the ISQG-Low value was exceeded at the Iron Pot (10 ng/g) and the marine club slipway at site 1 (30 ng/g). No detectable concentrations were found at the Boat Ramp site, however due to the guideline value being somewhat lower than the detection limits of this study it can't be known whether the ISQG-Low value has been exceeded or not.
- Arsenic in sediment indicated similar levels at all sites with the exception of the commercial slipway at site 2 where the concentration (13.3 mg/kg) was around 2-3 times greater than from the marine club slipways at sites 1 (4.7 mg/kg) and 3 (5.1 mg/kg), the Boat Ramp (7.0 mg/kg) and Iron Pot (5.9 mg/kg). It is probable that the higher levels of arsenic are attributable to contamination from paint chips and/or marine timbers treated with arsenical compounds. All sites were below the ISQG-low guideline value of 20 mg/kg.

- Sediment copper concentrations illustrate striking differences between sites located around areas of boat maintenance to those that are primarily associated with boat launching and berthing. The marine club slipways at sites 1 (435 mg/kg) and 3 (301 mg/kg), and the commercial slipway (site 2; 1070 mg/kg) sediments are significantly higher in copper (up to 35 times) than sediments taken from the Boat Ramp (33.0 mg/kg) and Iron Pot (31.2 mg/kg). The contamination of these sediments is likely to be largely due to copper based antifoulant products.
- Both the ISQG-low and ISQG-high copper guidelines are exceeded at the marine club slipways at sites 1 (435 mg/kg) and 3 (301 mg/kg), and at the commercial slipway at site 2 (1070 mg/kg). The samples collected at the Boat Ramp and Iron Pot sites were below the copper ISQG-low guideline of 65 mg/kg.
- Sediments adjacent to the commercial slipway at site 2 were shown to have extremely high concentrations of mercury (4.02 mg/kg) in comparison to all other sites sampled in this survey. Concentrations of mercury in sediment samples from the marine club slipways at sites 1 and 3, the Boat Ramp and Iron Pot are similar with lower concentrations of 0.11, 0.12, 0.16 and 0.08 mg/kg Hg found respectively. Mercury contamination of these sediments is likely to be from historic antifoulant paints treated with mercurial compounds and/or from fuel oil/hydrocarbon discharges.
- Both the ISQG-low and ISQG-high mercury guidelines were exceeded at the commercial slipway at site 2 (4.02 mg/kg). Of the remaining sites only the Boat Ramp sediments exceeded the ISQG-low guideline of 0.015 mg/kg.
- As for other trace metals, the sediment lead concentration (230 mg/kg) found at the commercial slipway at site 2 was far greater than at other sites. Sediment lead concentrations from the other sites in this survey were in the range of 3-9 times lower with recorded values from the marine club slipways at sites 1 and 3, the Boat Ramp and Iron Pot of 40.8, 70.7, 61.6 and 26.1 mg/kg Lead respectively. It is possible that lead contamination is due to historic organolead paint applications but more likely it is as a result of contamination from leaded fuels. The presence of high lead concentrations at the Boat Ramp site would tend to support this suggestion.

- Both the ISQG-low and ISQG-high lead guidelines are exceeded at the commercial slipway at site 2 (230 mg/kg), while only the ISQG-low was exceeded at site 3 - Marine Club Slipway (70.7 mg/kg), and Site 4 - Boat Ramp (61.6 mg/kg) site. The marine club slipway at site 1 and Iron Pot sites were below the lead ISQG-low guideline of 50 mg/kg.
- The commercial slipway at site 2 indicated the highest zinc contamination with 689 mg/kg being recorded. This result was significantly higher than at the marine club slipways at sites 1 (227 mg/kg), and 3 (129 mg/kg), the Boat Ramp site (116 mg/kg) and the Iron Pot site (184 mg/kg). High sediment zinc concentrations are possibly due to antifoulant co-biocides such as Zinc pyrithine (ZPT) and/or discharges from fuels and oils.
- Both the ISQG-low and ISQG-high zinc guidelines were exceeded at Site 2 – commercial slipway (689 mg/kg) while only the ISQG-low was exceeded at Site 1 - marine club slipway (227 mg/kg). All other sites were below the zinc ISQG-low guideline of 200 mg/kg.

5.0 RECOMMENDATIONS

Through the compilation of this work, several areas where further work is required were noted. These include:

- Initiation of better policy and surveillance with regards to the management of boat hull washing wastewaters.
- Further sediment sampling to determine the extent and zone of contamination of trace metals and antifoulant compounds.
- Depth profiles of sediments to determine whether contamination inputs are declining, particularly for DDT and TBT.
- Determine the bioavailability of contaminants bound to paint flakes in sediments. It is possible that despite exceedances of the ANZECC (2000) guidelines there may be little that is actually bioavailable to benthic organisms.
- Determine whether there are any effects to community structures around the areas of boat maintenance sites and if so, to what extent.
- Conduct shellfish sampling (for trace metals and antifoulants) particularly near areas of main contamination. Shellfish gathering has been noted within 50 meters of the commercial slipway at site 2 where the highest contamination occurs.

6.0 REFERENCES

- Albanis, T.A., Lambropoulou, D.A., Sakkas, V.A., and Konstantinou, I.K. (2002). Antifouling paint booster biocide contamination in Greek marine sediments. *Chemosphere* 48, 475-485.
- Almeida, A.C., Wagener, L.R., Maia, C.B., and Miekeley, N., (2004): Speciation of organotin compounds in sediment cores from Guanabara Bay, Rio de Janeiro (Brazil) by gas chromatography-pulsed flame photometric detection. *Applied Organometallic Chemistry* 18, 694-704.
- ANZECC. (2000). National water quality management strategy: Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australia.
- Biselli, S., Bester, K., Huhnerfuss, H. and Fent, K. (2000). Concentrations of the antifouling compound Irgarol 1051 and of organotins in water and sediments of German North and Baltic Sea marinas. *Marine Pollution Bulletin* 40, 233-243.
- Burggraaf, S., Langdon, A.G., and Wilkins, A.L. (1994): Organochlorine contaminants in sediments of the Tauranga Harbour, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 28, 291-298.
- Coomber, S.D.W., Gardner, M.J., and Boxall, A.B.A. (2002b). Survey of four marine antifoulant constituents (copper, Zinc, diuron and Irgarol 1051) in two U.K estuaries. *Journal of Environmental Monitoring* 4, 417-425.
- Diez, S., Lacorte, S., Viana, P., Barcelo, D., Bayona, J.M. (2005): Survey of organotin compounds in rivers and coastal environments in Portugal 1999-2000. *Environmental Pollution* 136, 525-536.
- Holland, P.T., Hickey, C.W., Roper, D.S., Trower, T.M., (1993): Variability of organic contaminants in inter-tidal sandflat sediments from Manakau Harbour, New Zealand. *Archives of Environmental Contamination and Toxicology* 25, 456-463.

- Iwata, H., Tanabe, S., Ueda, K., Tatsukawa, R., (1995): Persistent organochlorine residues in air, water, sediments and soils from the Lake Baikal region, Russia. *Environmental Science and Technology* 29 (3), 792-801.
- King, N., Miller, M., de Mora, S. (1989). Tributyl tin levels from seawater, sediment, and selected marine species in coastal Northland and Auckland, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 23:287-294.
- Lee, K.T., Tanabe, S., and Koh, C.H. (2000): Distribution of organochlorine pesticides in sediments from Kyeonggi Bay and nearby areas, Korea. *Environmental Pollution* 114, 207-213.
- Long, E. R., MacDonald, D. D., Smith, S. L., and Calder, F. D. 1995: Incidence of adverse biological effects within ranges of concentrations in marine and estuarine sediments. *Environmental Management* Vol 19 (1) pp 81-97.
- Ministry for the Environment (1998). Report on the working party reviewing the use of antifoulants containing organotins in New Zealand. Ministry for the Environment, Wellington. ISBN:0-477-05843-4.
- Nhan, D.D., Loan, D.T., Tolosa, I., and De Mora, S.J. Occurrence of butyltin compounds in marine sediments and bivalves from three harbour areas (Saigon, Da Nang and Hai Phong) in Vietnam. *Applied Organometallic Chemistry* 19, 811-818.
- Pereira, W.E., Hostettler, F.D., Cashman, J.R., Nishioka, R.S., (1994): Occurrence and distribution of organochlorine compounds in sediment and livers of striped bass (*Morone saxatilis*) from the San Francisco Bay-delta estuary. *Marine Pollution Bulletin* 28 (7), 434-441.
- Salazar, M.H., and Salazar, S.M. (1991). Assessing site-specific effects of TBT contamination with mussel growth rates. *Marine Environmental Research* 32(4) 131-150.
- Stewart, C. (2002). Interpretation of Organotin data for sediments and shellfish, Waikawa Bay, Picton. Report prepared for Marlborough District Council.

Stewart, C. (2003). Antifouling co-biocides in New Zealand Coastal Waters. Report prepared for the Ministry for the Environment.

Stewart, C., personal communication October 2005.

Strong, J.M., 2004: Survey of Sediment Quality Within Major Stormwater Drains of the Napier and Hastings Districts. Report for the Hawke's Bay Regional Council. 27pp.

Strong, J.M., 2005: Background Sediment Trace Metal Concentrations of Major Estuarine, Riverine, and Lagoon Systems in the Hawke's Bay Region, New Zealand. "A Tool for the Management of These Resources" MSc Thesis – The University of Auckland, New Zealand. 139pp.

Tanabe, S., Nishimura, A., Hanaoka, S., Yanagi, T., Takeoka, H., Tatsukawa, R., (1991): Persistent organochlorines in coastal fronts. *Marine Pollution Bulletin* 22 (7), 344-351.

Thomas, K.V., McHugh, M., and Waldock, M. (2002). Antifouling paint booster biocides in U.K. coastal waters: inputs, occurrence and environmental fate. *The Science of the Total Environment* 293, 117-127.

Thomas, K.V., McHugh, M., Hilton, M and Waldock, M. (2003). Increased persistence of antifouling paint biocides when associated with paint particles. *Environmental Pollution* 123, 153-161.

Voulvoulis, N., Scrimshaw, M.D., and Lester, J.N., (1999a). Alternative antifouling biocides. *Applied Organometallic Chemistry* 13, 135-143.

APPENDIX 1: SITE PHOTOS

Photo 1: Commercial Slipway (Site #2)



Photo 2: Marine Club Slipway (Site #1)



Photo 3: Marine Club Slipway & Maintenance Berth (Site #3)



Photo 4: Boat Ramp (Site #4)



Photo 5: Iron Pot (Site #5)



Photo 6: Paint flakes in sediment from the Marine Club Slipway (Site #1)



Photo 7: Paint Flakes and over-spray at Marine Club & Maintenance Berth (Site #3)



APPENDIX 2: LABORATORY RESULTS