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Preliminary investigation into contamination on the foreshore downstream of Minim Cove, Mosman Park

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PRELIMINARY INVESTIGATION INTO CONTAMINATION OF THE FORESHORE DOWNSTREAM OF MINIM COVE, MOSMAN PARK

Report of the Swan River Trust

REPORT No 38

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EXECUTIVE SUMMARY

In December 1995 and January 1996, the Swan River Trust and the Water and Rivers Commission undertook a limited sampling program along 450m of the McCabe Street foreshore (embankment, beach and river) adjacent to the current Landcorp development site.

The purpose of the sampling was to analyse water, sediment and mussels to provide an indication of whether contamination levels had changed and to assess whether any cleanup of the foreshore was required.

The Trust collected samples from a range of sites and media, including 11 mussel samples, 4 embankment sediments, 9 beach sediments (surface and subsurface), 11 river sediments, 5 groundwater, and 8 river water samples.

The results indicated that there is an area of significant contamination of embankment and beach sediments for about 150m (between sites 10 and 17). Highest contamination occured in the embankment sediments.

A health risk assessment of the area, based on current use and accessibility, concluded that the extent of contamination represented a marginal health risk. The contamination appeared to exist as 'hot spots' of contamination which would decrease the likelihood of accidental sediment ingestion. These areas could be selectively removed. A full health risk assessment was limited because the full length of the foreshore had not been sampled.

The results indicate that cleanup of some sections of the foreshore are required. To further define the extent of the contamination the Swan River Trust has undertaken an additional 20m grid sampling of the embankment and beach sediments. This information will clarify the full extent of any cleanup or remediation required.

1. INTRODUCTION

In 1995, the Environmental Protection Authority issued an approval for Landcorp to develop, for urban purposes, land between McCabe St Mosman Park and the river. The land was formerly used for fertiliser manufacture and gold extraction. As part of the conditions of development, Landcorp was required to clean up the majority of the site but not the beach and foreshore. The bulk of the contaminated material is to be placed in a secure containment cell.

The land at Rocky Bay in North Fremantle was progressively leased from the Crown by CSBP between 1909 and 1961 for the manufacture of fertilisers and agricultural products. Norseman pyrites were roasted at the site from 1952 until 1961. From about 1952 roasted pyrite cinders were dumped onsite and over the embankment to the river because they were thought to be largely inert and would not harm the environment. Gold smelting and mercury distillation for gold recovery was also carried out and residues dumped on site. All leases were terminated in 1973.

A range of investigations of the contamination on the site and the foreshore have been undertaken by Rockwater (1980), Analab (1981), Technical Assessment Group (TAG) (1983), Maunsell (1986) and recently by the Swan River Trust.

In late 1995, the local community expressed concern about pyrites slurry dumps at the Thomas Perrott Reserve, outside the development area. The Department of Environmental Protection (DEP) contracted the Chemistry Centre of WA (CCWA) to undertake an investigation of the reserve. Three investigation and monitoring bores were constructed in November 1995. One bore was drilled through a pyrites dump within the development site and the other two (one through pyrites and the other through landfill) were outside the development area. The results indicated groundwater was contaminated by cyanide, mercury and arsenic.

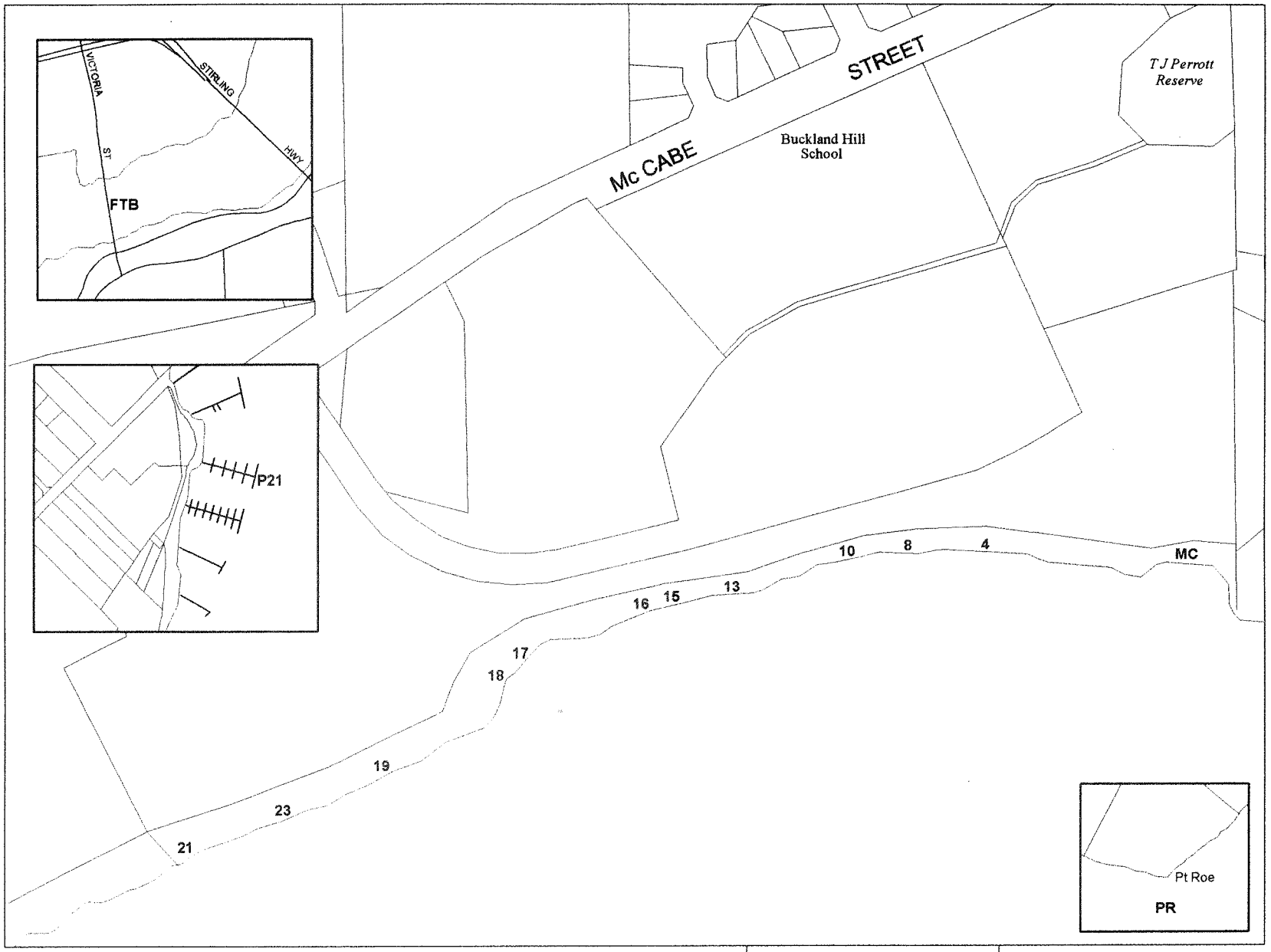
The results of this investigation, and increasing community concern about the level of foreshore contamination, prompted the Swan River Trust (SRT) to undertake a limited site investigation of water, sediment and mussels (December 1995 and January 1996) associated with the foreshore.

2. AIM AND SAMPLING STRATEGY

In December 1995, the Swan River Trust decided, after consultation with the local community, to undertake a limited investigation of the level of foreshore contamination levels in the vicinity of Minim Cove, Mosman Park.

The aim of the investigation was to analyse water, sediment and mussels to provide an indication of whether contamination levels had changed, and to assess whether any cleanup of the foreshore was required.

MAP 1 LOCATION OF SITE AND SAMPLE REFERENCE NUMBERS



LEGEND

Shoreline

Cadastral boundaries

21 Site locations

N

0 100m

Swan River Trust

January 1996

The foreshore investigation for this report extended from Minim Cove to approximately 450m downstream (Map 1). Additional water, sediment and mussel samples were collected from areas upstream and downstream of the site as a basis for comparison.

3. SAMPLING ASPECTS

Details of all sampling methods, site locations, site descriptions and analytical techniques are presented in Appendix 1.

3.1 Sample analysis

Table 1 provides a summary of the range of analytes for each sample medium collected.

Element	Toe of the embankment sediment	Beach sediment	River sediment	Ground water	River water	Mussels
Arsenic As	X	X	X	X	X	X
Cadmium Cd	X	X	X	X	X	X[1]
Copper Cu	X	X	X	X	X	X[1]
Lead Pb	X	X	X	X	X	X
Zinc Zn	X	X	X	X	X	X[1]
Inorganic Arsenic						X
Mercury Hg	X	X	X			X
Nickel Ni	X[1]	X[1]	X[1]			X[1]
Iron Fe	X[1]	X[1]	X[1]			X[1]
Vanadium Va	X[1]	X[1]	X[1]			X[1]
Hydrocarbons & Cyanide CN	Minim Cove only	Minim Cove only				

Table 1. Analytes determined for each sample medium

Table notes
X[1] = December samples only

Sample numbers include a code designating the type of sample. The codes used were toe of the embankment sediment (ES), beach sediment (BS), river sediment (RS), groundwater (GW), river water (RW), mussels (M). These codes appear in the tables of the report and Figure 1 illustrates where the samples were collected.

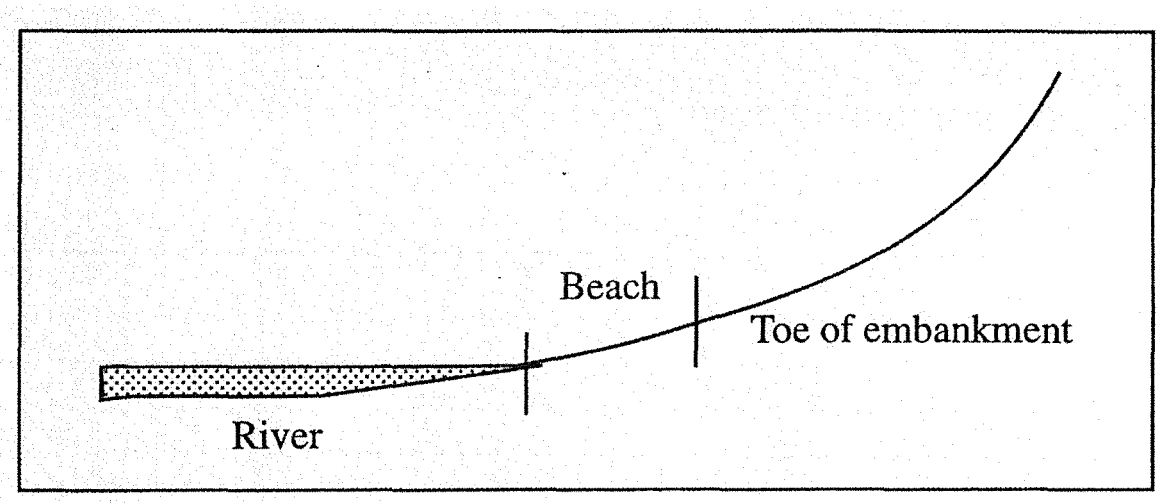


Figure 1. Illustration of sample collection areas on the foreshore

3.1.1 Reporting Limits

All results presented in the analytical reports are an average of two determinations which is a standard chemical procedure. The reporting limits are those used by Chemistry Centre of WA for metal analysis (Table 2).

Element	Water (mg/L)	Sediment (mg/kg dry weight)	Mussels (mg/kg drained weight)
Cyanide CN	0.01	0.1	na
Mercury Hg	0.0005	0.01	0.01
Arsenic As	0.005	0.5	0.05
Cadmium Cd	0.001	0.1	0.1
Copper Cu	0.001	0.1	0.1
Lead Pb	0.001	0.5	0.1
Zinc Zn	0.02	0.1	0.1

Table 2. Reporting limits for heavy metals in water, sediment and mussels

Table notes
mg/l = milligram per litre
mg/kg = milligram per kilogram

3.2 Chemical criteria to assess public health and environmental impact

The data were reviewed using the guidelines presented in Table 3. The levels listed in these guidelines generally indicate levels at which further investigations of a site should be undertaken. Levels higher than those quoted do not automatically imply unacceptability or that the levels are likely to pose a significant health risk. They provide an indication of investigation threshold for health and environmental concerns. Generally, criteria for clean-up of a site are developed on a case by case basis, taking into account any risks and the cost of cleanup.

The Australian Food Standard Code A12 (AFSC) and the draft NH&MRC Drinking Water Guidelines are the strictest standards applying to human health. The criteria are based on a lifetime's consumption of food and/or water at those levels. Therefore, the application of these standards to acute pollution levels will provide only a general indication of the acceptability of the water against these standards.

Currently there are no criteria set in WA for groundwater discharging into an estuarine water body. The drinking water criteria, combined with the ecosystem protection criteria mentioned below, provide the best guidance for the level of contamination in groundwater in this instance. The standards applied to the

groundwater in this report are the highest standards available for marine protection.

The ANZECC/NHMRC (1992) Australia and New Zealand Guidelines for the Assessment and Management of Contaminated Sites list the proposed guidelines for health investigation and environmental investigation. The health investigation guidelines relate to arsenic, cadmium and lead. These criteria are referred to in this report in assessing the levels of contamination in sediments. Section 7 and Appendix 2 focus on the health guidelines and the main text of the report deals with the environmental guidelines.

These values have been set as guidance values only and site specific factors will influence their use. The EPA (1993) recommended that these values be set as the site cleanup criteria. This was further endorsed by Ministerial approval in February 1994. Consequently these values have been used to identify contamination levels on the foreshore (beach, embankment).

The ANZECC (1992) ecosystem protection water quality values are set for the long-term maintenance of organisms in marine systems. Exceedence of the guidelines would result in the environmental value (i.e. protection of the aquatic ecosystem) not being maintained. The guidelines to protect aquatic ecosystems are often the most stringent and generally ensure that environmental values, such as edible fish, shellfish, and wildlife are also protected (ANZECC, 1992).

There are no criteria for comparing contamination levels in estuarine sediments. The ANZECC/NHMRC (1992) guidelines have been used to provide a broad indication of pollution. Greater emphasis is placed on comparison of heavy metal levels found in other parts of the river system.

Public health and environmental risk factors are the two key components used in assessing the impact of the contaminants in the environment. The risk assessment process is a determination of the level of risk for humans or the flora and fauna. The level of risk is associated with specific doses of the pollutants which could result from either or both, direct and indirect exposure.

Health risk assessment is a process of predicting whether adults or children are likely to suffer adverse health effects from exposure to levels of contamination over certain periods. Precise risks cannot always be defined but the aim is always to be conservative and allow a margin for safety.

Some forms of contamination, such as hydrocarbons and heavy metals may persist for long periods of time. This may represent an ongoing potential risk to health and the environment in a localised area.

Medium	Criteria/ Guidelines	Arsenic As	Cadmium Cd	Copper Cu	Lead Pb	Mercury Hg	Zinc Zn
Mussels	Food Standard Code A12 (1994) mg/kg wet weight	1 (inorganic)	2	70	2.5	0.5	1000
Sediments [1]	ANZECC/ NH&MRC Environmental Investigation Guidelines (1992) mg/kg dry weight	20	3	60	300	1	200
Sediments [2]	ANZECC & NH&MRC Health Investigation Guidelines (1992) mg/kg dry weight	100	20	-	300	-	-
Water	ANZECC ecosystems protection (1992) mg/l	0.05	0.002	0.05	0.005	0.0001	0.05
Water	NH&MRC Drinking Water(1992) mg/l	0.007	0.002	1	0.01	0.001	3

1 used by SRT for environmental assessment in this Report

2 used by HDWA Health Risk Assessment (Appendix 2)

Table 3. Criteria and guidelines for establishing the significance of contamination.

4. MUSSEL RESULTS

Generally, mussels are used as an indicator species for pollution of waterways. Mussels are filter feeders, meaning that they filter food material from the surrounding water. As mussels are sedentary any accumulation of pollutants provides an indication of the level of pollution in the local area. Fish and other animals which are mobile do not provide as clear an indication of pollution as mussels because the contamination they accumulate may have been incorporated from a number of areas.

Results of the chemical analysis for mussels are sumarised in Table 4. All mussel samples, except one sample which was 3 times higher than the maximum permitted concentration (MPC - AFSC, 1994) for lead, complied with the MPC for heavy metals.

Maunsell's investigation found that one mussel in an area (Site 12) was contaminated with mercury above the MPC (AFSC, 1994) for commercial shellfish and the TAG (1983) report found one sample above the MPC for lead.

mg/kg wet weight	Arsenic As Inorganic	Arsenic As Total	Cadmium Cd	Copper Cu	Lead Pb	Mercury Hg	Zinc Zn
Criteria (AFSC, 1994)	1		2	70	2.5	0.5	1000
Site 8M		2.68	0.80	12.0	7.50	0.26	67
Site 10M		2.26	0.15	3.10	0.26	0.02	46
Site 13M	0.51	2.56	0.19	3.0	0.25	0.01	51
Site 17M	0.50	2.38	0.10	1.90	0.10	0.01	29
Site 17bM	0.08	2.27	0.12	2.10	0.47	0.01	33
Site 19M		2.44	0.14	3.70	0.55	0.03	43
Site 23M		2.73	0.45	8.50	0.38	0.08	62
Fremantle bridge M	0.10	2.30			0.40	0.02	
Pier 21M	0.10	2.10			0.40	0.01	
River channelM	0.10	2.10			0.50	0.01.	
Off Point Roe M	0.10	2.0			0.40	0.01	

Table 4. Chemical analysis (mg/kg wet wt) of mussel samples

Table notes
M = mussel sample
AFSC, 1994 = Australian Food Standards Code A12, 1994

5. FORESHORE SEDIMENT RESULTS

Samples were collected from three areas on the foreshore; the toe of the embankment, the beach and river sediment (transect at 5 m intervals between the beach and the river channel and 5 samples collected 10 metres from the shoreline).

Figure 1 illustrates where each sediment sample was collected.

5.1 Toe of the embankment results

Table 5 presents the results of the toe of the embankment sediment samples collected in December 1995 and January 1996.

mg/kg dry bass	Arsenic As	Cadmium Cd	Copper Cu	Lead Pb	Mercury Hg	Zinc Zn
Criteria (ANZECC/ NHMRC 1992)	20	3	60	300	1	200
Site 16ES	660 (33)	74 (24.7)	32000 (533.3)	2	0.03	27000 (135.0)
Site 15 ES	2700 (135)	41 (13.7)	570 (9.5)	2	0.01	150
Site 10 ES	280 (14)	9.3 (3.1)	1900 (31.7)	430 (1.4)	0.54	1800 (9.0)
Minim CoveES	31 (1.6)	0.6	42	72	0.12	180

Table 5. Chemical analysis (mg/kg) of sediments collected from the toe of the embankment.

Table notes
ES = toe of the embankment sediments
1 Site 15 are results collected from samples collected from a hole drilled 0.5m into the toe of the embankment
2 Results in brackets represent the approximate number of times the result exceeds the criteria. Where no bracketed number appears the exceedence was less than 1 times.

Arsenic levels in the toe of the embankment at sites 10, 15 and 16 ranged from 280 - 2700mg/kg. The sediments collected were targeted at areas that showed visible staining.

Cadmium levels were elevated at sites 15 and 16, ranging from 41 to 74mg/kg. Copper levels ranged between 570 and 32000mg/kg at sites 10, 15 and 16 respectively. Lead levels were generally within the criterion. Mercury levels were below the criterion. Zinc levels showed elevations at sites 10 (1800mg/kg) and 16 (27000mg/kg). Comparative data is limited as will be discussed in Section 8.2. Maunsell (1986) sampled eight (8) sites along the foreshore but only three (3) sites represented samples taken from the toe of the embankment.

Table 6 presents the same data as a graded shading to represent the areas of contamination. The dots show samples that were below the environmental investigation criteria (ANZECC/NHMRC, 1992). This table clearly shows that there are elevated levels of heavy metals at sites 10, 15 and 16, particularly arsenic, cadmium, copper and zinc.

West	Site number									East
	21	23	19	18	17	16ES	15ES	10ES	4	Minim Cove ES
	ns	ns	ns	ns	ns				ns	
As										
Cd										•
Cu										•
Pb						•	•			•
Hg						•	•	•		•
Zn							•			•

Table 6. Exceedence of the criteria for the toe of the embankment samples

Table notes
ES = Toe of the embankment sample
ns = not sampled

Code	Exceedence above criteria
•	<1 times
	1 - 10 times
	10 - 100 times
	100 - 600 times

5.2 Beach Sediments Results

Table 7 presents the data for surface and subsurface beach sediments. Surface beach sediments were elevated in arsenic, cadmium, copper and zinc at sites 15, 16 and 18. At sites 15 and 16 this corresponded with elevated levels in the toe of the embankment sediments. Site 18 was not sampled for the embankment. Beach sediment sampling was more extensive than the embankment

Subsurface beach sediments were generally within the criteria. This indicates that the contamination is confined to the surface of the beach.

mg/kg dry basis	Arsenic As	Cadmium Cd	Copper Cu	Lead Pb	Mercury Hg	Zinc Zn
Criteria (ANZECC/ NHMRS, 1992)	20	3	60	300	1	200
Site 21BS	13	0.6	43	9	0.02	24.0
Site 18BS	200 (10)	4.2 (1.4)	1100 (18.3)	2100 (7.0)	1.6 (1.6)	500 (2.5)
Site 17BS	17	0.6	29	67	0.02	86
Site 17BSsub	30 (1.5)	0.5	82 (1.4)	18	0.01	190
Site 16BS	210 (10.5)	5.8	1000 (16.7)	740 (2.5)	0.26	950 (4.8)
Site 16BS sub	13	1.2	35	6	0.16	150
Site 15BS	260 (13)	32 (11)	25000 (416.7)	520 (1.7)	<0.01	16000 (80.0)
Site 10BS	12	1	22	20	0.3	90
Site 10BS sub	9	0.8	2	1	0.02	4.9
Site 4BS	25 (1.2)	0.8	8.7	25	0.98	20
Site 4BS sub	26 (1.3)	0.9	3.9	6	1.9 (1.9)	7.7
MC1BS	13	0.7	28	130	0.18	60
MC1BS sub	10	0.8	39	120	0.39	81
MC2BS	13	0.5	65 (1.1)	32	0.17	56
MC2BS sub	15	0.7	6.5	31	0.1	42

Table 7. Chemical analysis of beach sediments (surface <0.2m and subsurface 0.5m).

Table notes
BS = Beach sediments
1 Results in brackets represent the approximate number of times the result exceeds the criteria.

Tables 8 and 9 presents Table 7 data as a graded shading to represent the areas of contamination. The dots show samples that were below the environmental investigation guidelines (ANZECC/NHMRC, 1992).

West	Site number								East
	21BS	18BS	17BS	16BS	15BS	10BS	4BS	Minim Cove 1BS	Minim Cove 2BS
As	•		•			•		•	•
Cd	•		•			•	•	•	•
Cu	•		•			•	•	•	
Pb	•		•			•	•	•	•
Hg	•	•	•	•	•	•	•	•	•
Zn	•		•			•	•	•	•

Table 8. Exceedence of criteria for the beach - surface sediments (<0.2m deep).

Table notes for Table 8 & 9
ES = Toe of the embankment sample
ns = not sampled

Code	Exceedence above criteria
•	<1 times
	1 - 10 times
	10 - 100 times
	100 - 600 times

West	Site number								East
	21BS ns	18BS ns	17BS ns	16BS	15BS	10BS	4BS	Minim Cove 1BS	Mini m Cove 2BS
As				•		•		•	•
Cd			•	•		•	•	•	•
Cu			•	•		•	•	•	•
Pb			•	•		•	•	•	•
Hg			•	•		•		•	•
Zn			•	•		•	•	•	•

Table 9. Exceedence of criteria for the beach - subsurface sediments (0.5m deep).

5.3 River sediments

Table 10 presents the results for river sediments collected in a transect out from site 15 to the navigation channel at 5m intervals and at 10m distance from shore for other sites. The results of all the river samples generally are 1 - 10 times above the ANZECC/NHMRC levels for investigation. It is interesting to note that this level of elevation is evident at least 20m out from site 15.

The area of highest contamination was recorded in the river out from sites 15 and 16. These two sites showed contamination of beach and embankment sediments.

mg/kg dry basis	**Arsenic As**	**Cadmium Cd**	**Copper Cu**	**Lead Pb**	**Mercury Hg**	**Zinc Zn**
Criteria (ANZECC/ NHMRC, 1992)	20	3	60	300	1	200
Transect sites						
Site 15aRS	24.0 (1.2)	1.3	51	9.0	0.1	90.0
Site 15bRS	79.0 (4.0)	3.2 (1.1)	400 (6.7)	1000.0 (3.3)	0.84	850.0 (4.3)
Site 15cRS	56.0 (2.8)	2.1	170 (2.8)	520.0 (1.7)	0.24	360.0 (1.8)
Site 15dRS	45.0 (2.3)	2.3	74 (1.2)	130.0	0.19	360.0 (1.8)
Site 15 channelRS	15.0	0.6	5.9	15.0	0.13	22.0
10m Sites						
Site 4RS	12.0	0.5	10	23.0	0.93	45.0
Site 10RS	12.0	18 (6)	26	59.0	0.18	88.0
Site 16RS	81.0 (4.1)	33 (11)	590 (9.8)	2300.0 (7.7)	0.88	1300.0 (6.5)
Site 17RS	36.0 (1.8)	1.3	53	59.0	0.12	160.0
Site 21RS	15.0	0.6	8	19.0	0.09	33.0
Site MC3RS	13	0.6	7.6	22	0.16	28

Table 10. Chemical analysis (mg/kg) of river sediments

Table notes
RS = River sediment
a = 5m from shore
b = 10m from shore
c = 15m from shore
d = 20m from shore

Tables 11 and 12 present Table 10 data as a graded shading to represent the areas of contamination. The dots show samples that were below the criteria.

West	Site number						East
	21RS	17RS	16RS	15RS	10RS	4RS	Minim Cove 3RS
As	•				•	•	•
Cd	•	•				•	•
Cu	•	•			•	•	•
Pb	•	•			•	•	•
Hg	•	•	•	•	•	•	•
Zn	•	•			•	•	•

Table 11. Exceedence of criteria for river sediments 10 metres from shore.

Table notes for Tables 11 & 12.

RS = River sediments

Site 15RS = Site 15aRS taken 10m part of the transect out from site 15.

Code	Exceedence above criteria
•	<1 times
	1 - 10 times
	10 - 100 times
	100 - 600 times

West		Site number			East
	15aRS	15bRS	15cRS	15dRS	Channel RS
Metre from shore	5		15	20	
As					•
Cd	•		•	•	•
Cu	•				•
Pb	•			•	•
Hg	•	•	•	•	•
Zn	•				•

Table 12. Exceedence of criteria for an offshore transect at site 15.

Source	This study		Chegwidden, 1980			Hosja et al, 1993	
Element mg/kg	Transect results	10m samples	Chidley Point	Lilac Hill	Bayswater Main Drain	Perth Water	Melville Water
Cadmium, Cd	0.6 - 3.2	0.5 - 33	0.6- 1.4	<0.3 - 1	0.35- 3.9		
Copper, Cu	5.9 - 400	7.6 - 590	18 - 71	2.7 - 13	10 - 118		
Zinc, Zn	22 - 850	28 - 1300	5.4- 255	18 - 80	63 - 900	70 - 640	33 - 300

Table 13. Comparison of river sediment results (mg/kg) with other studies.

Table 13 compares the results from previous investigations into heavy metals levels in sediment of the Swan River system with those collected during this study. The levels of heavy metals recorded in river sediments adjacent to the McCabe St site are higher than those recorded elsewhere in the river. However, the massive volume of water passing the site each day significantly reduces the risk of the contamination becoming a threat to the river ecology.

Further work will be undertaken prior to an assessment of whether cleanup of the river sediments would be required.

Further work will be undertaken prior to an assessment of whether cleanup of the river sediments would be required.

6. WATER RESULTS

6.1 Groundwater Results

There are no specific guidelines for groundwater discharge to the river. Consequently the ANZECC ecosystem protection and the NH&MRC drinking water guidelines have been used to provide an indication of pollution.

Groundwater samples generally complied with both drinking water and marine water criteria for ecosystem maintenance for arsenic, cadmium, copper and lead (Table 14). Slightly elevated results were recorded at site 16 for cadmium and zinc and at Minim Cove and site 10 for zinc. The level of exceedence was less that 5 times the marine criteria and dilution by river water would greatly reduce the concentrations.

One groundwater, sample collected from site 4, recorded levels of mercury 560 times the marine criteria. Continued leaching of mercury into the river system is of concern, as mercury can rapidly accumulate in the food chain. Removal of the source of any ongoing mercury contamination is necessary.

This site where the high mercury was recorded was below the slurry dump for gold wastes. This waste dump is to be removed during the cleanup of the site. Monitoring of groundwater should continue after the cleanup is complete.

This result indicates that there is groundwater contamination in the area of Minim Cove, however, the extent and severity cannot be determined from the data collected.

The groundwater results of samples collected in December have not been included in this report. The water samples were unfiltered and contained sediments. The results therefore gave no indication whether elevated contamination levels were due to localised sediment from the sampling area or were present in the groundwater itself. The 100 - 600 times levels of heavy metals reported in the samples are clearly a reflection of the sediment component of the samples rather than the groundwater component. This is supported by the results of groundwater monitoring reported above.

	Arsenic As	Cadmium Cd	Copper Cu	Lead Pb	Mercury Hg	Zinc Zn
Criteria (ANZECC, 1992)	0.05	0.002	0.05	0.005	0.0001	0.05
Criteria (NH&MRC, 1994)	0.007	0.002	1	0.01	0.001	3
Site 4GW	0.005	0.001	0.006	0.002	0.056	0.03
Site 10GW	0.005	0.001	0.005	0.003	<0.0005	0.08
Site 16GW	0.005	0.004	0.022	0.002	<0.0005	0.24
Site 17GW	0.006	0.001	0.025	0.005	<0.0005	0.04
Minim Cove 2GW	0.005	0.001	0.004	0.005	<0.0005	0.11

Table 14. Chemical analysis (mg/L) of groundwater samples

Table notes
GW = Groundwater sample

6.2 River water

Samples were collected at a distance of 10m from the foreshore in the local area. Background samples were collected from Fremantle Traffic Bridge and in the middle of the navigation channel opposite the site. The sample was collected approximately 10 cm above the sediment.

River water samples were all at or below the criteria for the long term maintenance of the ecosystem (ANZECC, 1992) for arsenic, cadmium, copper, lead and zinc (Table 15).

mg/l	Arsenic As	Cadmium Cd	Copper Cu	Lead Pb	Zinc Zn
Criteria (ANZECC, 1992)	0.05	0.002	0.05	0.005	0.05
Site 21RW	<0.005	<0.001	0.002	0.005	0.02
Site 17RW	<0.005	<0.001	0.002	0.005	<0.02
Site 16RW	<0.005	<0.001	0.002	0.003	<0.02
Site 10RW	<0.005	<0.001	0.002	0.004	<0.02
Site 4RW	<0.005	<0.001	0.002	0.004	<0.02
Minim Cove 3RW	<0.005	<0.001	0.002	0.005	<0.02
Fremantle bridgeRW	<0.005	<0.001	<0.001	0.004	<0.02
Adjacent to McCabe StRW	<0.005	<0.001	<0.001	0.001	<0.02

Table 15. Chemical analysis (mg/L) of river water samples.

Table notes
RW = River water sample

7. HEALTH RISK ASSESSMENT

A limited health risk assessment for the foreshore area was undetaken by the Health Department of WA. The assessment was limited because the number of samples collected was inadequate for complete characterisation of the area. The assessment was based on the current use and accessibility of the foreshore. The Health Department's full report is attached in Appendix 2 and the conclusions are provided below.

The data are adequate to show that the site is contaminated, however, the full extent of the contamination is not clear. It is possible that contamination of any health concern only exists as 'hot spots' which would decrease the likelihood of accidental sand/sediment ingestion. Such hot spots could be removed selectively. A more complete site assessment would be required in order for this to be determined and this has been undertaken.

Some accidental ingestion of sand or sediment is likely during normal beach play by children. Based on the available data, it is doubtful that there would be appreciable health risks associated with occasional visits by children to the beach. However, lead and arsenic contamination is sufficiently high to be of concern for children who frequently visit and play on the beach. These children may accidentally ingest sufficient sand or sediment to exceed the safe or tolerable levels for these substances set by the WHO, and this may pose a health risk if exposure continues in the long term.

Currently, public access to the foreshore is limited, but access is likely to increase following development of the McCabe Street site. It is unlikely that children will have continuous exposure to high levels of contaminants, limiting any risks to health. However, the exposure of children on an infrequent basis cannot be ignored because intake from this source would contribute to the total body burden of these contaminants from all sources.

The extent of contamination at the foreshore site represents a marginal health risk and it would be inappropriate to restrict public access to the beach. Signposting to inform the public about the presence of the contamination would be appropriate prior to any cleanup or remediation.

8. DISCUSSION

8.1 Relating sediments, mussels and water

Mussels

All mussel results indicate that mussels were generally within acceptable limits for consumption. There was one exception and that was a sample which had lead levels 3 times the acceptable food limit. This indicates that contamination on the foreshore is not generally being accumulated by mussels in the area and subsequently not being passed on up the food chain.

Toe of embankment sediments

Sediment results from the toe of the embankment identify an area of contamination at sites 10, 15 and 16, corresponding with discoloration of the sediment. However, sampling was only conducted in this area and at Minim Cove. Consequently results from Maunsell (1986) have also been reviewed. These results also indicated areas of contamination between sites 10 and 16. Maunsell (1986) sampled only three toe of the embankment areas and these have been replicated in the recent survey. No investigations of the levels of contamination of the toe of the embankment have extended further than between sites 10 and 16. A more detailed investigation of the contamination levels in the toe of the embankment is required before clear definition of the contamination could be made and this has been undertaken.

Beach Sediments

Beach sediment samples clearly showed contamination at sites 15,16 and 18, particularly for copper, again corresponding to discoloration of the sediment. Contamination was confined to the top 20cm of sediments. Substrate samples collected below this depth did not exceed the criteria.

River sediments

Some contamination of the river sediments was evident. Further work is required to identify the extent and severity of this contamination and whether any cleanup is necessary.

Groundwater

Groundwater samples were generally within acceptable limits for drinking water and dilution with river water should further reduce the levels. One sample (Site 4) of groundwater exceeded the mercury criteria by 560 times. The cause of this high level is almost certainly the gold residue dump on the shore which will be removed as part of the site cleanup. Monitoring of the groundwater should continue at this site.

River water

River water samples indicated no contamination derived from the site.

8.2 Comparing previous results

TAG (1983) reported that the sediment contamination of the foreshore was primarily around the drainage outfalls, particularly at Site 10. All these samples were collected from the beach area.

Maunsell (1986) reported that about 250 metres of the foreshore was contaminated with a range of toxic metals between 1-130 times ANZECC/NHMRC (1992) guidelines for contaminated sites and recommended removal to minimise public risk.

Comparative data are limited as will be discussed. Maunsell (1986) sampled eight (8) sites along the foreshore. Three samples were collected from the toe of the embankment (sites 10B, 10C and 16C), three from the beach (sites 9, 16C and 18) and two sites (13 and 15) where it is unclear whether the samples were beach or toe of the embankment. However, the results from these sites (13 and 15) are similar to those collected in the recent survey from the beach.

8.2.1 Toe of the embankment sediments

The toe of the embankment sediment results presented in Table 16 are similar between the two studies suggesting that there is no new contamination on the foreshore.

mg/kg	Arsenic	Cadmium	Copper	Lead	Mercury	Zinc
Site 10						
Maunsell 10B	200	6.3	1100	2300	0.75	270
Maunsell 10C	850	5.1	3300	3100	0.8	3100
SRT	280	9.3	1900	430	0.54	1800
Site 16						
Maunsell	780	95	26500	190	0.78	40000
SRT	660	74	32000	2	0.03	27000

Table 16. Comparison of toe of the embankment sediment data.

8.2.2 Beach Sediments

There are only very limited data available for comparison between previous investigations and the current results. However, the general similarity in the results suggests that the contamination is not recent. Table 17 presents the limited data available for comparison.

mg/kg	Arsenic	Cadmium	Copper	Lead	Mercury	Zinc
Site 15						
Maunsell	540	35	6650	45	0.62	11000
SRT	260	32	25000	520	<0.1	16000
Minim Cove						
TAG	3.4	1	32	18	1	17
SRT1	13	0.7	28	130	0.18	60
SRT2	13	0.5	65	32	0.17	56

Table 17. Comparison of beach sediment data

Table notes
SRT1 = Minim Cove1
SRT 2 = Minim Cove 2

9. ISSUES AND GENERAL CONCLUSIONS

Mussels

The mussels collected from the immediate foreshore were within limits for human consumption, except one sample (site 8) which was three times the maximum permitted concentration for lead. This indicates that contamination on the foreshore is not generally being accumulated by the mussels in the area and is not being passed up the foodchain.

Toe of the embankment sediments

There is an area of significant contamination of toe of the embankment between sites 10 and 16, and beach sediments between sites 10 and 18 on the foreshore. Highest contamination levels occur on the toe of the embankment but significant contamination was recorded in the top 20cm of beach sediments. This suggests that material has fallen down the bank into the river and is not the result of recent leaching through groundwater.

It is estimated that about 140 metres of the toe of the embankment between sites 16 and 10 has been contaminated with elevated arsenic, copper and zinc. This distance is the extent of sampling of the toe of the embankment and further investigations are required if conclusions are to be made about the entire 450m of foreshore. This work has been undertaken and will be report separately.

The evidence of contamination of the toe of the embankment, which appeared to coincide with prominent colours, suggests that other visibly stained areas of the toe of the embankment and beach may have similar levels of contamination to those sampled. The levels of contamination identified by this investigation indicate that some site remediation of the foreshore is required.

Beach sediments

Contamination of the beach sediment is evident, particularly at sites 15, 16 and 18 (about 120m). These results and those of previous investigations suggest that the contamination is not recent and was the result of on-site dumping.

The accessible part of the beach from the existing cycle way has levels of contamination that exceed the contaminated site investigation criteria (ANZECC/NHMRC, 1992), particularly for copper and zinc.

River sediments

Some contamination of the river sediments was evident. Further work is required to identify the extent and severity of this contamination.

Groundwater

There are no specific guidelines for groundwater discharge to the river. Consequently the ANZECC ecosystem protection and the NH&MRC draft Drinking Water Guidelines have been used to provide an indication of pollution. Groundwater samples were generally within acceptable limits for drinking water and dilution with river water should further reduce the levels. One sample (Site 4) of groundwater exceeded the mercury criteria by 560 times.

The cause of this high level is almost certainly the gold residue dump on the shore which will be removed as part of the site cleanup. Monitoring of the groundwater should continue at this site.

River water

River water samples were all below the criteria for the long term maintenance of the ecosystem (ANZECC, 1992) for arsenic, cadmium, copper, lead and zinc.

Limited health risk assessment

The risk assessment provided by the Health Department concluded that the extent of contamination represents a marginal health risk. The contamination appears to exist as 'hot spots' of contamination which would decrease the likelihood of accidental sediment ingestion. These areas could be selectively removed. The site assessment was qualified by the available data which were inadequate for full site characterisation.

10. RECOMMENDATIONS

1. The levels of contamination identified by this investigation indicate that some site remediation of the toe of the embankment and beach is required.

2. The extent of contamination at the foreshore site represents a marginal health risk and it would be inappropriate to restrict public access to the beach. Signposting to inform the public about the presence of the contaminants should be erected pending implementation of a remediation strategy.

3. A more detailed investigation of the contamination levels in the toe of the embankment would be required before clear definition of the extent of toe of the embankment contamination could be made. The Swan River Trust has commenced this work which will be reported separately.

4. Monitoring of groundwater should continue after the cleanup is complete particularly at site 4.

11. REFERENCES

Analabs; 1981; University of WA Mosman Park Land - Results of Soil Testing for Heavy Metals at North Fremantle Lot 416

Australian Food Standard Code A12 (AFSC); (1994)

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Hosja W, Schulz RS, & Deeley DM; 1993; Chromium and zinc levels in water, sediment and biota of the Swan-Canning Estuary, Perth, Western Australia; Swan River Trust, Report No 9

Maunsell & Partners; 1986; McCabe St Development Study - Final Report

National Health and Medical Research Council (NHMRC); 1994; Drinking Water Guidelines (draft)

Rockwater; 1980; University of WA Mosman Park Land - Results of Testing Groundwater Quality North Fremantle Lot 416

Technical Assessment Group (TAG); 1984; CSBP fertiliser works Mosman Park; Report of the Technical Assessment Group

12. APPENDICES

Appendix 1.

Details of the sampling strategy

1.0 Aim

The original intention of the investigation on the 28 December 1995 was to collect preliminary samples of sediment and mussels to assess whether it was necessary to undertake a more intensive monitoring program in the area.

1.1 Sampling techniques

1.1.1 Monitoring bore construction

Five boreholes were drilled along the foreshore at approximately high water level mark to depths of between 0.55 m and 1 m below surface. Boreholes have been numbered MC 4 to MC 8 inclusive, (these bore holes are located at the sites shown on fig 1 as follows: MC4, site 17; MC5, site 16; MC6, site 10; MC7, site 4; MC8, Minim Cove 2).

Because of the inaccessibility of the shoreline to a conventional drilling rig, each bore was drilled using a hand au ger and a portable jack hammer. The latter was required to break through the limestone substrate to enable soil samples to be taken.

Each bore was constructed with a length of 0.4 mm slotted PVC casing. The PVC extends from the base of the bore to approximately 0.2 m above the surface. The annulus was allowed to collapse around the lower 0.5m of the bore and was back filled with a gravel pack to surface. The top of each bore is secured with a 50 mm end cap.

Development of each bore was accomplished using a pulsed centrifugal pump to clear any debris. Sampling was not begun until the groundwater contained in the casing was clear. Decontamination of the pump and ancillary equipment was conducted between each borehole.

1.1.2 Beach sediment sampling

Two soil samples were recovered from each bore, a surface sample of the first 0.2 m and a second substrate sample to the base of the bore. Each sample was sealed in 500 ml glass jars. The jars were pre-washed in an acid solution prior to sampling. Additional beach sediments were collected from sites where bores were not installed.

Beach sediment samples were analysed for Arsenic (As), Cadmium (Cd), Copper (Cu), Lead (Pd), Mercury (Hg) and Zinc (Zn).

1.1.3 Embankment sediment sampling

Samples were collected from the surface and sealed in a pre-acid washed 500ml glass jar.

A sample was collected at site to a depth of about 0.5 metres using the handheld jack hammer. This sample was also sealed in an pre-acid washed 500ml glass jar.

Embankment sediment samples were analysed for Arsenic (As), Cadmium (Cd), Copper (Cu), Lead (Pd), Mercury (Hg) and Zinc (Zn).

1.1.4 River sediment sampling

Sediments were collected by divers using a 0.5m length of 50mm diameter PVC pipe hammered into the sediment using a rubber mallet. A PVC end-cap was fitted to the top of the pipe once it had been driven into the substrate to a depth of 20cm, and another fitted to the other end upon extraction of the pipe and core. The pipe was subsequently transported to the surface where it was stored on the support vessel.

The core sample was left upright to settle for 10-15 minutes before decanting the excess water from the top of the pipe. The core was then extracted from the bottom of the pipe straight into an acid-washed, polyethylene container. The exercise was repeated a number of times in order to provide sufficient sample.

For those sites where the substrate was too hard to penetrate with the corer, sediment was scraped into a glass beaker and then transferred into the plastic containers back on the vessel.

River sediment samples were analysed for Arsenic (As), Cadmium (Cd), Copper (Cu), Lead (Pd), Mercury (Hg) and Zinc (Zn).

1.1.5 Groundwater sampling

Bores created as described in Section 1.1.1 were sampled for groundwater. Each sample was recovered using an individual teflon disposable bailer. This was done to ensure that no cross-contamination of groundwater samples occurred.

Groundwater samples were analysed for Arsenic (As), Cadmium (Cd), Copper (Cu), Lead (Pd), Mercury (Hg) and Zinc (Zn).

1.1.6 River water sampling

Water samples were collected in 1L acid washed, plastic bottles by divers. The bottles were uncapped and filled with water as close to the sediment/water interface as possible, taking care to avoid any suspended solids stirred up from the sediment.

River samples were analysed for Arsenic (As), Copper (Cu), Cadmium (Cd), Lead (Pd), and Zinc (Zn).

1.1.7 Mussels

Mussels were collected from the rocks along the McCabe Street foreshore and from a number of different wood and concrete substrates upstream and downstream of the site. The mussels sorted by size and cleaned of growth with distilled water. The mussels were kept in sealed plastic sample bags and stored on ice until delivery to the laboratory.

Mussels were shucked with titanium knife and flesh was removed and placed on blotting paper before digest. Mussels were analysed for Total Arsenic, (As) Inorganic Arsenic, Cadmium (Cd), Copper(Cu), Lead(Pb), Mercury(Hg), and Zinc(Zn). A number of mussels were collected at each site and these were homogenised in a specially constructed mincer using titanium blades.

2.0 Analytical techniques

Sediment

Element	**Method**
Arsenic	Two acid attack ICP-AES finish
Cadmium	Two acid attack ICP-AES finish
Copper	Two acid attack ICP-AES finish
Zinc	Two acid attack ICP-AES finish
Lead	Same as acid attack for arsenic but flame AAS
Mercury	Triacid attack in the presence of vanadate and VGAAS finish

Water

Element	**Method**
Arsenic	Acid digest VGAAS
Cadmium	UV radiation digest followed by Anodic stripping voltametry
Copper	UV radiation digest followed by Anodic stripping voltametry
Zinc	ICP-AES
Lead	UV radiation digest followed by Anodic stripping voltametry
Mercury	Mercury digest and VGAAS

Mussel

Element	**Method**
Arsenic	Acid digest VGAAS
Cadmium	Two acid attack ICP-AES finish
Copper	Two acid attack ICP-AES finish
Zinc	ICP-AES
Lead	Two acid attack ICP-AES finish
Mercury	Mercury digest and VGAAS

3.0 Site characteristics

3.1 River site characteristics.

Substrate characteristics from which the samples were collected varied from limestone rubble to course, grey sand as shown in Table 1.

Table 1: Site descriptions for McCabe St foreshore investigation

Site name	Distance from north shore	Substrate characteristics	Sampling comments
Site 4	10m	Unbroken limestone, "pools" of sand	
Site 10	10m	90% broken rock, small sandy patches	
Site 16	10m	Even mix of rubble and sand	
Transect 1	5m	Unbroken limestone	No sediment (core) sample taken
Transect 1	10m	Loose rock and sand	
Transect 1	15m	Course, grey sand over shallow limestone	
Transect 1	20m	Course, grey sand	5m deep
Site 17	10m	Sandy beach	
Site 21	10m	Loose rock and course sand	Downstream site
Minim Cove	10m	Very rocky	Upstream site
Transect channel marker	50m	Sandy bottom, lots of broken shell	Mussel sample only, 4m deep
Pt Roe channel marker	5m	Not checked	Mussel sample only
Pier 21	0m	Not checked	Mussel sample only
Fremantle Traffic Bridge	50m	Not checked	Mussel sample only

20m Transect: The transect consisted of samples collected in a straight line at 5m intervals perpendicular to the northern shore. The slope along the line was consistent down to a depth of 5.5m at the 20m marker. Sampling points were determined by using a marked and weighted rope laid out along the length of the transect.

Water and sediment samples were collected between 8:00 and 11:00 in the morning during low tide to minimise the inconvenience caused by tidal currants through the river mouth.

All recovered samples were stored in cooled "Esky" storage containers and submitted to the Chemistry Centre of WA at the completion of the drilling program.

3.2 Beach site characteristics

Beach sediment characteristics from which the samples were collected is summarised below.

MC4

0.00 - 0.10m	BEACH SAND, Yellow, fine to medium grained, moderately sorted , subrounded.
0.10 - 0.15	LIMESTONE, Cream brown rocks, root casts and sand fine to medium grained. Sand is accreted on root casts up to 0.5 cm thick
0.15 - 0.50	SAND. Brown, orange brown and dark brown staining fine to medium grained, subrounded, moderately sorted.
0.50 - 0.75	LIMESTONE / SAND. Cream brown, hard. Sand is fine to medium grained, moderately sorted, subrounded.

MC5

0.00 - 0.10m	LIMESTONE ROOT CASTS, Cream, red brown, and orange brown. Small root cast, predominantly at surface, minor shells, numerous pieces of broken glass
0.10 - 0.15	LIMESTONE, Cream brown, hard, saturated.
0.15 - 0.55	LIME SAND. Cream brown, fine grained, no clay moderately to well sorted.

MC6

0.00 - 0.05m	LIMESTONE ROOT CASTS, Cream brown minor dark staining, small to large.
0.05 - 0.25	SAND, Cream brown, fine to medium grained, minor limestone nodules, shells at base.
0.25 - 0.48	LIMESTONE / SAND, Cream brown, sand is fine to medium grained.
0.50 - 0.75	SAND. Cream brown, fine to medium grained, moderately sorted, subrounded.

MC7

0.00 - 0.01m	LIMESTONE ROOT CASTS, small cream and brown, minor dark brown staining.
0.01 - 0.05	LIMESTONE, Orange brown stained, hard.
0.05 - 0.25	LIME SAND, Brown, green brown and dark brown staining, fine to medium grained, subrounded, poorly sorted, nodules of limestone.
0.25 - 0.30	SAND, Brown, strongly stained, fine grained, silty in part.
0.30 - 0.60	LIME SAND, Dark brown, brown, orange brown, fine to medium grained, moderately to poorly sorted, subrounded, nodules of limestone. Water table at 0.30m

MC8

0.00 - 0.25m	BEACH SAND, Yellow, fine grained, moderately sorted , subrounded, minor dark minerals, minor organic root material.
0.25 - 0.50	SAND, Dark brown, fine grained moderately sorted, minor limestone.
0.50 - 0.70	SAND, Grey brown, strongly discoloured, fine to medium grained, moderately sorted.
0.70 - 1.00	LIME SAND. Cream brown, grey, fine to medium grained, moderately sorted, subrounded.

Appendix 2

Health Department of WA

McCabe Street - Swan River foreshore contamination investigation

Health Risk Assessment

Background

A number of samples of mussels, water and sand/sediment have been collected from several sites on the Swan River foreshore off McCabe Street. Map 1 (in the main text) shows the loctaions of sampling sites. Initial samples, collected on 28 December 1995, showed high levels of a number of heavy metal contaminants in sand/sediment collected from targeted areas of visually evident contamination. High heavy metal concentrations were also found in stony mixtures of water and sediment. With the exception of lead levels in mussels at one site (7.5 mg/kg, site 10), mussel meat conformed to food standards for the heavy metal contents.

Additional samples were collected on 19 January 1996. These included ground water and river water, and sand/sediment samples from areas of the foreshore not overtly contaminated.

River water showed trace levels of some contaminants in some samples but for the most part levels were below detection limits. Ground water on the foreshore contained trace heavy metals at most sites although mercury was high compared to drinking water standards at site 4 (0.056 mg/L). This water is not available for drinking and therefore does not pose a health risk to people visiting the foreshore.

Analysis of sand/sediment samples taken at 5 m intervals along a transect from site 15 (the area of highest contamination) showed low levels of heavy metal contamination at 5m but high levels at 10m. Concentrations declined in samples taken at 15 and 20 m, and only low levels of the heavy metals were identified In samples collected from the channel. Elevated levels were also found in samples collected from the river bed 10 m from shore at a number of other sites along the beach.

Public access to the high concentrations of heavy metals in river-bed sediments is extremely liminted and the contamination does not pose a direct health risk. Shell fish which are prone to concentrate heavy metals, have not shown elevated concentrations indicating that the riverbed contamination has not seriously affected the food chain in the area. Therefore, there does not appear to be an indirect public health risk through consumption of river fauna.

Sand/sediment on the foreshore was contaminated with high heavy metal concentrations at some sites and these are available to public access and may, therefore, pose a health risk. Sand/sediment collected at sites 4BS, lOBS and 17BS contained low concentrations of heavy metals. Sediment samples collected from a 100m stretch of foreshore near sites 15 and 16 and at site 18 showed high levels, particularly of lead and arsenic. Although other metals (e.g. copper, zinc) were high in

some samples, these metals do not possess the hazardous properties and do not constitute the same order of health risk as lead or arsenic.

Assessment

The SRT data indicate a patchy distribution of heavy metal contamination. The major source of contamination is sand or sediment in the beach environment and, therefore, the major route of absorption of heavy metals will be incidental ingestion of sand or sediment. Because of the physical and chemical properties of the metals, other routes (inhalation and dermal absorption) will be negligible in comparison.

Currently, there are no health guideline criteria for contaminated sand or sediment on beaches, and no information on 'normal' levels of contaminants which may be expected on beaches. Health investigation criteria for some contaminants have been established for soil by the NHMRC/ANZECC. However, because activity on the beach is very different from activity around the home, transferring the soil guidelines to the beach environment would not be appropriate.

An alternative, more valid approach would be to estimate the amount of sand or sediment which could be taken in without causing an adverse effect on health. This may be achieved using safe or tolerable levels established by regulatory agencies on the basis of toxicological evaluation of the contaminants. Provided intake of the contaminants through ingestion of sand and sediments does not exceed the tolerable levels, there should be no health risk.

One of the major contaminants at the site is lead. Since infants are most sensitive to lead toxicity, associated with higher intake through hand-to-mouth activity, increased absorption compared to adults, and more sensitive target organ toxicity (the central nervous system), infants should be considered the target population for the purposes of risk assessment. A body weight of 10 kg is assumed in this assessment. Other hazardous contaminants which appeared to be present at high concentrations in some samples were arsenic, cadmium copper, zinc and mercury.

The NHMRC assumes an intake of 100 mg of soil per day by children in the 1 - 5 year age group. This represents the total intake from ingesting soil through hand-to-mouth activity, soil on food or objects put into the mouth, and inhalation of soil from dust in the air. This value is appropriate for children playing around the home and/or child care facility, spending some time indoors and some outside. However, the types of activity undertaken by small children on the beach, for example digging in the sand and splashing in shallow water, could give rise to the ingestion of relatively large amounts of sand or sediment in excess of the assumed 100 mg/day soil intake. Precisely how much sand or sediment a child may ingest whilst on the beach is unclear.

Safe or tolerable levels of heavy metal intake have been established by the World Health Organisation (WHO). Values are listed below (Table 1) as maximum tolerable daily (MTDI, PMTDI) or tolerable weekly (PTWI) intakes depending on the potential of the compound to accumulate. The values are based on an estimate of the amount of substance, expressed in terms of body-weight, that can be ingested daily over a lifetime without appreciable risk to health.

Table 1: Tolerable intake of heavy metals

Element	Guideline type	Guideline value mg/kg	Tolerable daily intake µg/kg/day
Lead	PTWI	0.025	α 3.5
Cadmium	PTWI	0.007	α 1.0
Copper	PMTDI	0.5	α 500
Zinc	MTDI	1.0	α 1000
Arsenic	PTWI	0.015	α 2.0
Mercury	PTWI	0.005	α 0.7

α = proportional to
µg = micrograms

The sites showing highest levels of contamination were sites 15BS, 18ES, 10ES and 16ES (targeted sites sampled on 28/12/95), site 16BS (a foreshore sand sample collected on 19/1/96) and site 15aES (a sample taken at a depth of 0.5 m into the foreshore embankment). Concentrations of contaminants in these samples is given in the following table (table 2). The final column gives the NHMRC guideline investigation value for soil.

Table 2: Concentration of heavy metals in sand or sediments (mg/kg)

Element/ site	15BS	16BS	18BS	10ES	16ES	15aES	NHMRC
Lead	520	740	2100	450	2	2	300
Cadmium	32	5.8	4.2	9.3	74	4.1	20
Copper	25000	1000	1100	1900	32000	570	-
Zinc	16000	950	500	1800	27000	150	-
Arsenic	260	210	200	280	660	2700	100
Mercury	<0.01	0.26	1.6	0.54	0.03	0.01	-

BS = beach sediment
ES= embankment sediment
15aES = sample collected from 0.5m into the embankment

Using these levels of contaminants and the WHO-based tolerable intake values in Table 1, the amount of sand or sediment which can safely be ingested may be calculated. Table 3 shows the amount of sand or sediment which could be ingested at each of the sites without the WHO value being exceeded. The right-hand column shows how much sand/sediment could be ingested if contamination was at the NHMRC health investigation level for soil.

Table 3: Mass of sand/sediment ingested (mg) without exceeding WHO tolerable intake values

Element/ site	15BS	16BS	18BS	10ES	16ES	15aES	NHMRC
Lead	67	47	17	78	>1000	>1000	117
Cadmium	313	>1000	>1000	>1000	135	>1000	500
Copper	200	>1000	>1000	>1000	156	>1000	-
Zinc	625	>1000	>1000	>1000	370	>1000	-
Arsenic	77	95	100	71	30	7	200
Mercury	>1000	>1000	>1000	>1000	>1000	>1000	-

BS = beach sediment
ES= embankment sediment
15aES = sample collected from 0.5m into the embankment

For most sites sampled, a child would need to ingest a considerable amount of sand or sediment on a daily basis in order to take in enough cadmium, copper, zinc or mercury for there to be a health risk. Site 16 may be an exception where a child would need to ingest only 135 mg of sand per day to exceed the WHO guideline for cadmium.

Only small amounts of sand or sediment would need to be ingested for guideline values for lead and arsenic to be exceeded. Sites 16ES and 15BS for arsenic and sites 18BS and 16BS for lead were particularly contaminated. Site 15aES was sampled at a depth of 0.5 m into the embankment and may not normally be accessible to children. Sites 18BS and 16BS were sand samples not obviously associated with visible contamination and it is possible children could play in these areas without obvious exposure.

Lead accumulates and low level repeated exposure may result in blood-lead levels high enough to cause subtle but long-term adverse effects on the health of children. Arsenic also accumulates and repeated low level exposure through ingestion is related to adverse effects on the skin (including cancer) and the nervous system.

The WHO tolerable intake values are based on ingestion of substances from all sources, including food, water and environmental contamination. The values in table 3 are expressed assuming that all exposure to the contaminants occurs at the foreshore. The amounts of sand or sediment which can safely be ingested would reduce in proportion to the intake from other sources.

It is important to note that WHO tolerable intakes are also based on daily intake over a lifetime. The WHO recognise that the values may be exceeded for short periods without an associated health risk. Thus, children would need to visit the foreshore and ingest sand or sediment on a daily basis for a considerable period for any adverse health affects to be realised. Whilst this does not appear to be a problem currently, future development at the site may be associated with increased foreshore use.

Conclusions

The currently available data are inadequate for complete characterisation of the site. Whilst the data are adequate to show that the site is contaminated, the full extent of the contamination is not clear. It is possible that contamination of any health concern only exists as 'hot spots' which would decrease the likelihood of accidental sand/sediment ingestion. Such hot spots could be removed selectively. A more complete site assessment would be required in order for this to be determined.

Some accidental ingestion of sand or sediment is likely during normal beach play of children. Based on the available data, it is doubtful that there would be appreciable health risks associated with occasional visits by children to the beach. However, lead and arsenic contamination is sufficiently high to be of concern to children who frequently visit and play on the beach. These children may accidentally ingest sufficient sand or sediment to exceed the safe or tolerable levels for these substances set by the WHO, and this may pose a health risk if exposure continues in the long term.

Currently, public access to the foreshore is limited. However, access is likely to increase following development of the McCabe Street site. It is unlikely that children will have continuous exposure to high levels of contaminants, limiting any risks to health. However, the exposure of children on an infrequent basis cannot be ignored because intake from this source would contribute to the total body burden of these contaminants from all sources.

Recommendations

The extent of contamination at the foreshore site represents a marginal health risk and it would be inappropriate to restrict public access to the beach. However, signposting to inform the public about the presence of the contaminants would be appropriate pending implementation of a remediation strategy.

The NHMRC health guidelines for lead (300 ppm) and arsenic (100 ppm) in soil are adequate to guide the clean up of the foreshore.