

2015

Trace element pollution in marine sediments from Botany Bay and Port Hacking estuary, NSW, Australia

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Alyazichi, Yasir Muyasser Mohammed, Trace element pollution in marine sediments from Botany Bay and Port Hacking estuary, NSW, Australia, Doctor of Philosophy thesis, School of Earth and Environmental Sciences, University of Wollongong, 2015. <https://ro.uow.edu.au/theses/4770>



**Trace element pollution in marine sediments from
Botany Bay and Port Hacking estuary, NSW, Australia**

Faculty of Science, Medicine and Health
School of Earth and Environmental Sciences

This thesis is presented as part of the requirements for the
award of the degree of

Doctor of Philosophy

from the

University of Wollongong

by

Yasir Muyasser Mohammed Alyazichi

Master of Environmental Sciences

2015

CERTIFICATION

I, Yasir Muyasser Mohammed Alyazichi, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Earth and Environmental Sciences, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Yasir Muyasser Mohammed Alyazichi

هلل الرحمن الرحيم

فأخبركم الماعلي تشبون أنتم أنتموه من المزن أم نحن المظنون

لنشاء جئنا به أجفأ ولا تشكرون

سورة الواقعة / الآيات (68-70)

In the name of Allah, the Beneficent, the Merciful
Then tell me about the water that you drink. It is you who cause it
from the rain-clouds to come down, or are we the causer of it to
come down. If we willed, we verily could make it salt: why then do
you not give thanks (to Allah)? Al Waqiah (68-70)

I dedicate this dissertation to:

My parents.....

My wife.....

My daughters....

My family.....

Abstract

Anthropogenic trace element pollution comes from a combination of urbanised catchment areas, road surfaces, stormwater outlets, mining sites, sewage overflows, soil erosion and illegal discharges, as well as atmospheric emissions. Estuaries play an important role as sinks for trace elements and other pollutants which can be detrimental to aquatic ecosystems and human health via the food chain (flora and fauna).

The objective of this research was to assess how field and laboratory techniques could be used to investigate and understand the spatial and vertical distribution of trace element pollution in marine sediments. Additionally, an assessment of the applicability of lower cost techniques to permit similar investigations in remote or less-developed regions has been made. A total of 428 surface sediment samples, along with 51 subsurface samples from eight cores in the Botany Bay and Port Hacking estuaries, New South Wales, Australia, were collected. Contemporary techniques were used to measure all samples. These techniques included a Malvern Mastersizer 2000 to obtain sediment grain size, X-ray fluorescence (XRF) to measure the total trace element concentrations, X-ray diffraction (XRD) to identify mineral percentages, and inductively coupled plasma mass spectroscopy (ICP-MS) analysis for lead isotopes. The findings of trace element concentrations were plotted using the Kriging method of interpolation in the ARC geographic information system software, as well as applied risk assessments and statistical analysis, hierarchical cluster analysis (HCA) and principal component analysis (PCA).

Overall, the results indicated that although most of the study areas, especially South West Arm and Hacking River and their catchment areas, had normal and near background concentrations of trace elements, some sites in bays had raised abnormal and unhealthy concentrations of pollution. The highest concentrations of trace elements were found to be in Salt Pan Creek. Other polluted sites were located in the inner and middle portions of bays and rivers, close to discharge points and stormwater outlets and around boatyards and watercraft. In addition, at these sites there were high percentages of clay minerals, such as kaolinite, chlorite and illite as well as pyrite and organic matter, which can trap trace elements. Concentrations of trace elements declined with increasing sediment depths

in cores, which reflected the accumulation of trace elements since European settlement around these areas.

One objective of this research was to assess how low-cost techniques could be used to investigate and understand the spatial and vertical distribution of trace element in marine sediments. In this research a field program was developed, using Lagrangian methods, to measure and track current and tide velocities in order to provide more insight and explanation of the spatial distribution of sediment particles and trace element pollution in the estuaries.

More advanced hydrodynamic methods have been used in developed countries in order to establish models for the distribution of sediment particles and trace element pollution. The simple method to track ebb current pathways and velocity that was applied in this study provides a descriptive measure to assess the main trajectory of currents, sediment particles and chemical pollutant dispersal in the estuaries and bays. The application of these techniques and monitoring could be used effectively in developing countries and remote areas where more detailed analyses are difficult for both cost and technical reasons. The results of hydrodynamic measurements showed that the ebb current velocities had the capability to transport fine and very fine particles away from discharge points in the bays, and the trace elements were distributed along the main current pathways.

The concentrations of trace elements in South West Arm, the Hacking River and samples located at the edges of the bays were found to be below the ANZECC and NHMRC (2000) guideline low trigger value (ISQG-low), whilst some of the trace elements, such as Zn and Cu in Salt Pan Creek, as well as some sites in other bays exceeded the high trigger value. Moreover, other sites in the bays varied between ISQG low to high values. Several factors have affected the distribution of trace elements in both the depositional basins. These include tidal and current flows, wind (speed and direction) effects, sedimentary fractions and marine activities. Also, this study suggests new places with low concentrations of trace elements and shallow sites suitable for aqua-culturing oysters.

The major source of trace element pollution in the study area was from local urbanised catchment areas, and included pollution from stormwater outlets, road dust, discharge points, sediment erosion and atmospheric emission, as well as from boatyards and

watercraft. Remediation strategies to remove pollutants from stormwater outlets, which include physical, biological and chemical treatment methods, are recommended. The best remediation to remove the trace element pollution from urban drainage involves filtration using sand with a sorbent, such as zeolite, alumina, dust and fly ash, which would be cost-effective.

This study provides useful information as far as management and future water quality planning are concerned. It is necessary to investigate the distribution and degree of trace element pollution in order to protect environmental ecosystems from accumulating pollution and to provide basic information for coast utilization and management.

ACKNOWLEDGEMENTS

Firstly, I would like to express my heart felt and sincere appreciation to my principal supervisor Associate Professor Brian Jones. I am particularly grateful to him for his expertise, encouragement, advice and patience throughout my study and for his knowledge and expertise in this area of research to develop my PhD thesis. Also, I would like to extend thanks to my co-supervisor Errol McLean, most notably for his discussion and understanding of hydrodynamic activities within the study areas. Warmest thanks to both of them.

I wish to thank the Ministry of Higher Education and Scientific Research in Iraq for financial support to complete my PhD research. Further, I give great thanks to the School of Earth and Environmental Sciences at the University of Wollongong for providing facilities, which include field work requirements, using instruments and the University's library for searching and borrowing books and up-to-date journal articles.

Among all the people who assisted me at the University of Wollongong, I am particularly grateful to academics in the School of Earth and Environmental Sciences, especially Prof. John Morrison, Dr. John Bradd, Prof. Colin Murray-Wallace, and A/Prof. Chris Fergusson for their advice and discussion through my study years.

I acknowledge the technical and field work support at the School of Earth and Environmental Sciences by Josef Stocker, Jose Abrantes, Heidi Brown and Alex Ullrich.

Last, but not least, special thanks to my parents, my wife, my beautiful daughters Rafal, Reem and Rusul, who encouraged and supported me in this journey to achieve my dissertation.

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- 1- Alyazichi, Y. M., Jones, B. G. & McLean, E. 2015. Spatial and temporal distribution and pollution assessment of trace elements in marine sediments in Oyster Bay, NSW, Australia. *Bulletin of Environmental Contamination and Toxicology*, 94, 52-57.
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Acronyms and Abbreviation

Al	Aluminium
Si	Silicon
Fe	Iron
Na	Sodium
Mn	Manganese
Ca	Calcium
Pb	Lead
Zn	Zinc
Cu	Copper
Cr	Chromium
Ni	Nickel
Co	Cobalt
As	Arsenic
Sn	Tin
Cd	Cadmium
Sr	Strontium
Br	Bromine
Rb	Rubidium
Ba	Barium
E_r^i	Monomial Potential Ecological Risk Factor
T_r^i	Coefficient for the Toxicity of Single Trace element
AME	Mean Standard Error
ANZECC	Australia New Zealand Environment and Conservation Council
AWQG	Australian Water Quality Guidelines
BDL	Below Detection Limit
CF	Contamination Factor

EC	Environment Canada
EF	Enrichment Factor
Eh	Redox Potential
ERL	Effect Range Low
ERM	Effect Range Median
GIS	Geographical Information System
GPS	Geographic Positioning System
GSD	Grain Size Distributions
GsKew	Skewness
H₂S	Hydrogen Sulfide
HAL	High Alert Concentration
HCA	Hierarchical Cluster Analysis
ICP-MS	Inductively Coupled -Plasma Mass Spectrometry
ISQG	Interim Sediment Quality Guidelines
ISQV	Interim Sediment Quality Value
LAL	Low Alert Concentration
mC_d	Modified Degree of Contamination
MSE	Mean Standardized Error
NHMRC	National Health and Medical Research Council
NOAA	National Oceanic and Atmospheric Administration
OME-SLG	Ontario Ministry of Environmental Screening Concentration Guidelines
PCA	Principle Component Analysis
PEL	Probable Effect Concentration
pH	Hydrogen ion concentration
PLI	Pollution Load Index
RI	Potential Ecological Risk Index
RMSE	Root Mean Square Prediction error
RMSS	Standard Root Mean Square
StdD	Standard Deviation
TEC	Threshold Effect Concentration
EPA	Environmental Protection Agency
WHO	World Health Organization
WWTPs	Wastewater Treatment Plants
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence

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Chapter 1

Introduction

1.1 Introduction

This chapter describes the coastal and estuarine marine environments and their classification, as well as explaining the presence, sources and effects of trace elements in sediment and aquatic marine ecosystems. Furthermore, it provides the objectives and significant contribution of this study to science in this research area.

1.2 Coastal Environments

Oceanic and coastal marine waters completely surround Australia, with approximately 20,000 km of coastline, and approximately 783 estuaries, bays, coastal lakes and lagoons have been recognised along the coastline (Daniel and Saenger, 1989; Short and Woodroffe, 2009). Approximately 137 estuaries and coastal lagoons occur along the New South Wales coastline (West et al., 1985).

The morphological and sedimentological properties of estuaries show different development because of various rates of sedimentation and deposition within palaeo-valleys before and since the culmination of the recent postglacial marine sea concentration rise (Thom and Roy, 1985; Yassini and Jones, 1995; Sloss et al., 2007; Sloss et al., 2011). Rainfall in the coastal river systems contributes to the water volume in the estuarine and embayment catchment areas. This volume of water is related to seasonal climatic events in New South Wales, which has a predominance of rainfall during the summer period. Therefore, the estuaries in New South Wales are influenced by low salinity during the summer time (Yassini and Jones, 1995). The amounts of sediment and soil that discharge into the marginal marine environment by rivers in New South Wales are small compared to other world river discharges. However, during the Holocene and recent period, more terrestrial debris has been contributed by the large rivers in the northern part of New South Wales, especially since European settlement (Roy, 1984; Short and Woodroffe, 2009).

1.3 Classification of estuaries and bays in coastal New South Wales

Numerous studies have evaluated the morphology, sedimentary facies and stratigraphy of estuaries and bays in New South Wales (Roy and Thom, 1981; Chapman et al., 1982; Roy, 1984; Thom and Roy, 1985; Sloss et al., 2007; Short and Woodroffe, 2009; Lewis et al., 2013). Three main types of coastal water bodies are recognised:

- 1- barrier estuaries, such as saline coastal lakes and coastal lagoons;
- 2- open estuaries (drowned river valley estuaries); and
- 3- sheltered oceanic embayments.

In the Sydney region all the major estuarine areas can be classified as open estuaries.

1.4 Open estuaries (drowned river valley estuaries)

These types of estuaries are most numerous on the central coast of New South Wales. For instance, in the study areas, Botany Bay and Port Hacking are open estuaries, as are the Georges River, Sydney Harbour and Hawkesbury River in the Sydney area, and Port Stephens farther north (Thom et al., 1986; Yassini and Jones, 1995). In the Sydney district the open estuaries have been described as deep, narrow palaeo-valleys with sheer rocky sides carved into resistant Triassic sandstone (Thom et al., 1986; Short and Woodroffe, 2009). These estuaries contain marine sand at their mouths, and are muddy in the deeper sites with preserved organic matter (Yassini and Jones, 1995). All the estuaries are tidal even though the valleys are steep and sheer and restrict intertidal environments to deltaic areas in the upper parts of each estuary.

1.5 Contamination of marine sediments and sources of pollution

Assessment of the aquatic environment indicates that most contamination arises from anthropogenic activities. Such as, aquatic environments are vulnerable ecosystems, widely distributed along the coast. The contamination concentrations of trace elements in aquatic environments can be detected by analysing the water, organisms and sediments.

For several reasons, water analysis was not adopted in this study. The first reason is that chemical analysis of water does not supply details on the bioavailability of trace elements within the environments (Morillo et al., 2005). Secondly, the trace element concentrations often lie near and/or under detection limits of available instruments (Rainbow, 1995). The third reason is that water concentrations dramatically fluctuate due to water flow and

discharge during different seasons (Guerra-García et al., 2010). Thus, sediment analyses are more appropriate to monitor the contamination concentrations in aquatic environments worldwide (Birch and Davey, 1995; Jones et al., 2003a; Acevedo-Figueroa et al., 2006; Alagarsamy, 2006; Abraham and Parker, 2008; Birch and Mc Cready, 2009; Xu et al., 2009; Xiao et al., 2012; Ye et al., 2012; Yu et al., 2012). In addition, sediments are considered important for the transportation and accumulation of trace elements emanating from both natural and anthropogenic activities (Morrissey et al., 2000; Swales et al., 2002; Liaghati et al., 2004; Morillo et al., 2004; Selvaraj et al., 2004; Morelli et al., 2012). Sediment has the potential to affect the water column because it is directly connected with water quality. Moreover, polluted sediments are considered to provide a long-term record of dispersion, even when water contamination has declined. In other words, data from sediments provide time-integrated mean values of significant time stability compared to data on variable pollutant concentrations from the water (Hakanson, 1980).

Over the past century numerous anthropogenic sources have discharged into coastal and marine aquatic systems. This has occurred as a consequence of atmospheric emissions from smelters, mining, domestic waste, tourist boats, sewage, urbanization, oil pollution, agriculture and consumption of fossil fuels (Birch and Davey, 1995; Mortvedt, 1995; Radenac et al., 2001; Cundy et al., 2003; Pekey, 2006a; Ye et al., 2012; Attia et al., 2012). High concentrations of trace elements, such as Pb, Cd, As, Ni, Cu, Hg and Zn, are considered to be detrimental to the diversity of marine life (Gray, 1997; Ip et al., 2005; Tittensor et al., 2010; Tarique et al., 2012; Zhang et al., 2012a). Thus, trace elements have become a critical problem in aquatic ecosystems around the world.

1.6 Trace element pollution in aquatic environments

Numerous sources can cause contamination of aquatic environments, such as estuaries, bays, rivers, lakes and lagoons, by trace elements. These sources include discharge from urban development, industrialisation, municipal waste water, waste incineration, atmospheric deposition and agricultural uses (Kaimoussi et al., 2002; Cobelo-Garcia and Prego, 2003; Mucha et al., 2003; Chen et al., 2004; Dai et al., 2007; Meng et al., 2008; Besser et al., 2009; Hosono et al., 2011; Morelli et al., 2012). Trace elements are dispersed in aquatic habitats and then deposited in aqueous environments and combined

with sediments and soils by various processes such as adsorption, absorption, ion exchange, metal substitution and dissolution (Abraham and Parker, 2002; Shahidul Islam and Tanaka, 2004; Jain, 2004; Abraham and Parker, 2008; Turner, 2010).

Moreover, clay minerals are especially considered as the ultimate sinks for the accumulation of trace elements. This is due to several reasons: clay minerals have large surface areas because they are comprised of very fine particles ($< 2\mu\text{m}$), a variable crystal structures (tetrahedral and octahedral), and the variable chemical compositions of the clay minerals (aluminosilicate) that commonly results in them being negatively charged at the end of the silicon–oxygen chains. Thus trace elements can enter the crystal structure and/or be absorbed onto their surface coating, which leads to the accumulation of trace elements (Singh et al., 2005; Mendiguchía et al., 2006; Al-Juboury, 2009a,b; Kalo et al., 2013).

Trace element concentrations in sediments and soils can play a critical role in the contamination of aquatic environments. This is due to the toxicity, persistence, slow degradation and rapid accumulation of these trace elements (Klavinš et al., 2000; Yuan et al., 2004; Dural et al., 2007; Hu et al., 2011). However, the trace elements can be released from sediments and soils as free ions, and/or complex compounds into the water column by physical disturbance, chemical processes and diagenetic factors such as changes in pH, influx of sediments, redox potential (Eh), bioturbation and organic degradation (Tessier et al., 1979; Santschi et al., 1990; Long et al., 1995; Aegese et al., 1997; Tam and Wong, 2000; Zoumis et al., 2001).

Increasing concentrations of trace elements are deleterious for marine flora and fauna such as surface dwelling organisms, fish and other micro-organisms like foraminifera and ostracoda that may experience reduced growth because of impaired reproduction, decline in species diversity and death. Trace elements may also enter into human bodies through the food chain, with high accumulations resulting in serious health problems such as brain damage, weakness and various other types of illness (Poggio et al., 2008; Cao et al., 2010; Yi et al., 2011; Zhao et al., 2012; Olawoyin et al., 2012; Alves et al., 2013; Huang et al., 2013).

1.7 Relationship of trace elements with sediments

Trace elements are involved with sediments and soils in different phases and forms depending on chemical, physical and biological environmental conditions (Gjoka et al., 2011; Protano et al., 2014). Table 1 illustrates the various processes and relationships of trace elements in sediments and soils (Hakanson, 1980).

Table 1: Trace elements associations with sediments and soils (modified from; Forstner, 1977).

Minerals/ Trace elements	Conditions	Forms
Mineral detritus (mainly silicates)		Metal bonding mostly in inert positions
Trace element hydroxides, carbonates and sulphides		Precipitation as a result of exceeding the solubility product in the water
Clay minerals (sorption)	pH	Physical-sorption (electrical attraction) Chemical-sorption (exchange of H^+ in $SiOH$, $AlOH$ and $Al(OH)_2$)
Bitumen, lipids, humic substances residual organics	pH	Physical-sorption Chemical-sorption ($COOH-OH$ -groups) Complexes
Hydrous Fe/Mn-oxides	pH	Physical-sorption Chemical-sorption Co-precipitation by exceeding the solubility product
Calcium carbonate	pH	Physico-sorption Pseudomorphosis (supply and time) Co-precipitation

1.8 The aims of this research

Although highly technical methodologies have been established in developed countries to assess the chemical pollution and sediment distribution in estuaries, they have not really addressed the need to provide methodologies applicable to remote or low-cost technology countries or locations. In the latter regions instruments or methods are limited to low-cost, simple to construct or operate techniques that can still obtain data of a quality that could be incorporated into later work if additional technical and financial support for further study became available. It is essential that the methodologies and data used are upwardly compatible with any more sophisticated studies. This allows low cost investigations to be reported as part of the international body of research into the distribution of pollutants in

the coastal environment. To this end the selection of inexpensive portable instrumentation and the employment of local labour can partly substitute for the more advanced collection, monitoring and modelling available with a high level of technology and finance. It should be emphasized, however, that this does not prevent the use of advanced instrumentation entirely as relatively cheap instruments such as GPS and water level loggers, portable XRF, basic GIS software and small portable computers can be employed in remote areas. This thesis specifically addresses the need for optimal methods for this purpose. The objectives are designed to satisfy scientific rigour, as well as provide the base for a cost effective methodology to apply in less financially affluent or remote areas.

Within this context this study has several objectives:

- 1- To assess the distribution of the total trace element concentrations in the surface and subsurface sediments within the study area comprising selected bays in the Botany Bay and Port Hacking areas.
- 2- To determine areas with high concentrations of trace elements in marine sediments that require further investigation to determine the bioavailability of the trace elements.
- 3- To examine the sediment properties (grain size parameters and mineralogy) in all the bays, and find the relationship between the sediment parameters and the trace element concentrations.
- 4- To determine how current and tidal hydrodynamics affect the concentration and dispersal of sedimentary particles and trace element pollutants.
- 5- To evaluate the environmental impact of human activities in the study areas by comparing the current results with baseline sediments prior to European settlement and with ANZECC guidelines.

1.9 Significance and original unique contribution to science

The research covers and analyses embayments in Botany Bay and Port Hacking (Figure 1) by using sediments as sensitive indicators for both spatial and temporal trends monitoring total contaminant loads in marginal marine environments.

A new and practical method of measuring hydrodynamic processes that affect pollutant dispersal will be established by this study. This will be achieved by building a simple and cost-effective methodology to track current and ebb tide velocities to map and explain the distribution pattern of trace element pollution and sediments within these bay systems. Hence this study provides useful information about determining sediment trends and geochemical properties that may lead to knowledge transfer to other bay systems, including those in remote areas, especially in developing countries.

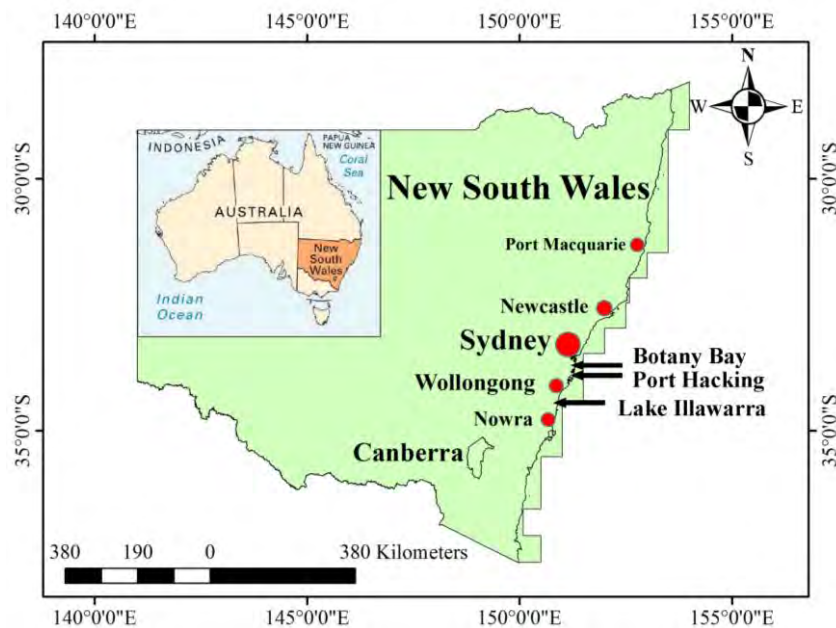


Figure 1: Location of study areas in New South Wales.

1.10 Dissertation structure

Chapter one: Introduction

This chapter generally describes the coastal marine environment and certain details of bays in New South Wales, Australia. Moreover, it informs the reader about trace elements in the marine sediments and sources of this pollution.

Chapter two: Previous studies

This chapter presents previous research which has examined pollution by trace elements in international marine sediments, as well as contamination of soils and sediments in Australia. Furthermore, it gives information about the effect of hydrodynamic activities on sediment and trace element dispersal.

Chapter three: Study areas and methodology

This chapter has two sections. The first section of this chapter provides details of the study areas (Botany Bay and Port Hacking, NSW, Australia) and the sample collections, while the second section pertains to the methods and equipment that were used for sample analysis.

Chapter four: Sedimentary parameters

In this chapter the results of sediment analysis, including grain size distributions and mineralogy, are presented. Relationships between sediment fractions and minerals are also discussed.

Chapter five: Geochemical

The spatial and temporal distribution of total trace element concentrations within the study areas is demonstrated in this chapter. The influence of stormwater and wastewater outlets, as well as sediment status, evaluated using geochemical factors. In addition, the distribution, accumulation and sources of lead, measured by lead isotopes, are investigated.

Chapter six: Hydrodynamic observations

This chapter presents and describes a method to describe the distribution of sediment particles and trace element patterns and how they can be affected by currents and tidal action.

Chapter seven: Discussion

This chapter uses statistical analysis on all the variables that were measured in the bays, and the results of hydrodynamic measurements from the study areas, to discuss the causes and effects of pollution. Moreover, management options of stormwater outlets are discussed in order to reduce the effect of pollution into estuaries.

Chapter eight: Conclusions and recommendations

This chapter provides a summary of what has been achieved by this project and some suggestions for further studies.

Chapter 2

Literature review

2.1 Introduction

This chapter has three main aims. The first one is to review research literature on the distribution of trace elements in marginal marine surface sediments around the world. The second is to review spatial and temporal occurrences of trace elements in Australian estuaries, and the practice of grain size normalisation of sediments. Thirdly, to evaluate the impact of hydrodynamic conditions on the distribution of sediment particles and trace elements.

2.2 International development of Sediment Quality Guidelines (SQGs)

Over the last few decades, international Sediment Quality Guidelines (SQGs) have been proposed by the U.S. National Oceanic and Atmospheric Administration (NOAA). The combination of impact-range guidelines emanated from a great series of chemical and biological data determined from North American coastal regions. Data were collected from both fieldwork and laboratory studies using various chemical and biological methodologies (MacDonald et al., 2000b; Ingersoll et al., 2001). Consequently, these guidelines provide a basis for calculating the potential for deleterious biological effects of various polluted soils and sediments. Furthermore, the guidelines are used to classify and to establish a database of polluted locations for further investigation. Different approaches to establishing guidelines were used to formulate the SQGs, including the effect range, and the effect concentration beyond the apparent effect threshold approach used to develop the range.

Changes in chemical concentrations consistent with the 10th and 50th percentiles of the deleterious biological effects can be labelled as Effect Range Low (ERL) and Effect Range Median (ERM). These two values for each chemical were derived by the U.S. National Oceanic and Atmospheric Administration (NOAA) to distinguish soils and sediments that show harmful biological effects rarely (<ERL) or frequently (>ERM); (NOAA; Long et al., 1995; MacDonald et al., 2000a; Ligerio et al., 2002; Bakan and Özkoç, 2007). Two basic concepts were used to set up these theory guidelines: firstly, a

threshold effect concentration (TEC) beneath which deleterious effects are assumed not to occur; secondly, a probable effect concentration (PEL) which if exceeded indicates the probability that deleterious effects can happen (MacDonald et al., 2000a). In addition, the thresholds between TEC and PEL illustrate a range of concentrations within which a deleterious effect may happen sometimes for sensitive invertebrates, however, a low overall risk is present (Table 2.1; Pekey et al., 2004; Bakan and Özkoç, 2007).

Table 2.1: Sediment Quality Guidelines (SQGs) for trace elements in sediment (Spencer and Macleod, 2002; Abdel Ghani et al., 2013; Kalantzi et al., 2013).

Effect	SQGs	As mg/kg	Cd mg/kg	Cr mg/kg	Cu mg/kg	Pb mg/kg	Zn mg/kg	Ni mg/kg
Threshold	NOAA-ERL	8.2	1.2	81	34	47	150	21
	EC-TEL	7.2	0.7	52	19	30	124	--
	SQO Netherlands -Target	2.9	0.8	--	36	85	140	--
	Hong Kong – ISQV- low	8.2	1.5	80	65	75	200	--
	OME-SLG-lowest effect concentration	6	0.6	26	16	31	120	--
	Low alert concentration (LAL)	0.5	0.04	4	2	2	5	3
	TLV	15	1		75	100	200	--
Midrange	NOAA-ERM	70	9.6	370	270	220	410	52
	EC-PEL	42	4.2	160	108	112	271	--
	SQO Northlands- limit	55	2	--	36	530	480	--
	Hong Kong – ISQV-high	70	9.6	370	270	218	410	--
	Norwegian moderate	80	1	300	150	120	700	--
Extreme	OME- SLG - SEL	33	10	110	110	250	820	--
	SQO Netherlands – intervention	55	12	--	190	530	720	--
	High alert concentration (HAL)	70	9.6	370	270	218	410	50

Where: **ERL**: effect range low, **TEL**: threshold effect concentration, **ISQV**: interim sediment quality value, **SQO**: sediment quality objective, **LEL**: lowest effect concentration, **ERM**: effect range median, **PEL**: probable effect concentration, **SEL**: severe effect concentration, **TLV**: threshold limit value; **NOAA**: National Oceanic and Atmospheric Administration, **EC**: Environment Canada, **OME-SLG**: Ontario Ministry of Environmental Screening Concentration Guidelines, **LAL**: Low alert Concentration, **HAL**: High alert concentration.

The normal background concentration is determined by monitoring the quantity of pollution present everyday through most of the population (Zhang et al., 2007). The Environmental Protection Agency (EPA) in the United States, Australia and New Zealand has categories for sediments based on their pollutants. The background concentrations of

trace elements and trace elements have been achieved by using soil samples from original and non-industrial areas and heavily polluted areas (Table 2.2).

Table 2.2: US, Australia and New Zealand EPA guidelines for sediments (mg/kg dry weight).

Trace Elements	EPA Guidelines		
	Non- polluted	Moderately polluted	Heavily polluted
As	< 3	3-8	>8
Cd	---	----	>6
Cr	<25	25-75	>75
Cu	<25	25-50	>50
Pb	<40	40-60	>60
Zn	<90	90-200	>200
Ni	<20	20- 50	>50

2.3 The main source of the pollutants

Trace element pollution is considered to be a predictable result from urban, agricultural, atmospheric and industrial developments. Evidence of this pollution is recorded in the sediments, including marginal marine sediments (Abd El Wahab et al., 2011). Consequently, there are many sources and types of pollutants around the world with urban and transport pollution adding to trace metal concentrations.

Numerous studies have attempted to explain the source of trace elements in marine sediments (Attia et al., 2012; Tarique et al., 2012; Zhang et al., 2012b). Trace elements mainly emerge from industrialization, commercial and domestic waste activities, wastewater discharges, dredging, localized oil pollution, and the use of antifouling products, anticorrosive paints and metallurgical processing. The soils and sediments within industrial and surrounding areas undergo various types of contamination (Table 2.3) and sources of pollution in sediments have been noted by ANZECC and NHMRC (2000). Natural activities such as erosion, weathering of sediments and soils, flood cycles can increase sediment inflows and introduce background concentrations of trace elements. Moreover, the clearing and deforestation of catchment areas can cause additional erosion and weathering of soils and increase the sedimentation rate in both terrestrial and coastal marine systems (Chenhall et al., 1995; Hosono et al., 2011).

Table 2.3: Sources of trace elements from various industrial and land uses in Australia (ANZECC and NHMRC, 1992).

Acid / Alkali plant formulation	Mining & Extractive industries
Airport	Oil production & Storage
Asbestos production & disposal	Paint formulation & industrial
Chemicals industrial & formulation	Pesticide industrial
Defence works	Pharmaceutical industrial & formulation
Drum reconditioning works	Power stations
Dry cleaning establishments	Railway yards
Electroplating & heat treatment premises	Scrap yards
Engine work	Service stations
Explosives industry	Tanning & associated trades
Gas work	Waste storage & treatment
Iron & steel works	Wood preservation
Land fill sites	Metal treatment

Therefore, both point and non-point dispersal of trace elements can occur in marginal marine estuaries and lagoons and they can be derived from both natural and anthropogenic sources. In the other words, the lithology and surface processes in the catchment areas influence the background concentration of trace elements in both soils and marine deposits (Martley et al., 2004).

Areas surrounding many industrial and commercial centres contain particularly high concentrations of trace elements. These concentrations result from the inflow of untreated or poorly treated runoff onto the land or waterways. In addition, atmospheric emissions from industrial activities produce fallout on the land (Martley et al., 2004). As a result, the global distribution of toxic trace elements such as Hg, As, Pb, Cu, Zn, Cd, Ni and Se in the atmosphere are considered to represent one of the environmental crises associated with rapid economic development around the entire world. Marine sediments in estuaries, lagoons and bays effectively act as sinks and/or a secondary source for anthropogenic pollutants comprising trace elements and organic matter (Chapman and Underwood, 1996; Qiu et al., 2011). Trace elements are released again into the water column when there are changes in chemical, physical and biological process, such as pH, Eh and bioturbation. Consequently, premeditated and/or unintentional human activities, such as waste disposal and discharge of waste into the marine system (estuaries, lagoons and bays) causes contamination and often disperses into the vicinity of the marginal marine setting (Chenhall et al., 2004).

The distribution of trace elements in surface sediments from Izmit Bay, Turkey, was evaluated by Pekey (2006a) and found to be influenced by contamination in a local stream. The results demonstrated that the most concentrated element was Sn. Moreover, trace elements such as Cd, As, Pb and Zn were considered to be moderately concentrated within the bay. In contrast, only background concentrations of elements such as Co, Cr, Cu, Fe, Mg, Mn and Ni were found. The study suggested that the increased concentration of some trace elements coincides with an increased source of anthropogenic pollution, which arises from increased urbanization and industrialization, and organic matter from industrial plant developments and shipping traffic.

Assessment of contamination by heavy metals such as Cr, Pb, Zn and V in soils at the Jahmau and Unnao areas of the Ganga Plain, India was completed by (Gowd et al., 2010). The results showed that the impact of anthropogenic activities increased the amount of heavy metals in the soils of the study areas. They were found to be extremely contaminated because of many years of random dumping of hazardous waste and the free discharge of drains by a number of industries, such as cotton and wool textile mills, tanning and leather manufacturing, fertilizer factories and several arms factories.

Estimation of enrichment factors for contamination by heavy metals such as Pb, Cu, Ni and V in the surface and subsurface sediments of Koumounfourou Lake, Greece was investigated (Karageorgis et al., 2009). The sources of these heavy metals were various industries and oil refineries. Furthermore, the lake receives freshwater from underwater springs and water outlets from industrialised catchment and Athens landfill.

Another study carried out by (Amin et al., 2009) also evaluated the concentration and distribution of trace elements to determine the pollution status of the coastal surface sediments near Dumai, Indonesia. The results showed that the sediments in Dumai City and its vicinity had higher trace elements concentrations compared to other sites in the area. The concentration of trace elements was also compared to other regions of the world by using the standard sediment quality guidelines, and trace elements were not deemed to be significant pollutants in this moderately polluted coastal environmental. Research has suggested that the main source of contamination from trace elements in coastal sediments emanates from human activities and industrial development (Romano et al., 2004; Amin et al., 2009). Moreover, coastal topography and transfer by water currents have been

shown to have an important role in the concentration of trace element contaminants in sediment, especially in the eastern Dumai coastal lagoon.

2.4 Effects of sediment disturbance and remobilization of pollutants

2.4.1 Chemical effects

Trace elements incorporated into the sedimentary sink may be influenced by many post-depositional factors, such as physical, chemical and biological impacts, which can influence their redistribution, remobilization and solubility (Tipping et al., 2003). Shallow areas have many characteristics that can effect precipitation, remobilisation, solubility and bioavailability of sediment-bound trace elements, such as changes in Eh, lowering of pH, increases in hydrogen sulfide (H₂S), increases in salinity, changes in temperature and preservation of organic matter (Forstner et al., 1984; Hatje et al., 2003; Stockdale and Bryan, 2013; Hamzeh et al., 2014). The sediment–water interface also plays an important role in carbonate deposition. In addition, absorption and ion exchanges of trace elements occur within the near-surface sediment particles where photosynthetic organisms thrive (Figure 2.1).

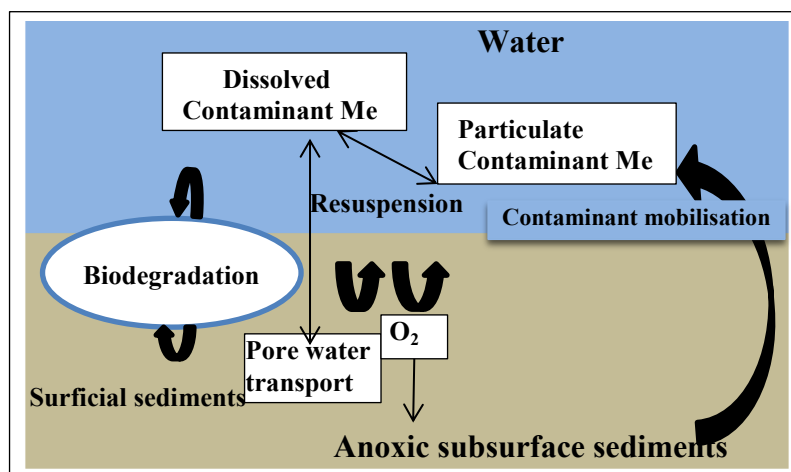


Figure 2.1: Transport and transformation of elements in sediments after (Hamzeh et al., 2014).

Both pH and Eh are considered to influence the mobility of trace elements in sediments and soils (Table 2.4; Ho et al., 2012; Ye et al., 2012). Therefore, the pH and Eh of sediments play important roles in assessing the risk related to the presence of potentially toxic elements in aquatic environments (Ye et al., 2013).

Table 2.4: Relative mobility of trace elements and trace elements in sediments as a function of pH and Eh (Mattigod and Page, 1983; Campbell et al., 1983; Plant and Raiswell, 1983).

Relative Mobilities	Electron activity		Proton activity	
	Reducing	Oxidizing	Neutral-alkaline	Acid
Very low Mobility	Al, Cr, Mo, V, U, Se, S, B, Hg, Cu, Cd & Pb	Al, Cr, Fe & Mn	Al, Cr, Hg, Cu, Ni & Co	Si
Low Mobility	Si, K, P, Ni, Zn Co & Fe	Si, K, P & Pb	Si, K, P, Pb Fe, Zn & Cd	K & Fe ³⁺
Medium Mobility	Mn	Co, Ni, Hg, Cu, Zn & Cd	Mn	Al, Pb, Cu, Cr & V
High Mobility	Ca, Na, Mg & Sr	Ca, Na, Mg, Sr, Mo, V, U & Se	Ca, Na, Mg & Sr	Ca, Na, Mg, Sr, Zn Cd, Hg Ni, Co & Mn
Very high Mobility	Cl, I & Br	Cl, I, Br, S & B	Cl, I, Br, S, B, Mo, V, U & Se	Cl, I, Br, S & B

The Eh of shallow water over intertidal muddy areas (silt and clay) varies, being controlled by photosynthesis, sulphides and oxidation by bacteria (Friedman and Foner, 1982). Moreover, green algae often produce wide changes of Eh and pH in the overlying water while in areas with good light intensity sea grasses are usually common (Tipping et al., 2003). Changes in environmental conditions (e.g. from reducing to oxidizing) can have an effect on the mobility of typical chalcophilic trace elements such as Zn, Pb, Cu, Hg and Cd, while elements such as Fe and Mn have low mobility under oxidising conditions (Ho et al., 2012). Trace elements such as Al, Mn and Zn, and perhaps Cd, Co and Ni (Campbell et al., 1983), increase their mobility in acid environments when the elements exist in non-crystalline form in the soil, whereas elements such as S, As, Se, Cr and Mo have anionic species and good solubilities.

Plants, algae and/or photosynthetic bacteria can also affect photosynthesis that is the biogenic master reaction in their environments. This may cause changes to either Eh or pH or both of these properties. Initially, the pH in shallow water demonstrates a decrease at night. Also, the dissolved hydrogen sulfide (H₂S) in water with high organic matter (muddy) regularly rises at night, whereby H₂S increases by 5 mg/L in intertidal sediments at night as well as over disturbed surface sediment layers (Hansen et al., 1978). Therefore, these chemical conditions affect the mobility and solubility of trace elements in surface sediments in shallow water. Thus Pb, Zn, Cd and Cu contents rise in shallow water above polluted surface sediments during increased oxidation, whereas Fe and Mn increase in reduced environments (Sakellari et al., 2011). Furthermore, extreme changes of

temperature and salinity may occur in shallow water at low tide, especially when the water is stagnant. Sullivan, (1977) asserted that trace elements become more toxic to micro-organisms and juvenile fish during periods of increased temperature and decreased salinity in the surface waters.

2.4.2 Physical characteristics

The solubility and remobilization of trace elements are affected by physical parameters which accompany strong winds and/or wave activities. Such disturbed conditions occur in shallow water, so it tends to remobilizes trace elements along with silt and clay from the underlying sediment. Moreover, winds and waves can disturb anoxic sediments in deeper water and cause the release of sulphide minerals and/or the oxidation of the sediments (Warren, 1981; Warren et al., 2012). A significant amount of trace elements are produced in sediments near contamination sources, such as smelters, and these can be redistributed by currents, wave action and dredging.

2.5 Effect of organic and inorganic compounds on human health and the environment

The health and environmental authorities have established standard concentrations for trace elements in sediments to examine which pollution concentrations in sediment and soil need to be investigated. Increasing concentration of trace element concentrations are detrimental to marine life (flora and fauna), and cause a slowdown of growth of fish and other organisms, impaired reproduction, decline in species diversity, abundance and death. They can contaminate surface and ground water resources (Bergin et al., 2006; Chabukdhara and Nema, 2012) and move up the food chain since benthic micro-invertebrates are an important food for higher order predators such as fish.

The deleterious environmental consequences of high concentration effects from trace element contamination of soil, sediment and the water column in terrestrial and marine environments have been recognised by Long et al. (1995) and Gao and Chen (2012). These consequences play an important role in the bioaccumulation of toxic trace elements. The latter may be transferred to humans via the food chain. Consequently, they can pose a threat and cause severe human health problems such as brain damage, kidney dysfunction, immune system disjunction, hypertension, emphysema, asthma and anemia

(Yi et al., 2011; Zhao et al., 2012; Olawoyin et al., 2012; Alves et al., 2013; Huang et al., 2013).

The findings of a study carried out by Min et al. (2013) to evaluate the environmental activity and ecological hazard assessment of trace elements at a Chinese zinc leaching deposit, show that the environmental activity of trace elements decreases in the order $Cd > Zn > Cu > As > Pb$. Moreover, the most significant element for potential ecological risk was Cd. Assessment of the impacts of trace element pollution shows that there is a large problem because of the threat to the ecosystem and the potential for bioaccumulation and biomagnification from exposure for both plants and animals.

2.6 Assessment and control of contamination

In Australia, the rehabilitation and control of polluted areas is determined by state health and environmental offices and organizations, which establish reference guidelines to better investigate potentially contaminated areas. The Australia New Zealand Environment and Conservation Council (ANZECC) and National Health and Medical Research Council (NHMRC) have delivered modified guidelines from studies and information based on international research. This approach can be used for the assessment and management of polluted sites (Figure 2.2).

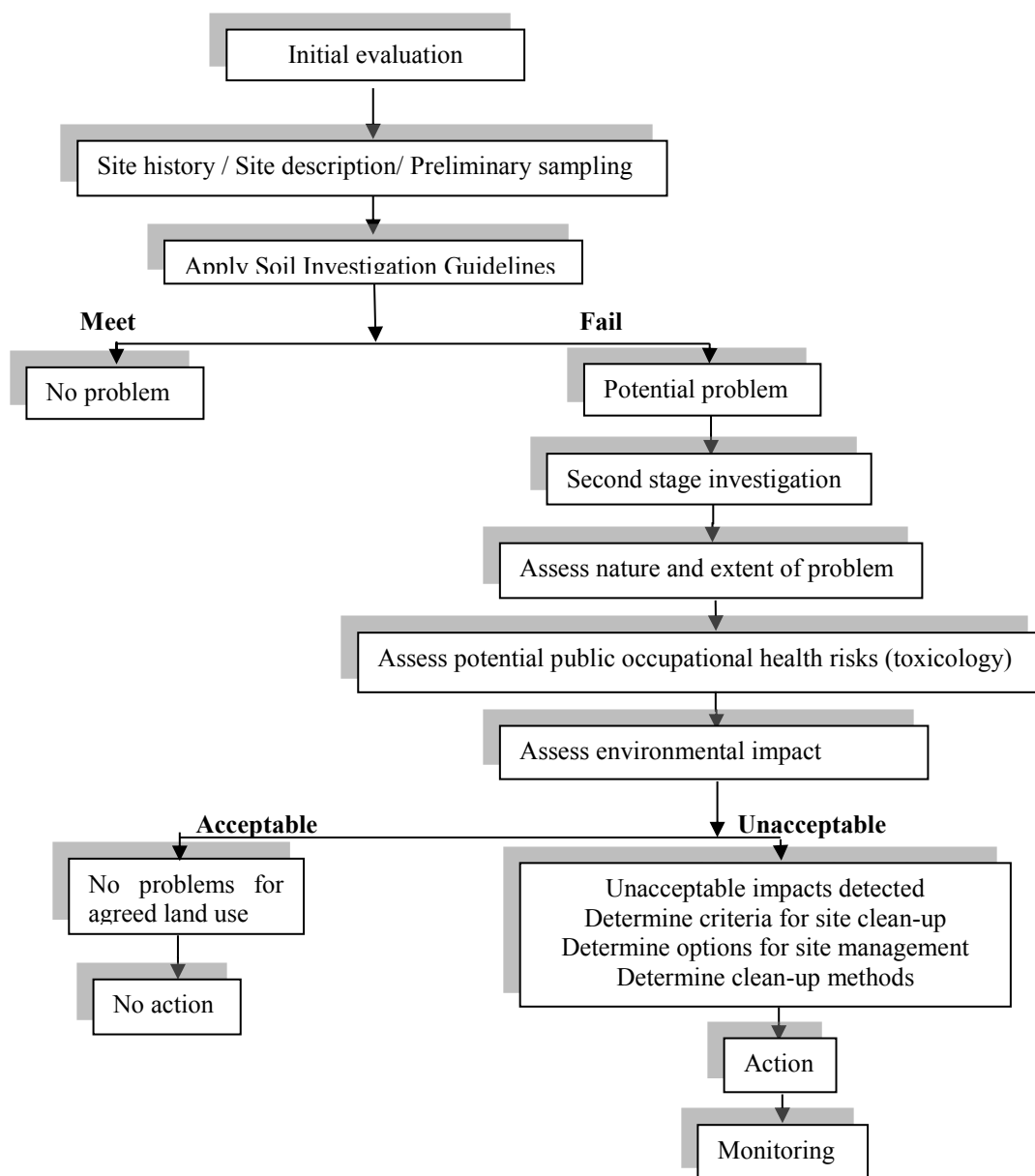


Figure 2.2: Recommended approach for the assessment and management of a potentially polluted areas after (ANZECC and NHMRC, 1992).

The natural remediation of polluted sediments is slow compared with industrial (human) remediation. Therefore, urgent remediation is often required to prohibit any penetration of trace elements within a soil that may cause potential contamination of groundwater (Burgos et al., 2013). Clean-up of metal pollution from soil can be carried out by physical processes such as extraction and isolation; chemical processes such as modification and soil washing in connection with other treatment techniques, or biological processes such as bioavailable contaminant stripping (BCS). Many studies have discussed and used procedures in order to rehabilitate soils and sediments (Bandala et al., 2008; Pedron et al.,

2009; Villa et al., 2010; Burgos et al., 2013; Rosas et al., 2013) to reduce and prevent the pollutants being dispersed through the soil into the ecosystem.

Polluted sediments and soils can be removed to a suitable or pre-industrial depth, and then transported to another site for disposal. The disadvantage of this remediation is that it creates new problems in another place for land use and also creates society concern (Hvitved-Jacobsen et al., 1994). Isolation of the polluted soils can be achieved by using an impermeable bed in order to reduce water infiltration before coating with new clean soil. The isolation approach can be combined with clean soil or soil with a very low concentration of contamination.

Dissolution or precipitation processes can be applied to control toxic elements such as arsenic (Martínez-Villegas et al., 2013). Modification of the polluted sediments by in-place treatment is the easiest processes for organic chemicals. This can be carried out in many ways such as leaching, heat treatments and biodegradation (Tiller, 1992). Furthermore, heating through injection steam/vapour wells is another method that was recently applied for remediation of a contamination site located underneath a building (Marschalko et al., 2012; Marschalko et al., 2013; Kempa et al., 2013).

2.7 Distribution of trace elements in marginal marine surface sediments – international examples

Marginal marine areas, estuaries and bays have been widely investigated by numerous authors around the world, in order to determine the presence and identify any indication of trace elements in sediments and seawater. Such trace elements play a significant role in affecting the ecosystem and are deleterious to public health through the transfer of toxic elements via the food chain. The following research has shown trace elements in sediments.

2.8 Geochemical studies of organic and inorganic compounds

2.8.1 Lead pollution

The distribution of trace elements and the environmental status of western Xiamen Bay in China displayed similar trace element concentrations to the Chinese marine sediment standard. Nevertheless, the enrichment factor and geo-accumulation index showed moderate pollution with Pb (Zhang et al., 2007). The main sources of Pb were local

industrial activities and the authors recommend the need for attention to control and manage the waste.

Kim et al. (2009) measured the concentration of Pb and Cd in marine sediments at a waste discarding site in the Yellow Sea, South Korea. The authors analysed grain size, mineralogy and the concentration of trace elements in the surface and bottom sediments at seven stations. The results revealed that the trace elements in surface sediments had higher concentrations of Pb and Cd compared to the subsurface sediments, which had backgrounds. However, the grain size and mineralogy did not show any significant variation between surface and bottom sediments. The main source of Pb and Cd was ocean dumping, which started in 1994 and reached high concentrations after 1999. The authors recommended that more attention should be paid and monitoring should be undertaken in order to manage the dumping ground through more planning for control.

Work carried out by Chabukdhara and Nema (2012) examined the distribution of trace elements in surface sediments of the Hindon River, India. This river is considered to be contaminated with industrial and domestic waste. The results showed that Cd, Pb and Cu were at high concentrations compared to normal limits in most of the locations. The authors recommended that more supervision and monitoring should be applied. Moreover, more remediation of waste water before discharge into the river was recommended.

2.8.2 Zinc pollution

Zinc is an essential nutrient for both plants and soils (Kochian, 2001) but it is considered to be a toxic element that can cause harm to aquatic biota when it exceeds standard concentrations. It has a positive relationship with iron and magnesium oxide, as well as clay minerals and organic matter, because its deposition in soils is related to these components (Fernández-Calviño et al., 2012). According to the National Oceanic and Atmospheric Administration (NOAA) and Canada Environment (1999) the concentration of zinc becomes deleterious to the biology of aquatic biota and causes a decline in diversity and abundance of benthic organisms when it exceeds background concentrations and may cause death and behavioral changes in organisms. The toxicity of zinc in soils can be reduced by sediment particles that have the potential play to a protective role

(CanadaEnvironment, 1999). For instance, the toxicity of soils containing zinc can be reduced by the presence of sulphides and organic matter (Sibley et al., 1996).

The adverse biological effects of zinc exposure at a particular place are dependent on many factors, such as sensitivity of individual species and differences in physio-chemistry (pH and Eh), geochemistry (fraction size, organic matter, metal oxide and sulphide content) and biology (incorporation rate and feeding behaviour). These factors can influence the bio-availability of zinc (CanadaEnvironment, 1999).

2.8.3 Copper pollution

Copper is an essential element for ecosystems but can also be toxic to aquatic organisms when it exceeds the standard concentration. Copper can accumulate in soils and shows a positive relationship with organic matter, iron and magnesium oxides and clay minerals (Campbell and Tessier, 1996).

However, excessive copper has an adverse biological impact on benthic organisms that live in sediments as it causes a decline in species richness and abundance, increased death and behavioral changes (CanadaEnvironment, 1999). The harmful effects of copper on ecosystem life are various, based on the response of individual species. Moreover, these effects depend on several factors: firstly, changing physiochemical characteristics such as pH, Eh and particle size; secondly, geochemical characteristic including organic matter, oxide-hydroxide elements and sulphides; and finally the biological ability to uptake and incorporate the element (Chen et al., 2010; Hu et al., 2011).

2.8.4 Arsenic pollution

Both natural and anthropogenic activities are considered to be sources of As in aquatic environments through atmospheric emission and water runoff (Chapagain et al., 2009). Arsenic has a strong positive relationship with iron and magnesium oxides due to its preferential deposition in soils containing these mineral compounds.

However, arsenic is considered a toxic element because of its toxic and carcinogenic effect on marine invertebrates and humans (Oremland and Stolz, 2003; Routh and Hjelmquist, 2011). Benthic invertebrates may uptake As from sediment particles or dissolved As on land and in water. As a result, arsenic is categorized as a primary source of contamination of ecosystems by the Environmental Protection Agency of the United

States (USEPA, 1998). Human activities also affect the natural biogeochemical cycle of arsenic. The amounts of As released to ecosystems and its transfer into marine and non-marine environments have increased. Suspended particles absorb the As, after which it is deposited in sediments causing increased As concentrations (Szefer et al., 1995; Duan et al., 2011).

Both spatial and temporal distributions of As in marine sediments in the East China Sea were investigated by Duan et al. (2013). The results demonstrated As ranges between 1.7-22.1 µg/g, with an average of 11.5 µg/g. The values of As had a positive relationship with the fine sediments (silt and clay) and total organic carbon. Furthermore, statistical analysis, such as the geo-accumulation index and sediment quality guidelines, showed that As in the East China Sea posed a low risk but had a moderate concentration of contamination. In addition, lead dating (^{210}Pb) in sediment cores showed that the As concentration rose from the 1900s to 1990s, with maximum values in 1980s and 1990s, dropping after this period to lower values by 1998.

2.8.5 Cadmium pollution

According to Sohrabi et al. (2010) surface sediments along the southern Caspian Sea were strongly contaminated with Cd. However, other trace elements such as Zn, Ni and Cu were found to be non-contaminating in the surface sediments. The authors suggested that the source of the Cd was from anthropogenic activities such as domestic and industry waste as well as chemical pesticides and fertilizers from agricultural activities. Another examination of the concentration of trace elements in surface sediments was carried out in Safaga Bay, Egypt (Abd El Wahab et al., 2011). The enrichment factors and geo-accumulation index were established. The results showed that the bay sediments had higher concentrations of Cd correlated with high amounts of phosphorous, which were derived from anthropogenic pollutants such as industry waste and sewerage, as well as a certain amount from suspended particles that are associated with guano type deposits. The descending order of the elements in the sediment within Safaga Bay was $\text{Fe} > \text{Mn} > \text{Zn} > \text{Pb} > \text{Ni} > \text{Co} > \text{Cu} > \text{Cd}$.

2.8.6 Mercury pollution

The distributions of total mercury in surface sediments in Lake Taihu, China, were determined by Chen et al. (2013). Their results demonstrated that the Hg content ranged

between 23-168ng/g, with an average of 55ng/g, which exceeded the baseline concentrations. Moreover, high values of Hg occurred in the northern area and the concentrations of Hg on the edges of the lake were higher than those in the central area. The authors suggested that the sources of Hg were human activities such as urbanization, industrialization, shipping and waste discharge.

Minamata Bay was found to be heavily polluted 70 years ago by wastewater dumped into Hyakken Harbour, mixed with mercury and methylmercury (MeHg). This was a result of the Chisso factory in Minamata City, Kumamoto Japan producing acetaldehyde from acetylene and carbide using mercury sulfate (Logar et al., 2001; Matsuyama et al., 2010).. The highly toxic compound bio-accumulated in fish and shellfish in the bay which, when eaten by the people living around the bay, gave rise to Minamata disease, affecting more than 10,000 people.

The total mercury concentrations and mercury isotopes were also investigated in three sediment cores in a lake adjacent to metal smelting operations in Canada. The results showed that concentrations of Hg were high close to the smelter. In addition, mercury isotope ($\delta^{202}\text{Hg}$) enrichment was low in the bottom of the sediment core and increased towards the top of the core. Furthermore, the heavy mercury isotope abundance was related to the high concentration of mercury. Ma et al. (2013) concluded that the mercury isotope ratio is a possible tool for detecting the source of mercury pollution.

2.8.7 Nickel pollution

A study carried out by Attia et al. (2012) investigated the distribution of trace elements in surface sediments of Mabahiss Bay, north Hurghada, Egypt. The results showed that Mabahiss Bay is considerably contaminated by toxic elements such as Ni, As, Co and Cd. The sources of trace elements include water sewage, solid waste; cargo boats as well as incidental oil spills in the bay have all increased as a consequence of human activities. The authors suggested that the sediment in Algeciras Bay was also contaminated by anthropogenic activities such as domestic and industrial waste from Hurghada city and adjacent areas.

The distribution of trace elements and organic carbon in the surface sediments at Homa lagoon, eastern Aegean Sea, Turkey, were determined by Uluturhan et al. (2011). The

results indicated that Ni is considered to be a toxic element in the Homa lagoon because there are high concentrations of it compared to sediment quality guidelines, some of which exceed the threshold effect concentration (TEL) and probable effect concentration (PEL). Consequently, Ni and Cr are considered to show moderate contamination at some of the sites. The main sources of trace elements were agricultural drainage, and industrial and municipal waste water which is provided by the Gedize River that discharges into the Homa lagoon.

2.8.8 Chromium

Chromium is considered to be a universal pollutant and is broadly used in many industries such as stainless steel production, antifoul paints and electroplating (Wang and Choi, 2013). Chromium (Cr^{3+}) is widely dispersed in natural conditions as a hydrated chromium ion ($\text{Cr}^{3+}(\text{H}_2\text{O})_6$). Cr^{3+} is an important nutrient for humans and has low toxicity in the Cr^{3+} form (Alloway, 1995), whereas Cr^{6+} presents as the chromate ion (CrO_4^{2-}) shows various physiochemical parameters involving bioavailability, toxicity and mobility (Shen et al., 1996). Moreover, Cr^{6+} is considered more soluble and bioavailable in environmental ecosystems. Potential redox conditions have major effects on chromium speciation. Chromium may also be present in a reduced form in sediments along with ferrous iron, sulfide and organic matter. It can react with iron sulfide (Berner, 1982). Moreover, many invertebrates (e.g. bacteria) can use Cr^{6+} through the degradation process of organic matter and transform it to Cr^{3+} during nitrate reduction conditions (Shen et al., 1996; Zhu et al., 2006).

2.9 Distribution of trace elements in Australian sediments

Many studies have been conducted in order to define and evaluate the sources of contamination by trace elements and toxic elements in the marginal marine areas of Australia, such as lakes, estuaries, embayments and harbours.

2.9.1 National Sediment Quality Guidelines (SQGs)

Sediments are considered to be a source of, and to act as a sink for, the accumulation of pollutants (ANZECC and NHMRC, 2000), and to be sensitive indicators for both spatial and temporal trend monitoring of contaminants in aquatic environments. Because pollution by trace element concentrations can be released again into the water column

under various chemical, physical and biological processes, the Australian Water Quality Guidelines were established for the management of both fresh and marine water, which were measured by atomic absorption and ICP-MS (Table 2.5).

Table 2.5: Detection limits, Australian Water Quality Guidelines (AWQG) and World Health Organization (WHO) drinking water guidelines for trace elements in Australian water.

Metal	Detection limit (mg/L)	Australian guideline (mg/L)	WHO guideline (mg/L)
Al	0.01	0.2 ^A	–
As	0.001	0.007	0.01 ^B
B	0.001	0.7	0.7
Be	0.001	–	–
Ca	0.01	–	–
Cl	0.1	250 ^A	–
Cr	0.001	0.05	0.05 ^B
Cu	0.001	1 ^A ; 2	2
F	0.01	1.5	1.5
Fe	0.001	0.3 ^A	–
Pb	0.001	0.01	0.01
Mg	0.1	–	–
Mn	0.001	0.1 ^A ; 0.5	0.4 ^A
Mo	0.001	0.05	0.07
Ni	0.001	0.02	0.07
NO ₃ ⁻	0.1	50 ^C	50 ^C
K	0.03	–	–
Se	0.001	0.01	0.01
Na	0.1	180 ^A	–
Sr	0.001	–	–
S	0.001	–	–
SO ₄ ²⁻	1.0	250 ^A ; 500	–
Ti	0.001	–	–
U	0.001	0.02	0.015 ^B
V	0.001	–	–
Zn	0.001	3 ^A	–
TDS	–	500 ^A	600 ^A

A: Aesthetic-based guideline.

B: Provisional guideline due to scientific uncertainty regarding toxicology/epidemiology and/or due to difficulties regarding technical achievability.

C: Guidelines recommended protecting against methaemoglobinaemia in bottle-fed infants (short-term exposure).

ANZECC and NHMRC guidelines have established ranges for trace elements accumulated into sediments, soils and water bodies (Table 2.6). These guidelines play a crucial role in evaluating pollution. When the concentrations of trace elements exceed these accepted ranges, fines and/or revocation of operating licences of factories can be implemented (ANZECC and NHMRC, (1992; , 2000).

Table 2.6: Sediment Quality Guidelines for concentrations of trace elements (ppm) in sediments (ANZECC and NHMRC, 2000).

Trace elements (ppm)	ISQG- Low	ISQG- High
Cr	80	370
Ni	21	52
Cu	65	270
Zn	200	410
As	20	70
Cd	1.5	10
Pb	50	220
Hg	0.15	1

The main goals of the sediment quality guidelines (ANZECC and NHMRC, 2000) are to define polluted areas that can be harmful to environmental health. The guidelines also demonstrate the potential for movement of pollutants through the aquatic environment and into the food chain. Furthermore, the guidelines recognize areas that are not influenced by anthropogenic activities (ANZECC and NHMRC, 2000).

In addition, the ANZECC and NHMRC established and published a set of guidelines that consider trace element contamination. These consist of a decision tree method, so the guidelines should not be employed on a permit or not-permit basis. If the trigger values are exceeded, additional action as outlined in the decision tree is required (Figure 2.3). The first concentration selection compares the total trace element pollutant concentration in the soil to the trigger values in the sediment quality guidelines (ANZECC and NHMRC, 2000).

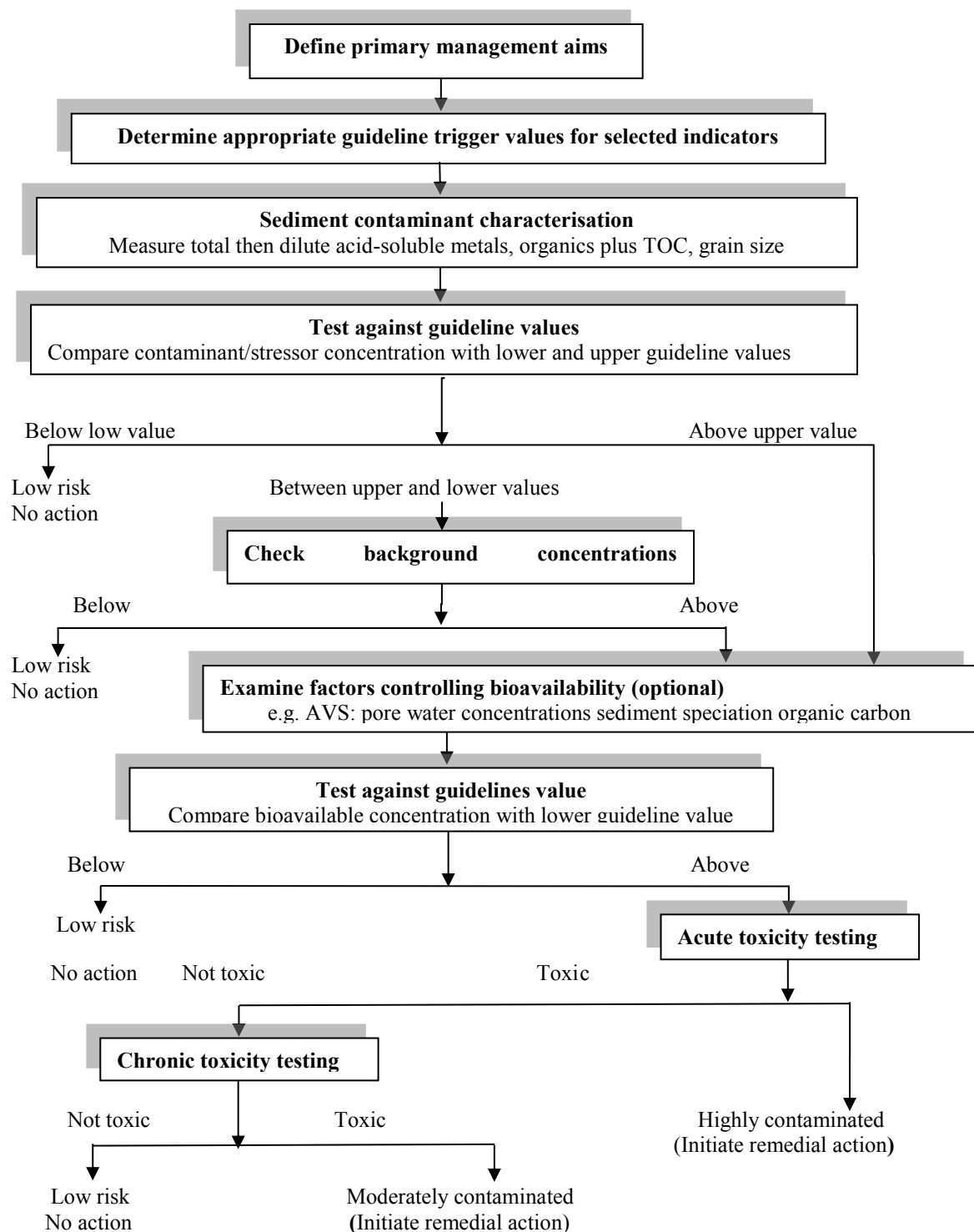


Figure 2.3: Decision tree to assess and evaluate polluted sediment and soil from (ANZECC and NHMRC, 2000).

2.9.2 Very polluted estuary areas

Many estuaries and bays are contaminated by trace elements in Australia, such as Lake Illawarra, Port Pirie, Derwent River, Port Hunter and Cockle Creek, Hawkesbury River, Port Jackson and Sydney Harbour. These estuaries are considered disposal sites for urban

and industrial waste, and are areas with major industrial expansion. Trace element concentrations have emerged from human activities since European settlement, including sewage, industrial and agricultural waste that are released to the nearshore marine environment (Irvine, 1980; Birch, 1996). Therefore, these systems have become contaminated. Considerable worry for public health has resulted from pollution of local estuaries and visible fouling of the famous Australian surfing beaches.

2.9.2.1 Lake Illawarra

The spatial and temporal distributions of trace elements in Lake Illawarra, NSW, and its vicinity have been investigated by many authors (Beavington, 1973; Ellis and Kanamori, 1977; Yassini and Jones, 1987; Chenhall et al., 1994; Chiaradia et al., 1997; Pacheco, 1999; Martley et al., 2004; Chenhall et al., 2004; Kachenko and Singh, 2006; Gillis and Birch, 2006; Jafari, 2009). The concentrations of trace elements are shown in Table 2.7.

The researchers found the main sources of pollution in Lake Illawarra and its vicinity emanated from anthropogenic activities such as the industrial complex of Port Kembla (copper smelter), Tallawarra power station, Kanahooka smelter, three coke works, agricultural activities, urbanisation and emissions from vehicles, especially from leaded petrol. Furthermore, natural processes such as erosion, weathering and transportation of soil and sediments from surrounding areas of Lake Illawarra provided background trace element concentrations. Fine particles have been concentrated in the lake. According to Ellis and Kanamori, (1977) and Jafari (2009) the concentration of trace elements, such as Pb, Zn, Cu, Cd, As and Hg, from atmospheric emissions increased within subsurface sediments around the industrial complex until the 1980s and has subsequently decreased (Table 2.7).

Table 2.7: Trace elements (ppm) in soils around the Lake Illawarra region.

Concentrations of trace elements	Location of samples	References
Pb & Cd < 1, Zn 2.7 & Cu 5.3	Countryside around Wollongong	(Beavington, 1973)
Pb 21, Cd 2.8, Zn 82 & Cu 343	Soil around Port Kembla	(Beavington, 1973)
Pb > 150, Cd 1.22, Zn 471 & Cu 330	Soil around Port Kembla	(Kachenko and Singh, 2006)
Pb 114.5, Cd 11.7, Zn 357.5 & Cu 324	Soil around Port Kembla	(Jafari, 2009)

Furthermore, the highest concentrations of trace elements were found in Griffins Bay and Koona Bay (Jones et al., 1976; Chenhall et al., 2001; Martley et al., 2004). Kachenko and Singh (2006) evaluated the concentration of trace elements, such as Pb, Cu, Zn and Cd, in both soils (surface and subsurface) and vegetables in the Port Kembla and Boolaroo areas. The trace elements in soils dramatically declined with increasing depth, because the upper parts of soils represent recent anthropogenic pollution. In addition, the highest concentrations of trace elements at Boolaroo coincide with the highest Pb and Cd contents in vegetables. Most of the samples contained Pb and Cd concentrations that exceed the background concentrations (Table 2.8), whereas some vegetable samples from Port Kembla exceeded the high maximum safe concentrations of Pb and Cd. The source of pollution was mainly from atmospheric emissions and more attention should be given to vegetables as a risk to human health (Kachenko and Singh, 2006).

Table 2.8: Average concentrations of trace elements in sediment cores in Lake Illawarra. (1) from the northwest part of the lake (Chenhall et al., 2004), and (2) Griffins Bay (Jafari, 2009).

Depth (cm)	Zn (ppm)		Cu (ppm)		Pb (ppm)	
	1	2	1	2	1	2
0	----	350.2	----	88.2	----	58.8
10	200	349.2	175	61.8	150	61.3
20	175	63.3	145	38.1	130	29
30	100	66.7	135	17.1	100	7.2
40	90	10.6	120	48.4	60	3.3
50	80	12.5	115	9.6	45	3.9

2.9.2.2 Port Pirie

Trace elements such as Zn, Pb and Cd at a lead-zinc smelter at Port Pirie, North of Adelaide, South Australia, were evaluated by Cartwright et al. (1977) and Ferguson et al. (1983). Whyalla, Port Augusta and Wallaroo are also close to the industrial areas of Port Pirie. The industry smelted about 650,000 tonnes of lead-zinc concentrate per year (Table 2.9). The emission of fine particles, which are rich in trace elements, for over a century has led to very high trace element pollution of sediments in the Port Pirie ecosystem (Maynard et al., 2003). These sediments have the highest concentrations of trace elements compared with anywhere else in the Port Pirie area (Cartwright et al., 1977).

Table 2.9: Trace elements in surface sediments around Port Pirie and Whyalla compared with US, Australia and New Zealand EPA Guidelines (Harbison, 1984).

Trace elements (ppm)	EPA Guideline		Spencer Gulf sediments					
	Unpolluted	Heavily polluted & unacceptable for open water dumping	Port Pirie			Whyalla		
			WR ₂	WR ₃	2 km off shore	W ₂	W ₅	F ₁
Pb	40	60	335	208	600	635	607	448
Zn	90	200	1090	196	1000	2800	3240	2880
Cd	No limit established	6	23	3	105	6	1	3
Mn	300	500	148	950	NA	981	3330	810

NA=not available; WR, W and F = sample locations.

The results demonstrated that the concentration of trace elements decreased dramatically with distance from the smelter (Harbison, 1984). Moreover, both diffusion and concentration of trace elements in the soils are controlled by mineralogy and topography.

2.9.2.3 Derwent River

The Derwent River in Tasmania has been highly influenced by anthropogenic activities, such as contamination from the zinc smelter that has been discharging into the middle of the river since 1917 (Jones et al., 2003a). Over the past 100 years the industrial production of zinc has increased with current production being approximately 250,000 tonnes per year. Other contaminants include trace elements and dissolved sulphate and ammonia (Whitehead et al., 2010; Townsend and Seen, 2012). Furthermore, the discharges from municipal waste and agriculture since European settlement and waste from the paper mill industry, which includes wood fibre, suspended solids, resin acids, phosphorus and nitrogen, are elevated (Neal et al., 1998; Butler, 2006; Whitehead et al., 2010).

The results showed that the concentration of trace elements was very high near the zinc refinery; between (40-565) times the baseline values, and exceed the high-concentration Australian Interim Sediment Quality Guidelines (Table 2.10). In addition, the distribution of trace elements downstream from the zinc refinery is affected by currents and tides and had values higher than upstream (Jones et al., 2003a).

Table 2.10: Concentration of trace elements in the Derwent estuary and Interim Sediment Quality Guidelines (ANZECC and NHMRC, 2000; Jones et al., 2003a).

Trace Elements (ppm)	Upper Derwent Range	Lower Derwent Range	Range concentrations in the Derwent	Interim Sediment Quality Guidelines (ISQG) low/high
Fe	1210-2910	230-4530	70-6490	-----
Ni	14-31	<2-27	<2-35	21/52
Cr	30-72	10-183	<5-183	80/370
Zn	72-737	<2-3110	<2-22593	200/410
Pb	16-234	<6-1103	4-3866	50/220
Cu	17-51	<2-140	<2-1182	65/270
Co	24-43	8-16	8-95	-----
Sb	<0.2-1.3	<0.2-9	<0.2-51	2/25
As	3-20	2-46	1-657	20/70
Au	<5-9	<5-36	<5-161	-----
Cd	<10	<10-11	<10-180	1.5/10
Hg	<5	<5-11	<5-36	0.15/1

2.9.2.4 Port Hunter and Cockle Creek

Work was carried out by (Roy and Crawford, 1984; Birch et al., 1997) to evaluate the concentration of trace elements in the Port Hunter in the Newcastle region, NSW, where water from the Port Hunter flows through a heavily contaminated, industrialized area with a high population (crowding). The results showed that the concentrations of trace elements such as Cr, Co, Cu, Ni, Pb, and Zn upstream were all higher than the background values (Table 2.11).

The concentrations of these elements were also higher in the sediments around the industrial district compared with the light industrial areas of the Newcastle Harbour Creek. The author concluded that these elements in the latter area were emanating from atmospheric emissions, especially Pb from petrol. Also, Pb in the road dust was added to runoff into the local drainage system. In addition, some samples were located close to a sewage outlet which had high concentrations of these elements.

Table 2.11: Trace element concentrations in the Port Hunter 1 (Birch et al., 1997), and from Cockle Creek, Lake Macquarie 2 (Roy and Crawford, 1984).

Trace elements	Cu ppm	Pb ppm	Zn ppm	Cd ppm	Cr ppm	Co ppm	Ni ppm
Range ¹	19-283	25-843	32-5161	<0.1-8	21-167	14-22	14-41
Range ²	30-420	165-7050	390-6250	NA	NA	NA	NA

Where: NA not available

2.9.2.5 Pollution studies in the Sydney area

Many studies (e.g. Birch and Davey, 1995; Birch et al., 1996; Birch, 1996; Irvine and Birch, 1998; Birch and Taylor, 1999b, 2000; Birch and Taylor, 2002b; Birch and Taylor, 2002a; McCready et al., 2006; Birch, 2011) have been performed to determine the concentration of trace elements in the Port Jackson estuary at Sydney, and to examine the possible biological significance of the high pollutant concentrations in the region. Approximately, one thousand surface sediment samples were collected from both fluvial and estuarine sediments.

Trace elements such as Cu, Cr, V, Co, Cd, Fe, Mn, Ni, Pb and Zn were analysed in the muddy (silt and clay) samples. The results revealed that the highest concentrations of trace elements are found within two main rivers (Duck and Parramatta) as well as in smaller estuaries such as Homebush, Hen and Chicken, Iron Cove, Blackwattle and Rozelle Bays. Moreover, elements such as Cu, Pb, Zn, Fe, Mn, Ni, Cd and Co dramatically decreased from the upper Harbour toward the lower Harbour (Table 2.12). Furthermore, a previous study has reported the distribution of trace element pollution in marine sediments in Botany Bay (Birch et al., 1996) where they found trace elements in very high concentrations close to Cooks River as a result of waste dumps, sewage overflows and discharge points. Boat moorings and the airport are also responsible for enriching trace elements up to 50 times above background concentrations.

Table 2.12: Trace element categories within Port Jackson (Birch and Taylor, 1999b; Birch and Mc Cready, 2009).

Locations/Elements (Tonnes)	Cu	Pb	Zn
Port Jackson	1900	3500	7300
Lower Harbour	600	1300	2300
Upper Harbour	1200	2100	4600
Iron Cove	120	250	470
Homebush Bay	33	80	210
Rozelle / Blackwattle Bay	100	190	350
Hen and Chicken Bay	220	210	460
Middle Harbour	200	350	580

In Port Jackson elements such as Cu, Pb and Zn are in high concentrations in the upper reaches of the estuary when compared to background concentrations, with maximum concentrations of about 200 ppm for Cu, and >1000 ppm for both Zn and Pb (Table 2.13).

Birch and Taylor (1999b) concluded that the concentrations of trace elements in the Port Jackson estuary corresponded with previous works, which had been completed by Birch and Davey (1995) and Birch (1996). These trace elements emanated from industrial activities over the past many decades and municipal discharges from the biggest Australian capital city, Sydney. Port Jackson is deemed to have the highest concentrations of trace elements compared to other estuaries in Australasia (Table 2.13). Moreover, the sediments in broad areas of Sydney Harbour have deleterious effects on the fauna, especially because they include high concentrations of chlordane (Birch and Taylor, 1999b, 2000; Birch and Hutson, 2009).

Further research evaluated concentrations of dissolved Ni, Zn, Cd, Co and Mn in the Port Jackson estuary, Sydney (Hatje et al., 2003). The samples were collected from the water during winter and summer, under different flow conditions of the estuary, and they concluded that there was a very high salinity in the estuary. The results revealed that trace elements such as Zn, Ni, Cd and Mn were below Australian water guidelines, and that the concentrations of these elements during summer were low, due to temperature and biological activity. However, the concentration of Cu was highest in the summer, which was related to human activities. The study concluded that the region could be considered moderately contaminated.

Table 2.13: Trace element concentrations in Port Jackson, NSW from 1- Irvine and Birch (1998) and 2- Birch and Taylor (1999b).

Trace elements	Cu ppm	Pb ppm	Zn ppm	Cd ppm	Cr ppm	Co ppm	Ni ppm	Mn ppm	Fe %
Range ¹	13-1078	44-1319	46-2246	< 1-10	7-698	3-60	12-86	30-408	1-7.8
Mean	124	268	548	3	118	19	38	144	3.8
Range ²	9.3-1053	37.9-3604	108-7622	BDL-24.3	---	2.2-54	5-245	27-578	0.5-10.6
Mean	188	364	651	0.8	---	8.3	21	118	3

Where: BDL= below detection limit.

Work carried out by Birch and McCready (2009) examined the sources of trace elements contamination, such as Co, Cr, Cu, Zn Ni and Pb, in the Sydney Harbour catchment. They also determined the influence of water runoff on the sediment quality in the study of the basin. The results showed that the high concentrations of trace elements emanated from domestic activities and road dust. They passed through the valley to the water canal in the

Iron Cove catchment. The materials are transported as bed load, suspended load and dissolved phases and then deposited within the basin. Some concentrations of trace elements were at high concentrations and this could be harmful to the benthic biology if the concentrations exceed the soil quality guidelines and extractable methods for the sediments. In addition, the concentrations of these elements were found to decline away from the water canal (Birch and Mc Cready, 2009). The authors recommended that more controls and treatment should be applied to reduce the concentration and effect of trace elements before these elements enter into the estuary from the catchment area.

2.9.3 Low-metalliferous pollution

A study was conducted by Macfarlane and Booth (2001) on the sediments from Cowan and Berowra Creeks in the Hawkesbury River in order to evaluate the presence of pollutants such as Cu, Pb, Zn, phosphorous and nitrogen. The findings demonstrated that the concentrations of trace elements were of normal status according to the sediment guideline values for biological effects. Nonetheless, the authors recommended more attention to recording any changes in the concentrations of trace elements at these locations. Studies have been carried out at Oatley Bay, NSW (Birch, 1996; Catchlove, 1999; McLean and Hinwood, 2007; Pease, 2007), in order to evaluate the distribution of trace elements, sediment size and foraminifera. The main results of these studies showed that the concentrations of trace elements had normal average concentrations throughout most of Oatley Bay and its catchments compared with ANZECC and NHMRC (2000) guidelines (Table 2.14).

However, the elements such as Zn, Pb and Cu were contaminated in the surface sediments within some locations, such as the upper eastern area, the eastern arm and the most eastern lagoon in the north causeway of Oatley Bay. Moreover, the particle sizes were characteristically dominated by clay and silt in inner part of the bay, and sandy areas along the shoreline, with increasing concentrations close to the recent urban development and discharge points, as well as watercraft and boatyards (Catchlove, 1999). Moore Reserve, the western arm and a discharge drain had high concentrations of trace elements, derived from contaminated sources of landfill sites in the catchment area, such as Poulton Park and Moore Reserve.

Table 2.14: Average concentrations of trace elements within Oatley Bay, NSW, and ANZECC guidelines (Pease, 2007).

Trace elements (ppm)	Zn	Cu	Pb	As	Ni	Cr
Oatley Bay	195.5	39.9	117	23.9	14.5	39.5
ANZECC (low/high)	200/410	65/270	50/220	20/70	21/52	80/370

The first serious discussion and analysis of pollution in Burraneer, Turriell and Dolan Bays in the Port Hacking area of southern Sydney was carried out by Aljawi (2010). The highest concentrations of trace elements were found within Dolan Bay. Many sediment sites contained Br, which is related to the organic matter content in the bay. Furthermore, concentrations of elements such as Cr, U, Ti, Pb and Zn had high concentrations within Burraneer Bay compared with these elements in the Lake Illawarra background values. The research concluded that overall, the average concentrations of trace elements throughout Burraneer Bay did not constitute severe contamination according to ANZECC concentrations (Table 2.15).

Table 2.15: Average concentration of trace elements in surface sediments from Burraneer Bay and adjacent areas (Aljawi, 2010).

Trace elements (ppm)	Little Turriell Bay and Turriell point	Burraneer Bay	Dolans Bay	ANZECC (low/high)
Zn	23.4	49.3	66.8	200/410
Cu	7.3	31.8	32.8	65/270
Pb	11.9	29.8	38	50/220
As	4.2	5	5.8	20/70
Ni	3.6	5.3	7.2	21/52
Br	120.5	153.8	168.6	----
Sr	59	443.2	330.9	----
Ba	78.8	71.8	75.3	----
Rb	13.7	13.5	15.9	----
Sn	6.2	8.1	10.3	----

Another example of a relatively uncontaminated estuary is Tamar estuary, southern Australia. The results from surface sediments illustrated that the concentrations of trace elements were related to the amount of very fine sediments. Moreover, the average concentrations of these elements were of normal status (Table 2.16) and the source of these elements was from anthropogenic activities (Aquenal Pty Ltd., 2005).

Table 2.16: Trace elements in marine sediments at a proposed wharf location in the Tamar estuary, southern Australia Aquenal Pty Ltd, (2005).

Elements (ppm)	Range recorded ppm	Interim Sediment Quality Guidelines (ISQG) low / high ppm
Ni	2-8	21 / 52
Cr	4-15	80 / 370
Zn	17-61	200 / 410
Pb	< 5-11	50 / 220
Cu	< 5-9	65 / 270
Co	< 2-3	-----
As	5-8	20 / 70
Cd	< 1	1.5 - 10
Hg	< 0.1-0.2	0.15 / 1

Trace elements were also determined in sediments in Bells Creek, southeast Queensland, which is considered a non- industrialized coastal area, with a limited small population and agricultural land (Liaghati et al., 2004). Trace elements such as V, Cr, Ni, Cu, Zn, Pb As, Fe, Mn and Al were analysed. According to Covelli and Fontolan (1997) concentrations of trace elements were deemed to be at higher concentrations, except for Mn, compared with mean trace element contents of sandstone from the bedrock. However, the concentrations of these elements were of normal status when compared with parent rock after a normalization procedure. The authors concluded that the mineralogy and geochemistry of samples are clearly influenced by both natural and anthropogenic activities.

Several studies (Lawrence, 1993; Nolan, 1997) have been carried out on the surface sediments in Burrill Lake, on the NSW south coast, to evaluate its environmental status. The results revealed that the average concentration of trace elements within the lake was within, or less than, normal concentrations of trace elements (Table 2.17). Nevertheless, in the vicinity of the northern margin of the estuary a significant amount of trace elements were present and represented a source of trace elements for Burrill Lake (Nolan, 1997) Several primary sources of contamination by trace elements included the Ulladulla waste and recycling depot, as well as urbanization close to the northern border of the lake.

Table 2.17: Trace element concentrations within Burrill Lake sediments compared to Dutch Guidelines for assessing polluted soil from Jones et al., (2003b).

Trace elements (ppm)	Range	Mean values	Dutch Guidelines		
			A	B	C
Pb	0-32	13 ± 9	50	150	600
Zn	3-82	29 ± 23	200	500	3000
Cu	5-80	32 ± 24	50	100	500
Ni	3-20	11 ± 4	50	100	500
Br	4-540	135 ± 155	--	--	--
Rb	12-69	41 ± 16	--	--	--

Zinc contents were found to be up to 82 ppm, while the value of Ni was more than 20 ppm (Table 2.17). The trace element concentrations in sediment samples were below the Dutch guideline (Nolan, 1997; WBM, 2001). Jones et al. (2003b) collected many samples from surface sediments and six cores in order to determine the concentration of trace elements such as Ni, Zn, Pb and Cu in Burrill Lake. Their findings suggested that the elements within the Burrill Lake catchment are caused by urbanization activities. There was an increase in the concentration of trace elements obtained from surface sediments in the lagoon in the vicinity of Bungalow Park and Kings Point to as much as twice their average values. In addition, concentrations of Pb, Zn and Cu were thought to be related to factors such as the abundance of fine sediments, organic matter, alkalinity and sulphate in the deeper water of Burrill Lake (Payne et al., 1997).

2.10 Grain size normalization

In order to evaluate the quality of environmental investigations, where the fine particles (<62.5µm) are considered to be chemically reactive, or to describe source to sink relationships and diagenetic processes, the geochemical signatures of the fine sediment components have used for interpretations (Clark et al., 2000). Generally, normalization procedures are applied to determine the equivalent trace element concentrations in the fine particles (<62.5 µm) within the whole sediment samples, since these fractions absorb most of the trace elements and nutrients (Birch, 2003).

Many methods have been used to normalise sediments contaminant concentrations in the fine sediment fractions (Clark et al., 2000; Akhurst et al., 2004; Akhurst et al., 2011, 2012). Methods include size normalisation (physical separation of the fine fraction by wet sieving prior to analysis) and post-extraction normalization where the whole rock sample

is analysed. In the latter case the normalisation may be based on the percentage of fine material in the sample, the use of a conservative element normally associated with clays (such as Rb) or by sequential extraction from a whole sediment sample (Figure 2.4).

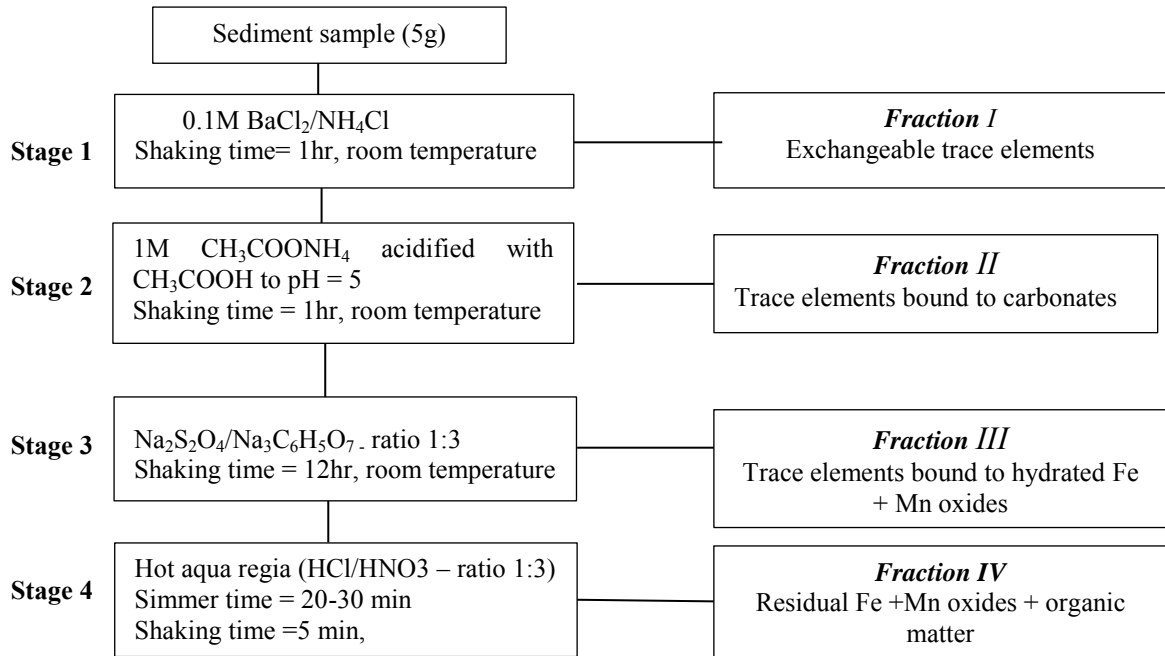


Figure 2.4: Trace element sequential extraction procedure and fractions removed (Clark et al., 2000).

The post-extraction normalisation (PEN) method is considered to provide a more ecologically and diagenetically interpretable demonstration of the partitioning of trace elements. Furthermore, sample collection for this method is faster and easier since smaller quantities of bulk sediment are required; as a result PEN is a cheaper alternative. In addition to providing data relevant to ecological health, the PEN method can also be used to determine sediment source and distribution patterns and relevant sedimentary diagenetic mobility data using a single sediment sample (Akhurst et al., 2011). Another study by (Akhurst et al., 2012) compared the sequential extraction and post-extraction normalization (PEN) techniques to assess the spatial distribution of trace and major elements in the sediments from Emigrant Creek Dam, NSW, Australia. The results of this research indicated that both the integrated sequential extraction procedure and post-extraction normalisation are suitable techniques to detect the concentration of trace elements in mineralogically and geochemically varied sediments. The data could be applied to both spatial mapping and sediment quality guidelines, which improved the interpretation of the data (Akhurst et al., 2012). According to the method described by

Clark et al. (2000), a sequential extraction involves four steps (Figure 2.4). The bioavailability of trace elements can be distinguished as the material extracted from the sample during fractions one to three (Clark et al., 2000). These analyses are expensive and time-consuming and are best applied to areas with known high concentrations of the target trace elements.

2.11 Lead isotopes ($^{204}\text{Pb}/^{206}\text{Pb}$, $^{207}\text{Pb}/^{206}\text{Pb}$ and $^{208}\text{Pb}/^{206}\text{Pb}$)

Lead pollution above background concentrations in ecosystems is derived from anthropogenic activities such as industry, mining, coal burning and gasoline-fumes. Lead is considered a toxic metal that is harmful to the human body and can cause serious diseases such central nervous system disorders, kidney brain damage and high blood pressure (Needleman, 2004). Lead pollution increased in the early 1970s with gasoline-fumes in developed countries, and emissions from industrial activities (Needleman, 2004). It is an important issue in environmental investigation to identify the source of pollution and determine the transport history of pollutants (Cheng and Hu, 2010). A large number of sources of lead pollution occur in ecosystems including major contributions from urbanization, such as gasoline-air emissions, paints and insecticides, as well as from natural sources such as bedrock (Lu et al., 2011; Larsen et al., 2012).

Lu et al. (2011) stated that it is difficult to recognize which source contributed Pb and other trace elements by simply using concentrations analysed in the environment. The classic measurements of Pb were derived from serious statistical analysis of large data samples to categorize the source and transport of metal pollution. The chemical composition of trace elements can be an effective method to recognize the source of resources and to compare them by using “fingerprinting” (Qishlaqi and Moore, 2007). Several attempts have been made to fingerprint the isotopic composition of Pb and other elements which can play an important and powerful tool in tracking sources of pollution (Chiaradia et al., 1997; Renberg et al., 2002; Franco-Uriá et al., 2009; Cheng and Hu, 2010). It is known that lead isotope ratios can serve as a fingerprint for sources of contamination. Therefore, using isotopic ratios of elements is a more profound tracking method than using their concentrations alone to identify sources of contamination (e.g. carbon and chlorine; Sueker, 2001; Philp et al., 2002). In the same way Pb isotopic

composition may be used to trace the source and transport history of Pb (Chiaradia et al., 1997; Cheng and Hu, 2010; Lu et al., 2011).

2.12 Hydrodynamic activities

Exchange of water and materials between drainage basins and the coastal environment in estuaries is affected by a combination of tidal flows, freshwater discharged from upstream and sometimes impacts from coastal ocean waves and currents (Chen et al., 2012). Hydrodynamic systems in bays and estuaries are complex since the interaction between riverine and marine processes can cause the water movement to change continually (Chen et al., 2012). Many parameters can have an effect on estuary function. These include estuary shape, astronomical tides, river discharges and storm waves as well as wind direction and speed (McLean and Hinwood, 2000; Hinwood et al., 2001; Chen et al., 2012). Ebb currents and tidal activity have the capability to transport fine and very fine particles within the estuary as well as chemical pollution. Tide data are considered useful information for both civil and hydraulic engineers who provide hydraulic constructions, information for water quality model management and frameworks for evaluating sediment and chemical dynamics in bays (Mehta and Joshi, 1988; Hogan, 1999; Hinwood et al., 2001; McLean and Hinwood, 2007; Maanen et al., 2013).

2.12.1 Hydrodynamic modelling for estuaries

Hydrodynamic models have been designed and developed by several researchers (Hogan, 1999; Hinwood and McLean, 2000; Burchard et al., 2004; McLean and Hinwood, 2007; Hinwood and McLean, 2013) in order to calculate and predict tidal water movement in bays and estuaries. These models range from simple one or two cell models through to complex three dimensional models, which include the full hydrodynamic equations. There are three concentrations of models. Firstly, one-dimensional models that estimate flow in a narrow channel or river. These are often used for water quality modelling, but sediment transport equations can be added to model sediment transport. For example a one dimensional model was applied for unsteady flow routing to estimate the water stage during flash flood events in the Danshui River, Taiwan (Hsu et al., 2003).

Two dimensional models are used in more complex channels or bays where spatial distribution is important. In order to build such a model, some data, such as bathymetry, water concentrations for tides, current velocities, as well as wind direction and speed need

to be collected for model construction and input. This type of hydrodynamic model is widely used to provide a robust framework for better understanding the distribution of sediments and chemical pollution in large bays and estuaries. Such a model was used in the north-eastern Gulf of Mexico and Johns River in north-eastern Florida, where advanced storm surge and circulation models were used in order to simulate water surface assessments following storm events (Bacopoulos et al., 2009).

Finally, three dimensional models (width, length and depth) are applied where geomorphology is complex and there is needed to simulate flows in great detail. Consequently, in order to use such a model a large amount data for calibration is required. For example, a three dimensional model was used to mimic storm currents in Chesapeake Bay, USA, that had tide, residual intertidal and mudflat components (Shen et al., 2006; Lapetina and Sheng, 2014). Later three dimensional models include the capacity to both model sediment movement and update bed configurations.

For the bays under the study areas, two and three dimensional models could be applied especially, where prediction of sediment and trace element movements was required. It should be noted that this type of modelling comes at a considerable cost and needs high technical backup. Application of such a technique in low finance (developing) economies is difficult for both cost and technical reasons. However, it is important that any low concentration data collection for explanation of sediment and trace elements transport in these areas be upward-compatible with potential future modelling. Field data such as tidal regime, current track and wind speed and direction comprise such suitable data.

2.13 Conclusions

The distribution of trace elements (both spatial and temporal) in soils and sediments gives an idea of the environmental status of both the continental shelf and marine environments around the world, as well as the source of natural and anthropogenic contaminants. Marine sediments are considered to be a sink that collect and concentrate trace elements by chemical, physical and biological processes. Moreover, trace elements accumulate over time and do not degrade. In addition, trace elements can be released again into the water column by chemical, physical and biological processes. As a result, marine life (organisms and microorganisms) can be affected by contamination, and this contamination can then be transported to humans through the food chain.

Chapter 3

Study areas and methodology

3.1 Introduction

This chapter has two sections. The first section describes the geomorphology of the study areas, including both sediments and catchment areas. The second section provides details about the fieldwork, samples collected (surface and subsurface sediment samples), and the equipment used to analyse the samples.

3.2 Study areas

This study covers two coastal areas classified as open estuaries, the Port Hacking and Botany Bay areas in New South Wales, Australia (Figure 3.1). These bays are described as deep and narrow, with high cliffs, severe rocky headlands, rock platform sites and a number of small bays (Branagan et al., 1979; Herbert, 1980; Yassini and Jones, 1995). Marine sand is found at the mouths of many of the bays, with muddy sediments and organic matter in various deeper sheltered parts of the bays (Yassini and Jones, 1995; Pease, 2007; Aljawi, 2010).



Figure 3.1: Location of study areas (Botany Bay and Port Hacking) and connections with Tasman Sea, NSW.

3.2.1 Geomorphology of Botany Bay district

Botany Bay is located approximately 15 km south of the central business district of Sydney (33° 55' S, 151° 11' E; Figure 3.2). It constitutes a large area, approximately 49 km² with a wide mouth, (approximately 1.1 km) and shallow bays, where the average depth is approximately 5m (Fraser et al., 2006). It is described as a semi-enclosed estuary with a wide coastal embayment that joins with the open sea. Nevertheless, it is partly protected from the oceanic tides and waves by headlands. The hydrodynamics of Botany Bay have been changed by anthropogenic constriction, which includes a shipping container port as well as the reclamation effects of Sydney's main airport on the northern side of Botany Bay (Gray et al., 2001; Fraser et al., 2006).

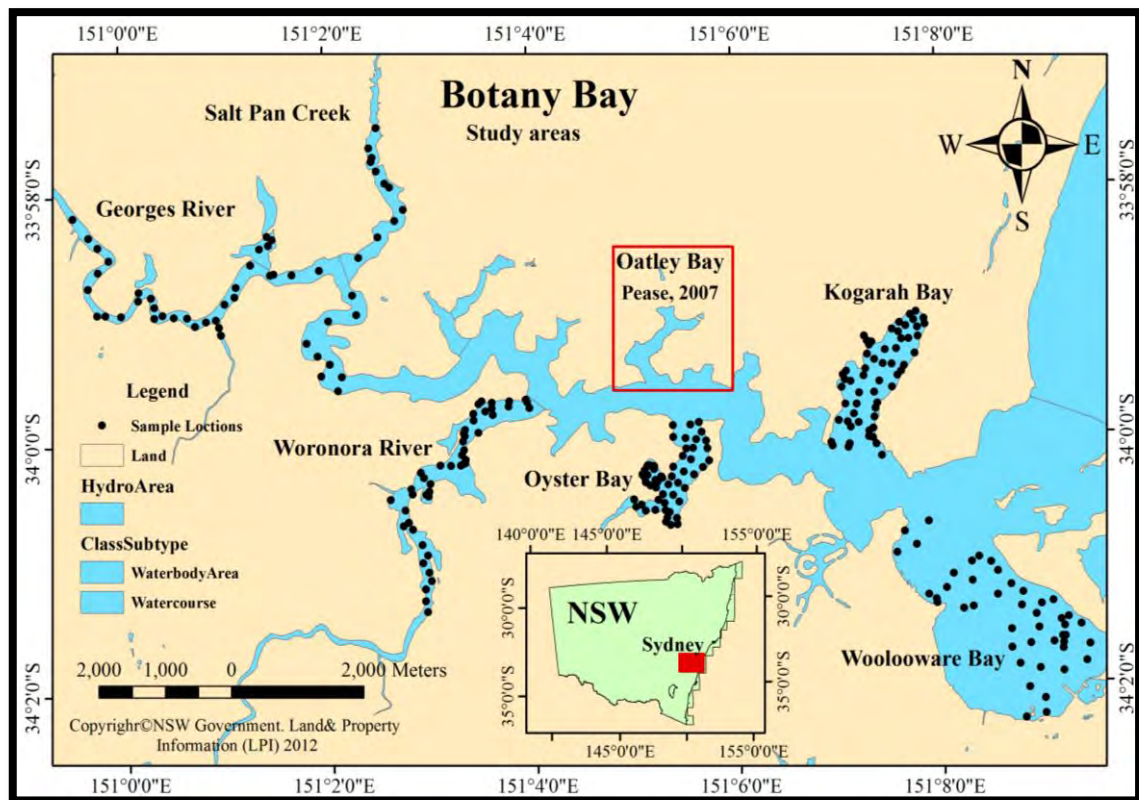


Figure 3.2: Sample locations in Botany Bay district, NSW, Australia.

Tidal flushing in the inner parts of Botany Bay have been limited by the size of the entrance resulting in a maximum tidal range of about 2 m (Kingsford and Suthers, 1996). Fresh waters are also discharged into Botany Bay from the Georges and Cooks Rivers (Gray et al., 2001), as well as runoff from small bays such as Kogarah Bay, Woollooware

Bay, Oyster Bay and Oatley Bay. The Georges River enters the bay from the south-west, between Dolls Point and Towra Point, while the smaller Cooks River enters the bay from a sheltered north-western corner (Figure 3.2).

Both rivers have catchment areas that extend into Sydney, as well as having large discharges of urban and industrial stormwater. Moreover, they feed Botany Bay with an annual water runoff of approximately $520 \times 10^6 \text{ m}^3$ (Brown and McPherson, 1992). This study covers bays, such as Kogarah Bay, Woollooware Bay, Oyster Bay, the Woronora River and the Georges River (Figure 3.3 a-e), and integrates with an earlier study of Oatley Bay (Pease, 2007).



Figure 3.3: View of marine areas a- Kogarah Bay, b- Woollooware Bay, c- Oyster Bay, d- the Woronora River and e- the Georges River off Botany Bay.

These bays have depths ranging between 0.5 m and 5 m throughout the embayment. However, the Georges River has depths of between 1 and 17 m and is deeply incised. It has a catchment area of about 96,000 ha and runs into Botany Bay before joining the marine environment (Birch, 1996). The smaller bays covered in the study are also considered to be sediment traps for fine and very fine particles and detritus that discharge from the rivers, creeks and drains. Surrounding the bays are urbanized areas with land use ranging from industrial to residential areas (Irvine, 1980; Fraser et al., 2006); only a few natural areas have been conserved.

3.2.2 Geomorphology of Port Hacking district

Port Hacking is located approximately 30 km south of the central business district of Sydney (34° 05' S, 151° 08' E; Figure 3.4). The head of Port Hacking begins at the Hacking River in the tidal upper regions and it extends about 27 km until it joins the Port Hacking estuary.

From the last glacial maximum to the present (Pleistocene - Holocene), sea level rose and drowned part of the valley, with marine water and sediments covering the lower section of the drowned valley forming the Port Hacking tidal delta affected by wave, current and tidal activities. Moreover, the surface runoff continued to bring sediments into the upper estuary and this created fluvial deltas at the upper end of the Port Hacking River and at the heads of side bays. Small amounts of sediment (especially silt and clay) have been deposited in small mud basins between the tidal delta and the different fluvial deltas (Figure 3.5). Therefore, some of the bays have remained almost at their original depths (Albani and Cotis, 2004). This is also the case where other creeks and streams such as North West Arm, South West Arm, Temptation Creek and Savilles Creek meet the estuary.

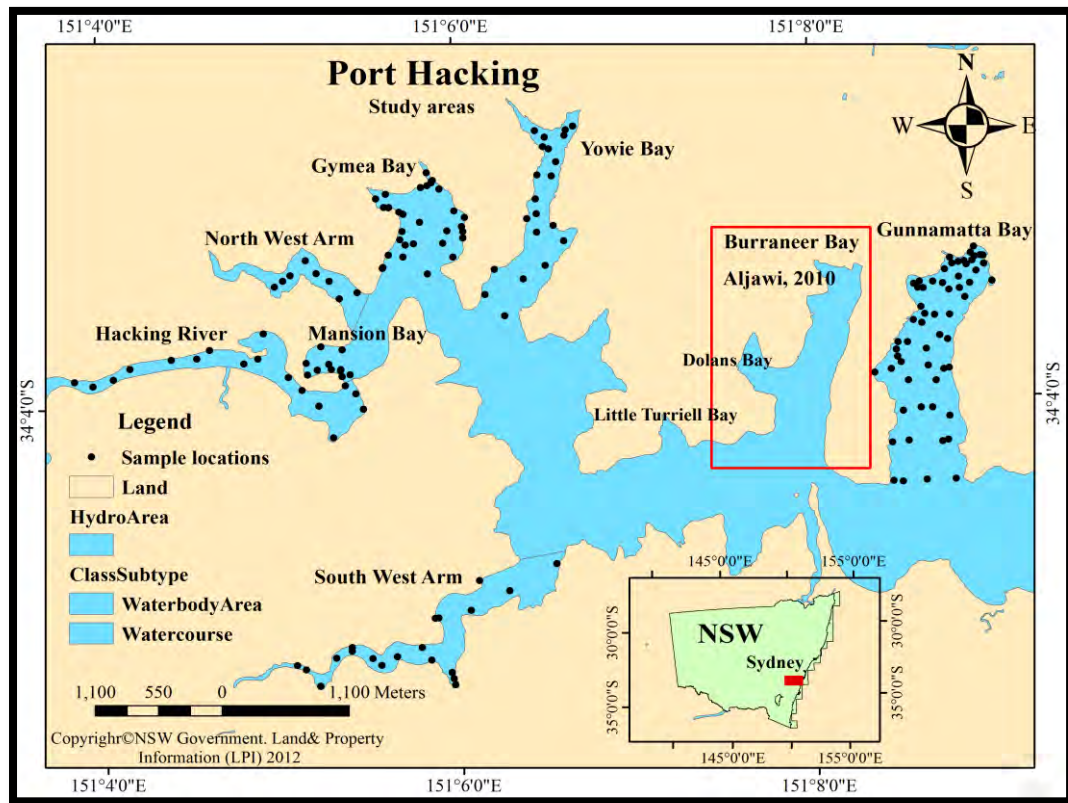


Figure 3.4: Sample locations in Port Hacking, NSW, Australia.

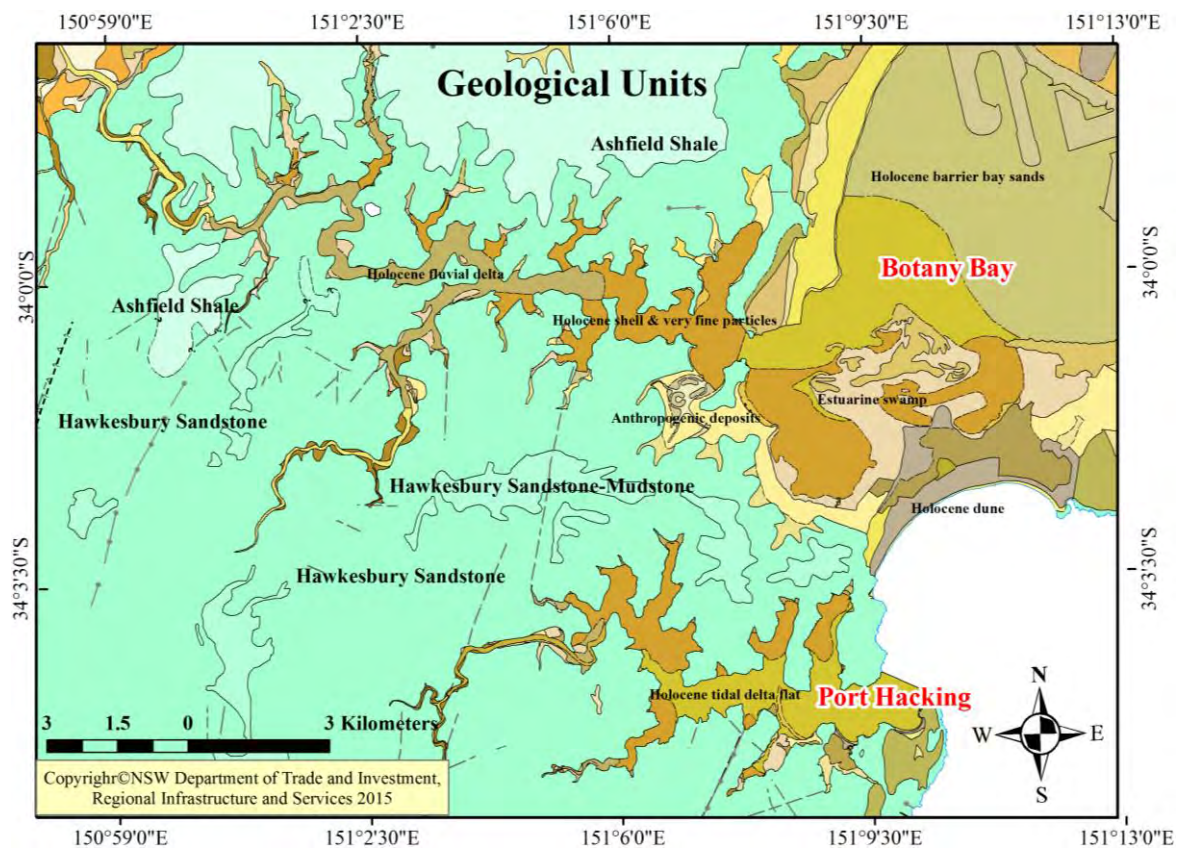


Figure 3.5: Geological units in the study areas. Brown & yellow units are Quaternary & Holocene deposits.

The Port Hacking estuary covers approximately 11 km² with a catchment area of about 208 km² (Sherwin and Holme, 1986). Natural bushland represents approximately 60% of this catchment area. Port Hacking contains of several bays and some shallow rivers and creeks.

Port Hacking is considered an open estuary, with flooding of its river valley some 7000 years BP. In many parts of its smaller bays, it does not have shallow shoreline areas. Instead, it has precipitous valleys that extend under the water to depths of 3 to 21 m (Aljawi, 2010). The Port Hacking area has several sheltered bays, such as Gunnamatta Bay, Burraneer Bay, Little Turriell Bay, Yowie Bay and Gynea Bay. It also has rivers and creeks, such as the Hacking River, South West Arm and North West Arm. This study covers Gunnamatta Bay, Gynea Bay, South West Arm, Mansion Bay and the Hacking River, North West Arm and Yowie Bay (Figure 3.6 a-f) and incorporates previous data from Aljawi (2010) for Burraneer and Little Turriell Bays. South West Arm mainly drains the Royal National Park and it has limited urban development, although it does have construction of marine craft in the lower reaches.

The study areas in Port Hacking have a variety of depths through the embayment sites ranging up to 21m. However, the river sites are shallow (0.5cm – 2.9m). Consequently, these deeper bays form sediment traps for fine and very fine particles and detritus that are discharged from the rivers and creeks. The tides within the main estuary of Port Hacking are considered strong, with the average tidal range in Port Hacking being 1m, which allows a substantial exchange of water with the Tasman Sea (Smith et al., 1990). As a result, sediments within the main estuary tend to be clean, sorted sand.

Surrounding many bays on the northern side of Port Hacking district are residential areas. In addition, the bays are attractive areas for private boat owners and large numbers of water craft are moored through the bays. Some sites have discharges of stormwater via domestic and municipal drains and road and sewerage overflow into the surrounding water (Davey, 1991; Birch and Taylor, 1999b).

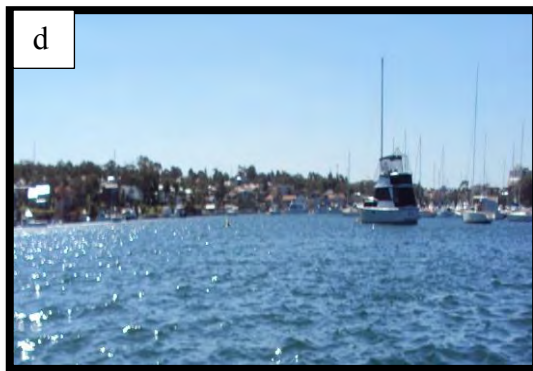


Figure 3.6: View of a-Gunnamatta Bay, b-Gymea Bay, c- South West Arm, d-Mansion Bay, e- North West Arm and f- Yowie Bay off Port Hacking.

3.3 Fieldwork

Surface sediment samples were collected using a grab sampler from the top 0 - 5 cm of subaqueous sediments. A total of 428 surface sediment samples were collected from both the Port Hacking and Botany Bay regions in New South Wales, Australia (Figures 3.2 and 3.4, and Appendix 1). An additional 51 subsurface sediment samples from eight (cores) were extracted by using a push core technique to obtain 30 - 50 cm long core samples within the sediments (Attached Appendix 1). Moreover, data (130 surface sediment samples) from previous works (Pease, 2007; Aljawi, 2010) are incorporated into the study areas, as well as subsurface sediment samples from deeper core 2.5m from (Pease, 2007) were used as a uniform background.

The samples were collected from various water depths (0.5 cm – 21 m) from all the bays within the survey areas. A variety of sites within bays were sampled in order to obtain a realistic distribution of the sediments from the bays and the river delta areas. Moreover, samples were collected in the vicinity of stormwater channel discharge points, to provide details of the distribution of trace elements. The locations (latitude and longitude) and depth of water were recorded by using Geographic Positioning System (GPS) instruments and a depth sounder at each site where samples were collected, in order to plot their locations on maps. These data were added into a GIS map through an Arc GIS desktop program, to create maps for each sampling site (Figures 3.7 - 3.19). The samples were stored in labelled plastic bags in a cool room ($>4^{\circ}\text{C}$) to prevent deterioration of the samples prior to analysis and during the duration of the research.

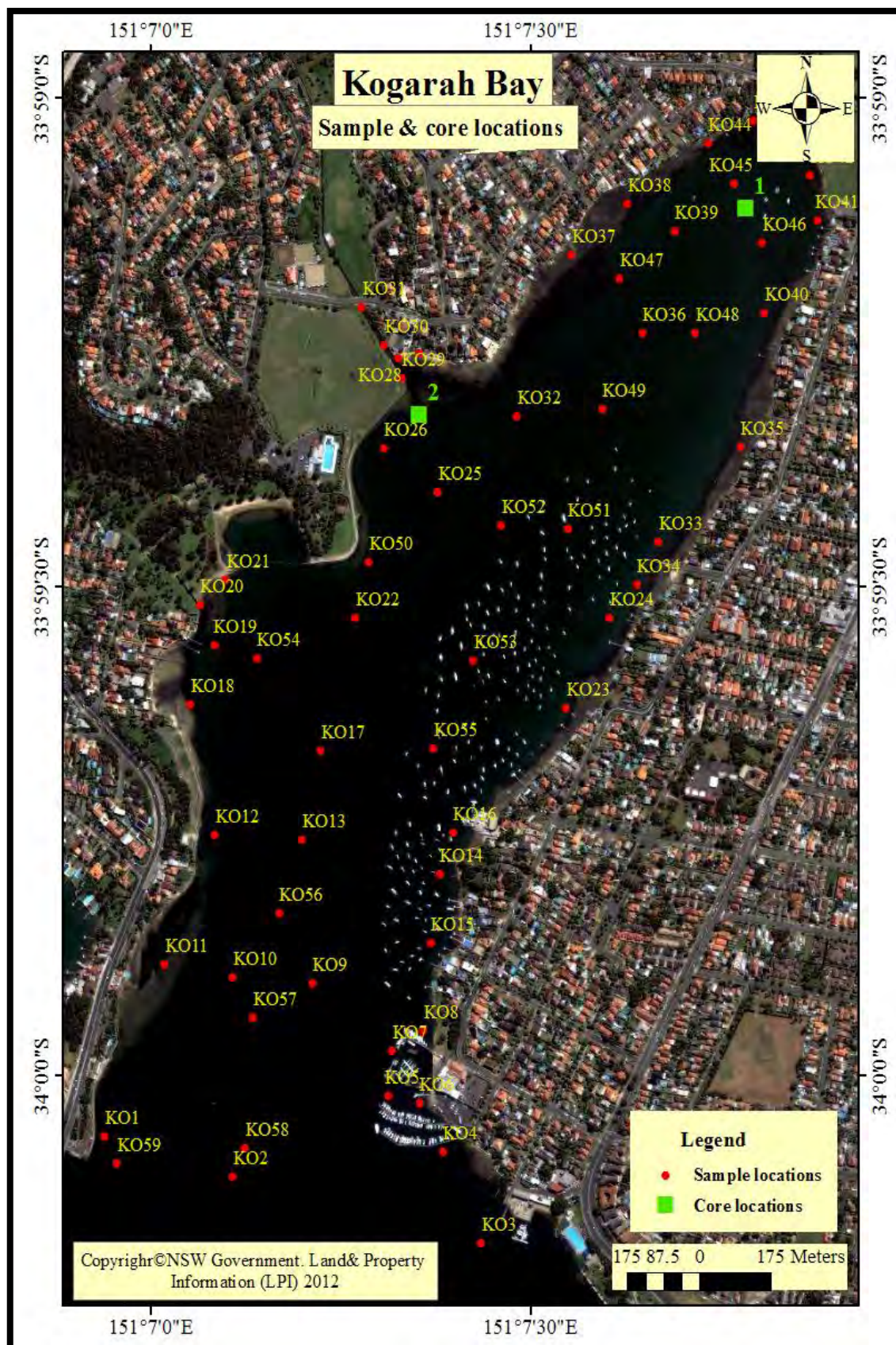


Figure 3.7: Kogarah Bay showing surface samples and core locations.

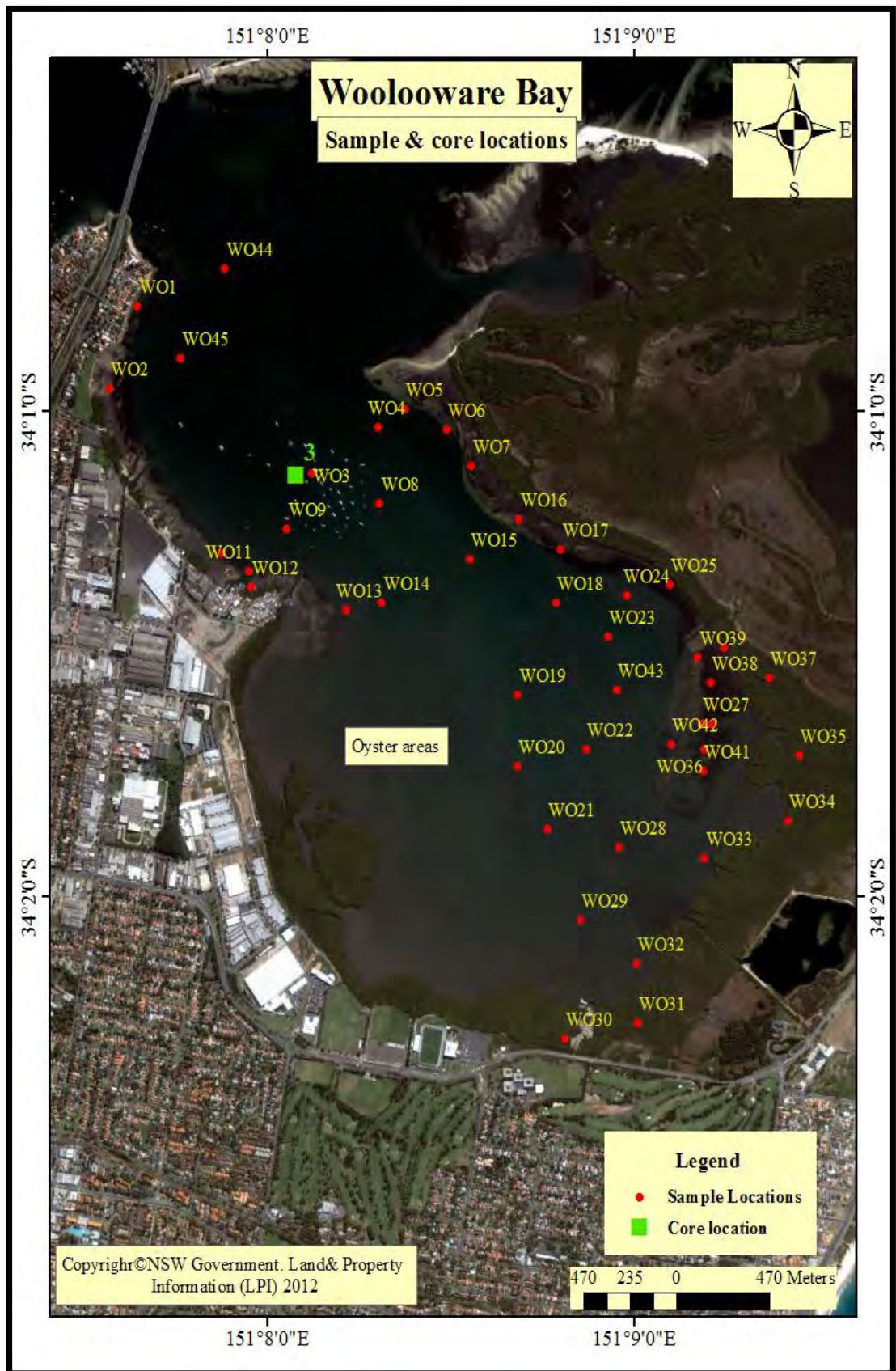


Figure 3.8: Woollooware Bay showing surface samples and core locations.

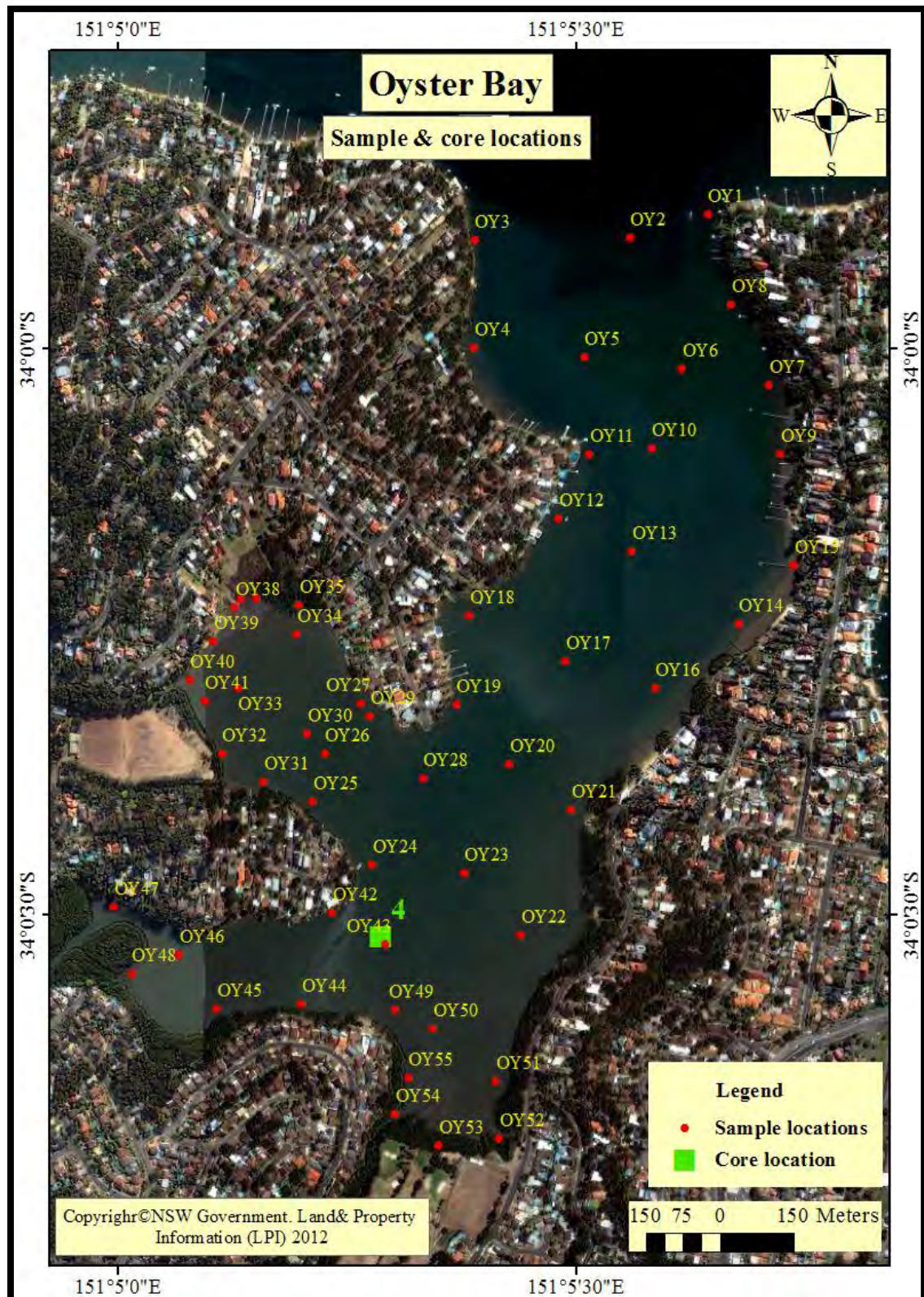


Figure 3.9: Oyster Bay present surface samples and core locations.

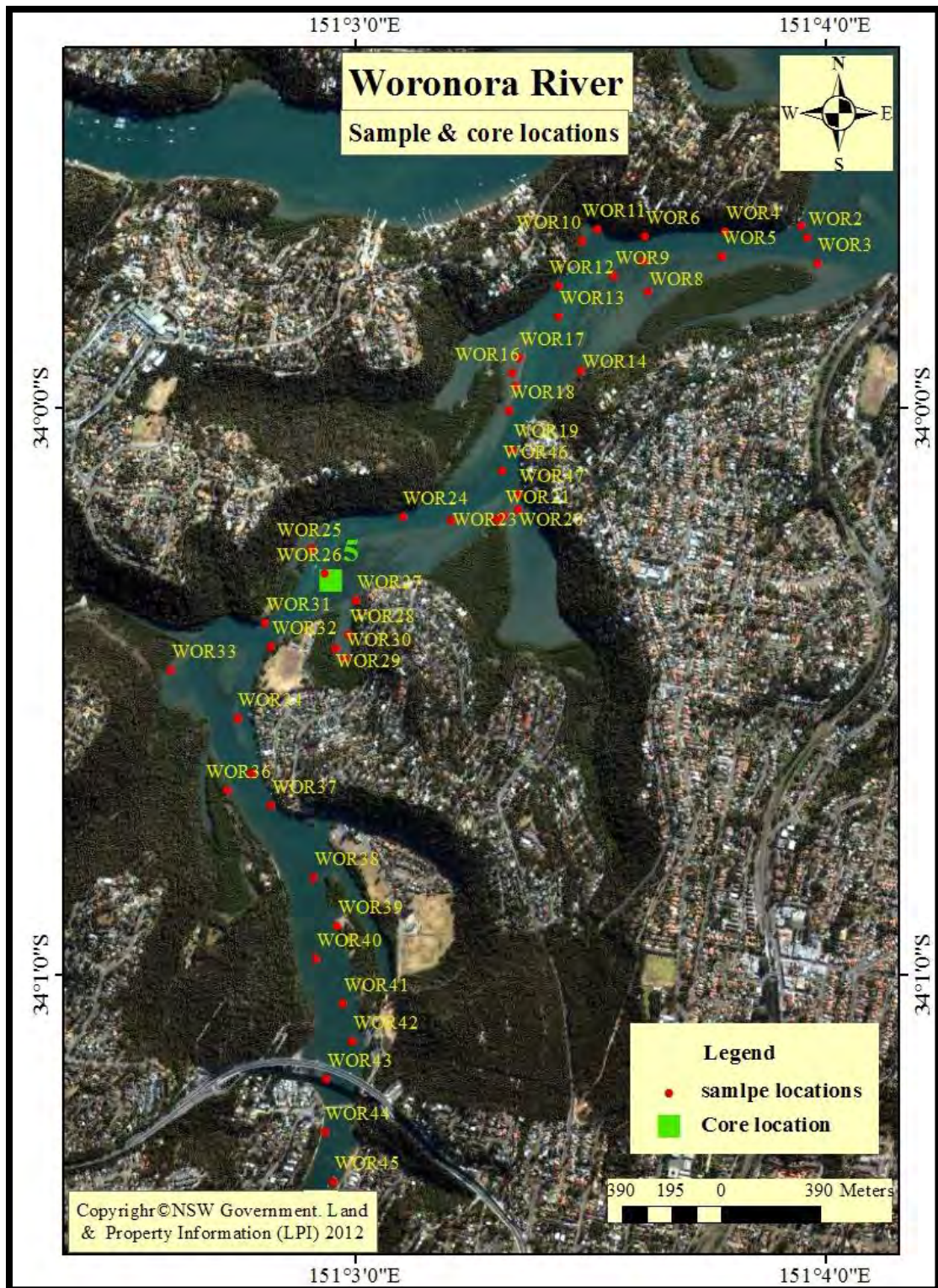


Figure 3.10: Woronora River showing surface samples and core locations.

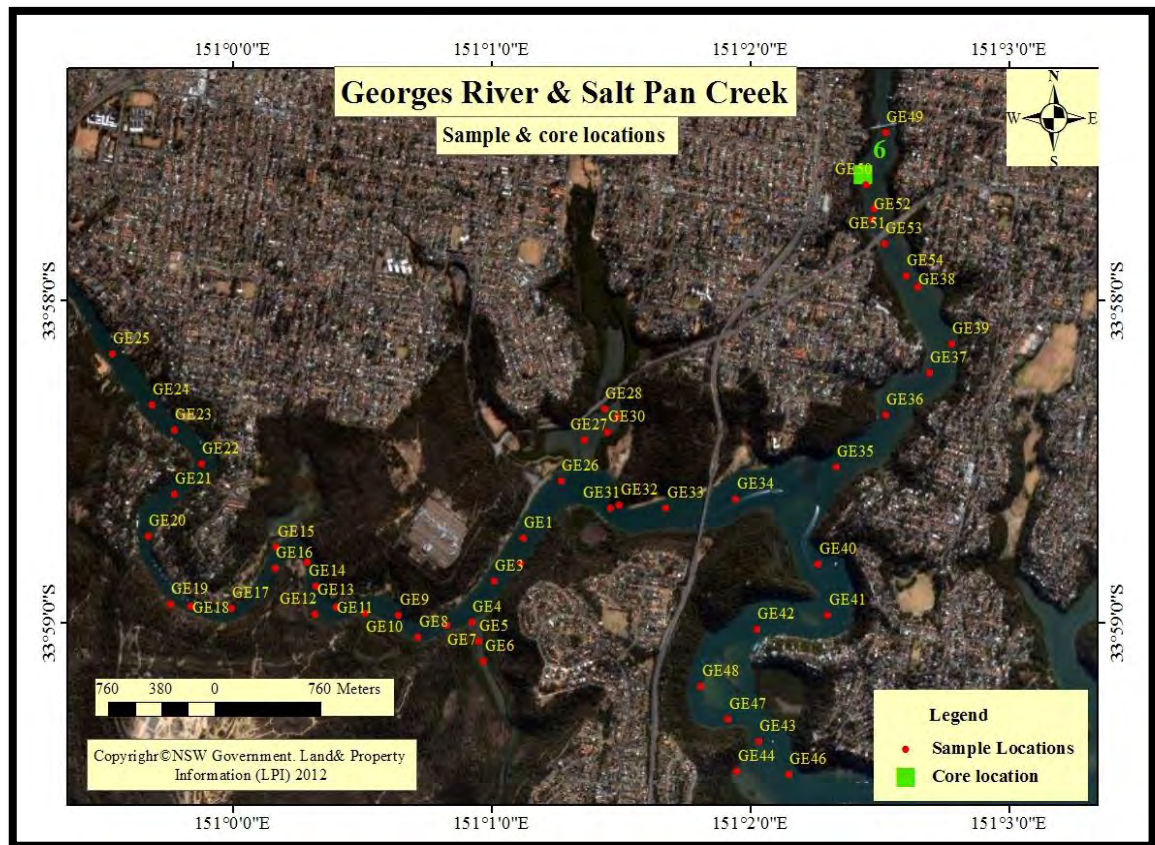


Figure 3.11: Georges River and Salt Pan Creek showing surface sample and core locations.

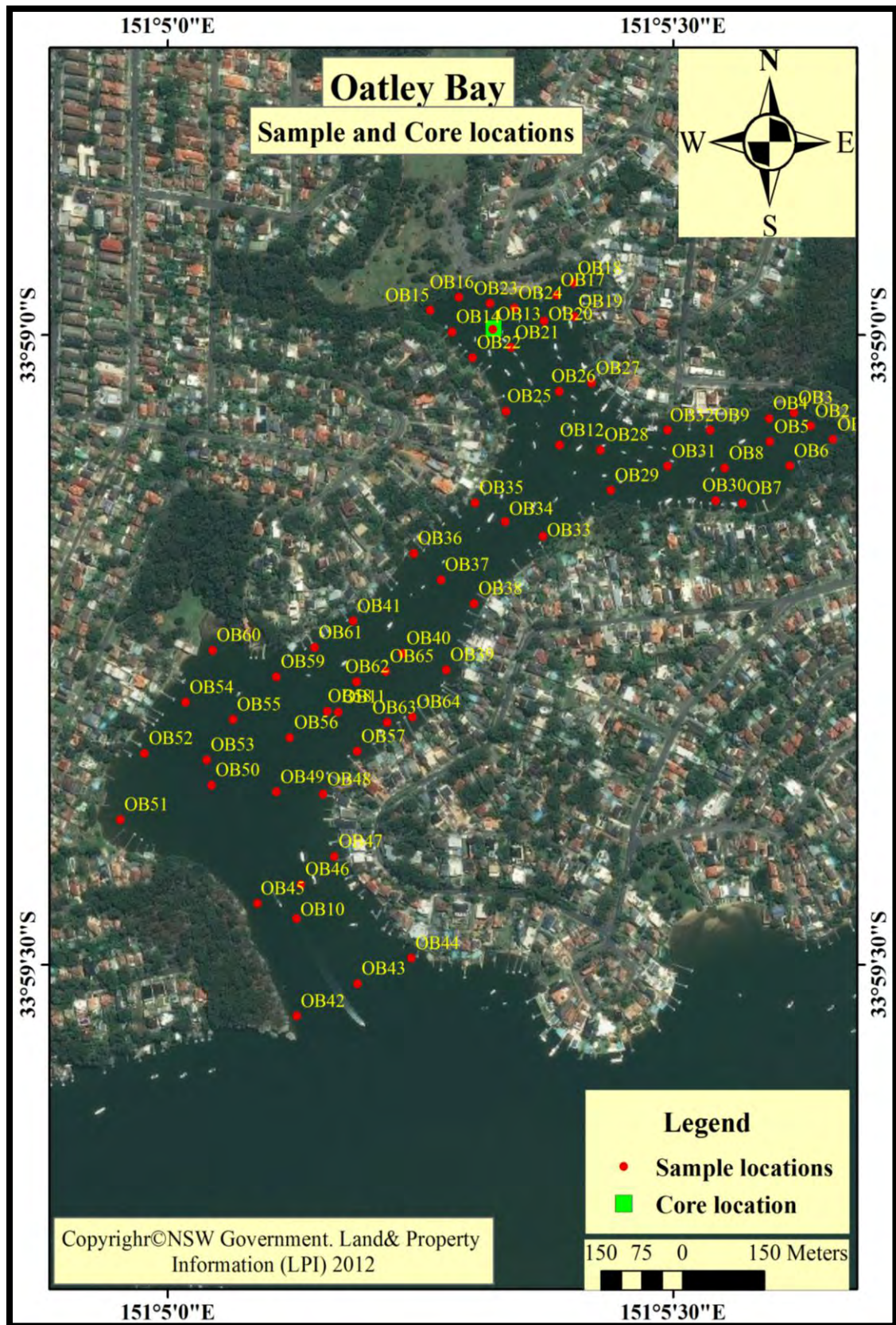


Figure 3.12: Oatley Bay showing surface sample and core locations after (Pease, 2007).

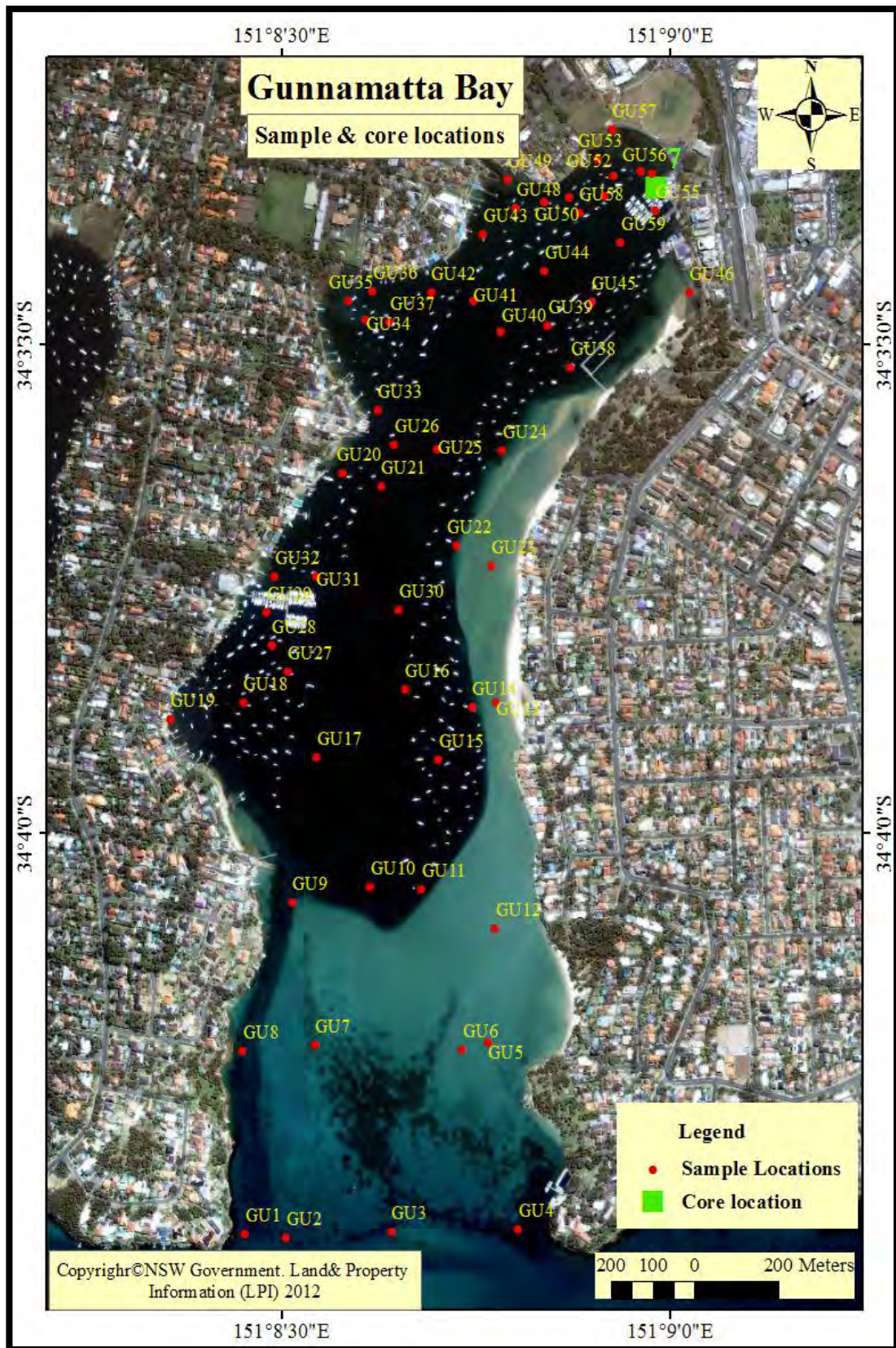


Figure 3.13: Gunnamatta Bay showing sample and core locations.

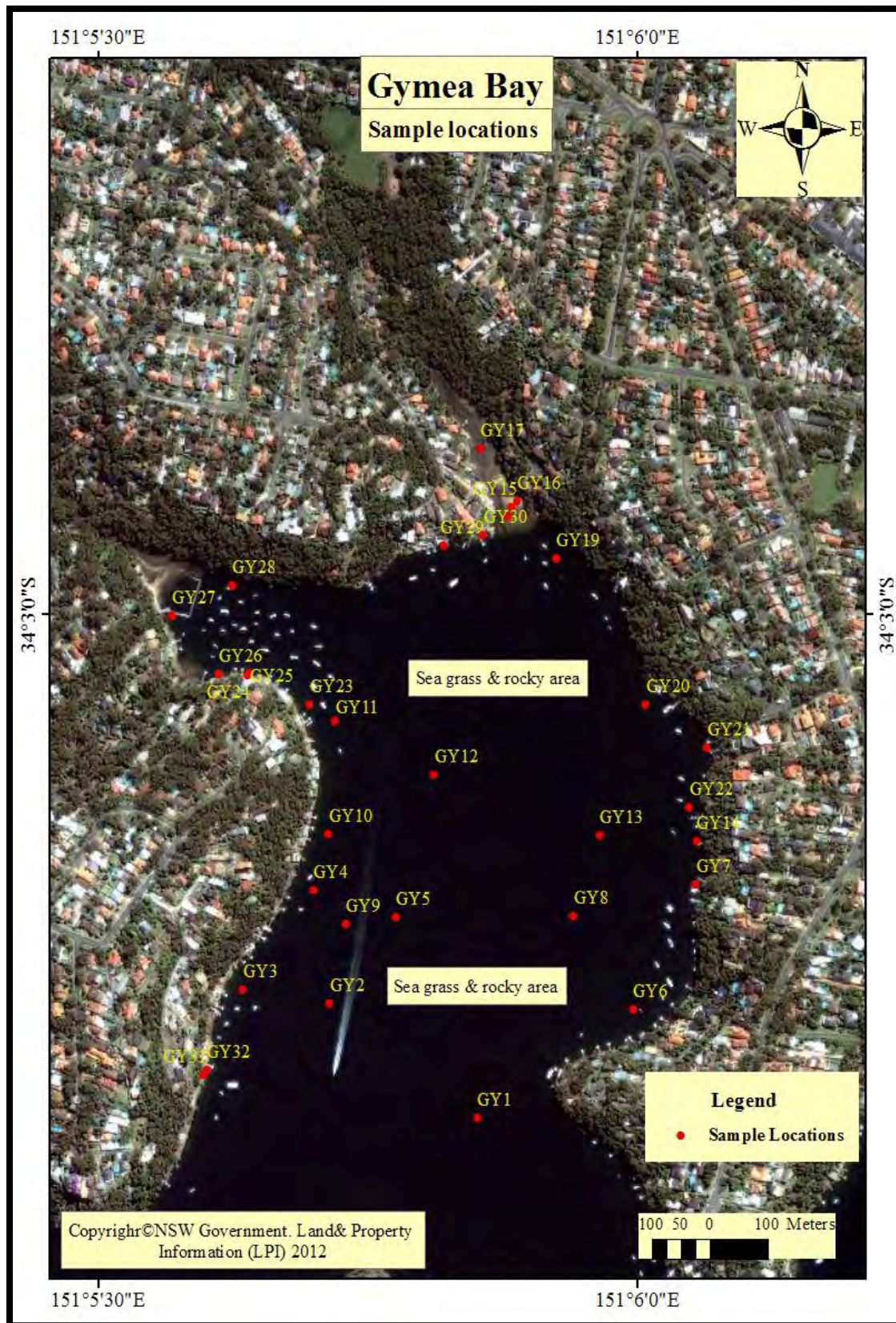


Figure 3.14: Gymea Bay showing sample locations.

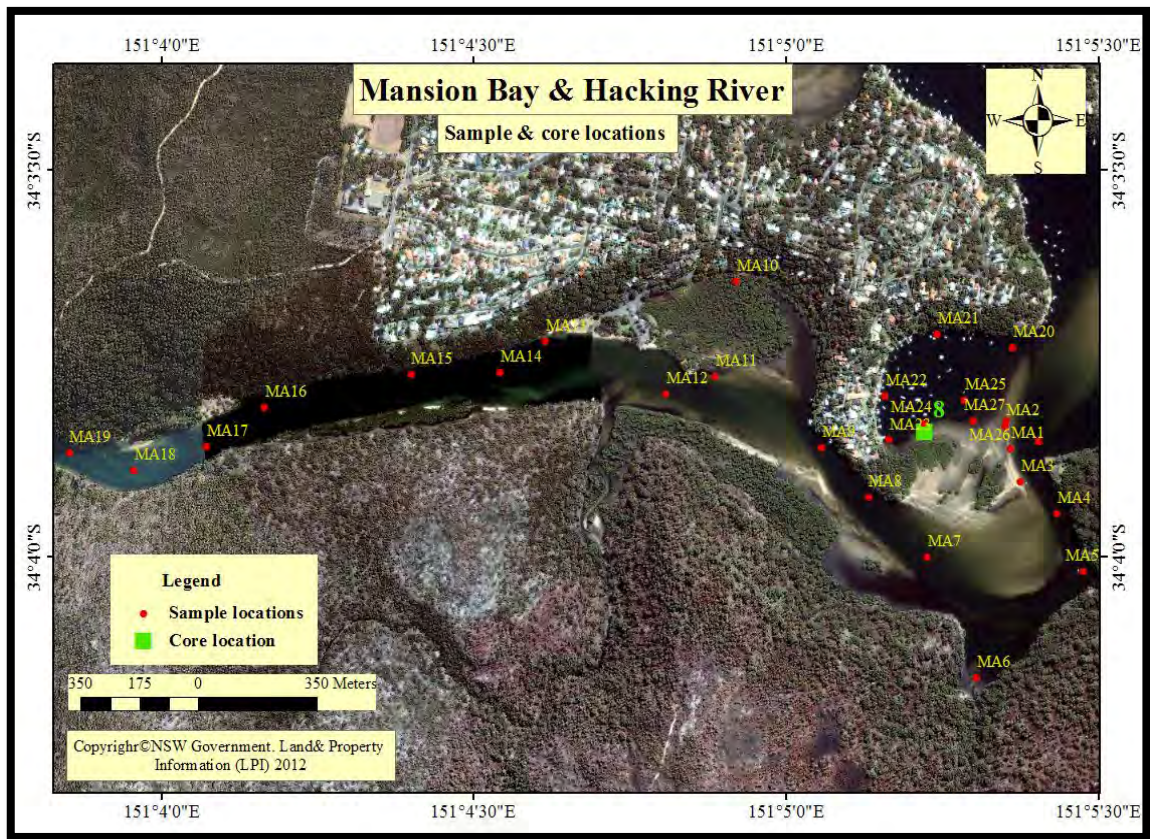


Figure 3.15: Mansion Bay & Hacking River showing sample and core locations.

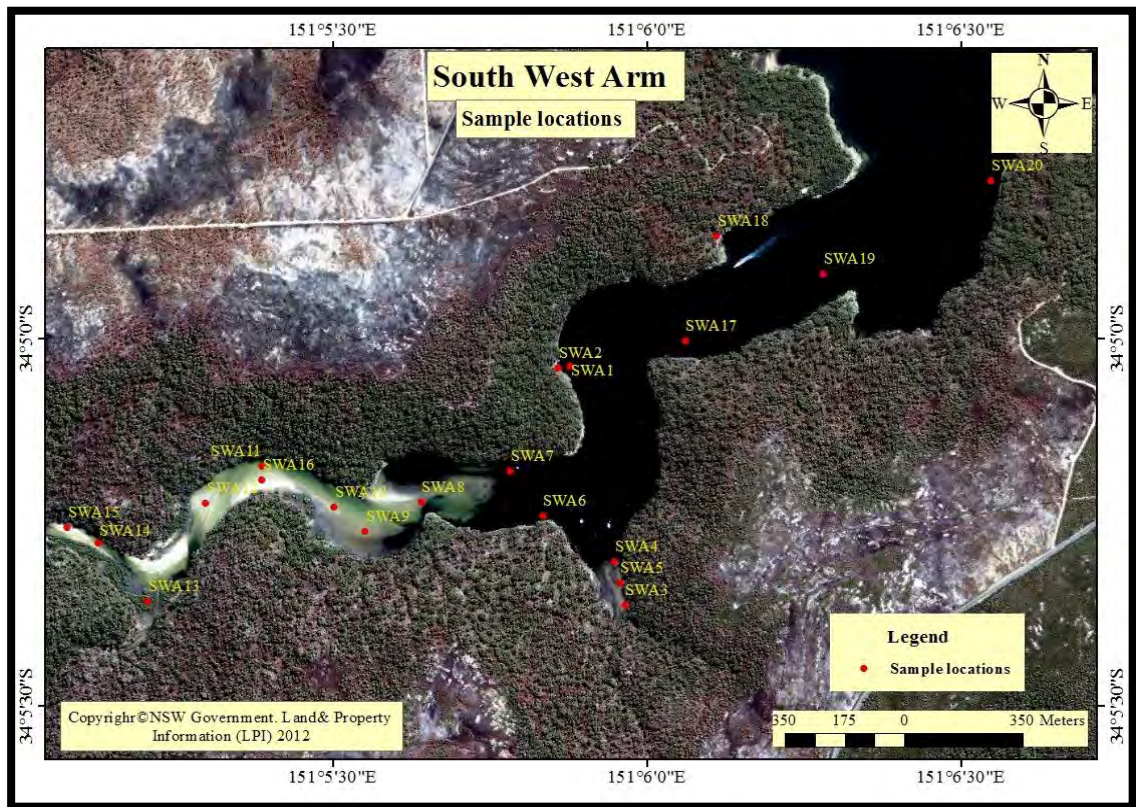


Figure 3.16: South West Arm showing sample locations.

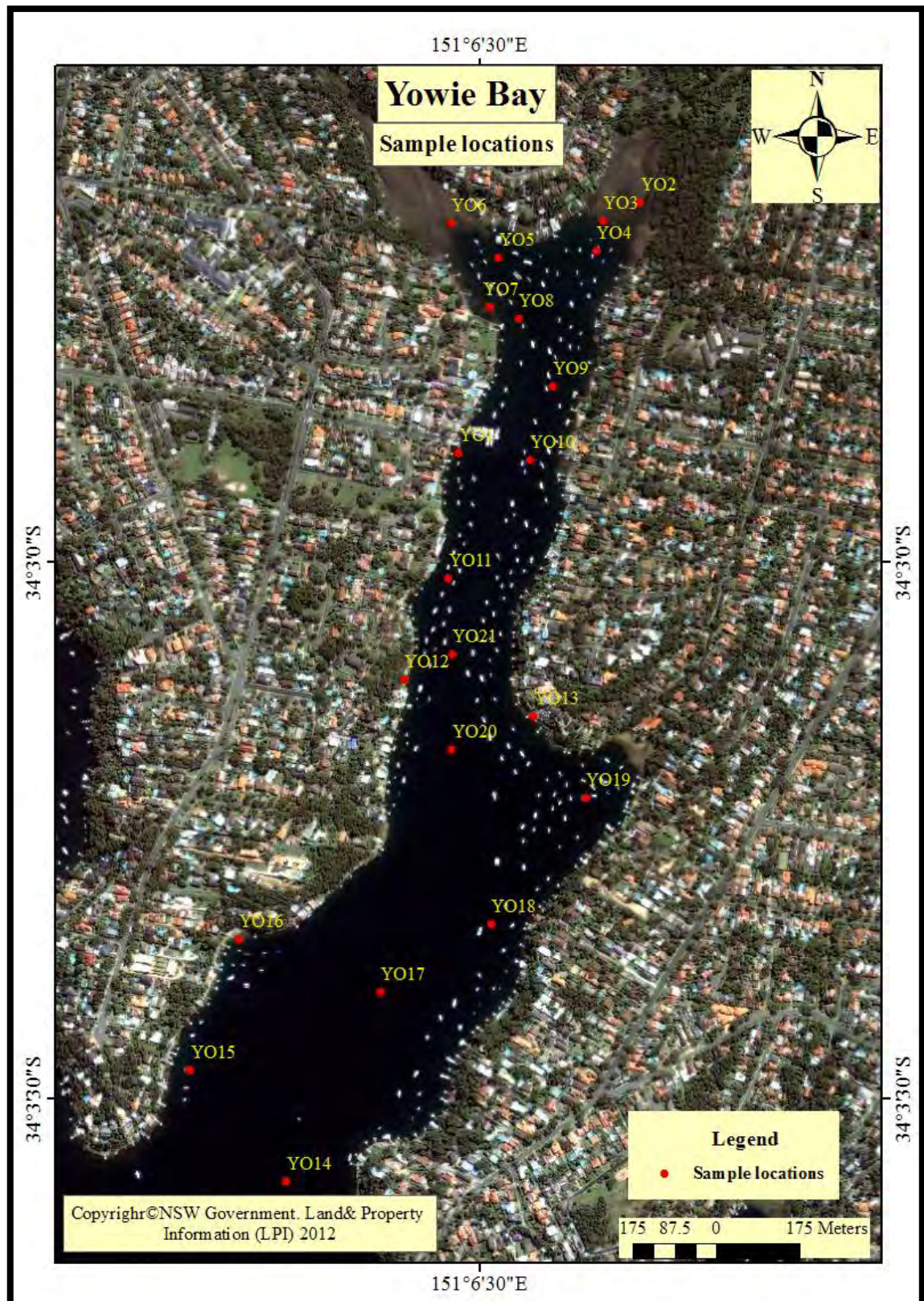


Figure 3.17: Yowie Bay showing sample locations.

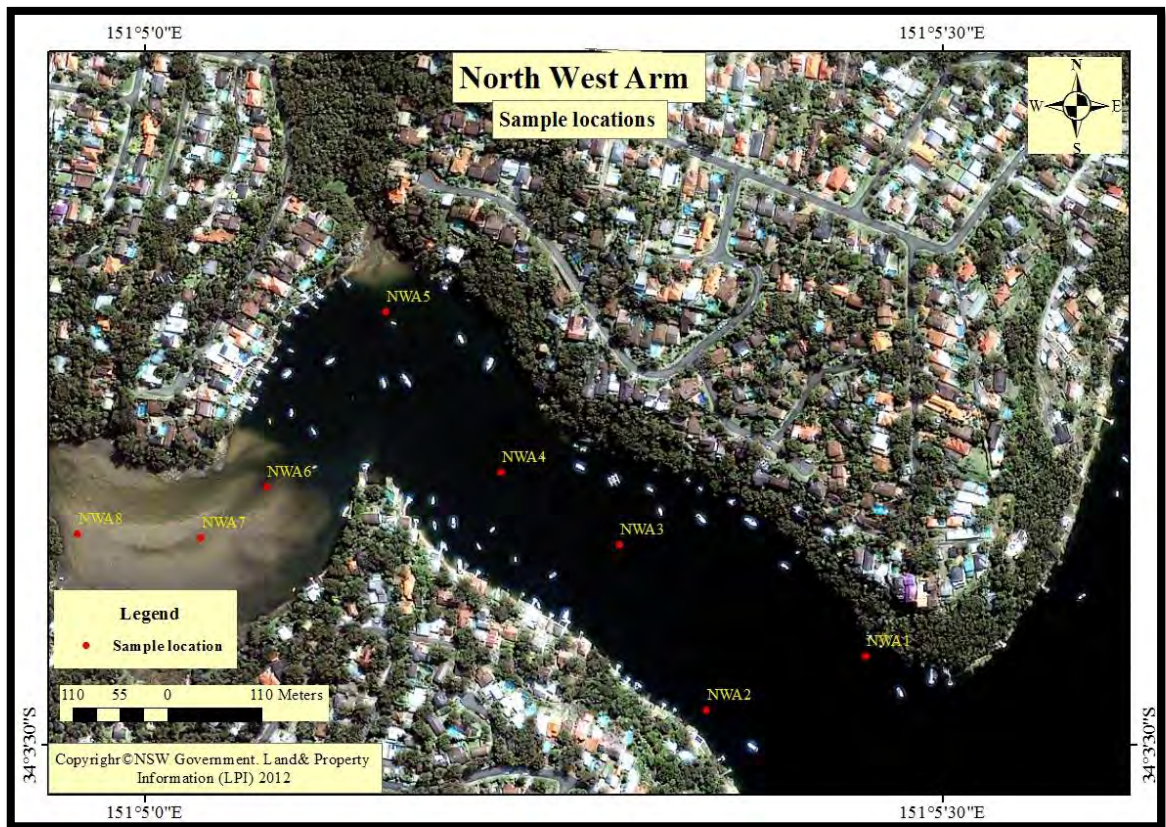


Figure 3.18: North West Arm showing sample locations.

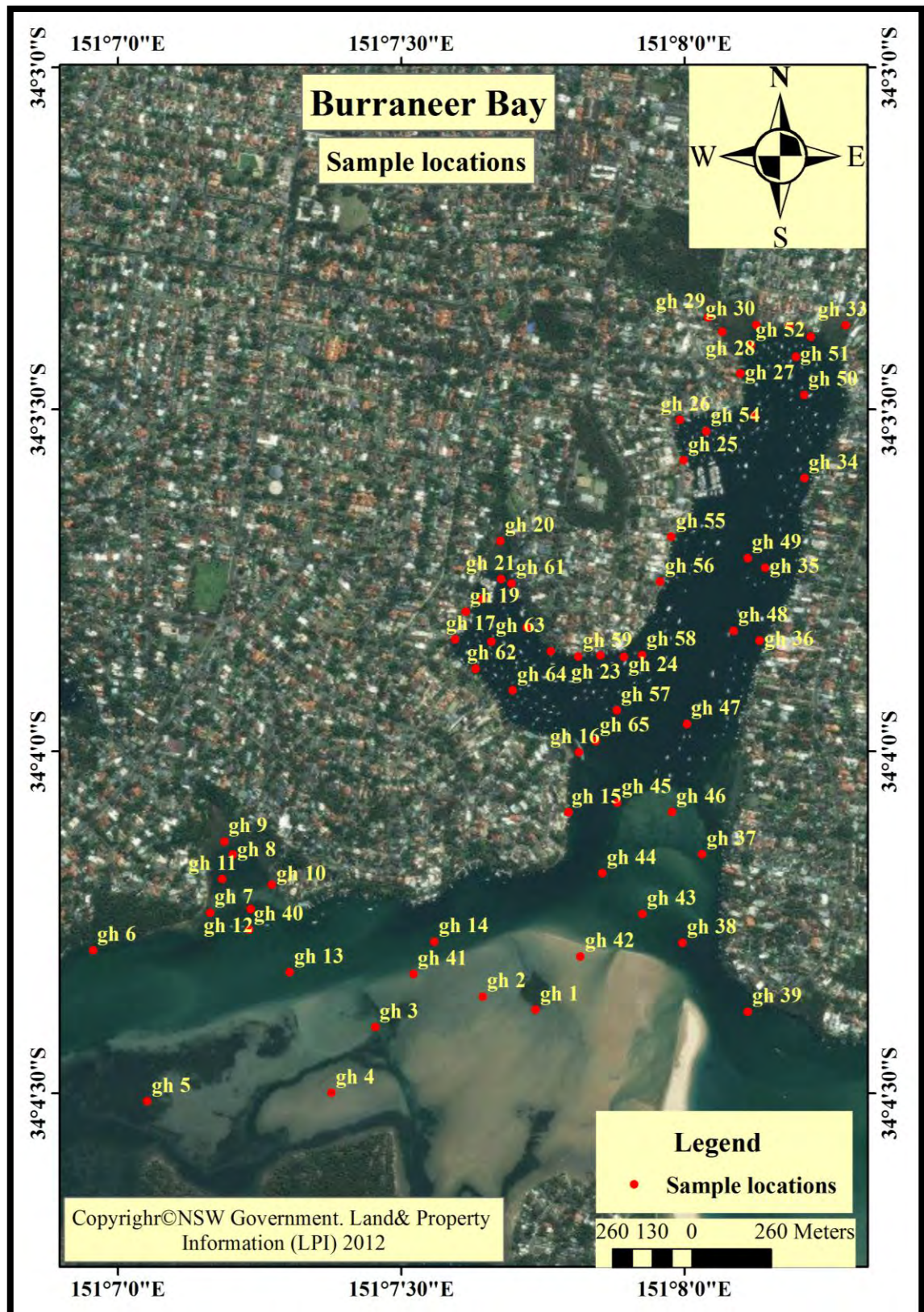


Figure 3.19: Burraneer Bay showing sample locations after (Aljawi, 2010).

3.4 Hydrodynamic method

Hydrodynamic conditions, especially ebb tidal currents in the study areas were measured using drogues. The measurements were limited to ebb currents for the following reasons: low current velocities at tidal slack water occur only over a short period affecting deposition within the water column, but not transport away from the pollutant source. Flood tidal movement may have some influence where sources are located along the sides of the bay but, because of the small tidal storage above these points, these currents are generally weaker and less influential than ebb currents in the bay. Ebb currents redistribute the inputs from stormwater drains into the bay and may be recorded as the most important mechanism for pollutant transport and distribution.

Collection of current velocity data is usually done for three main purposes.

- 1- To obtain a simple description of the trajectory of tidal currents, in which case, Lagrangian methods such as drogue tracking are used.
- 2- Calibration of mathematical models by the use of time series velocity data at specific point locations.
- 3- Tidal gauging of discharge through a cross-section to calibrate mathematical models.

Tidal discharge data are not relevant to the shorter; more open bays in this study and point-source current measurements are only relevant to modal input. The Lagrangian method has been selected in order to provide qualitative information on pollutant pathways, using a method that provides a quantitative measurement of current velocities and distribution that may still be used for future mathematical model calibration.

For this study, three drogues, modified from a previous design to permit deployment in shallow water, were constructed in the workshop at the University of Wollongong. The height of each drogue was 70 cm, and each drogue consisted of a buoy (ball) with waterproof enclosure to hold a small tracking GPS and a flashing light (Figure 3.20). The current vane was constructed with plastic fins to make it lighter. The plastic fins were removable so that they could be replaced if damaged and also if they needed to be moved. The length of the current vanes was 64 cm and was designed to be large in order to catch sufficient currents. A small GPS was put into the container, after being set up to make a

continuous recording. While the drogues used for this study were designed and built in a modern workshop, simple versions are easily constructed from readily available materials, such as plywood for vanes, plastic bottles for floats and discarded engine parts for weights. The only technical addition is a very low cost tracking GPS that may be fixed to the flotation component of the drogue.

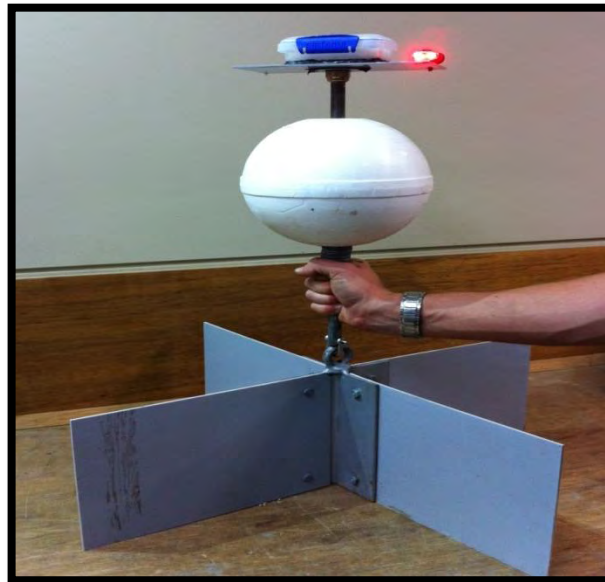


Figure 3.20: Modified design of the drogue to measure tides and currents.

A software program supplied with the GPS loggers was used to plot the movement and directions of the drogues and data from each site measured was uploaded into Google Earth map and kmz files. Data from the GPS has been smoothed to filter out GPS variations and to gain an estimate of average velocities over the drogue track.

3.4.1 Wind data

The climate records from the Bureau of Meteorology (BoM) for January to December 2013 show that the weather in the study area ranged from warm periods in summer to mild in autumn. Wind data (speed and direction) for the duration of the study was provided monthly by the BoM from the Botany Bay station, which is located close to the study area (Attached Appendix 2). While not directly applying this data to measured tidal current patterns it is used to illustrate the general wind patterns that will affect the selected bays, depending on season. Previous studies (McLean et al., 2002; Mc Lean and Hinwood, 2007; O'Callaghan and Stevens, 2011) have noted that wind action in shallow

bays deflect currents towards the lee shore as well as providing additional water mixing and sediment disturbance around shallow bay margins. Such information may not be available for remote areas and it is used qualitatively in this study to illustrate possible wind modification to tidal current patterns. Portable hand-held instruments could be used to measure wind velocity and direction at the time of tidal current tracking in areas where continuous wind data is not available.

3.5 Physical and chemical attributes

The methods of analysis used in this study of sediment samples were Mastersizer 2000, X-ray fluorescence, X-ray diffraction, inductively coupled plasma - optical emission spectrometry (ICP-OES), combustion and inductively coupled -plasma mass spectrometry (ICP-MS). The results, including grain size data, percentage of minerals, trace element concentrations and lead isotopes are displayed in tables in the appendices. The preparation of sediment samples, methodology and statistical analysis of each method will be discussed in the following sections:

3.5.1 Grain Size Distributions (GSD)

Grain size measurements were performed on all sediment samples in the sedimentation laboratory at the School of Earth and Environmental Sciences, University of Wollongong, using a Malvern Mastersizer 2000. This analysis was used to obtain details of the physical nature of the sediments and to assist with the explanation of the geochemical results.

About 9.0g of sand sample and 0.5g of each muddy sample were needed to carry out this analysis. The results of the software analysis gave the average grain size data, including percentages of sand, silt, clay and other characteristics, such as sorting (standard deviation, StdD) and skewness (GsKew), and were presented in a Microsoft Excel spreadsheet template (Appendix 2.1). The results of this analysis were classified according to the classification from Folk (1974; Tables 3.1 and 3.2).

Table 3.1 :Sorting classes (from, Folk, 1974).

Sorting Class	Sorting (ϕ)
Very well sorted	< 0.35
Well sorted	0.35 - 0.5
Moderately well sorted	0.5 - 0.71
Moderately sorted	0.71 - 1.0
Poorly sorted	1.0 - 2.0
Very poorly sorted	2.0 - 4.0
Extremely poorly sorted	> 4.0

Table 3.2 : Skewness classes (Folk, 1974).

Mathematically	Graphically	Values
Strongly fine-skewed	Large excess fine tail	+1.00 to +0.30
Fine-skewed	Excess fine tail	+0.3 to +0.1
Near symmetrical	Symmetrical	+0.10 to -0.10
Coarse-skewed	Excess coarse tail	-0.10 to -0.30
Strongly coarse-skewed	Large excess coarse material	-0.30 to -1.00

3.5.2 Sample preparation

After the grain size analysis all bulk sediment samples (sandy and muddy) were put in labelled aluminium cups, then placed in an oven (60 °C) to dry for 48 hours before any further analysis was commenced. In order to measure most of the trace elements the sand samples were pulverized to obtain a fine powder using a tungsten Tema (excluding Zn) and a chrome steel Tema (excluding Cr and Co) due to contaminate by Tema. While an agate mortar pestle was used to pulverize the muddy samples (fine silt and clay particles) in order to avoid any trace element contamination by using the other Tema equipment.

3.5.3 X-ray diffraction (XRD)

A few grams (3-4g) of each powdered sample were prepared for whole-rock XRD analysis. This was conducted in order to estimate the percentage of mineralogical components in each sample, including clay minerals in the muddy samples (Schmid et al., 2004; Zhang et al., 2008; Gier et al., 2008). The X-ray diffraction analysis used a Philips (PW 1771/100) goniometer, Spellman DF3 controller and Cu K α radiation, at 1 kW, and was carried out at the School of Earth and Environmental Sciences, University of Wollongong. In addition, software programs such as TRACES and SIROQUANT were used to identify the minerals and to evaluate the abundance of each mineral (Appendix 2.2).

3.5.4 Geochemical Analysis

Whole rock trace element geochemical analyses were undertaken in different ways, and comprised various preparation and analytical techniques. The geochemical analyses for this project are considered to be the main emphasis of this study.

3.5.4.1 X-ray fluorescence (XRF)

Total trace element XRF analysis of the samples was carried out using a SPECTRO - XEPOS energy dispersive spectrometer fitted with a Si-docile detector, following the procedure established by Norrish and Chappell (1977). International standards were used to calibrate concentrations of trace elements (accuracy and precision) in the study samples (Appendix 3.5). Detection limits for the trace elements ranged between 0.5 ppm and 4 ppm, but vary according to the matrix of the samples (Appendix 3.5).

About 5-5.5g of each powder sample was needed. Depending on the type of soil and/or sediment matrix, drops of polyvinyl acetate (PVA) solution were added to the samples. About 6-7 drops of PVA was added to sand samples and 2-3 drops added to silt samples, with 1 drop being added to clay samples. Samples were then mixed together well, placed in labelled aluminium cups and pressed at 2500 psi to form pellets. These pellets were then placed in an oven at 70 °C to dry for 24 hours before their composition was measured using XRF. The total concentrations of trace elements are displayed in Appendix 3.1.

3.5.4.2 Lead Isotopes ($^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{206}\text{Pb}$ & $^{208}\text{Pb}/^{206}\text{Pb}$)

Surface sediment samples with the highest concentrations of lead from various locations were analysed for lead isotopes, as well as some subsurface sediment samples that were used to determine background values. Powdered samples were analysed at the National Measurement Institute (NMI), NSW, Australia. Approximately 2g of each sample was digested in acid (nitric and hydrochloric) then measured for lead using inductively coupled plasma - mass spectrometry (ICP-MS) using a Perkin Elmer Elan DRCII, 1300 W, which has advantages for the analysis of lead isotope ratios in environmental samples (O'Connor and Evans, 2007; Komárek et al., 2008). A summary of the tuning parameters

for ICP-MS equipment, which is used during measurement of the samples, is presented in Table 3.3. The complete results of lead isotopes are shown in Appendix 3.3

Table 3.3: Tuning parameters and implication of the ICP-MS.

Parameters	Typical value/ range He mode
RF Power	1500w
RE matching	1.75 V
Sample depth	8 mm
Torch- H	0.8 mm
Torch- V	0.4 mm
Carrier gas	0.9 l/min
Makeup gas	0.15 l/min
Nebulizer pump	0.1 rps
Extract 1	4 V
Extract 2	-140 V
Omega Bias-ce	-16 V
Omega Lens-ce	1.8 V
Cell Entrance	-24 V
QP focus	-12 V
QP bias	-16V
Cell exit	-30 V

3.6 Evaluation of sediment contamination and risk assessments

In the interpretation of geochemical data and quantity the degree of trace element enrichment in sediments has been addressed. Choice of background values plays an important role. Several authors have used average shale values or the average crustal values (Turekian and Wedepohl, 1961; Esen et al., 2010; Banu et al., 2013) because they did not have local background values. In this study, the background values were obtained from long cores, hence they were used as a reference for the baseline of elements. Contamination factors (CF) and a modified degree of contamination were used to determine the contamination status of the study areas as well as how the CF reflects the trace element enrichment in the sediment (Pekey et al., 2004; Raj and Jayaprakash, 2008).

3.6.1 Contamination Factor (CF) and modified degree of contamination (mC_d)

The CF, C_d and mC_d were calculated using the following equations in Tables 3.4 and 3.5:

$$CF^i = C_{\text{sample}} / C^*_{\text{background}} \dots\dots\dots(1) \text{ (Reboredo, 1993).}$$

Where C is the measured concentration of each trace element and C* used the background value for trace elements from a previous study in Botany Bay (Pease, 2007).

Table 3.4: Contamination factor and contamination concentrations (Tomlinson et al., 1980; Hakanson, 1980).

Contamination factor (CF)	Contamination concentrations
$CF < 1$	Low contamination
$1 \leq CF < 3$	Moderate contamination
$3 \leq CF < 6$	Considerable contamination
$CF \geq 6$	Very High contamination

$$C_d = \sum_{i=1}^n CF^i \dots\dots\dots(2) \text{ (Hakanson, 1980; Reboredo, 1992)}$$

Abraham and Parker (2008) introduced a modified and generalised formula based on Hakanson's (1980) equation (2) to calculate the modified degree of contamination for trace element pollution in estuarine sediments. This modified formula was used in this study.

$$mC_d = \frac{\sum_{i=1}^n CF^i}{n} \dots\dots\dots(3) \text{ (Abraham and Parker, 2008)}$$

Where: mC_d is the modified degree of contamination, n is number of trace elements analysed, and CF^i is the contamination factor given in equation (1).

Table 3.5: Modified degree of contamination and associated classification (Tomlinson et al., 1980; Hakanson, 1980).

Modified degree of contamination (mC_d)	Classification and description of (mC_d)
$mC_d < 1.5$	Nil to very low degree of contamination
$1.5 \leq mC_d < 2$	Low degree of contamination
$2 \leq mC_d < 4$	Moderate degree of contamination
$4 \leq mC_d < 8$	High degree of contamination
$8 \leq mC_d < 16$	Very High degree of contamination
$16 \leq mC_d < 32$	Extremely high degree of contamination
$mC_d \geq 32$	Ultra high degree of contamination

3.6.2 Pollution Load Index (PLI)

The PLI was proposed by Tomlinson et al. (1980) to calculate contamination as it allows comparison of contaminant concentrations between locations at different times. The PLI was calculated by using the following formula:

$$PLI = (CF_1^i \times CF_2^i \times CF_3^i \dots\dots CF_n^i)^{1/n} \dots\dots(4) \text{ (Tomlinson et al., 1980; Sheppard, 1998)}$$

Where: CF^i = contamination factor (equation 1); n = number of trace elements. The values of **PLI** categories that are ≥ 1 indicate deterioration of site quality (pollution) and an immediate mediation is

required to improve their status, whereas values of **PLI** ≤ 1 indicate no pollution (Tomlinson et al., 1980; Harikumar et al., 2009). Later, PLI values were classified by (Singh et al., 2005; Table 3.6).

Table 3.6: Pollution load index and pollution status of sediments (Tomlinson et al., 1980).

PLI values	Pollution status
$0 < \text{PLI} \leq 1$	Unpolluted
$1 < \text{PLI} \leq 2$	Unpolluted to moderately
$2 < \text{PLI} \leq 3$	Moderately polluted
$3 < \text{PLI} \leq 4$	Moderately to highly polluted
$4 < \text{PLI} \leq 5$	Highly polluted
$\text{PLI} > 5$	Very highly polluted

3.6.3 Enrichment factor (EF)

The EF of trace elements is a useful indicator for evaluating the degree of enrichment and can be used to compare the pollution status in various environments. It is a universal formula to distinguish whether the trace element source is anthropogenic or natural (Table 3.7; Valdés et al., 2005; Rashed, 2010). In the current study EF was applied to quantify the enrichment of Cu, Zn and Pb in subsurface sediments (Chapter 7). The EF_s have been calculated using the following equation (Sinex and Helz, 1981):

$$\text{EF} = (C_X/C_{\text{Rb}})_{\text{sample}} / (C_X/C_{\text{Rb}})_{\text{background}} \dots\dots(5) \text{ (Sinex and Helz, 1981)}$$

Where: $(C_X/C_{\text{Rb}})_{\text{sample}}$ = ratio of concentration of the element to Rb in the sediment sample; $(C_X/C_{\text{Rb}})_{\text{background}}$ = ratio of the natural background concentrations of the element to Rb.

Rubidium (Rb) was used as the trace element of normalization because it is not anthropogenically enriched (Grant and Middleton, 1990). Also, Rb is similar to the value for Ca and higher than the mining interference factor (MIF) for Al and Zr, which are most often used as reference elements (Loska et al., 2004). The coefficient of variation (CV%) of Rb can be measured by the following formula:

$$\text{CV} = (\text{SD./Mean}) * 100 \dots\dots\dots(6)$$

This is a robust, nonparametric estimate that it is not affected by the presence of outliers. The CV for Rb was found to be 19%. This was then compared with the variability of reference elements commonly used in the environmental science literature: CV for Al 42%, Sc 50%, Ti 35% and Zr 39% (Reimann and Caritat, 2000, 2005).

Table 3.7: Enrichment Factor and its categories (Mmolawa et al., 2011).

Enrichment Factor (EF)	Categories
$EF < 2$	Deficiency to minimal enrichment
$2 \leq EF < 5$	Moderate enrichment
$5 \leq EF < 20$	Significant enrichment
$20 \leq EF < 40$	Very high enrichment
$EF \geq 40$	Extremely high enrichment

3.6.4 Risk assessments

The potential ecological risk index (RI) was used in order to evaluate the effects of the trace element pollution in the study areas. The RI was originally established by (Hakanson, 1980), and was calculated by using following formula:

$$E_r^i = T_r^i \times CF^i \dots\dots\dots(7)$$

$$RI = \sum_i^n E_r^i \dots\dots\dots(8)$$

Where E_r^i is the monomial potential ecological risk factor, T_r^i is the response coefficient for the toxicity of single trace element, which was adopted to be the evaluation criterion, (i.e. Cr=2, Ni=Cu= Pb= 5, Zn = 1 and As=10 Hakanson, 1980; Mei et al., 2011), CF^i is contamination factor, and RI is the sum of all risk factors for trace elements in the sediments. According to Hakanson (1980) the following terminology is designed to be applied for the RI values Table 3.8.

Table 3.8: Indices and Potential ecological risk of trace elements (Hakanson, 1980).

E_r^i	Potential ecological risk of single metal	RI value	Sum of all risk factors
$E_r^i < 40$	Low risk	RI < 30	Low risk
$40 \leq E_r^i < 80$	Moderate risk	$30 \leq RI < 60$	Moderate risk
$80 \leq E_r^i < 160$	Considerable risk	$60 \leq RI < 120$	Considerable risk
$160 \leq E_r^i < 320$	High risk	RI ≥ 120	Very high risk
$E_r^i \geq 320$	Very high risk		

3.7 Statistical analyses and geographical information system

The results of this research were applied in several software programs to interpret the data. Excel software was used in order to determine correlation coefficients (R^2), which

represent the strengths of the relationships between the variables in the samples. MATLAB R2011 software was used to plot the wind data (speed and direction). Moreover, hierarchical cluster analysis (HCA) and principle component analysis (PCA) have been utilised in this study in order to interpret and identify the relationships between all samples through cluster groups (Q-mode), and to determine the correlation coefficients and relationship between all variables (R-mode). These analyses were carried out using the JMP software and Arc GIS desktop software was used to create maps for all results in the study areas (Appendix 4).

3.7.1 Hierarchical cluster analysis (HCA)

HCA is a method of cluster analysis that endeavours to classify variables into two or more different groups depending on conditions. The purpose of this statistical analysis is to organize variables within groups that have similar characteristics Szekely and Rizzo, (2005). The strategies of HCA are generally of two types: agglomerative and divisive Zhang et al., (2013). This study used two options: distance measure (squared Euclidean distance) and linking method (between-groups linkage).

3.7.2 Principal component analysis (PCA)

PCA involves a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components. The varimax method was used as an orthogonal rotation method that minimizes the number of variables that have high loadings on each factor. This method simplifies the interpretation of the factors. Each principal component is a linear combination of the original variables. All principal components are orthogonal to each other so there is no redundant information (Jackson, 2003). The principal components as a whole form an orthogonal basis for the distribution of data. The PCA is a single axis in space; when projecting each observation on this axis, the resulting values form a new variable. The second principal component is another axis in space, perpendicular to the first (Davis, 2002). PCA is applied for two main objectives: to discover or to reduce the dimensionality of the data set and to identify new meaningful underlying variables (Karageorgis et al., 2009). PCA was applied to the multivariate data derived from the geochemical analysis of 558 stations in the study areas.

3.7.3 Geographical information system (GIS)

3.7.3.1 Kriging method

Arc GIS desktop software (Version 10) in the Spatial Analysis Laboratories at the School of Earth and Environmental Sciences, University of Wollongong, was used to plot the sample sites within the study areas, and to provide advanced geostatistical analysis to create maps. The Kriging method of geostatistical analysis was used. This is a moderately quick interpolator that can be exacted or smoothed depending on the measurement error model. It is a flexible means to evaluate graphs of spatial autocorrelation (Li and Heap, (2008). The Kriging method uses statistical models that generate a variety of map outputs, such as predictions, prediction of standard errors and probability. However, the flexibility of Kriging often requires decision-making. Kriging assumes the data is derived from a stationary stochastic process, while some other methods assume normally distributed data. Three main parameters, the nugget (C_0), the sill ($C + C_0$) and the range, emerged from the models used. This identified the spatial structure of the variables at the assumed scale (Li and Heap, 2008; Liu et al., 2013).

The spatial heterogeneity of regional variables was determined by the ratio of $C_0/(C + C_0)$ and revealed any spatial correlation among regional variables. Overall, a ratio of less than 25% shows strong spatial correlation; a ratio ranging between 25% to 75% indicates moderate correlation; and a ratio of more than 75% indicates weak spatial correlation (Spijker et al., 2005). In the present research, geostatistics used a semivariogram in order to quantify spatial autocorrelation, as well as to provide conditions for the optimal spatial interpolation. The results were a ratio of 20%.

Kriging interpolation can be rigorously evaluated according to several cross-validation indicators as follows: the absolute value of the average mean standardized error (MSE) should be close to 0; there should be a minimum root mean square prediction error (RMSE), which should be close to the mean standard error (AME); and the standard root mean square (RMSS) should be close to 1 (Webster and Oliver, 2000; Chen et al., 2013). These parameters are calculated by using the following equations:

$$ME = \frac{1}{n} \sum_{i=1}^n (P_i - M_i) \dots\dots\dots(9)$$

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (P_i - M_i)^2} \dots\dots\dots(10)$$

$$MSE = \frac{1}{n} \sum_{i=1}^n [(P_i - M_i)/\sigma_i] \dots\dots\dots(11)$$

Where: n is the number of sites; P_i and M_i are the predicted and measured values at site i , respectively; and σ_i is the Kriging standard error at site i .

Adherence to the parameters above can lead to more rigorous spatial interpolation. The cross-validation errors of Kriging interpolation were as follows: ME 0.030, RMSE 0.34, ASE 0.33, MSE 0.080 and RMSSE 1.0, indicating that the ordinary Kriging spatial interpolation method was more reliable for all trace elements predicted and calculated in this research (Li and Heap, 2008).

3.7.3.2 Solution for outliers in Kriging method

One of the most widespread problems when using the Kriging method to interpolate results is extreme data, which means the presence of data values that are either very large or very small compared with the remainder of the data (Wong and Lee, 2005; Krivoruchko, 2011). In this current research, when an attempt was made to plot the results and create maps for both trace elements and sediment fractions, a problem appeared. This problem was some extreme data, which emerged from high percentages or concentrations and/or low percentages or concentrations for each feature (e.g. sand% and Zn metal) in each bay, river and creek, had to be excluded in the first stage of the Kriging method. As a consequence, in the present study, in order to create accurate prediction maps for all variables, an appropriate semivariogram, model nugget, model and anisotropy were required for all the data in each study area.

Therefore, the Kriging model was split into two stages in order to find a valid solution for this problem. Firstly, the outliers were removed for the modeling and the selected data (without outliers), which have similar values, were used in the following the steps. A semivariogram model was built to model the spatial relationships between individual data points. Secondly, in order to create predications at new sites, the semivariogram and a dataset were used. Finally, both the outliers that were removed for the modeling, and the complete dataset, including outliers, were used in the prediction model. The workflow

was effective because the modeling was not influenced by the extreme values; however, the prediction surface still accounted for the outliers (Wong and Lee, 2005; Krivoruchko, 2011).

The first stage (model): The complete dataset, except for the extreme values, were selected, and the Geostatistical Wizard was used to construct a semivariogram to model the spatial relationships between the non-outliers. In the Arc Maps table of contents this geostatistical layer was added.

Second stage (prediction): After using the 'create geostatistical layers' geo-processing tool to create the model in the first step, predictions could be built using the whole dataset (including outliers). The Model stage was used via the geostatistical layer to input a geostatistical model source. From the input dataset, select a specific feature class (i.e. Zn ppm) and the field containing all the data including outliers. Finally, the output geostatistical layer will be given a name; this can provide an accurate prediction map.

Chapter 4

Sedimentary parameters

4.1 Introduction

This chapter describes and identifies the grain size analysis results, including the percentages of sand ($2000\ \mu\text{m} - 63\ \mu\text{m}$), silt ($63\ \mu\text{m} - 3.9\ \mu\text{m}$) and clay ($< 3.9\ \mu\text{m}$). In addition, mean and modal grain sizes, sorting, skewness and kurtosis are determined. Grain size distribution plays an important role in the understanding and examination of provenance, transport history and depositional conditions of the sediments (Folk and Ward, 1957). Moreover, this chapter also identifies and establishes percentages of mineral components in the estuarine sediments.

4.2 Dynamics of deposition of sediments in aquatic environments

Coastal marine environments (estuaries and embayments) are important because they act as a sink for sediments and trap large quantities of fine particles. These sediments are related to pollution because the fine particles have charged surfaces and occur in a protected environment, sheltered from fast currents, waves, tides and wind activities (Liaghati et al., 2004; Duan et al., 2011). Furthermore, both the sediment particles and pollutants may be derived from the adjacent land and transported by runoff, stormwater outlets, tidal activity and waves. The entrapment is due to estuarine environments having a circulatory current activity, which can inhibit the sediment particles from escaping the estuary (Salomons and Förstner, 1984). Therefore, the deposition processes of sediments within the estuaries are controlled by flocculation and transportation by tidal current activity and non-tidal waves. In addition, sediment size has an important role in the depositional processes since fine particles can be moved in suspension (McLusky, 1989; Palinkas et al., 2014).

However, the deposition of fine sediment particles can be inhibited by strong tidal activities and large river flow discharges, which occur at the mouth and head of the bay, respectively. Away from the mouth of the bay, the strength of tidal currents and waves declines. As a consequence, the deposition of sediment particles occurs gradually in the inner parts of bays mainly as a result of flocculation. Originally, the coarse sediment

fractions comprising pebbles and coarse sands are deposited close to river and stormwater discharge points. In other words, the deposition of coarse to fine sand occurs near the shoreline. However, fine to very fine sediment particles ($< 63\mu\text{m}$) are concentrated in the inner and upper reaches of the estuary, which contain sand, silt, clay and organic matter (McLusky, 1989; Hein et al., 2013).

Suspended particulate matter has been deposited in areas where current velocities are slow and wave activity is minor. This occurs when both river discharges and estuarine current activities meet at the fresh water - sea water interface. This zone is defined as having maximum turbidity (McLusky, 1989), and within the shallow parts of this zone large amounts of sediment tend to become resuspended by turbulence, thus adding to the maximum turbidity (King, 1975; McLusky, 1989; Yuan et al., 2004; McLean and Hinwood, 2007).

The diameter of sediment particles affects the velocity of particle settling and plays an important role in sediment deposition. Where the sediments are coarse, such as sand ($>63\mu\text{m}$), the settling velocity is influenced by the grain size of the particle, and varies according to the particle diameter. This relationship is illustrated by the equation:

$$V = 33\sqrt{d} \dots\dots\dots (\text{McLusky, 1989})$$

Where: **V** is the settling velocity (cm.s^{-1}) and **d** is the diameter of the equivalent spherical shape (cm).

In contrast, the settling velocity of fine sediment particles ($< 63 \mu\text{m}$, such as silt and clay) is defined largely through the viscous resistance of the fluid through which the particles are settling. Precipitation of the sediment particles follows Stokes Law.

$$V = 8100d^2 \text{ at } 16^\circ\text{C} \dots\dots(\text{McLusky, 1989})$$

Several factors such as particle shape, concentration, density and efficiency of dispersion have influence on the precise values for Stokes Law.

The setting velocity of various sized particles according to Stokes Law is shown in Table 4.1. It is apparent that the large diameter particles such as sand and coarse sediments settle at an accelerated rate in water, and particles larger than $15 \mu\text{m}$ can settle through a tidal cycle, whereas fine particles have much slower setting velocities than sand. Clay particles $< 4 \mu\text{m}$ in diameter cannot fall and settle during one tidal cycle (McLusky,

1989). However, through the flocculation process, the rate of deposition of fine sediment particles may be increased. Very fine charged particles (clay) agglutinate to each other in the saline water in estuaries and bays, thus creating larger particles which then have accelerated settling velocities (McLusky, 1989).

Table 4.1: Setting velocity of sediment particles in still water (from; King, 1975).

Materials	Median diameter (μm)	Setting velocity (m day^{-1})	Setting velocity (cm s^{-1})
Fine sand	250-125	1040	1.203704
Very fine sand	125-62	301	0.34838
Silt	31.2	75.2	0.087037
Silt	15.6	18.8	0.021759
Silt	7.8	4.7	0.00544
Silt	3.9	1.2	0.001389
Clay	1.95	0.3	0.000347
Clay	0.98	0.074	8.56×10^{-5}
Clay	0.49	0.018	2.08×10^{-5}
Clay	0.25	0.004	4.63×10^{-6}
Clay	0.12	0.001	1.16×10^{-6}

4.3 Botany Bay

4.3.1 Grain size analysis

Generally, the results of grain size analysis for sedimentary studies provide important information that can be used as a physical tool to classify sedimentary environments, to discriminate between various environments, to identify paleo-environmental conditions, and to evaluate subsurface depositional processes (Folk, 1974; Middleton, 1976).

The grain size results in Botany Bay show that the percentages of sand are lower than those of mud, silt and clay (Figures 4.1). In other words, muddy particles are dominant in the central parts of the inner of bays in Botany Bay, where grain size ranged between mud to very fine sand. In contrast, fine and medium sand become dominant close to shallow margins and entrances of the bays (Figure 4.2).

The sand contents within the bay ranged from 0% to 100% (Appendix 2.1). The highest percentages of sand have accumulated in shallow (<1 m, Figure 4.3) water, especially at the mouth and along the edges and shoreline of the bays (Figure 4.4), where wave, tidal and current activities are highest (Figure 4.3) cause transport of fine particles leaving medium and coarse particles close to shoreline. In addition, high percentages of sand were also found in the Woronora River and the main channel of Botany Bay.

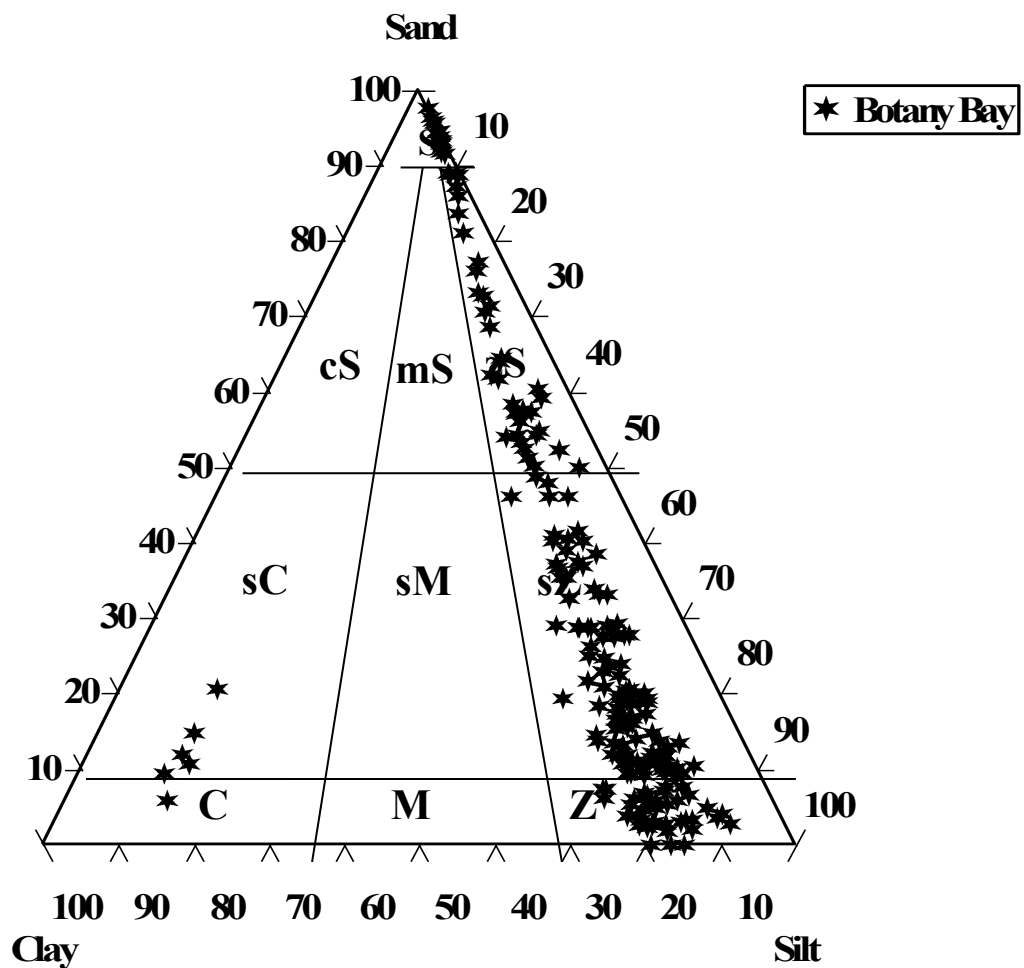


Figure 4.1: Classification of surface sediments in Botany Bay after (Folk, 1974).
Where: S: Sand, s: sandy, Z: silt, z: Silty, M: mud, m: muddy, C: clay and c: clayey.

The percentages of sand were found to have a negative relationship with water depth, as shown by the example of sediments from Kogarah Bay (Figure 4.5a). In general, the deepest water areas had the lowest percentages of sand. This is related to current activity, as there tends to be low current activity at depth within deeper areas and it does not disturb the bottom sediments. Furthermore, fine and very fine particles such as silt and clay can be transported by the currents and tides into the deeper water, and then gradually settle and concentrate in these deeper areas (Figure 4.7). The percentages of silt and clay were found to have a positive relationship with water depth (Figure 4.5b and c). Figure 4.6 shows the relationship between sediment types.

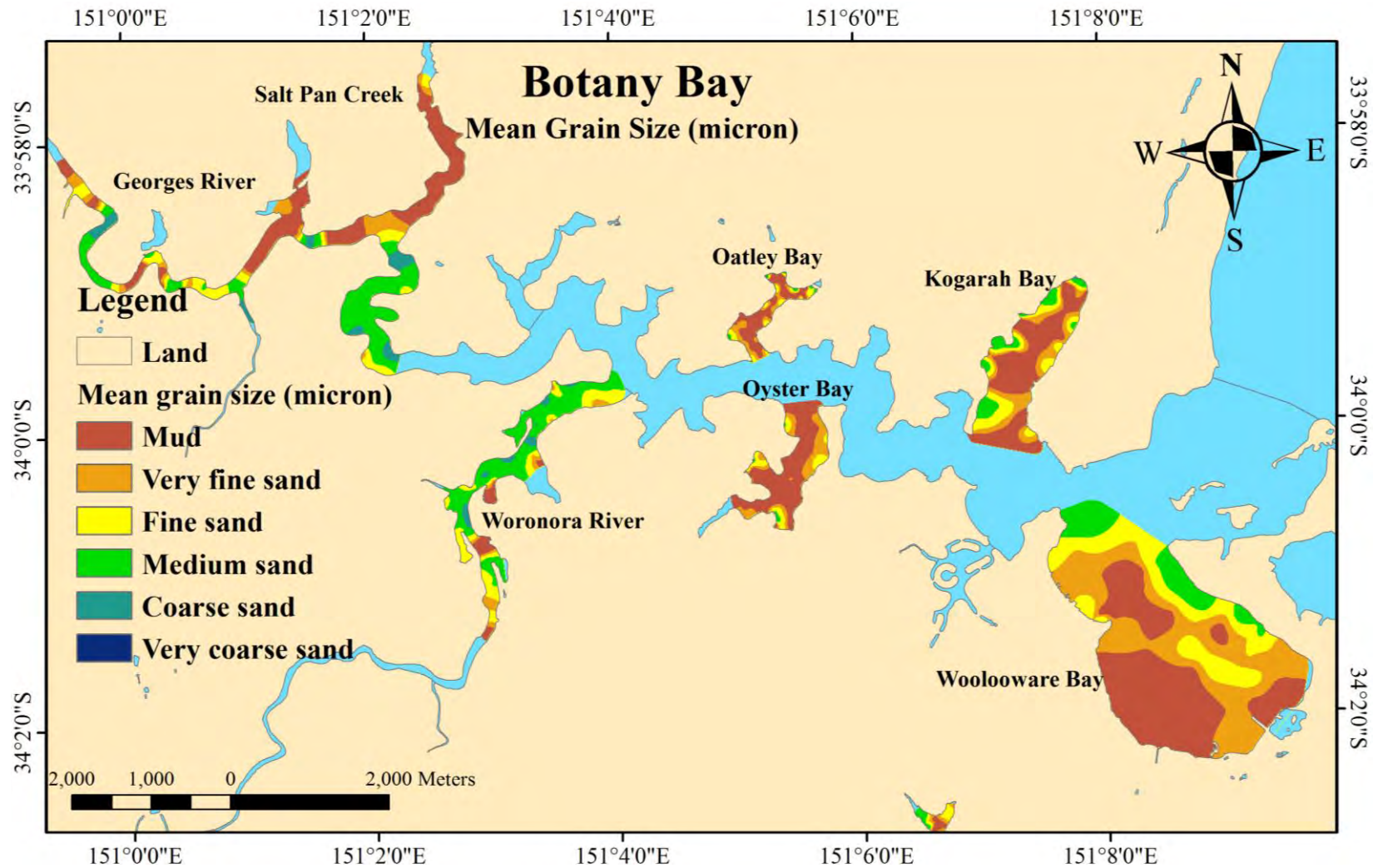


Figure 4.2: Mean grain size distribution within embayments in Botany Bay.

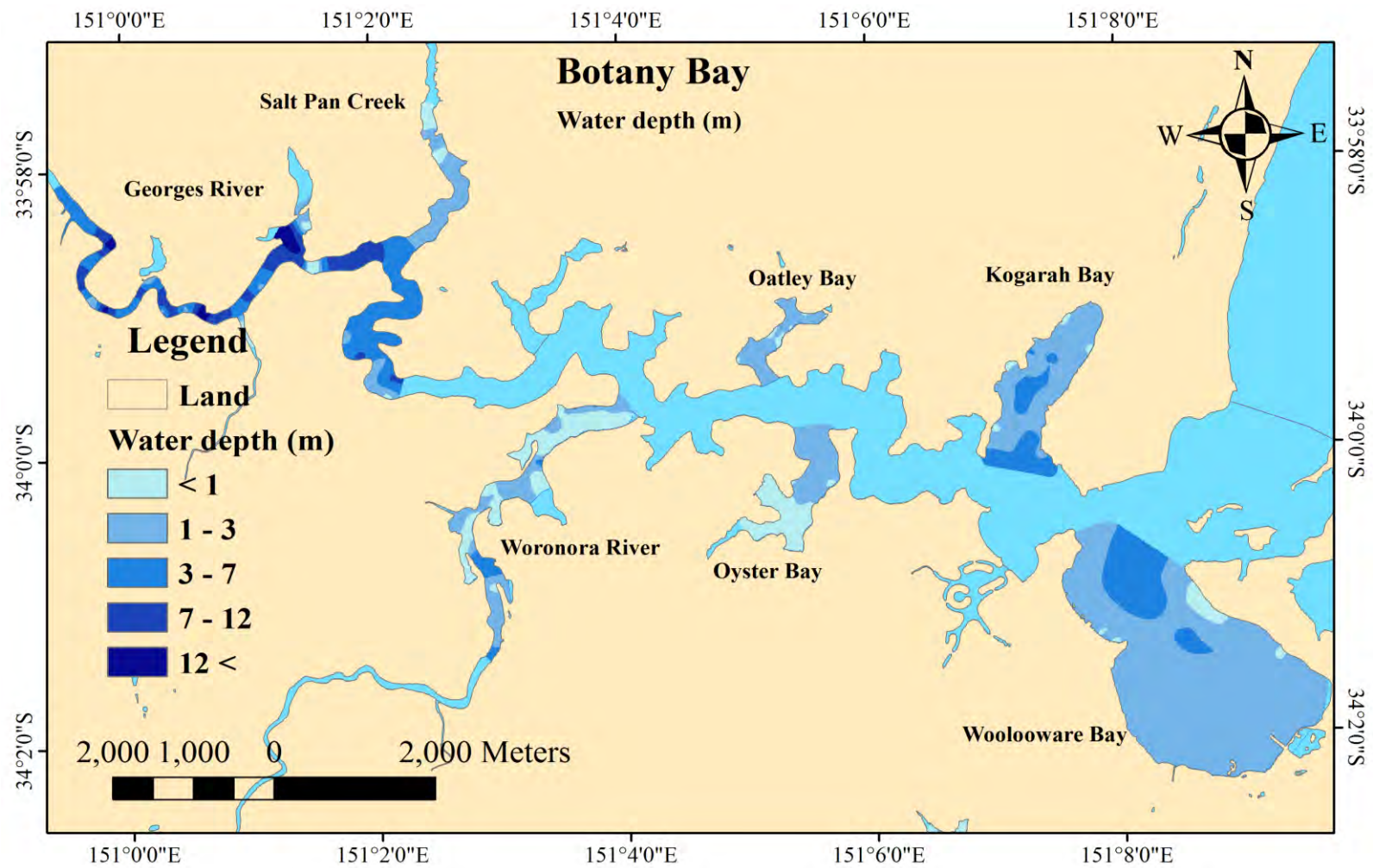


Figure 4.3: Water depth (m) within embayments in Botany Bay.

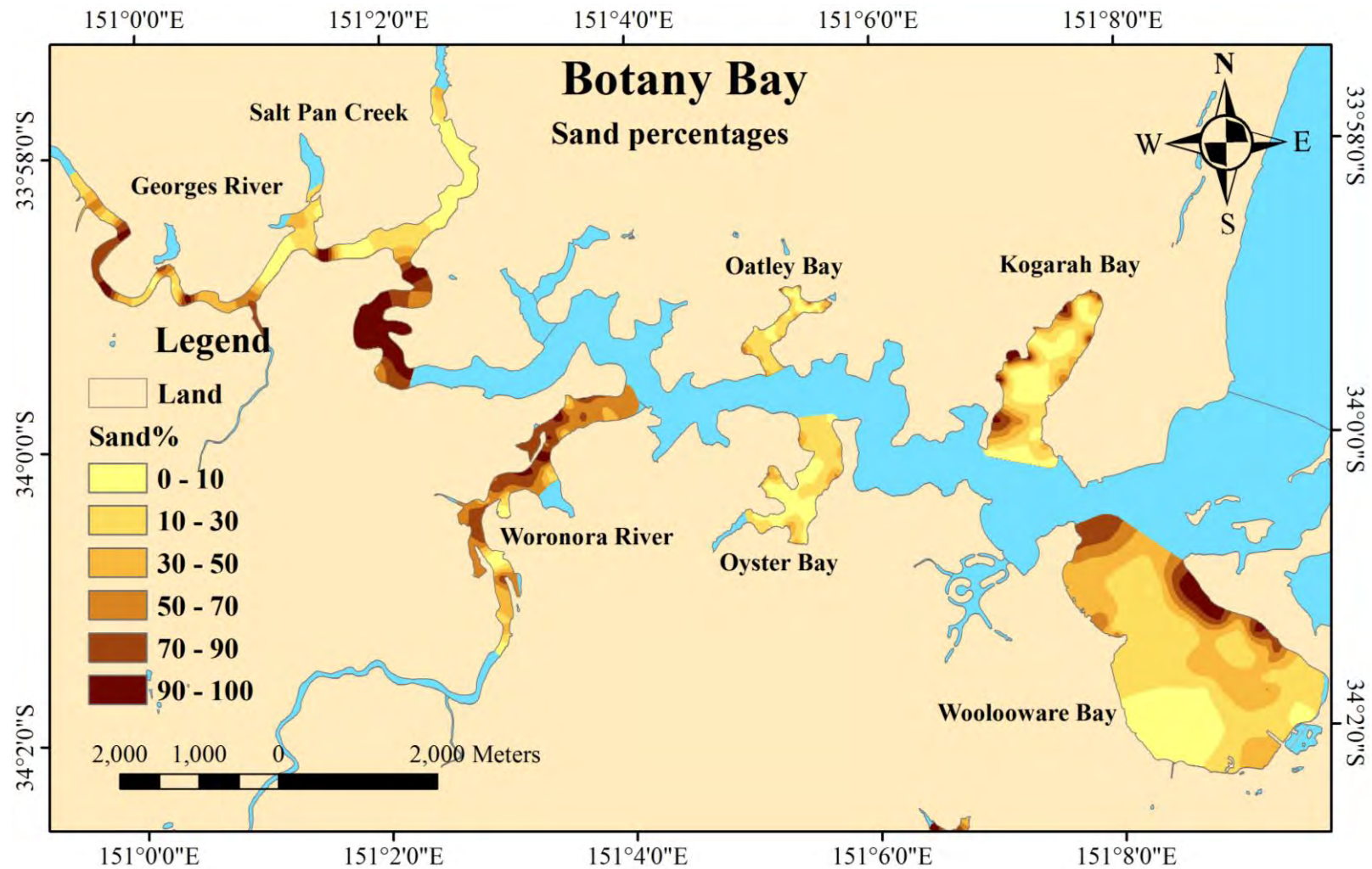


Figure 4.4: Sand percentages within embayments in Botany Bay.

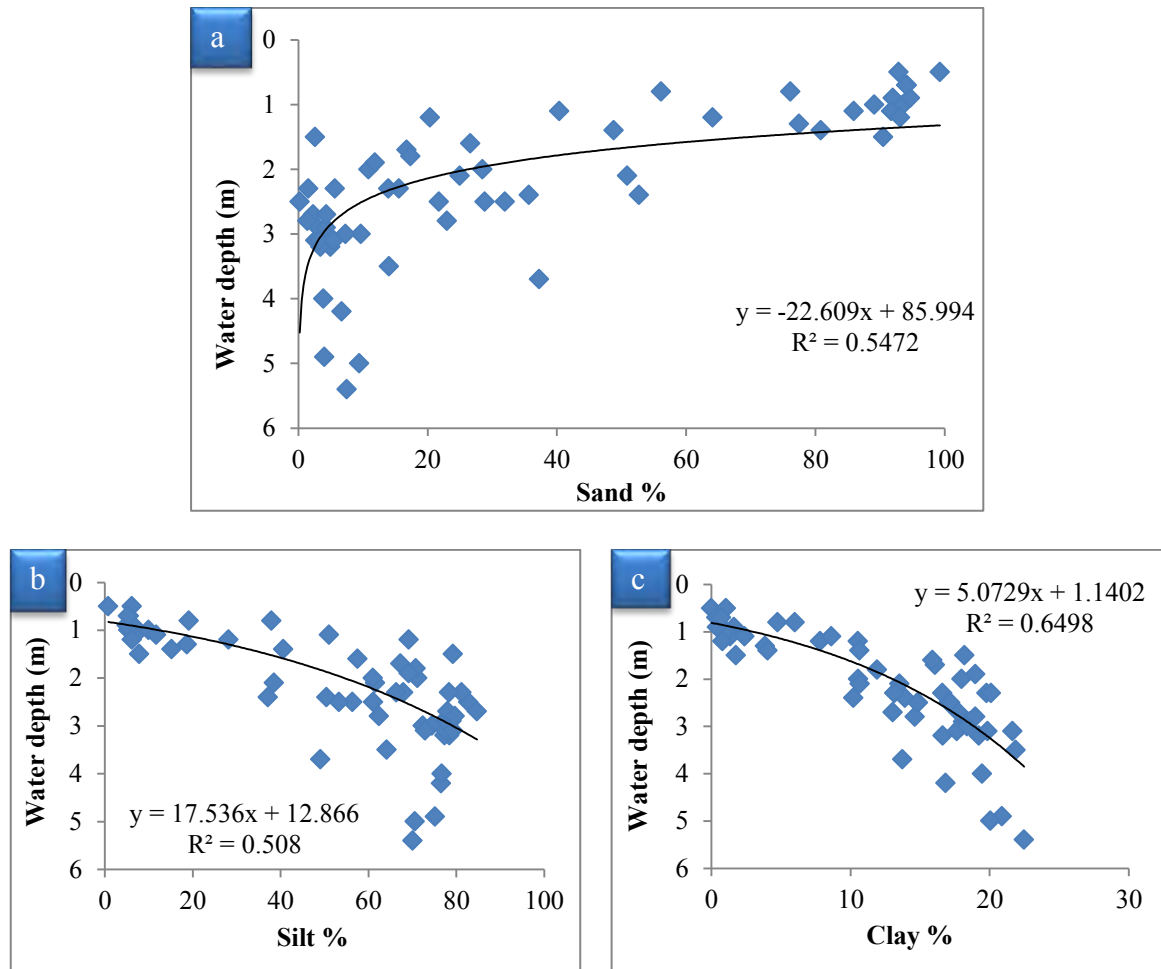


Figure 4.5: Relationship between a-sand, b-silt and c-clay percentages and water depth within Kogarah Bay.

The percentages of mud particles in the Botany Bay ranged between 0% and 100% (Figure 4.7). The clay particle percentages were low compared with those of silt and sand (Figure 4.1 and Appendix 2.1). The highest percentages of mud (silt and clay) accumulated in the inner and middle sites of the bays, such as Kogarah Bay, Oyster Bay, Oatley Bay and Woollooware Bay, because the wave and current activity is less there compared with the main channel. Mud content is low in the Woronora River, as well as around the edges and mouths of the bays, where river flows, currents and waves prevent deposition of fine particles or re-suspended them and these sites are dominated by sand (Alyazichi et al., 2015b). In addition, the percentage of mud declines as depth becomes shallower along the shoreline, at the mouth of the bays and towards the sand barriers (Figure 4.7). Fine organic matter can also stay undisturbed in deeper water areas because current velocities and waves are less effective.

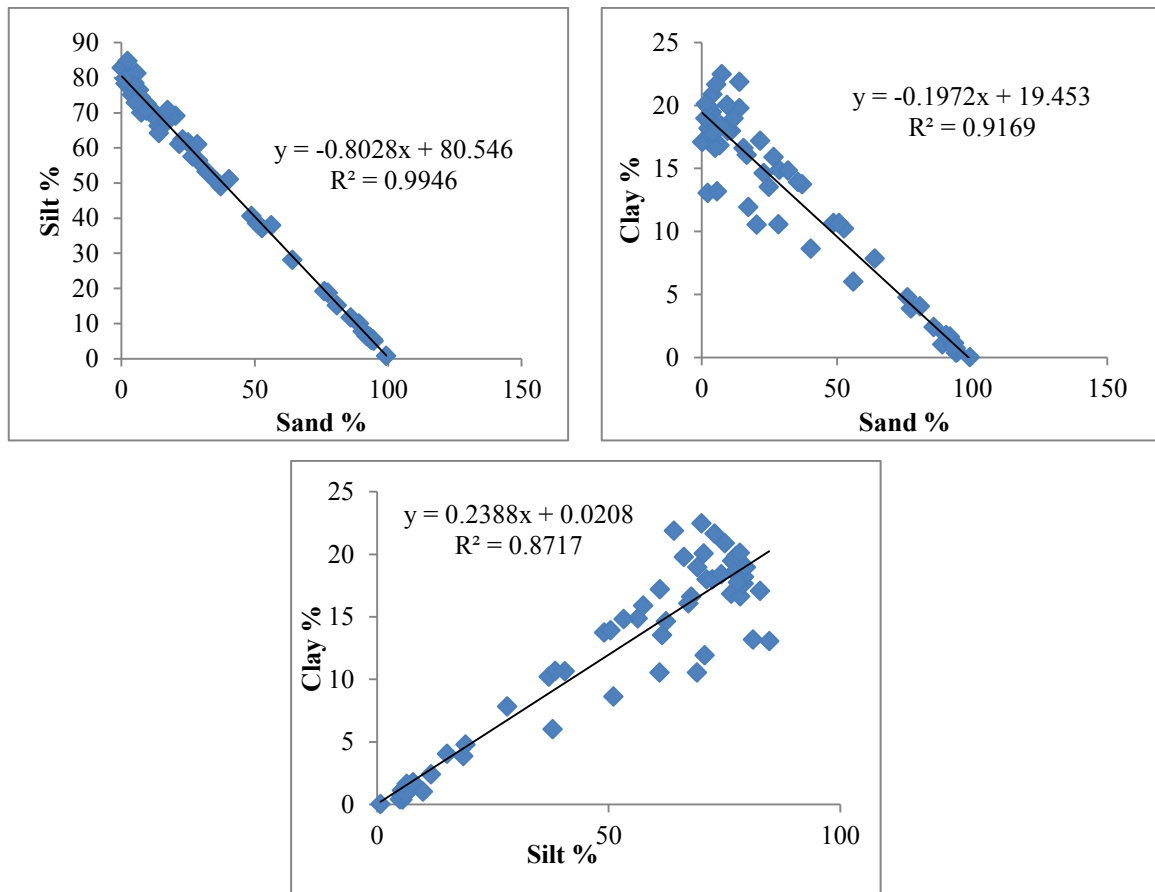


Figure 4.6: Relationships between sediment size grades in Kogarah Bay.

However, although some sites in Botany Bay, such as Salt Pan Creek and Oyster Bay had shallow water depths (< 1.5 m) compared with other bays in Botany Bay, they had low percentages of sand. In the other words, their sediment consisted of high percentages (approximately 80%) of mud (fine to very fine particles, Figure 4.7), which may have been because of the low wave activity within the Salt Pan Creek and Oyster Bay (Alyazichi et al., 2015b). Furthermore, this may be attributed to its sheltered environment, which prevents high winds from creating large waves, resulting in low wave and current activity in this bay compared with other more open bays such as Kogarah Bay (Alyazichi et al., 2015a). Consequently, the fine particles do not escape from Salt Pan Creek and Oyster Bay. Therefore, no significant relationship was found between water depth and mud contents in these two areas.

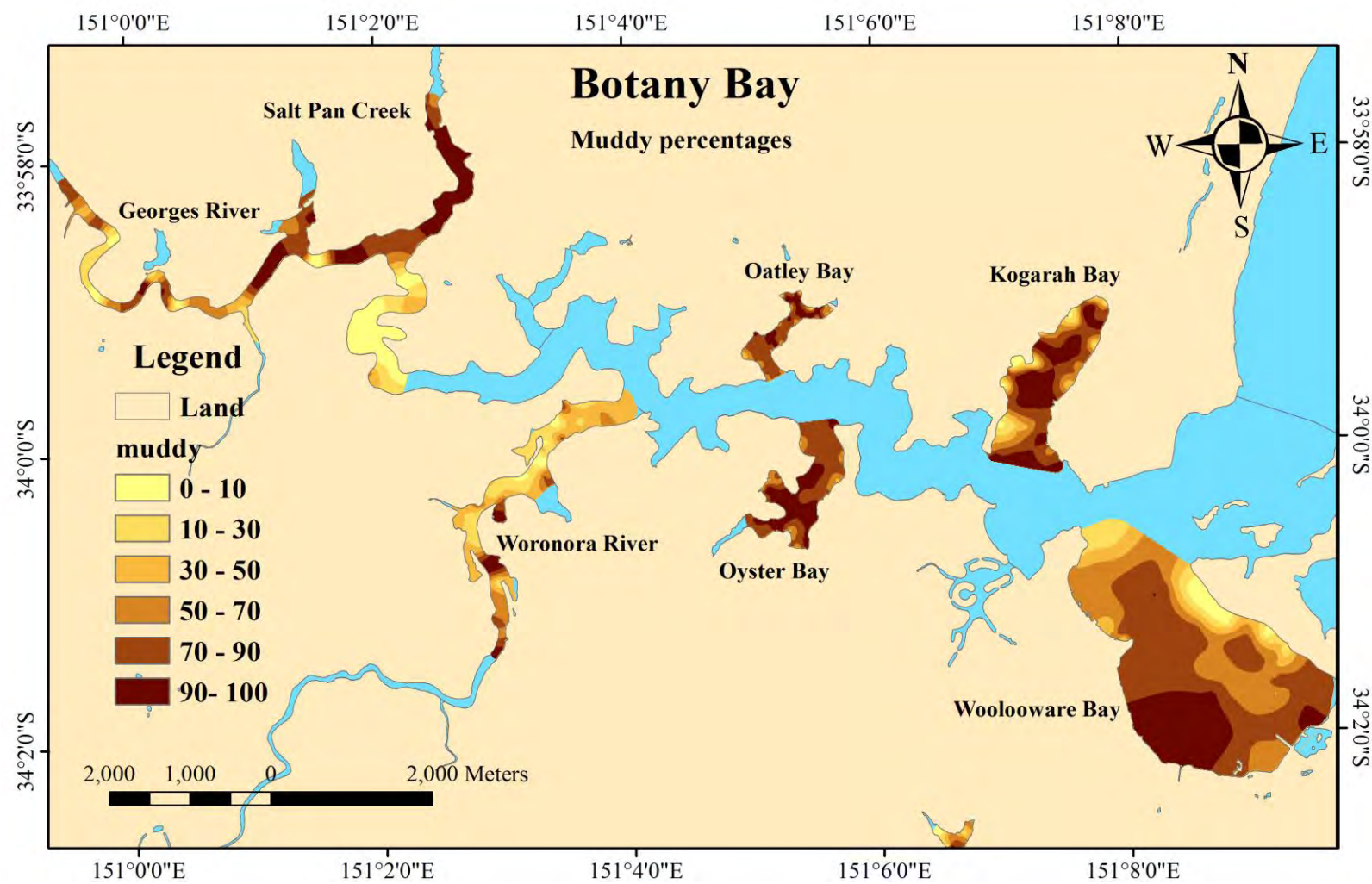


Figure 4.7: Muddy (silt and clay) percentages within embayments in Botany Bay.

4.3.2 Sorting and Skewness

The results for graphical standard deviation values were calculated by using percentile measurements of each sediment sample. The sorting (StdD) of Botany Bay sediments varied from 0.44 ϕ to 3.44 ϕ , which represents well sorted to very poorly sorted sediments (Appendix 2.1). Folk (1974) suggested that the degree of sorting also indicates the energy and current rates and/or duration during deposition, as well as during the transportation processes. The degree of sorting also depends on several factors such as unstable currents and the predominance of one grain size of sediment particles.

The latter depends on several factors such as unstable currents and the presence of a wide range of sediment particle sizes. The sediment samples from Botany Bay that have been classified as well sorted to moderately sorted, are dominated by medium to very coarse sand samples. These sediment samples are located towards the mouth of the bays, main channel of Georges River and Woronora Rivers in areas where currents are stronger (Figure 4.8). This indicates that the high energy of the waves and currents has caused the dominance of one grain size of sediment particles (Folk and Ward, 1957; Folk, 1974).

In contrast, the poorly to very poorly sorted samples are concentrated in the middle of the river and in the inner parts of the bays, such as Kogarah Bay, Oatley Bay, Woollooware Bay and Oyster Bay (Figure 4.8). This is because firstly, the surface sediments have large amounts of mud (silt and clay); secondly, the velocity of the current within these sites is low; and finally, the surface sediments have a mixture of sediment grain sizes from mud to fine sand, such as in the Woronora River (Folk and Ward, 1957).

The skewness values ranged between -0.49 and 0.78, with the mean 0.03 which shows that most of the sediments have near symmetrical size distributions. Some surface samples located in the middle and inner of the bays are classified as being positive to strongly positive skewed, which indicate accretion of fine particles. Other samples from the mouth and close to the shoreline and discharge points are negative to strongly negative skewed, which indicates excess coarse material in these sites (Duane, 1964; Figure 4.9). Graphs of the laser size analysis commonly show two or more modes in the sediment samples. The unimodal samples are usually dominated by sandy particles (Figure 4.9a). These samples are located close to edge and shoreline of the bays, where wave and

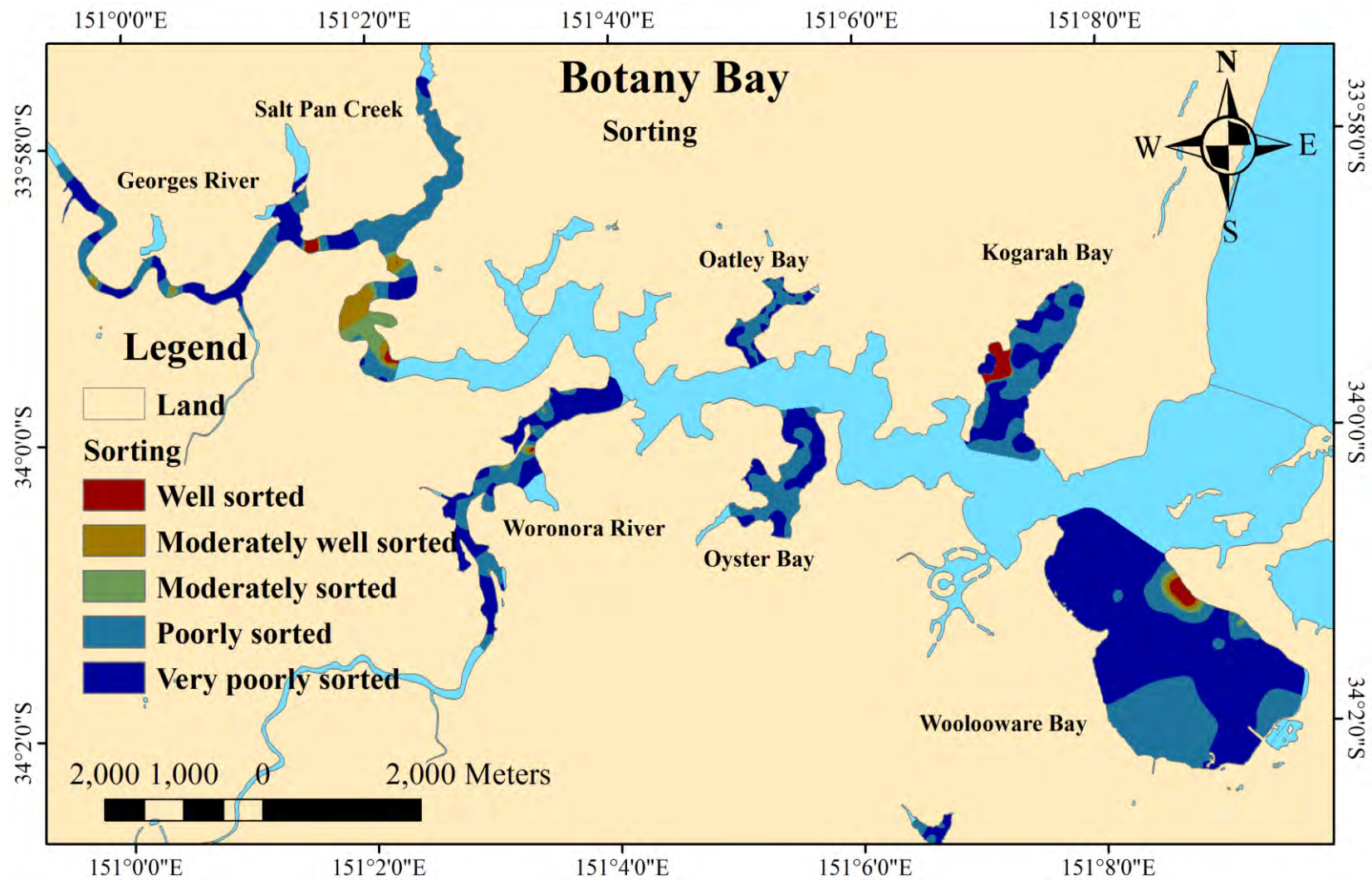


Figure 4.8: Classification of sorting within embayments in the Botany Bay.

tide activity is more pronounced. Samples dominantly consisting of fine particles (mud) may also be unimodal but are generally more poorly sorted. These samples are located in central and inner parts of the bays, where they are less affected by wave and tide activities (Figure 4.9b). Between these sand and mud dominated sample areas, the intervening samples show a bimodal character with a mix of fine and coarse sediment particles. These samples generally show a progression from sand sand dominated (Figure 4.9C) in the shallowed water to mud dominated (Figure 4.9d) towards the centres of the bays.

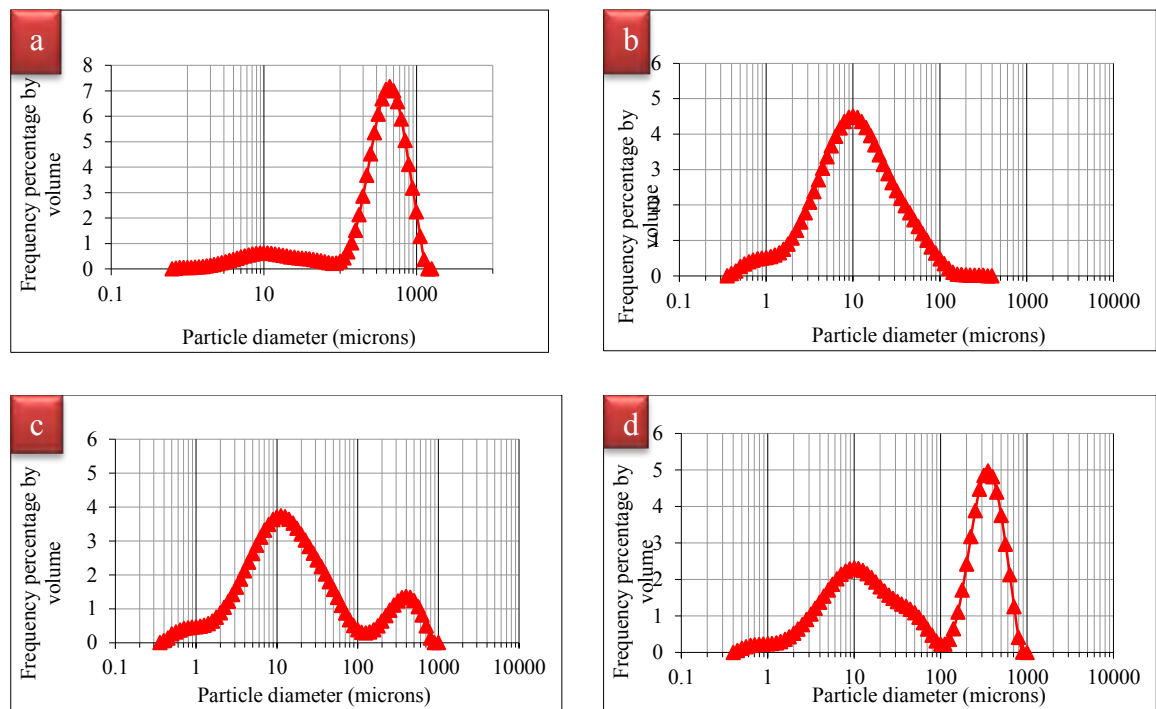


Figure 4.9: a- is poorly sorted, strongly positive skewed, b- Moderately sorted, near symmetrical skewed, c- bimodal, very poorly sorted, negative skewed and d- Moderately sorted, positive skewed.

4.3.3 X-ray diffraction

In this study all sediment samples (coarse and fine) were also analysed using X-ray diffraction. In addition to detrital minerals, sodium chloride (NaCl) was found in the all sediment samples from the study areas. It was precipitated from sea water when the sample was dried and was excluded from the reported mineral contents in the study areas.

A. Quartz

Quantitative analysis of the XRD traces indicated that quartz percentages range between 26.2% and 98.4% with a mean of 66.48% (Appendix 2.2). Quartz is the main component in the sand and plays a role in indicating the source of sediments in different areas. The

high percentages of quartz reflect the sediment sources, such as the quartz-rich Hawkesbury Sandstone (Herbert, 1987; Al Gahtani, 2012). High percentages of quartz were found to be concentrated in the along the edges of the bays, which have high percentages of sand and a low water depth (Figures 4.3 and 4.4), while the percentages of quartz declined towards the inner parts of the bays that have less sand. There is also evidence of wave activity that tends to be higher at the edges and mouth of the bays. Figure 4.10 shows the inverse relationship between quartz and clay minerals (kaolinite) in the bay.

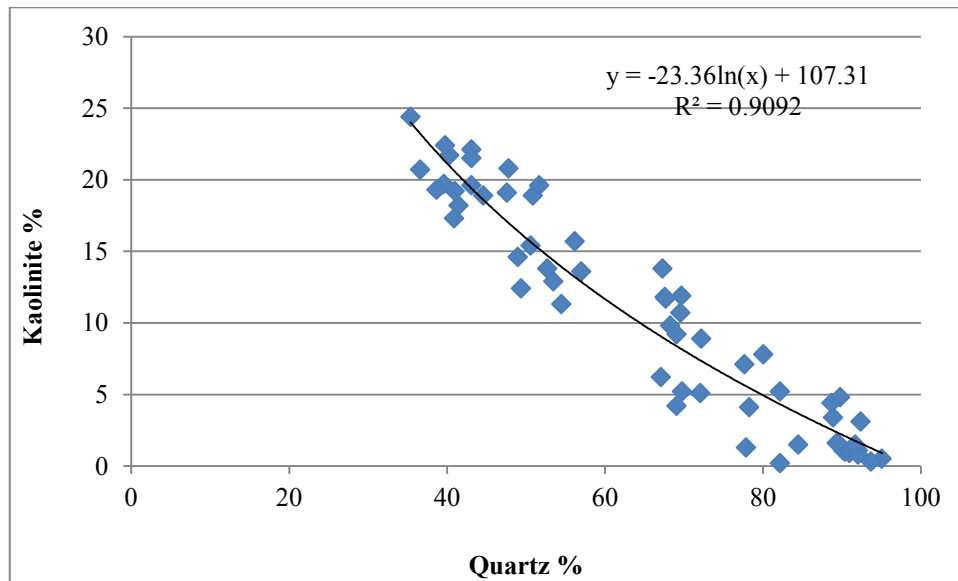


Figure 4.10: Relationship between quartz and kaolinite in Kogarah Bay.

B. Feldspar

Minor quantities of feldspar, including microcline (KAlSi_3O_8), albite ($\text{NaAlSi}_3\text{O}_8$), labradorite ($((\text{Ca},\text{Na})(\text{Al},\text{Si})_4\text{O}_8)$) and anorthite ($\text{CaAl}_2\text{Si}_2\text{O}_8$) are found in sand. The feldspar minerals also play an important role in determining the provenance of sand. The feldspar group minerals are less stable than quartz because of their cleavage and chemical reactivity. At the sample sites the percentages of feldspar ranged between 0.1% and 27.7% with an average 5.8% (Appendix 2.2). The very low percentages of feldspar illustrate the absence of igneous rocks in the source areas (Herbert, 1987). However, some samples, such as KO29, KO31, KO43 and KO44 located close to discharge points, were found to have high percentages of feldspar, probably because of runoff from basaltic road materials.

C. Clay minerals

The surface sediment samples contain (23.1%) of clay minerals in the embayments in Botany Bay. These include the very fine particles in a sand matrix, whereas muddy sediments have higher percentages of clay minerals. The percentages of these minerals increased towards the middle of the rivers and bays where mud is dominant. The highest percentages of clay minerals were in Salt Pan Creek (32.2%) and Oyster Bay (29.8%). In contrast, the lowest percentages were in parts of the main channel of the Georges River (6.8%) where stronger currents concentrated the sand particles. The three clay minerals are deposited under the same geochemical conditions.

C.1 Kaolinite

The chemical composition of kaolinite is $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$. It has tetrahedral sheets linked through oxygen atoms to octahedral sheets of alumina octahedral (Ding et al., 2012). The source of kaolinite is chemical weathering of aluminosilicate minerals such as feldspar (Al-Juboury, 2009a). The main direct source is from the Hawkesbury Sandstone (5-15% kaolinite; Al Gahtani, 2012). The percentages of kaolinite in the bays ranged between 0.1% and 27.1%, and were concentrated in the middle and inner parts of the bays (Figure 4.10).

C.2 Chlorite

The chemical composition of chlorite is a hydrous aluminum silicate, usually containing magnesium and iron. Moreover, chlorite minerals have silicate layers like in micas with a composition of $(\text{Mg,Fe,Al})_3(\text{Si,Al})_4\text{O}_{10}(\text{OH})_2$. The percentages of chlorite within the sediment samples varied from 0.1% to 12.6% and would have come from the Hawkesbury Sandstone (minor), Wianamatta Group, Narrabeen Group and weathering of basaltic road materials (Appendix 2.2).

C.3 Illite

The chemical composition of illite is $(\text{K}_2\text{H}_3\text{O})(\text{Al,Mg,Fe})_2(\text{Si,Al})_4(\text{Si,Al})_4\text{O}_{10}(\text{OH})_2(\text{H}_2\text{O})$ (Hong et al., 2014). It has no expanding layer in its crystal structure. Illite is produced from the alteration of other minerals, such as muscovite and feldspar groups, in weathering environments. The percentages of illite in the bay ranged between 0.1% and 37.8%. Illite has a good capability to absorb trace elements due to its three layer structure

(Oubagaranadin et al., 2010; Turan et al., 2011). It would have come from the same sources as the chlorite.

D. Pyrite

Pyrite is the most common sulfide mineral, with the formula FeS_2 . It is usually found with other sulfides in quartz veins, sedimentary rock, and as a replacement mineral in fossils (Oliveira et al., 2012). The percentages of pyrite in Botany Bay varied from 0.1% and 6.1%. Moreover, the percentage of pyrite was found to be positively related to the depth (Figure 4.11). Pyrite reflects the anoxic conditions needed for precipitation of the mineral (Abraitis et al., 2004). This is because sediments in the deeper fine-grained areas represent anoxic conditions with a negative oxidation potential (Eh) that prompts precipitation of sulphides. Pyrite can also incorporate trace amounts of other elements in the sulphide structure (Forstner et al., 1984; Derycke et al., 2013; García-Gómez et al., 2014; Franchini et al., 2015).

In contrast, at shallow water depths where oxidizing conditions are dominant, pyrite is rare, such as in the Woronora River (0.85%). If pyritic sediments are moved into oxic layers, associated trace elements may be released back into the water column (Alastuey et al., 1999; Diehl et al., 2012).

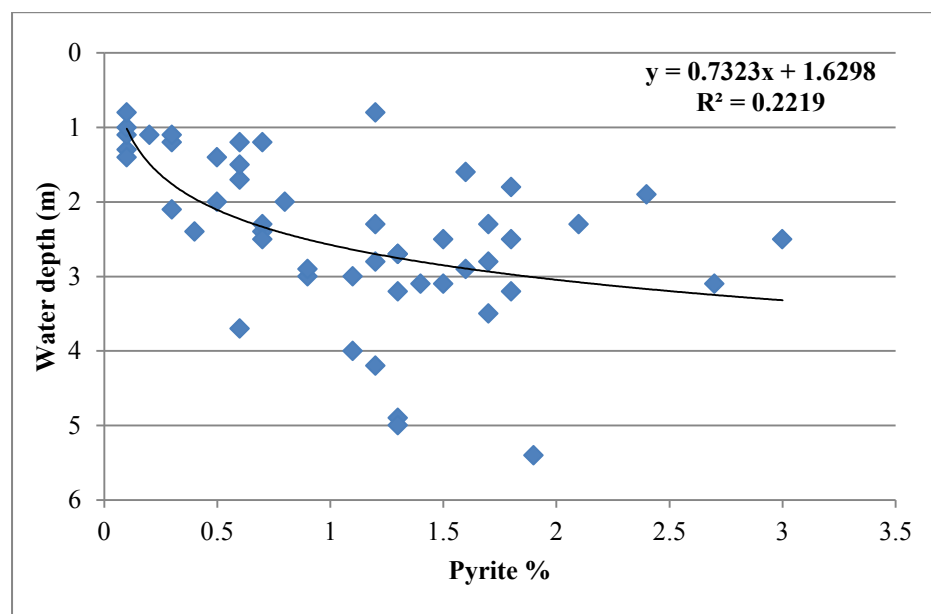


Figure 4.11: Relationship between water depths and pyrite.

E. Carbonate minerals

X-ray diffraction results indicate that the carbonate minerals include calcite (CaCO_3), ankerite ($\text{Ca(Fe,Mg,Mn)(CO}_3\text{)}$) and siderite (FeCO_3). The mean percentages of these minerals in this bay varied from 0.1% to 9.8%, 0.1% to 2.3%, and 0.1% to 2.9%, respectively. The study areas consist predominantly of clastic sediments (Slansky, 1984; Herbert, 1987). The low percentages of carbonate minerals mainly relate to shell material and erosion of outcrops and soils containing authigenic ankerite and siderite.

The calcite probably mainly reflects the chemical composition of molluscs and micro-organisms, such as ostracods and foraminifers, which secrete their carapace and shells (Bergin et al., 2006; Włodarska-Kowalczyk et al., 2013).

F. Gypsum

The chemical composition of gypsum is $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$. The percentage of gypsum in Botany Bay ranged between 0% and 5.4% (Appendix 2.2). Gypsum emerges in the dried sediment around the bay and is also precipitated in the sample during drying caused by oxidation of very fine pyrite reacting with shell fragments.

4.4 Port Hacking

The lower sections of Port Hacking are dominated by a large tidal delta which was progressively deposited during the rise in sea level after the last glacial period. Deeper areas behind this sand deposit trap finer sediments particles from the catchment in areas defined as mud basins Roy (1994). This is particularly important in the smaller embayments and rivers where tidal currents are less effective.

4.4.1 Grain size analysis

Most of surface sediment samples from Port Hacking are dominated by fine- to medium-grained sand and silty sand (Figure 4.12). As shown in Figure 4.13, coarse-grained sand is located in the main channel, the rivers, the bay mouths and in patches along the shoreline of the bays. Muds to very fine-grained sediments are concentrated in the inner and middle parts of the bays.

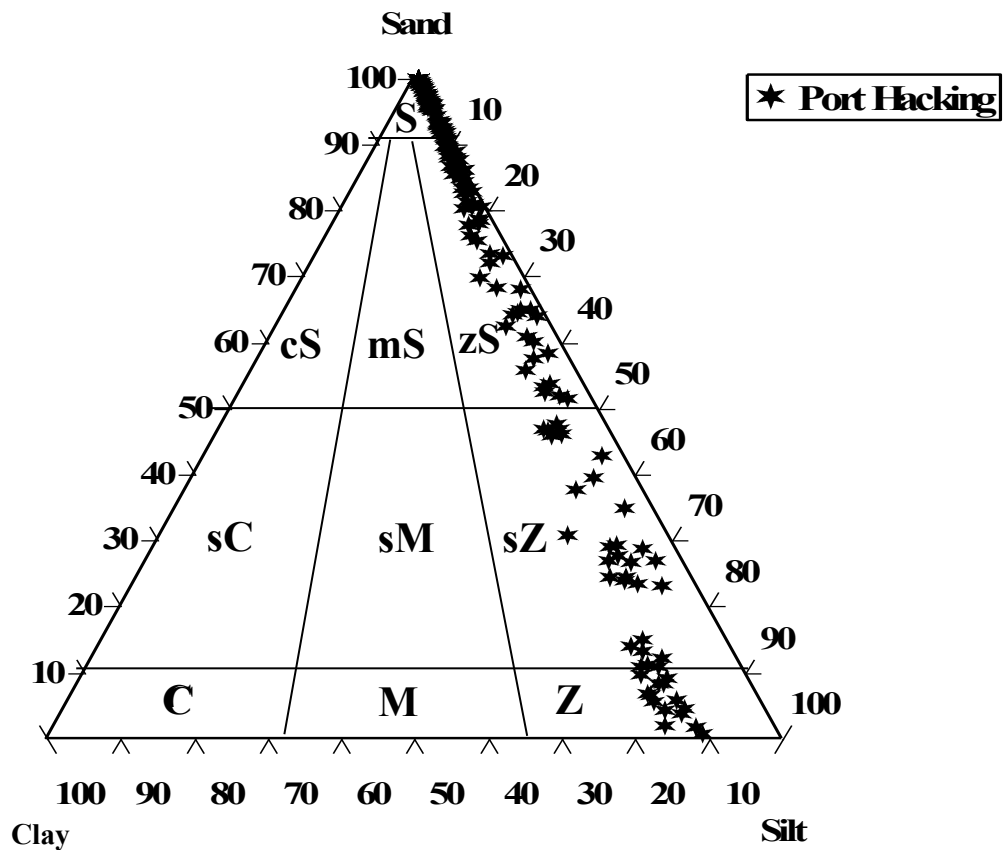


Figure 4.12: Classification of surface sediments in Port Hacking after (Folk, 1974).
Where: S: sand, s: sandy, Z: silt, z: silty, M: mud, m: muddy, C: clay and c: clayey.

The percentages of sand in Port Hacking embayments and rivers varied from 0.87% to 100% with an average 72.1% (Figure 4.14 and Appendix 2.1). The highest percentages of sand were concentrated around the shorelines and at the mouths of bays such as Burraneer Bay and Gunnamatta Bay. This was because these sites have sand barriers at the mouth of the bays and they have shallow water depths (<2 m, Figure 4.16) where the waves and currents are more active. As a result, the fine to very fine particles can be disturbed and move to the middle of the bays where they are gradually deposited. In addition, Hacking River and South West Arm had the highest percentages of sand (Figure 4.14) because they have shallow water depths (Figure 4.16) and they are periodically scoured by fluvial currents during flood events.

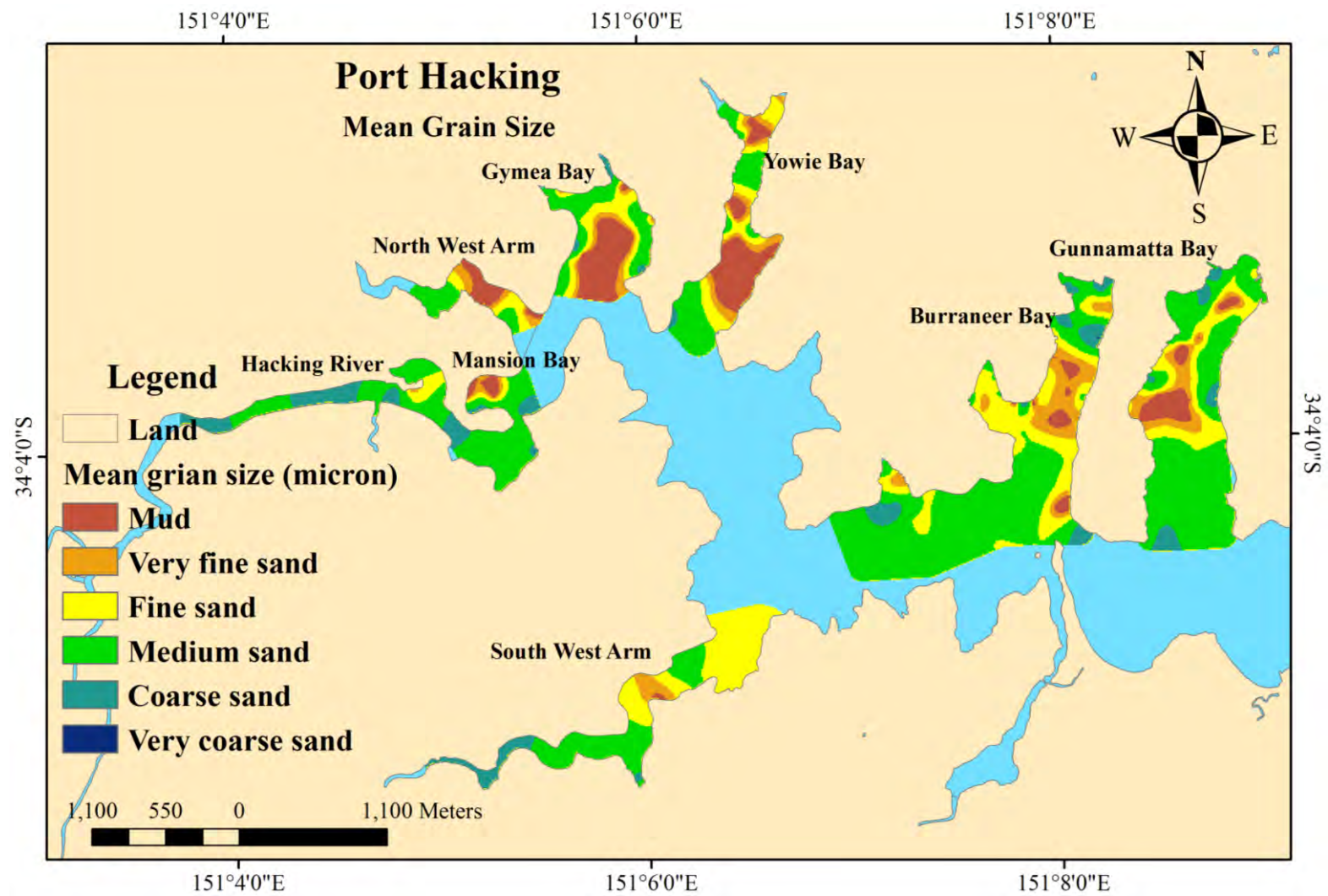


Figure 4.13: Mean grain size distribution within embayments in Port Hacking.

In general, Port Hacking had higher percentages of sand in the rivers and embayments, at an average of about 72%, compared with 35% in the study areas in Botany Bay. This may be attributed to the higher activity of waves within the Port Hacking, especially close to the mouth of the bay (McLusky, 1989; WBM, 2001). Another reason is that the large tidal delta, which was progressively deposited during the rise in sea level after the last glacial period, formed a marine sand barrier that extends from the mouth to near the middle of the Port Hacking estuary (Roy, 1994; Figure 4.14).

The percentages of mud particles in Port Hacking ranged between 0% and 99.1% with an average 27.8% (Figure 4.15 and Appendix 2.1). As illustrated in Figure 4.15, muddy particles predominantly accumulated in the inner and middle parts of the bays because of the greater water depth there (> 7 m, Figure 4.16). Also, the waves and currents become less active in the deeper areas compared to the edges and mouths of the bays. For this reason, the fine and very fine particles can flocculate and settle in these deeper areas (Alyazichi et al., 2014a). In comparison, the percentage of mud particles in Port Hacking (28%) is less than in the study areas in Botany Bay (65%).

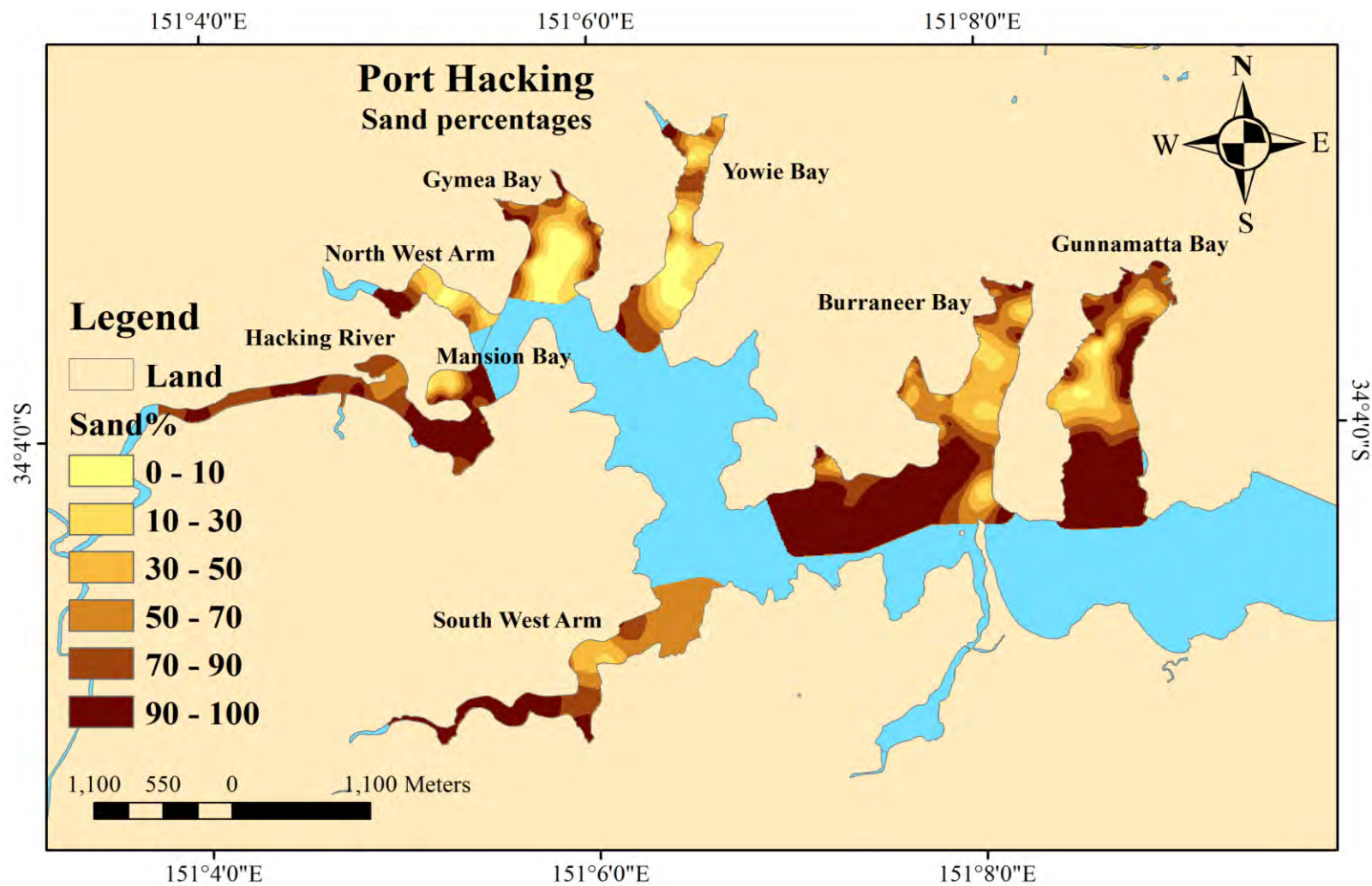


Figure 4.14: Sand percentages within embayments in Port Hacking.

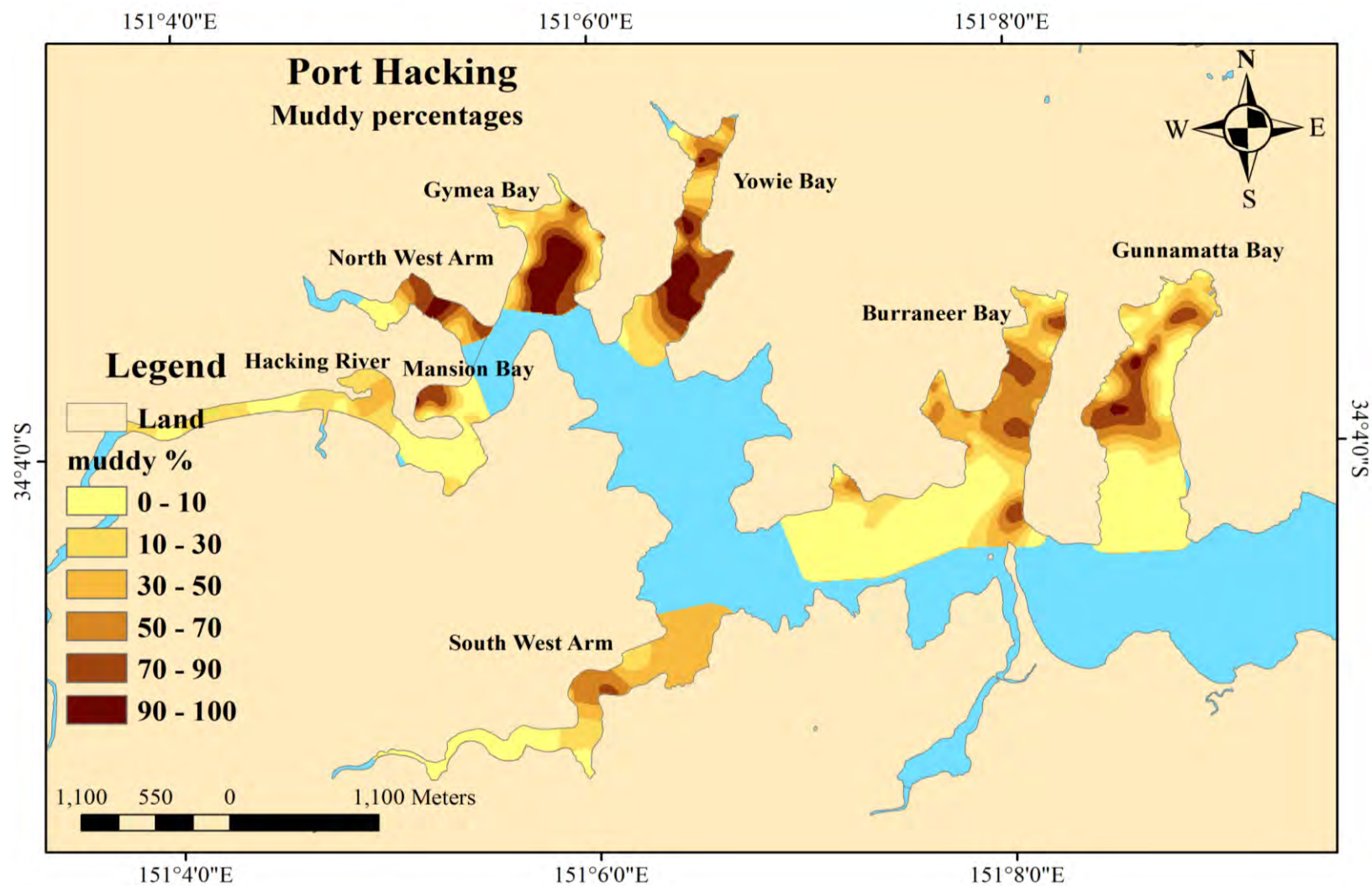


Figure 4.15: Mud percentages within embayments in Port Hacking.

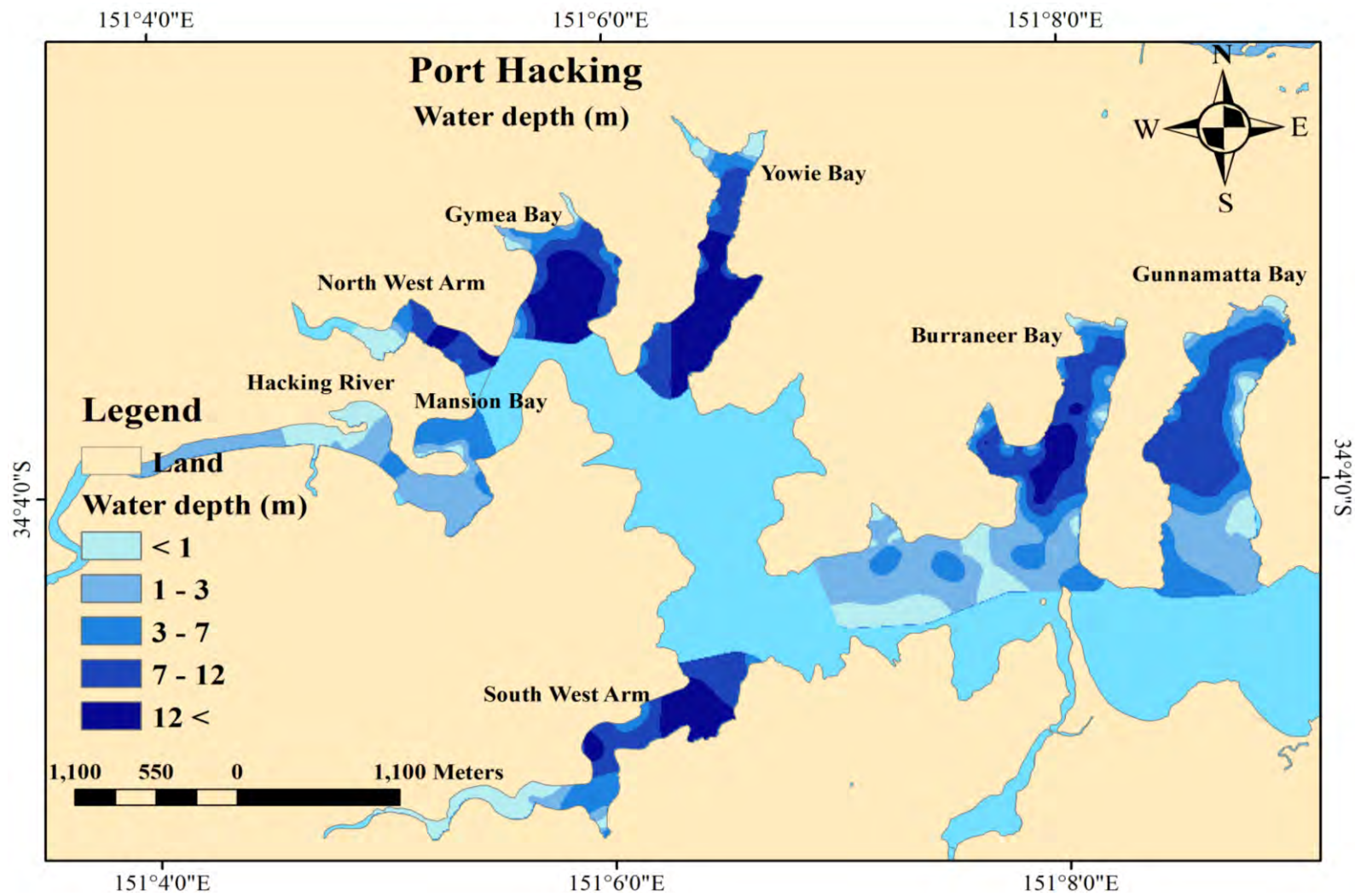


Figure 4.16: Water depth (m) within embayments in Port Hacking.

4.4.2 Sorting and Skewness

The sorting (StdD) of sediment samples varied from 0.40ϕ to 2.88ϕ which represents well to very poorly sorted sediments. Surface sediment samples located near the mouths of Gunnamatta and Burraneer Bays, close to the shoreline and samples in the South West Arm and Hacking River are characterized as well sorted to moderately well sorted sediments (Figure 4.17). This is due to the surface sediments having high percentages of sand caused by the higher energy waves and fluvial and tidal currents within Port Hacking (Folk and Ward, 1957; Folk, 1974).

However, surface sediment samples in inner and middle parts of the bays consist of poorly to very poorly sorted sediments (Figure 4.17). These sediments are part of the fluvial deltaic sediments which grade to fine sediments as catchment flows enter the deeper mud basin area of Port Hacking. Thbecause poorly sorted surface sediments are dominated by fine to very fine particles (muddy particles; Figure 4.15). Moreover, waves and current activities in the inner parts of the embayments became less effective, thus they do not disturb bottom sediments such as silt and clay. In other words, the fine and very fine particles are moved and concentrated within the inner parts of the bays, where water depths are higher (Figure 4.16). Furthermore, the inner sections of the bays are also sheltered from wave activity by the shallow tidal delta sands areas across its mouth and the restricted fetch within the embayments.

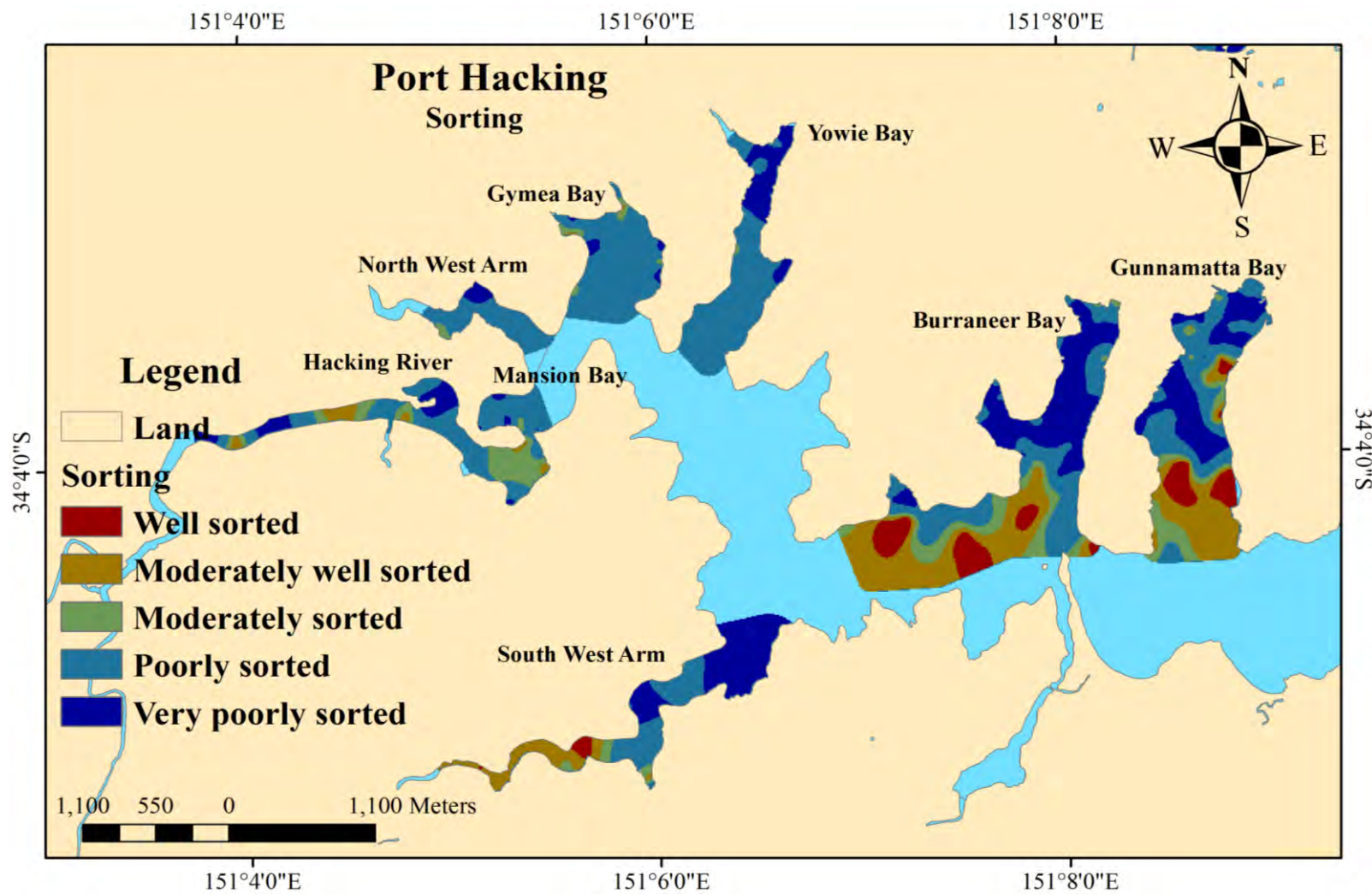


Figure 4.17: Classification of sorting within embayments in Port Hacking.

The skewness values varied between -0.31 and 0.7, which showed that the samples were strongly negatively to strongly positively skewed. For example, about 18 samples were strongly positively skewed, 22 samples were almost symmetrically skewed, and about 4 samples were negatively skewed (Figure 4.18).

Graphs of the laser size analysis commonly show one or more modes in the sediment samples. Most of the sediment samples from Port Hacking are almost unimodal and dominated by sandy particles (Figure 4.18). These samples are located close to edge and shoreline of the bays, where wave, river and tidal currents more active. Samples dominated by fine particles (mud) are commonly bimodal (Figure 4.18d). These samples located in the inner parts of the embayments where wave and tidal activities are less effective.

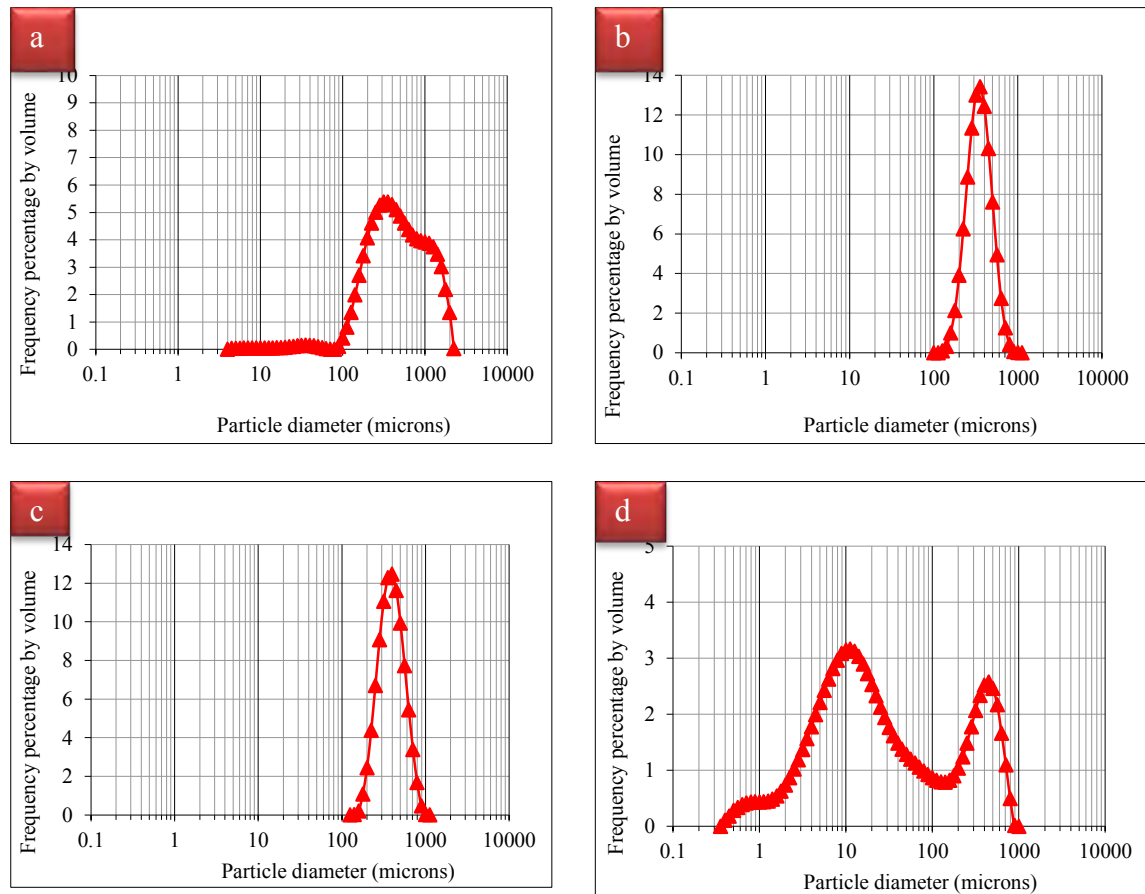


Figure 4.18: a- bimodal, poorly sorted, near symmetrical skewed, b & c well sorted, near symmetrical skewed a, and d very poorly sorted, negative skewed .

4.4.3 X-ray diffraction

A. Quartz

The quartz percentages varied from 20.8% to 99.1% with an average 73.5% (Appendix 2.2). Quartz was dominant on the north-east shoreline and in the southern part of the estuary that had high percentages of sand and shallow water depths (Figures 4.14 and 4.17), while the percentages of quartz declined towards the inner parts of the embayments (Appendix 2.2). The percentages of quartz in sediment samples from Port Hacking (73.5%) are higher than in samples from Botany Bay (66.4%). This is because most samples have high percentages of sand.

B. Feldspar

Percentages of feldspar ranged from 0.2% to 22.0% with an average 6.9 % (Appendix 2.2). Feldspar is less stable than quartz because of its cleavage and chemical reactions. Some surface sediment samples, such as GU13 and GU14, have high percentages of feldspar because they are close to discharge points (basaltic fragments from road runoff).

C. Clay minerals

The percentages of kaolinite, chlorite and illite varied within Port Hacking between 0.1% and 25.2%, 0.2% and 4.7%, and 0.2% and 23.6%, respectively, with an average 10.8% of clay minerals (Appendix 2.2). The highest percentages of clay minerals were found in Yowie Bay (19.2%). This was because the fluvial deltaic sediments grade to fine particles as catchment flows enter the deeper mud basin areas in the embayments at Port Hacking. The lowest percentages of clay minerals were in the South West Arm (6.5%) and Hacking River (2.7%), as well as at the mouth of Gunnamatta and Burraneer Bays (Appendix 2.2). This was because of the mud particles were flushed from these rivers during floods and only accumulated in the deeper parts of the rivers and in the inner and middleparts of the bays. In addition, the percentages of clay minerals in the Port Hacking samples (10.8%) were low compared with the Botany Bay samples (23.1%).

D. Pyrite

The percentages of pyrite in the embayments ranged between 0.1% and 5.6% in Port Hacking (Appendix 2.2) and increased with water depth. This reflects the anoxic conditions in the sediments at the deeper sites that can be deemed to have a negative

oxidation potential (Eh), causing precipitation of sulphides. Pyrite can also incorporate trace amounts of other elements in the sulphide structure (Forstner et al., 1984; Franchini et al., 2015). This can also help explain the accumulation of trace elements at greater water depths.

E. Carbonate minerals

The percentages of carbonate minerals calcite, ankerite and siderite in Port Hacking ranged between 0.1% and 29.5%, 0.1% and 2.4%, and 0.1% and 2.3%, respectively with an average carbonate content of 8.6% (Appendix 2.2). The percentages of calcium carbonate in the bay may attribute to a high diversity and abundance of shell particles in the marine sediments, including micro-organisms, which are composed of calcium carbonate (Rodriguez-Lazaro and Ruiz-Muñoz, 2012; Wang et al., 2013). The ankerite and siderite represent authigenic minerals derived from the catchment.

F. Gypsum

The percentage of gypsum ranged between 0.1% and 6.1%. The gypsum is a secondary mineral generated by the oxidation of pyrite and its interaction with shell material.

4.5 Conclusions

The grain size distributions and mineral compositions of surface sediment samples in the study areas have been described. Sites that have well to moderately sorted sediments are dominated by sand (dominance of one grain size over the others), and this indicates that the waves and currents have more strength within these sites because of their shallow water depths. In these situations the fine and very fine particles can be disturbed and transport by the waves and currents to settle in deeper areas. Consequently, these shallow sites have high percentages of quartz and very low percentages of clay minerals. The sources of clay minerals are from weathering and erosion of outcrops and probably from basaltic road materials.

Sites that have poorly to very poorly sorted sediments generally contain more fine to very fine particles such as silt and clay, which indicate less wave and current activity at these sites. In these deeper areas, the clay mineral percentages (kaolinite, chlorite and illite) are increased and they have lower percentages of quartz. These surface sediment samples located in inner parts of the bays.

Chapter 5

Geochemistry

5.1 Introduction

This chapter investigates the spatial and temporal distribution of total whole rock trace elements within the study areas of Botany Bay and Port Hacking, and how these are influenced by river, stormwater and wastewater outlets. In addition, the chapter discusses and evaluates the contamination factor of trace elements, and also provides details of the accumulation and source of lead pollution by measuring lead isotopes.

5.2 Background concentrations

In the current study, subsurface sediment samples (8 cores) were collected from sites which had the highest concentrations of trace elements in the surface sediments. However, uniform pre-European background subsurface trace element concentrations from deeper cores were used to assess contamination of the sediments (Pease, 2007). These concentrations were used because they were taken from 2.5 m below the sediment surface where stable background concentrations were apparent.

5.3 Normalization of results

The concentrations of trace elements in estuaries and coastal marine sediments are largely defined by fine inorganic particles produced by physical and chemical weathering of the land. Inorganic particles consist of a limited number of minerals, such as quartz, feldspar, mica and clay minerals, as well as smaller amounts of oxides and sulfides (Clark et al., 2000).

Trace elements are adsorbed by fine and very fine particles, especially clays, more than by coarse particles. The surface properties of the sediments can substantially influence pollutant retention by increasing the opportunity for metal cations to interact with a clay particle's negatively charged surface (Gunawardana et al., 2012; Gunawardana et al., 2014).

As a result, grain size influences variations of trace element concentrations in sediments and soils. This was examined by Förstner and Salomons (1980), who used a specific grain

size in order to correct for natural variability. However, as this method may not represent natural concentrations of sediments, they normalized the data to 100% mud, depending on combined geochemical and grain size data. The method can also be established by calculating the ratio of natural bulk concentrations to normalizing factors such as Li and Rb, which are not affected by contamination activities (Grant and Middleton, 1990; Loring, 1990; Loska et al., 2004). These two methods are known as granulometric and geochemical methods. The granulometric method is based on normalization against the total clay size particles existing in the sediments Loring, (1991); Loring and Rantala, (1992).

Within this study, Kogarah Bay was chosen as an example to show the normalization effect on surface sediments (Attached Appendix 4.1). The following formula proposed by Loring (1991) and Loring and Rantala (1992) was used to normalize trace element concentrations in this bay.

$$C_m = (\text{bulk metal concentration} \times 100) / (100 - \text{sand } \%)$$

As can be observed in Attached Appendix 4.1, the normalization findings were not considered to be useful to apply in this study. This is because the mud content in some of the surface sediment samples was low to very low (i.e. KO27, KO28 and KO31); hence the edges and shoreline of the bays produced very high or infinite concentrations of trace elements because of their very low mud content or absence of mud. As a consequence, using the granulometric method produced very unrealistic element concentrations for these areas.

Since the aim of this study was to measure the actual total concentrations of trace elements in sediments, normalization of the geochemical data was deemed to be inappropriate. The total trace element concentrations can be assessed against national and international sediment quality guidelines and can delineate areas with high concentrations that would require further investigation to determine the bioavailability of potentially dangerous trace elements.

5.4 Botany Bay

5.4.1 Spatial distribution of trace elements within sediment samples

The comprehensive and complete results for trace element concentrations in the surface sediments within Botany Bay are contained in Appendix 3.1. A total of 325 surface sediment samples were collected during this study (Figures 3.7- 3.11) and they were combined with sixty five samples from previous work (Pease, 2007; Figure 3.12). Generally, it was found that concentrations of trace elements had similar patterns in most embayments in Botany Bay with the highest concentrations at the head and in the middle of the bays. Nonetheless they varied between sites within the bay depending on the chemistry, hydrology and physical parameters (Clark, 2000). Figures 5.1 - 5.7 illustrate the concentrations of the trace elements Cr, Ni, As, Sn, Cu, Zn and Pb, respectively, in the surface sediments in the inner parts of Botany Bay. Trace elements such as Cu, Zn and Pb are concentrated within the deeper inner portions of the bays and show similar patterns. In addition, trace elements were concentrated around the harbors and marinas where many boats are moored. However, the concentrations of trace elements declined markedly towards the edges and mouths of the bays as well as the lowest concentrations of trace elements located in the main channel and Woronora River where the sandy sediments had the lowest concentrations of trace elements. This is because these oxidising environments had a high quartz content and the lowest percentages of clay minerals, pyrite and organic matter (Figures 4.4, 4.7 and 4.11).

Based on Figures 3.7 - 3.12 and Appendix 3.1, it can be observed that samples such as KO16, KO36, KO39, KO 41, KO45 and KO46 in Kogarah Bay, WO3, WO8, WO11, WO14, WO20, WO21 and WO23 in Woollooware Bay, OY19, OY29, OY24, OY43, OY44, OY47, OY52 and OY54 in Oyster Bay, WOR 27, WOR38, WOR 43 and WOR46 in Woronora River, GE37, GE38, GE39, GE49, GE50, GE 51, GE52, GE53 and GE54 in Georges River and Salt Pan Creek (Alyazichi et al., 2015a;b) and OBU13, OBU14, OBU19, OBU20, OBU21, OBU22 and OBU24 in Oatley Bay (Pease, 2007) had the highest concentrations of trace elements located around drains and discharge points and within the inner parts of the bays. There are several reasons for this pattern.

Firstly, the surface sample sites are close to discharge points and stormwater drains from roadways and residential areas. Sediment particles trend to combine with trace elements

and then flocculate and settle close to discharge points due to the mixing of fresh and salt water. Secondly, the surface sample sites are close to areas that contain boatyards where boats are painted to prevent fouling. There are also large numbers of moored watercraft with potential contaminant spills. Thirdly, the high percentages of mud (Figure 4.7), including clay minerals such as illite, kaolinite and chlorite at the surface sample sites can accumulate and trap trace elements through absorption, ion exchange and metal substitution with muddy particles (Shahidul Islam and Tanaka, 2004; Jain, 2004; Bradl, 2004; Abraham and Parker, 2008; Al-Juboury, 2009a; Turner, 2010; Gunawardana et al., 2013; Gunawardana et al., 2014; Alyazichi et al., 2015a). This is shown by the high concentrations of Rb between 50 ppm and 90 ppm in the inner part of the bays (Figure 5.8 and Appendix 3.1) that are typically associated with the aluminosilicate muddy particles. Finally, percentages of pyrite (FeS_2) and organic matter (total carbon) were higher at these deeper muddy sites (Sansalone and Kim, 2008). The concentration of Br, which has a positive relationship with organic matter, also ranged from 100 ppm to 300 ppm in the inner parts of the bays, and it exceeded 300 ppm in some bays such as Kogarah Bay and Woollooware Bay (Figure 5.9 and Appendix 3.1). Therefore, these sites represent anoxic conditions, which allow trace elements to be captured by the minerals and organic matter (Mayer et al., 1981; Clark et al., 1998).

According to previous studies (Lee et al., 1998; Martin and Kaplan, 1998; Clark, 2000; Zhao et al., 2014a), organic matter has an effect on chemical speciation transformation and the absorption of trace elements in sediments; thus it can affect the toxicity and bioavailability of trace elements in sediments. Finally, increased percentages of pyrite (FeS_2) and organic matter (total carbon) lead to an increased concentration of Br, from 100 ppm to 500 ppm in the inner parts of the bays, and it represents an anoxic environment in which trace elements can be captured (Appendix 3.1; Mayer et al., 1981).

Salt Pan Creek is considered to be a very high polluted creek, and has the highest concentrations of trace elements in the analysed samples from Botany Bay and Port Hacking. Concentrations ranged between 24-86 ppm for Cr; 17-30 ppm for Ni; 74-138 ppm for Cu; 349-789 ppm for Zn; 11-26 ppm for As; 12-17 ppm for Sn; and 138-268 ppm for Pb. This is due to many factors that affect the concentration of trace elements. Firstly, factories had previously produced and discharged large amounts of

trace elements into Salt Pan Creek and the Georges River, as well as discharges from stormwater and wastewater that are thought to be an important ongoing contributor to the general pollution of these waterways. Secondly, Salt Pan Creek contains high percentages of mud particles, ranging from 70% to 96%. Finally, the percentages of pyrite were 1.6-3.6% (Appendix 2.2) and the high Br contents (organic matter) represent anoxic conditions in which trace elements tend to be concentrated (MacDonald et al., 2004; Nath et al., 2013).

The concentrations of trace elements in Botany Bay are higher than in Port Hacking mainly because Botany Bay has more urbanisation and light industry as well as containing higher percentages of mud and clay minerals compared with Port Hacking (Tables 7.10 and 7.11 in chapter 7).

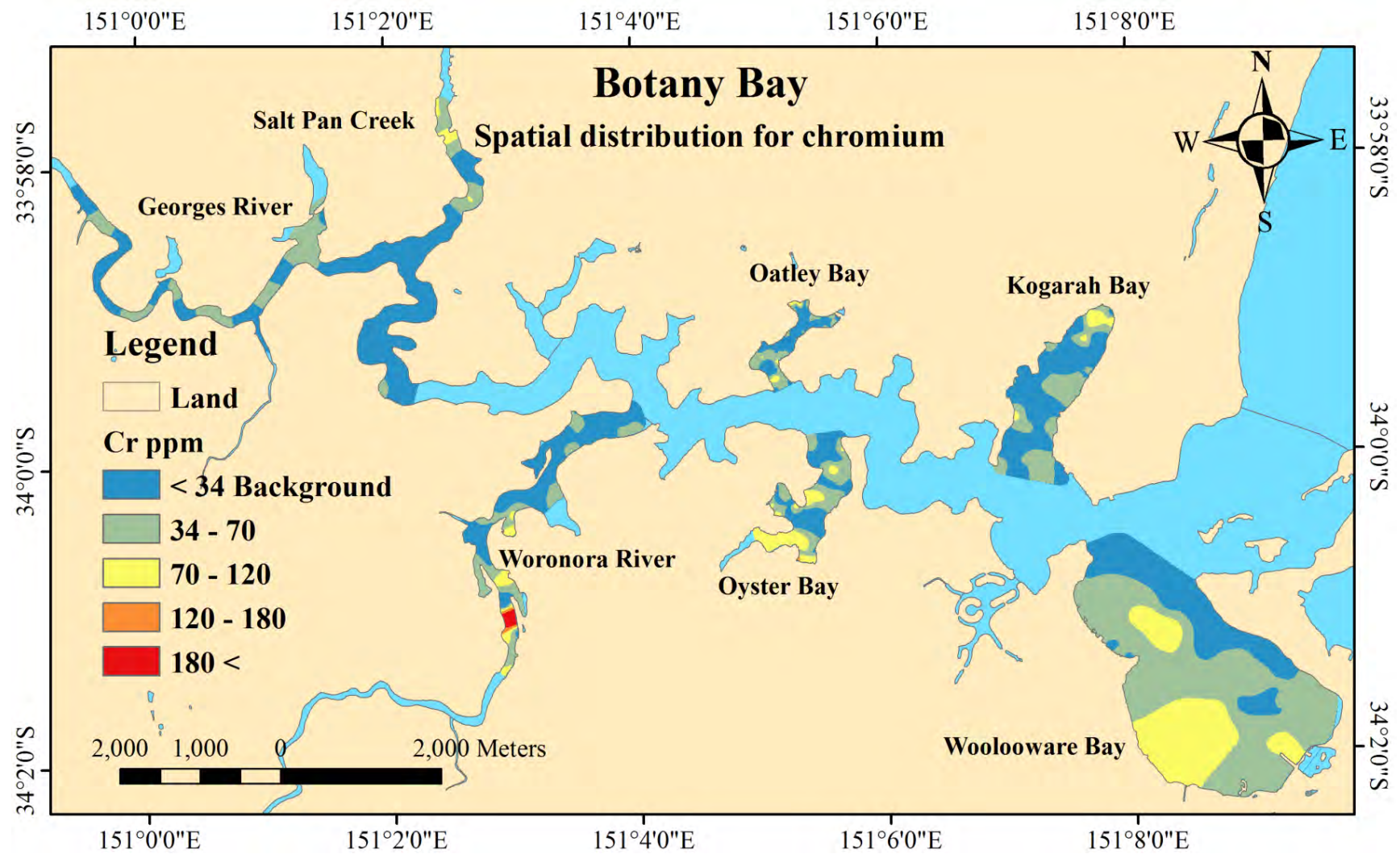


Figure 5.1: Spatial distribution of Cr (ppm) in surface sediments within embayments in Botany Bay.

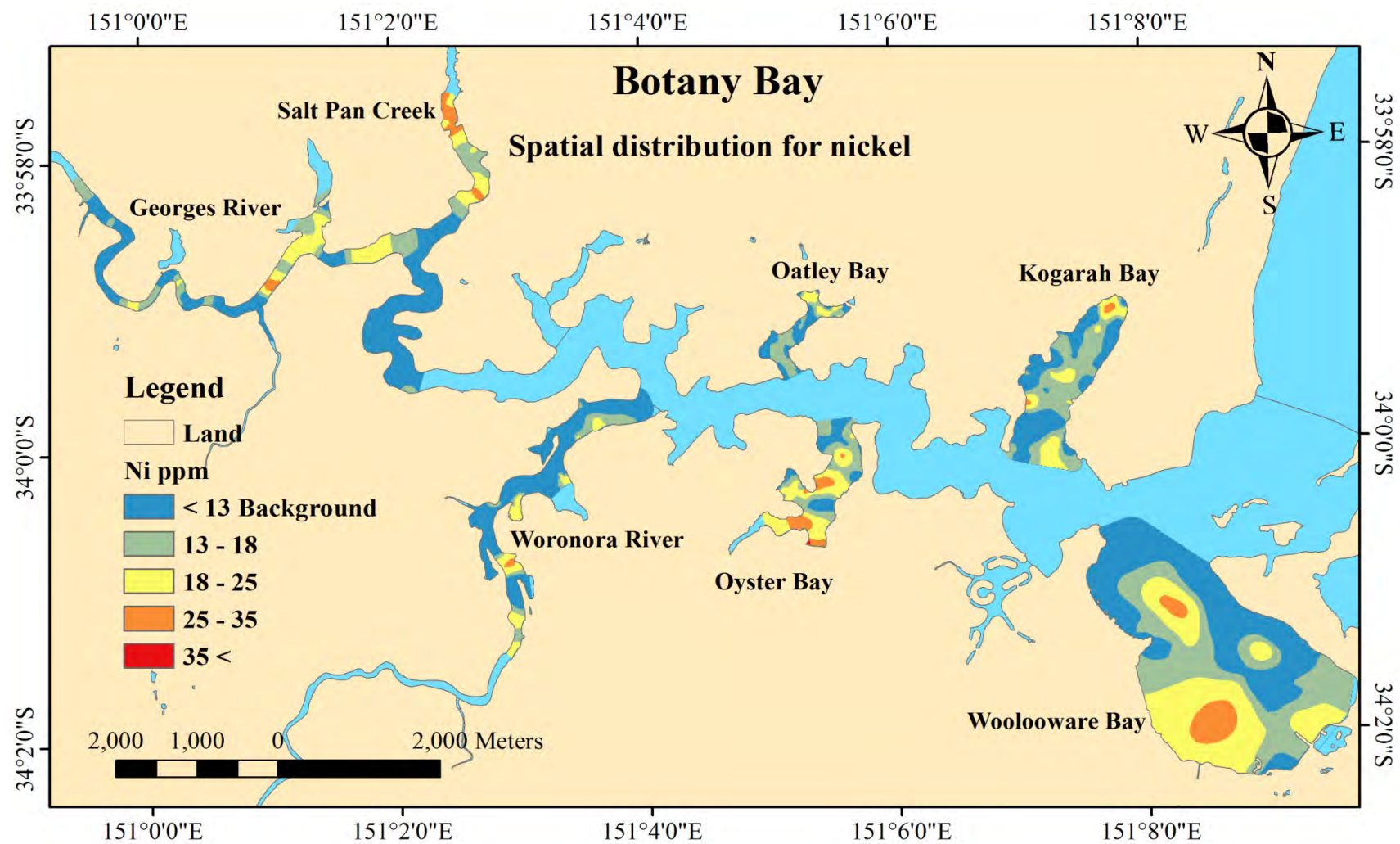


Figure 5.2: Spatial distribution of Ni (ppm) in surface sediments within embayments in Botany Bay.

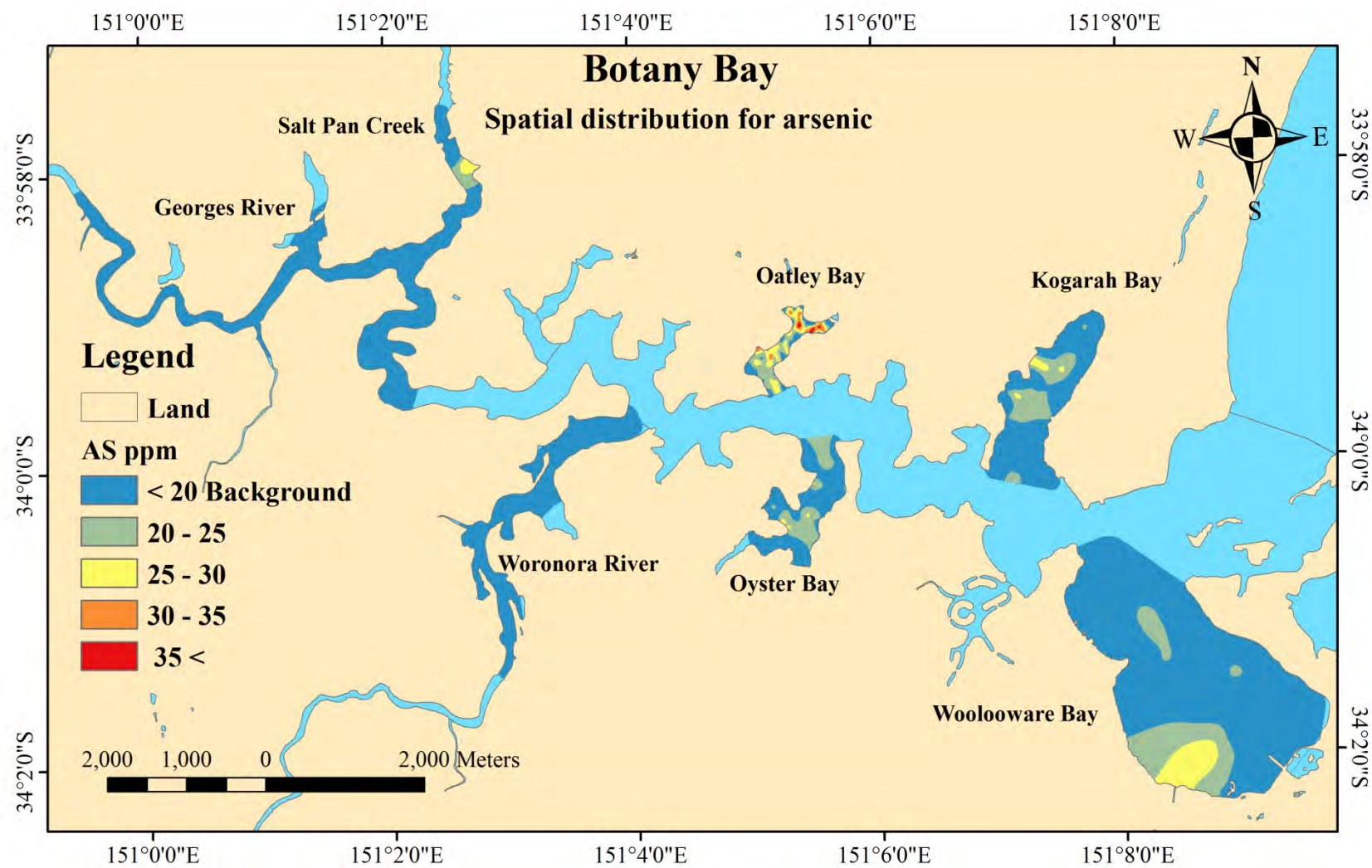


Figure 5.3: Spatial distribution of As (ppm) in surface sediments within embayments in Botany Bay.

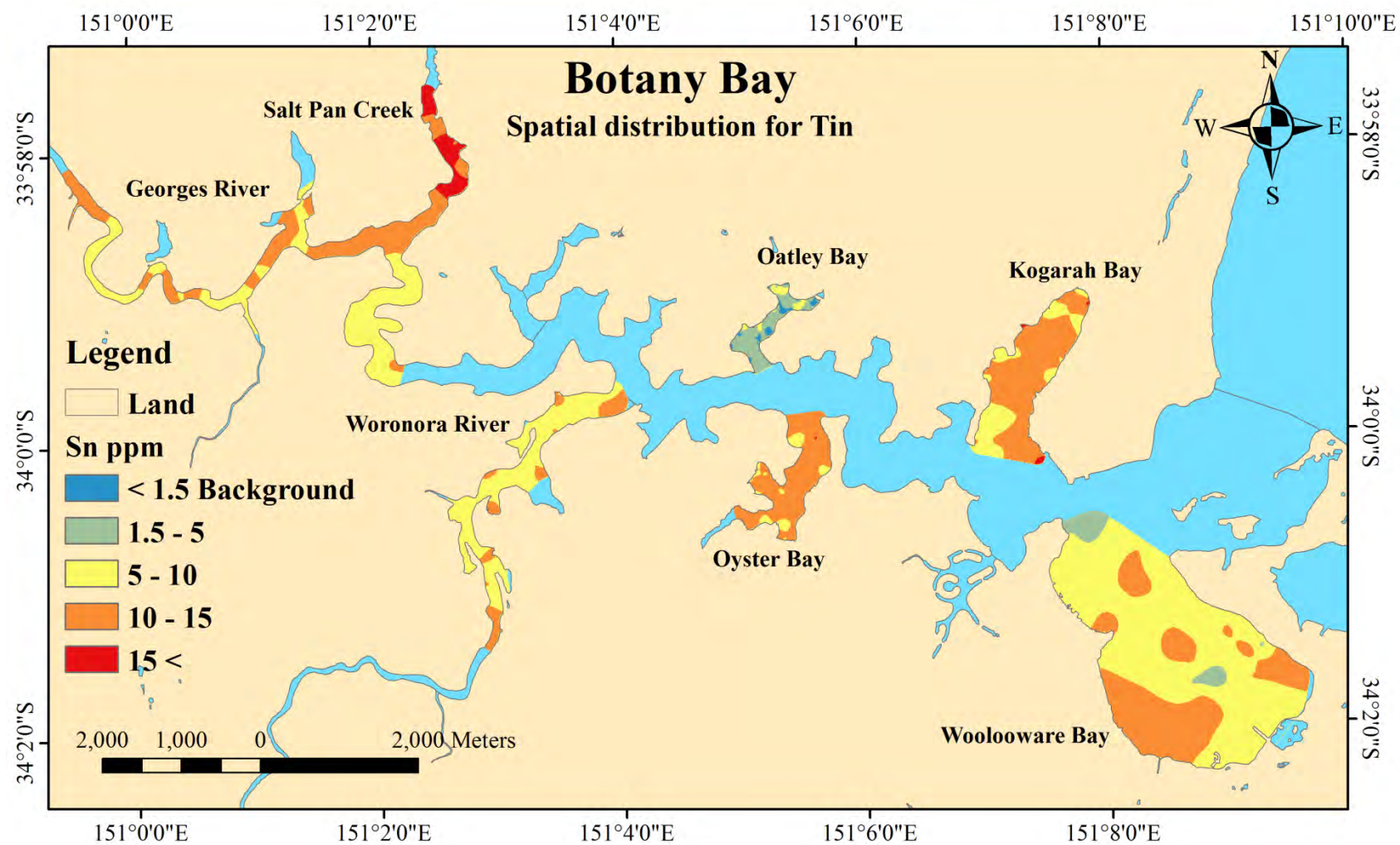


Figure 5.4: Spatial distribution of Sn (ppm) in surface sediments within embayments in Botany Bay.

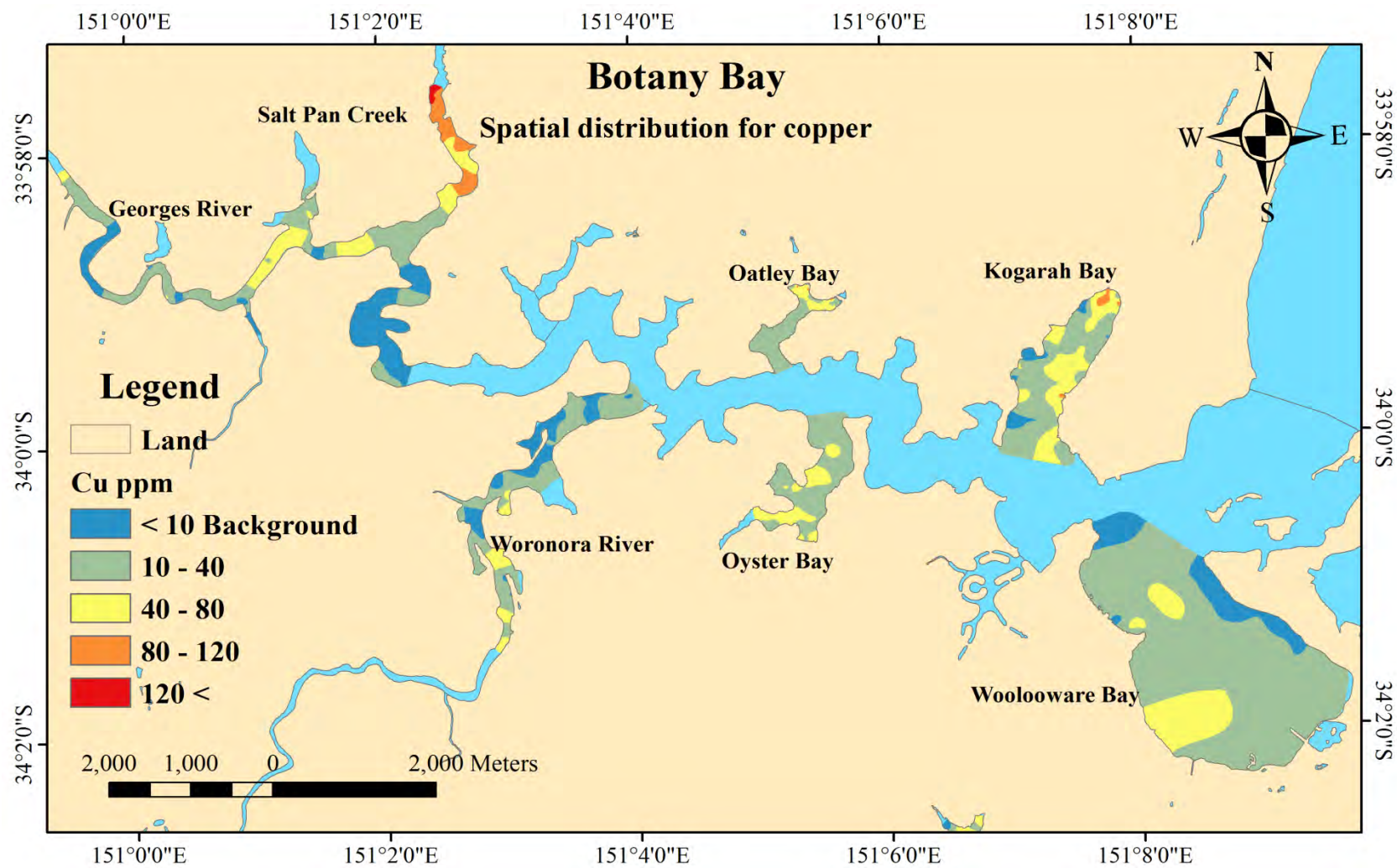


Figure 5.5: Spatial distribution of Cu (ppm) in surface sediments within embayments in Botany Bay.

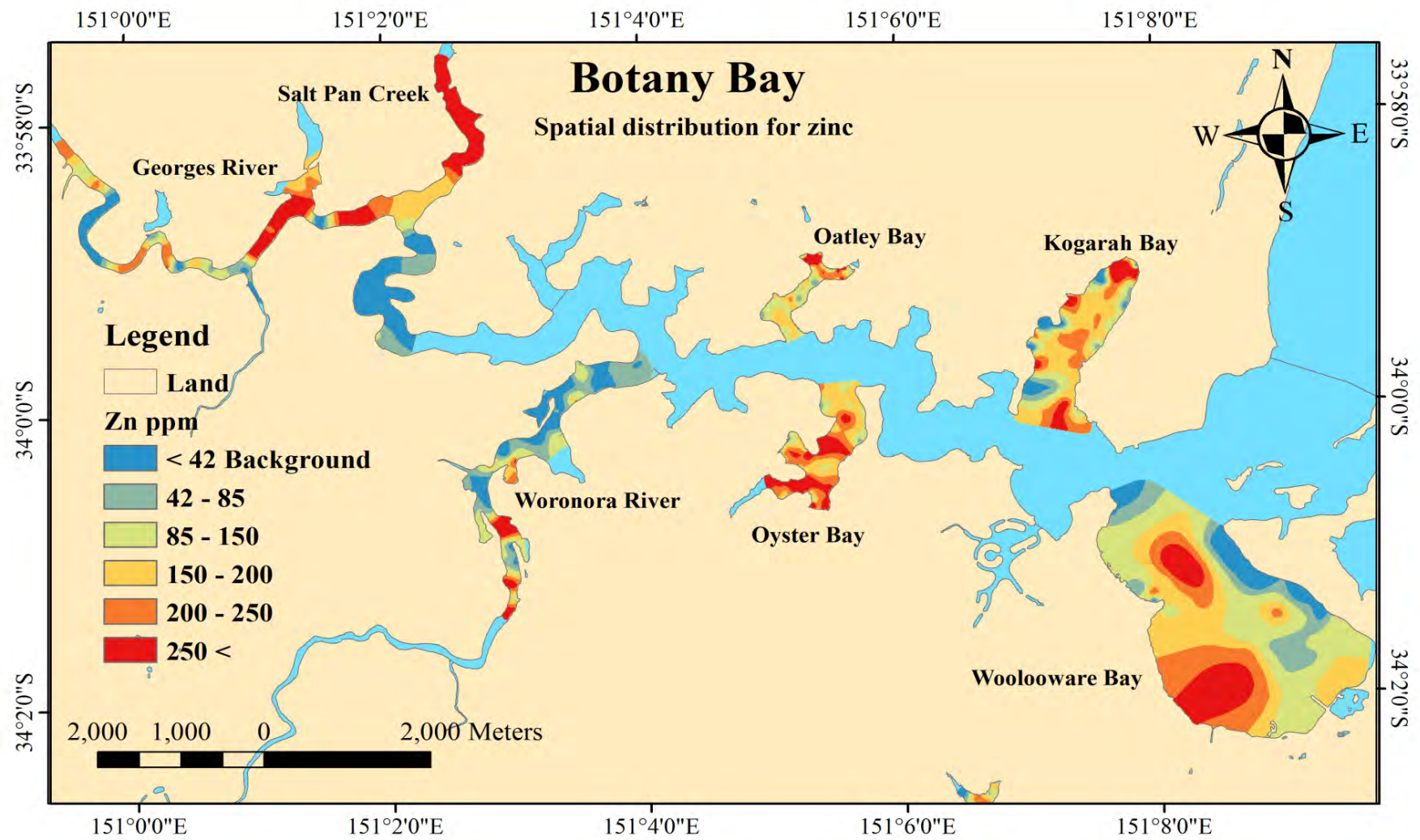


Figure 5.6: Spatial distribution of Zn (ppm) in surface sediments within embayments in Botany Bay.

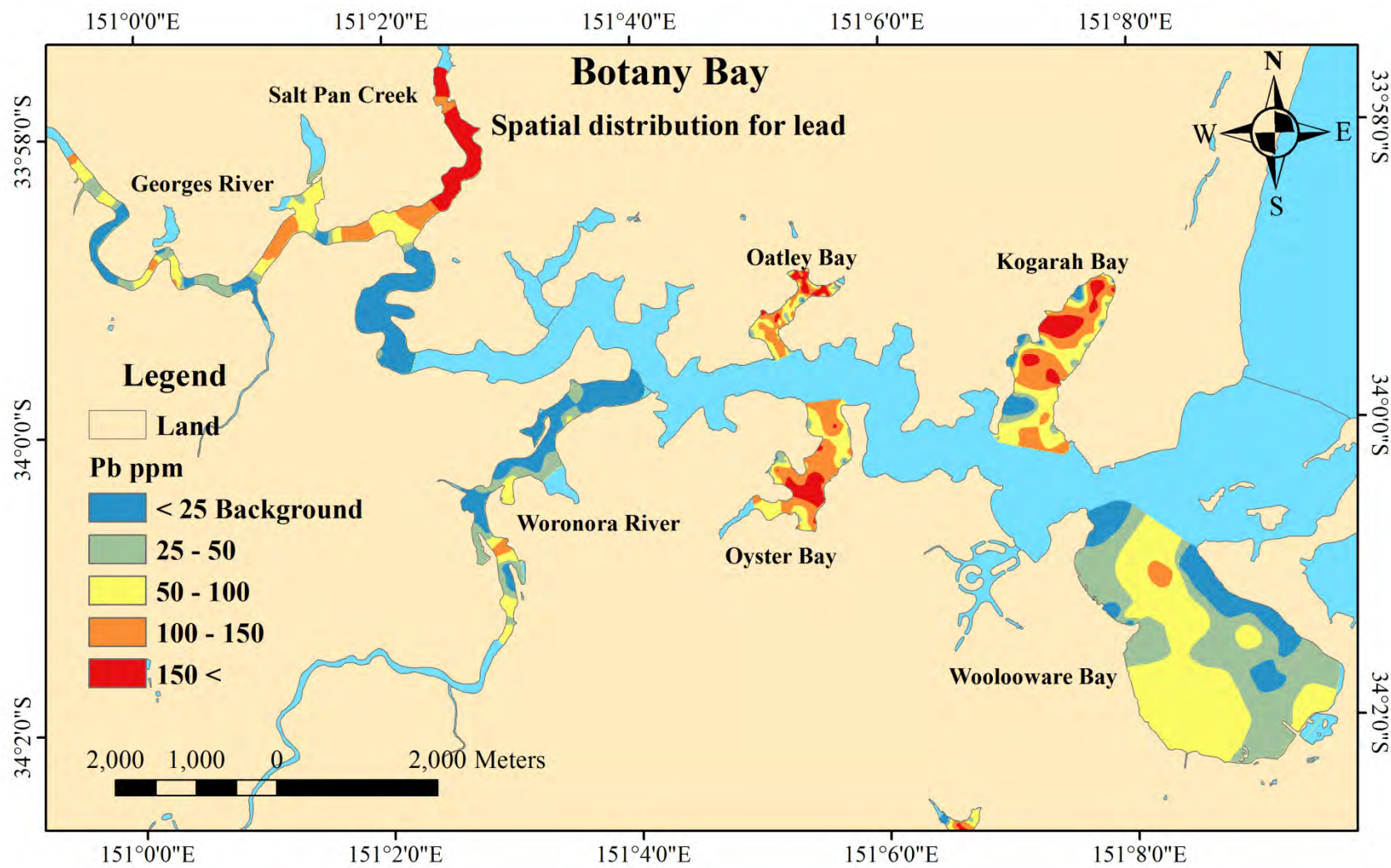


Figure 5.7: Spatial distribution of Pb (ppm) in surface sediments within embayments in Botany Bay.

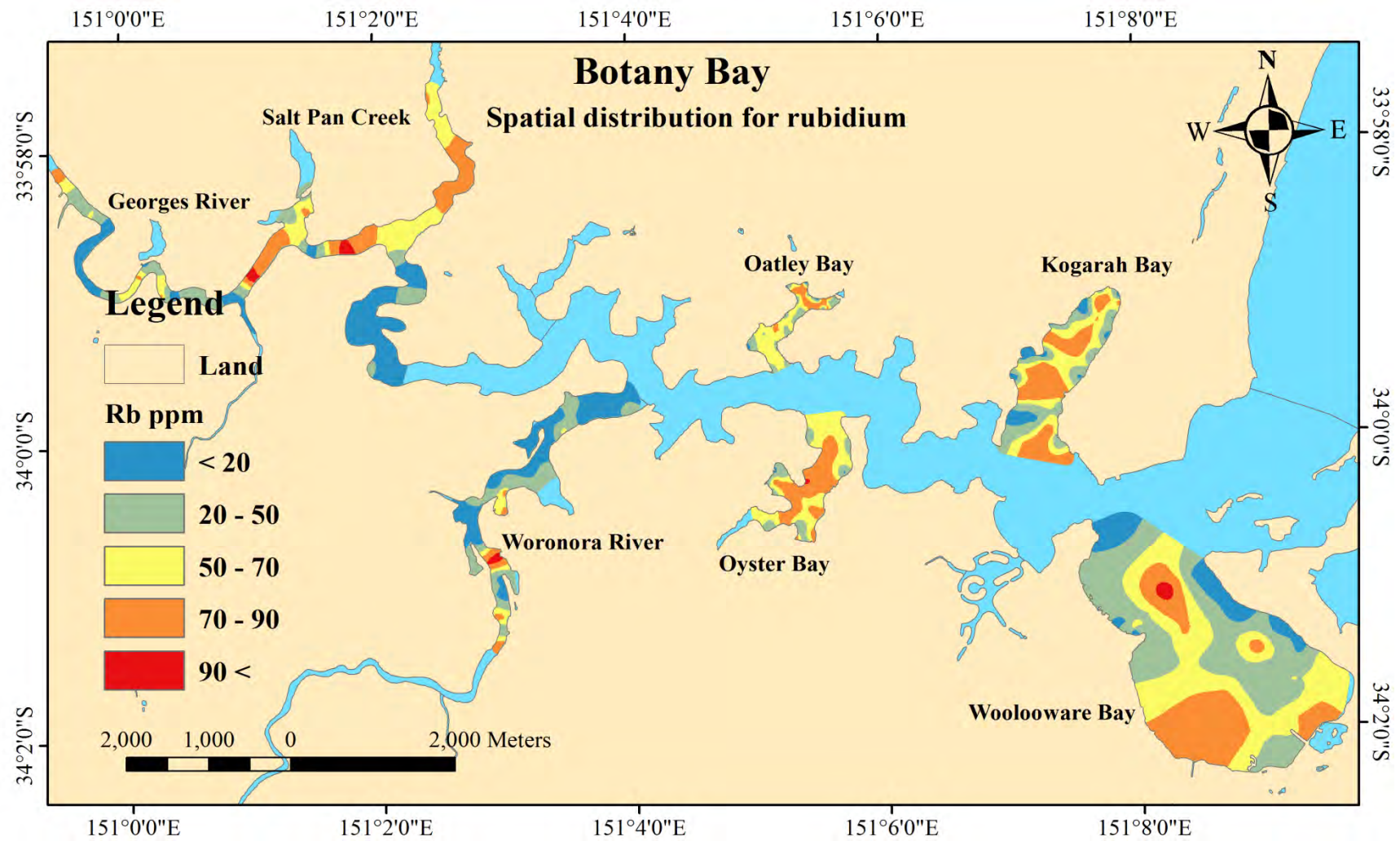


Figure 5.8: Spatial distribution of Rb (ppm) in surface sediments within embayments in Botany Bay.

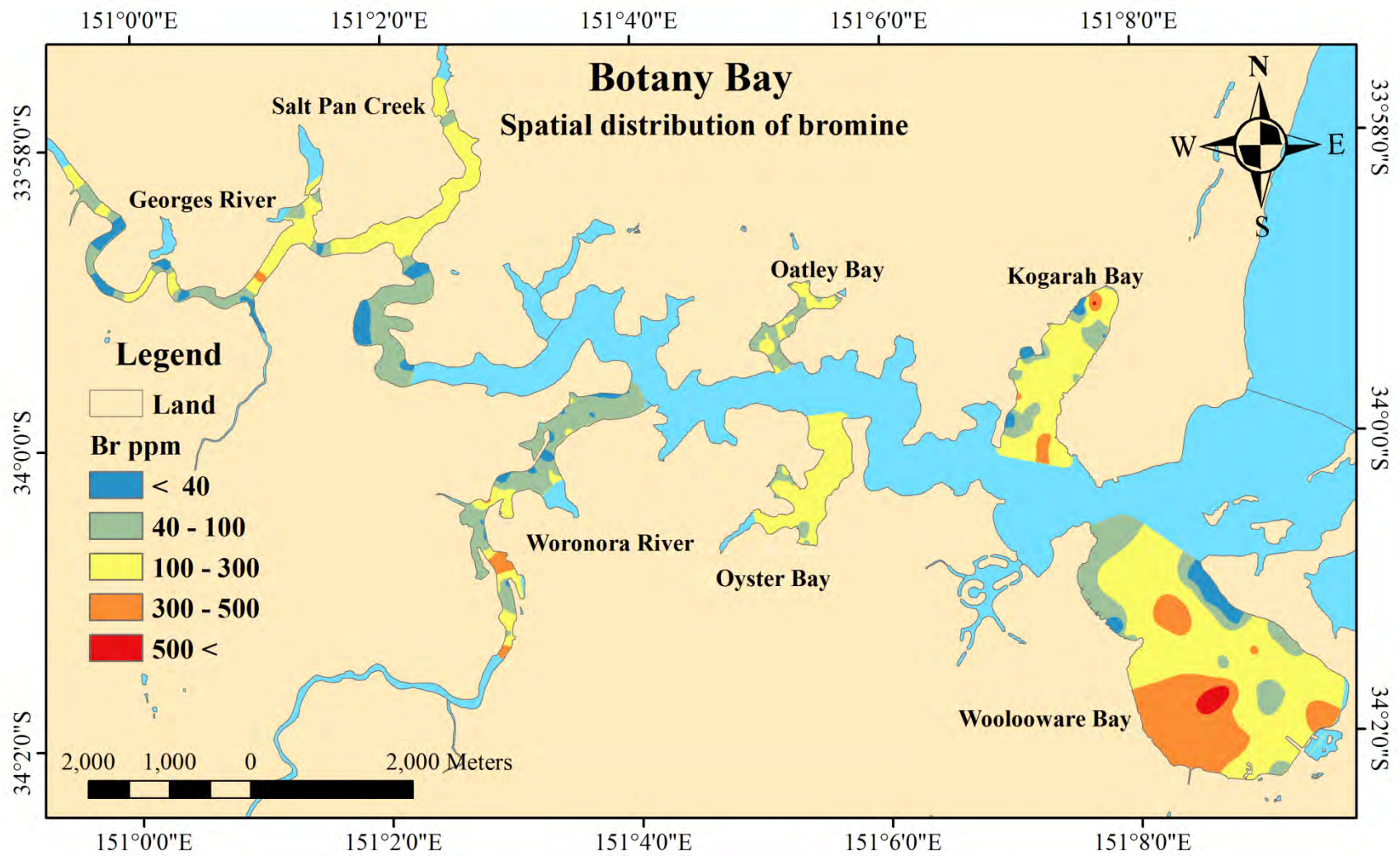


Figure 5.9: Spatial distribution of Br (ppm) in surface sediments within embayments in Botany Bay.

5.4.2 Background concentrations (temporal) of trace elements

The objective of this section of the research was to evaluate background concentrations of trace elements in marine sediments within the embayments in Botany Bay. Seven local cores were collected within Botany Bay from areas with the highest concentrations of trace elements (Figure 5.10a-g; Appendix 3.2). Figure 5.10a-g presents the pattern of temporal distribution of trace elements with sediment depth.

The surface sediments (0-5 cm) had the highest concentrations of trace elements, such as Cu, Zn, and Pb, but their concentrations decreased dramatically with increasing sediment depth. An exception occurs in a creek delta in Oatley Bay where fluctuating trace element contents (Figure 5.10g) correlate with alternating sand and mud layers reflecting flood pulses. A core from Oatley Bay shows uniform trace element concentrations below 200 cm (Pease, 2007) and was used to determine average background concentrations. These local background concentrations were then used to evaluate contamination factor.

The high concentrations of trace elements occur in anoxic areas with high percentages of clay minerals, pyrite and organic matter (sulfur) in the surface sediments (Mayer et al., 1981; Clark et al., 1998; Fernandes et al., 2011; Johnston et al., 2012; Alves et al., 2014; Fan et al., 2014). Therefore surface sediments can play an important role as a trap for trace elements, and reflect the accumulation of trace elements over the time since the contributing factors were established (e.g. Figure 5.10f in Salt Pan Creek) and after European settlement around these areas. However, the concentration of Cr fluctuated (Figure 5.10a and c) with sediment depth, and then declines gradually with increasing sediment depth. This is because it is not related to anthropogenic pollution from human activities, but may be sourced from heavy minerals such as hematite (Johnston and Chrysochoou, 2014).

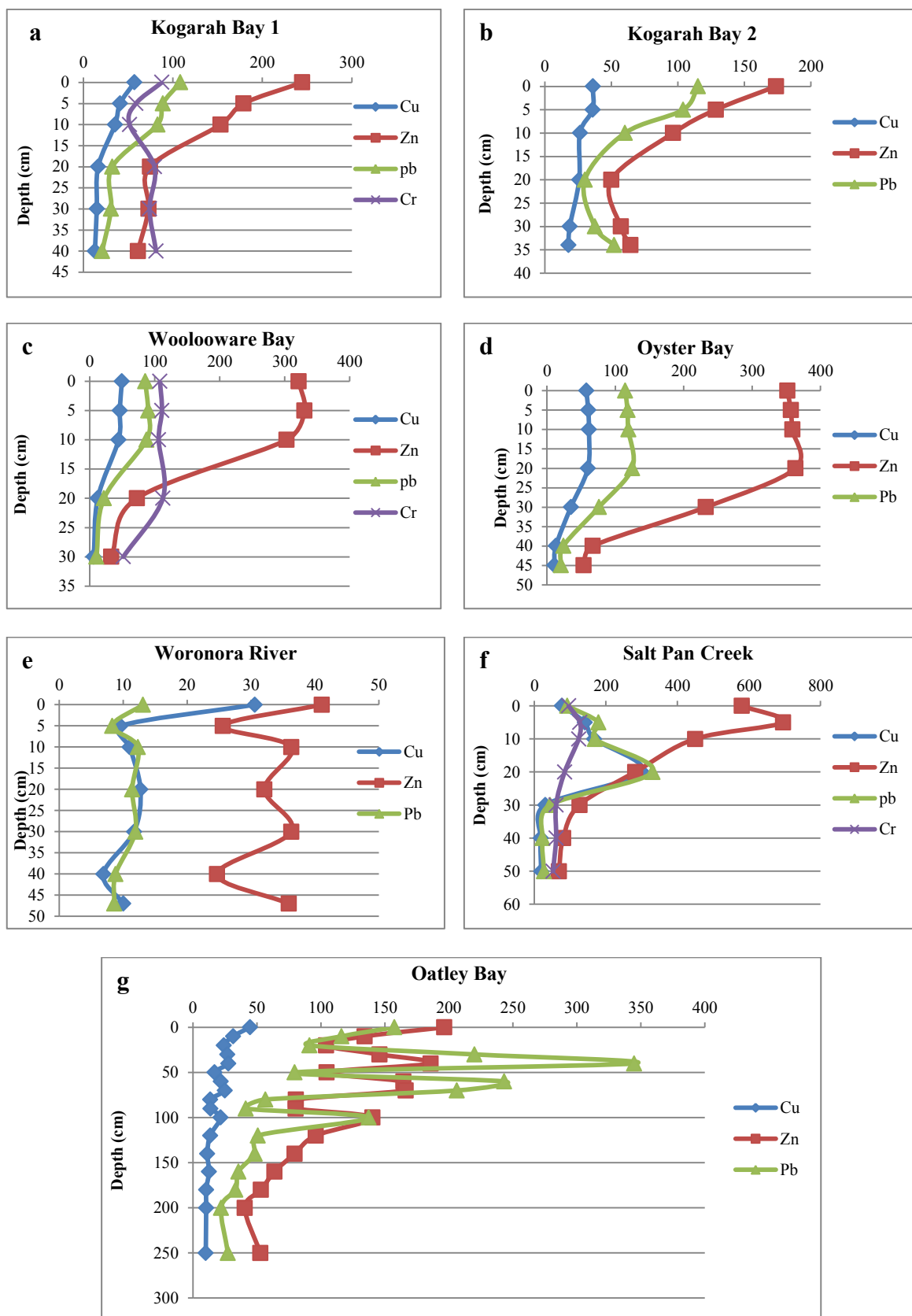


Figure 5.10: Variation for trace element concentrations (ppm) with sediment depth (cm), (a) Kogarah Bay 1, (b) Kogarah Bay 2, (c) Woollooware Bay, (d) Oyster Bay, (e) Woronora River, (f) Salt Pan Creek and (g) Oatley Bay.

As can be seen in Figure 5.10e and Appendix 3.2, the temporal distributions of trace elements in the Woronora River do not show significant trends since the concentrations of trace elements were low in the sandy surface sediments but they still decreased slightly with increased depth. This is because the subsurface core sediments contained high percentages of sandy silt as well as the core being located away from urbanized areas.

5.4.3 Assessment of sediment contamination

Three parameters such as contamination factor, potential load index and modified degree of contamination were applied to evaluate sediment contamination by trace elements (Tomlinson et al., 1980; Hakanson, 1980; Sinex and Helz, 1981; Mmolawa et al., 2011).

The background concentrations that were used in this study were obtained from uniform subsurface sediment samples (cores) from a previous study (Pease, 2007). The values of three contamination factors were found to vary between the sites in the same bay, and from one bay to another in the surface sediments. The values vary from very low and/or unpolluted to a high degree of contamination or pollution (Figures 5.11 - 5.15) and are controlled by variables, such as distance from source of pollution, type and amount of sediment grain size and mineralogy. All results for CF, PLI and mC_d are presented in Attached Appendix 4.2. Higher degrees of contamination or highly polluted samples occur in the inner parts of the bays and around watercraft where they are unaffected by more active waves and currents, for example in Oyster Bay samples, such as OY17, OY18, OY19, OY20, OY42, OY43, OY44, OY52 and OY54, as well as GE49, GE50 and GE51 in Salt Pan Creek. In contrast, low degrees of contamination or unpolluted values were found along the shoreline and in the mouths of bays, such as OY4, OY14, OY35, OY37 and OY38 in Oyster Bay and GE46, GE47 and GE48 in Georges River, which are dominated by sand because currents and waves more active can disturb fine particles.

As can be seen in Figures 5.13 - 5.15, the CFs for Cu, Zn and Pb, respectively, were very highly contaminated in Salt Pan Creek, which includes contamination from a previous manufacturing waste dump (Fraser et al., 2006). High CF also occurs in the inner parts of bays such as Kogarah Bay, Oatley Bay and Oyster Bay, and close to wastewater discharge points, stormwater outlets, moored boats and boatyard sites.

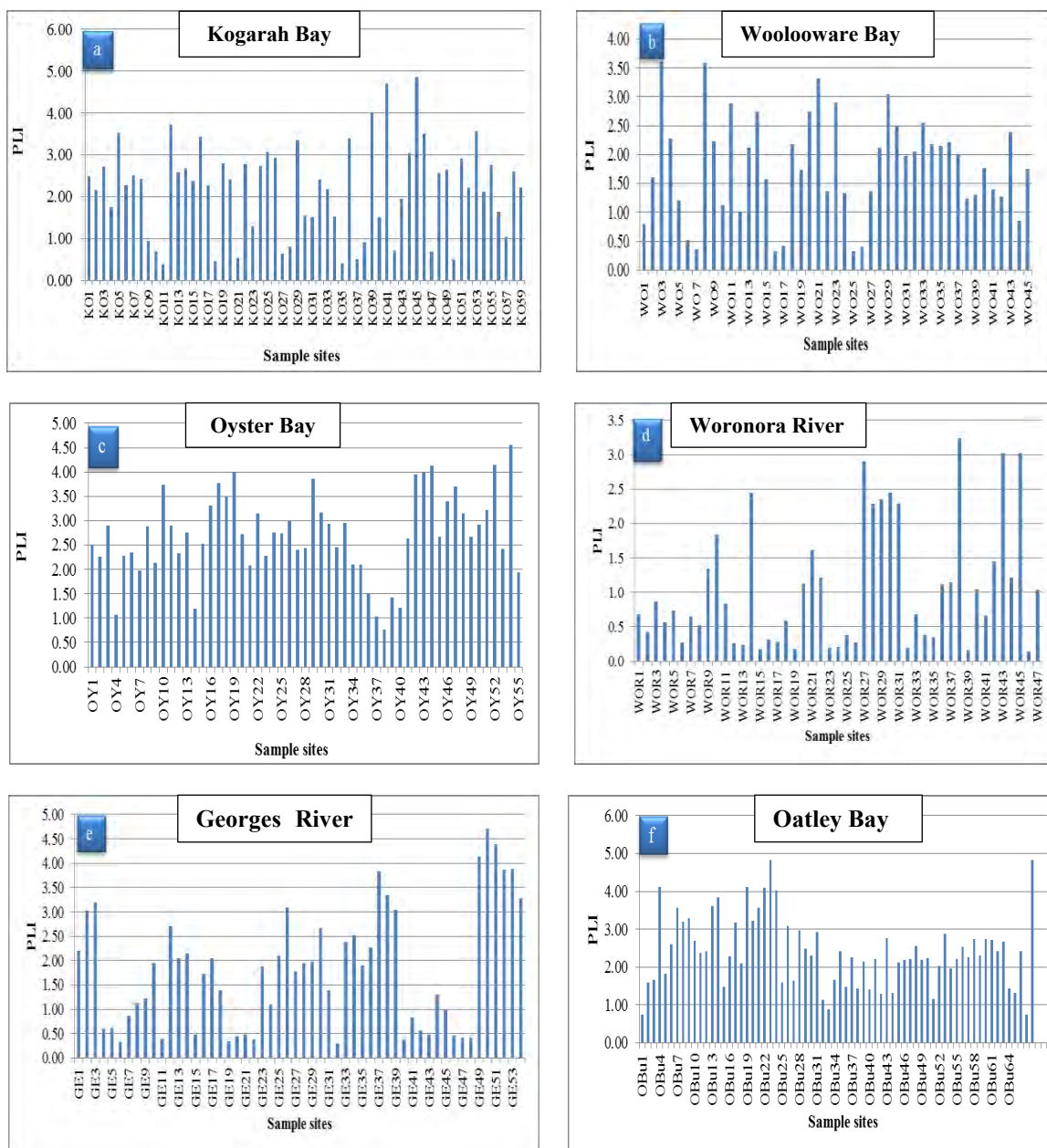
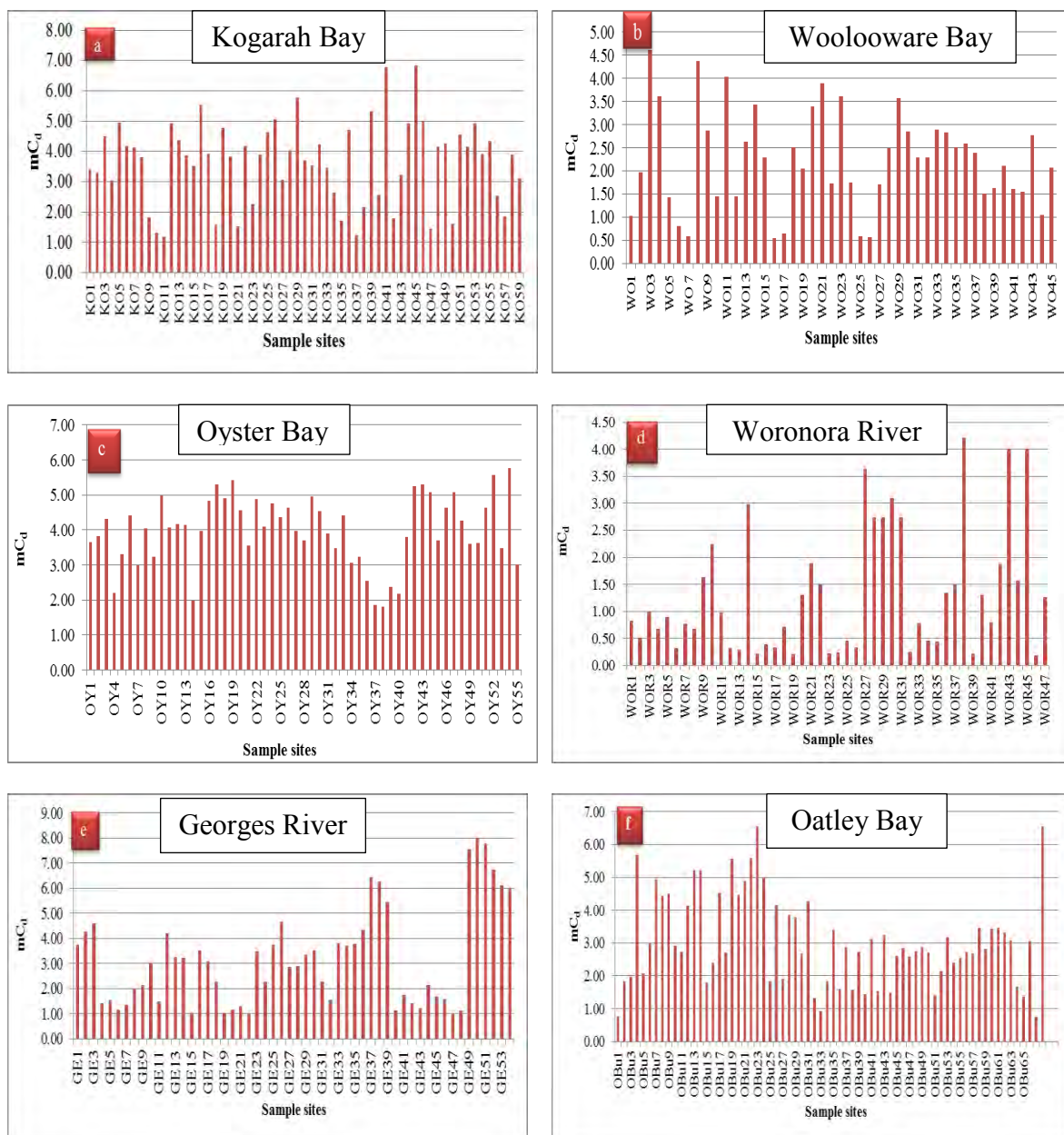


Figure 5.11: Potential load index (PLI): a-Kogarah Bay, b- Woollooware Bay, c-Oyster Bay, d-Woronora River, e-Georges River and f- Oatley Bay.



$mC_d < 1.5$	$1.5 \leq mC_d < 2$	$2 \leq mC_d < 4$	$4 \leq mC_d < 8$
Nil to very low degree of contamination	Low degree of contamination	Moderate degree of contamination	High degree of contamination

Figure 5.12: Modified degree of contamination a- Kogarah Bay, b- Woollooware Bay, c- Oyster Bay, d- Woronora River, e- Georges River and f- Oatley Bay in Botany Bay.

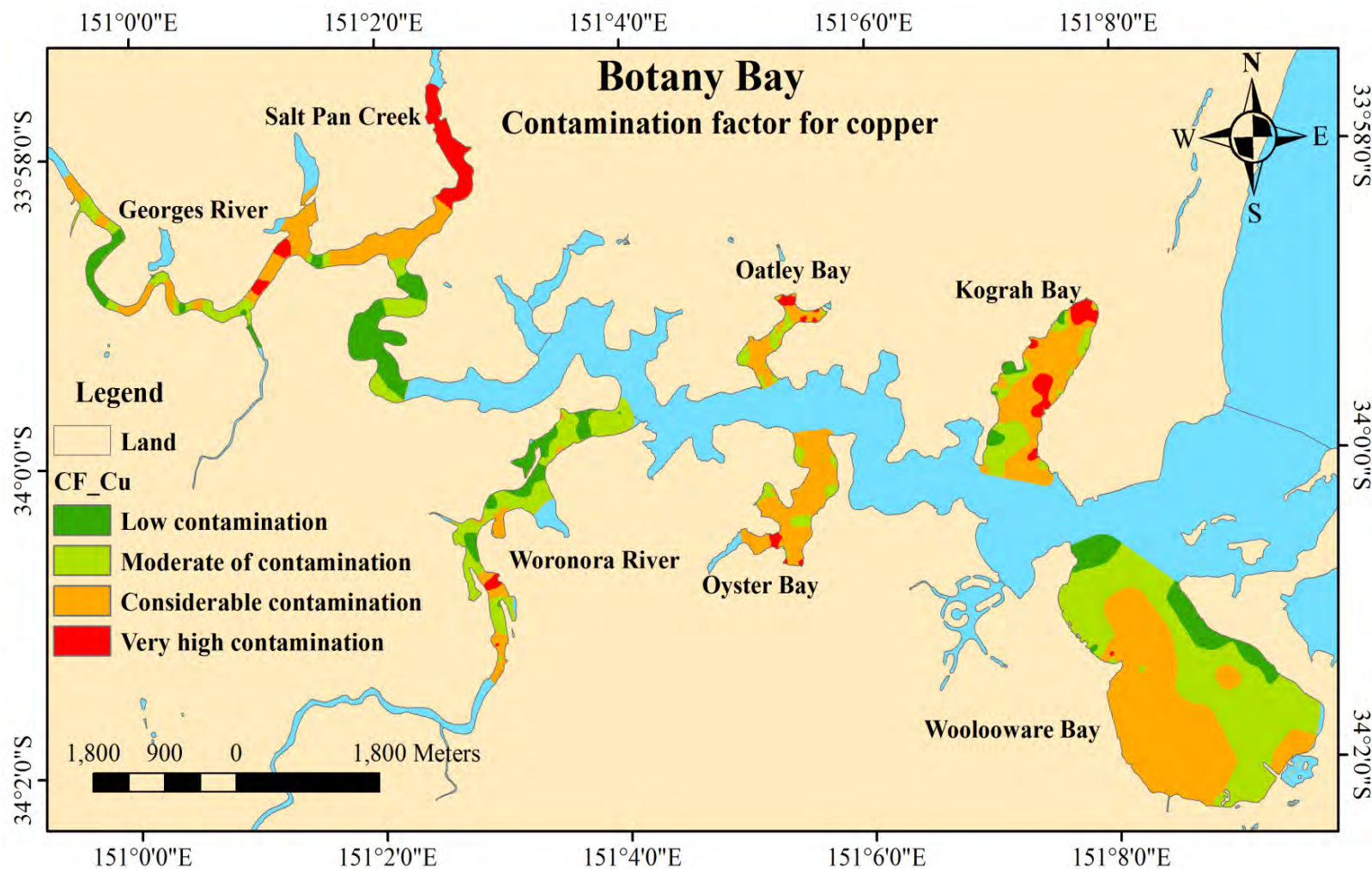


Figure 5.13: Contamination factor for Cu within embayments in Botany Bay.

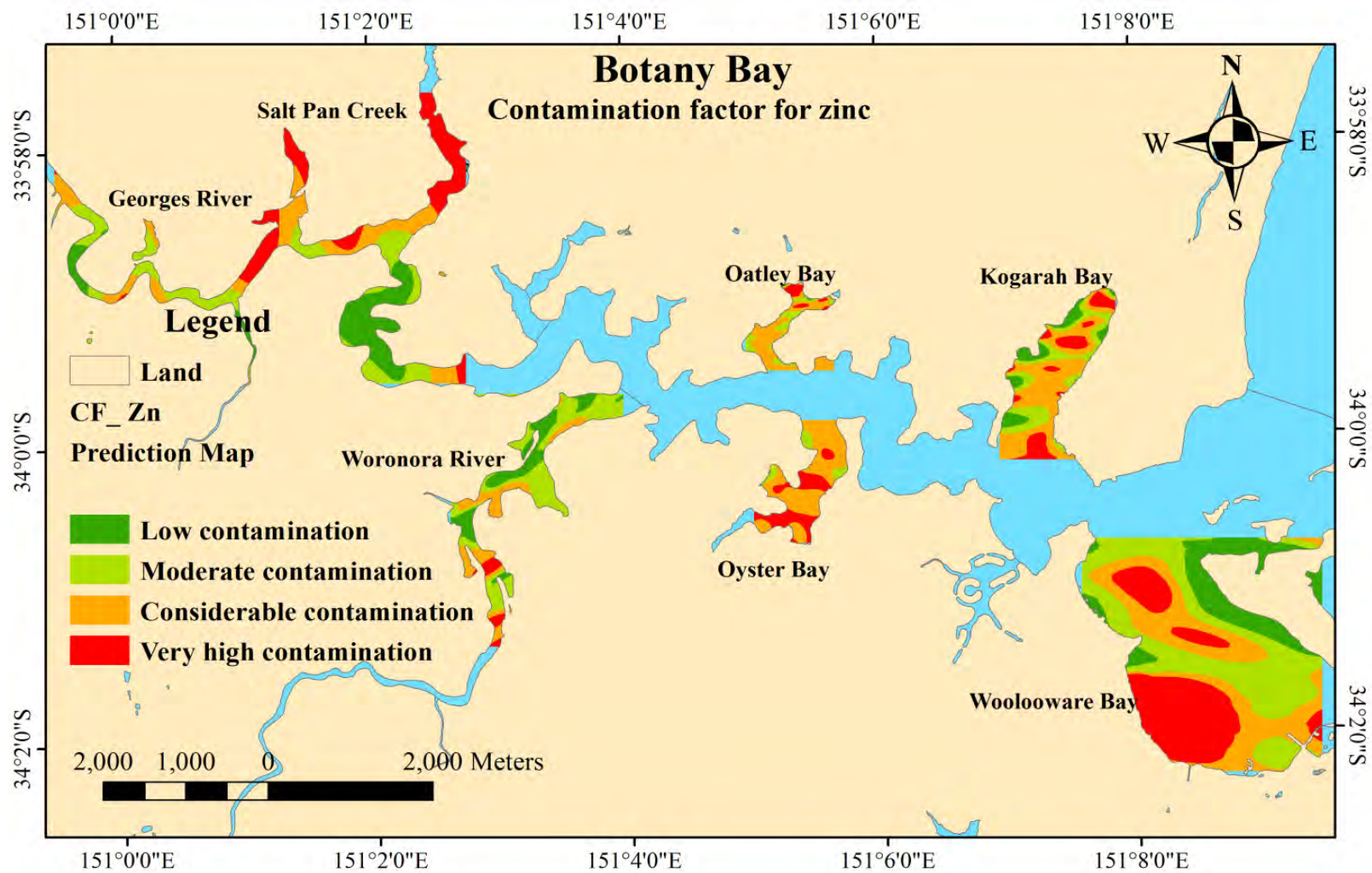


Figure 5.14: Contamination factor for Zn within embayments in Botany Bay.

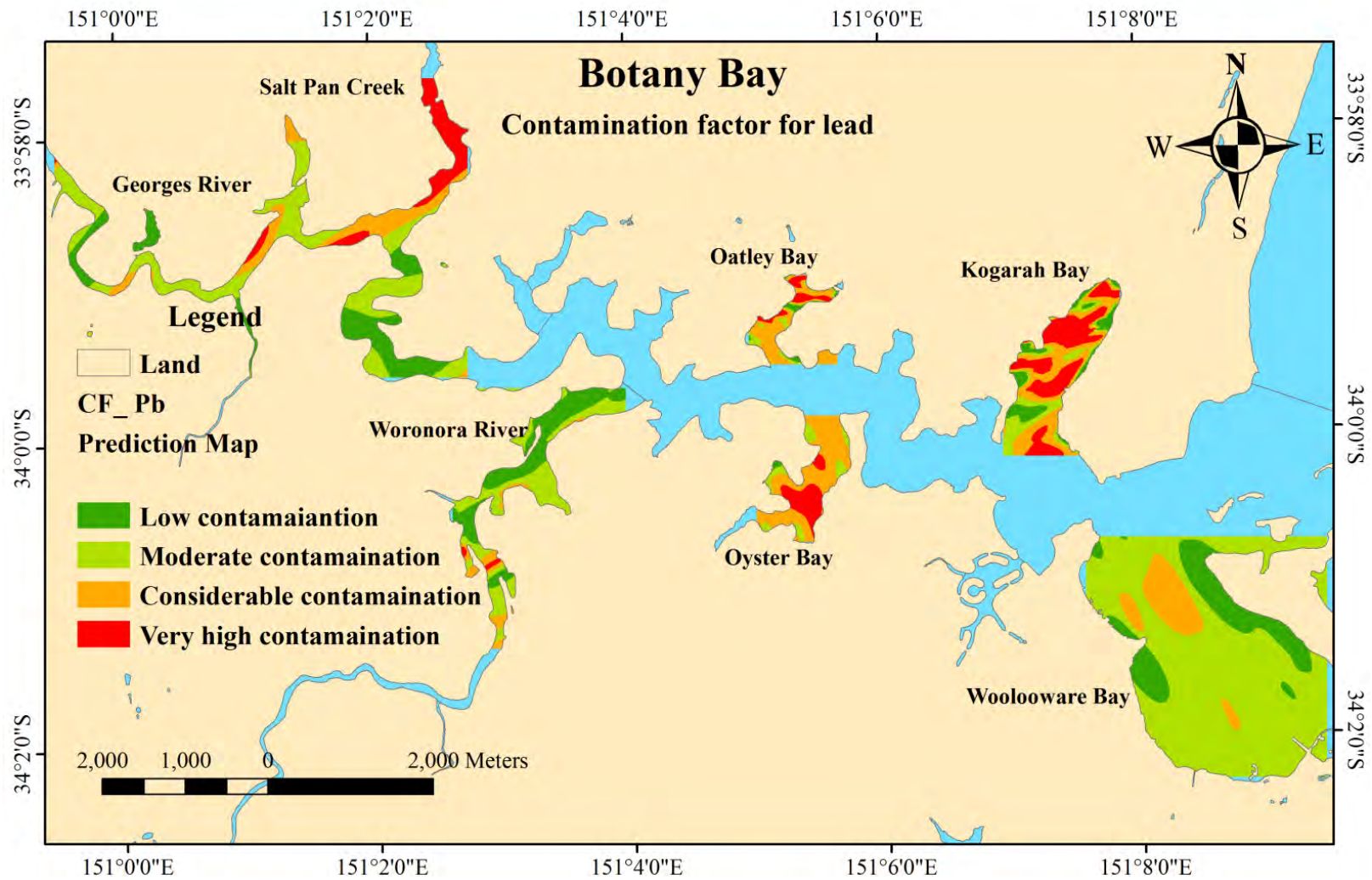


Figure 5.15: Contamination factor for Pb within embayments in Botany Bay.

These sites show considerable to very high contamination. In contrast, low contamination by all trace elements occurs in Woronora River, as well as along the edges and near the mouth of the bays that have high percentages of sand. Based on the mean CF values, the rank of trace element pollution was found to be $Zn > Pb > Cu$.

5.5 Port Hacking

5.5.1 Spatial distribution of trace elements within sediment samples

A total of 233 surface sediment samples were collected from Port Hacking (Figures 3.13-3.18) and combined with data sixty five samples from a previous study of Burraneer Bay (Aljawi, 2010; Figure 3.19). The concentrations of trace elements in surface sediments within the studied embayments in Port Hacking are given in Appendix 3.1 while Figures 5.16-5.22 illustrate the spatial distributions of Cr, Ni, As, Sn, Cu, Zn and Pb concentrations, respectively. The spatial distribution and concentration of trace elements show similar patterns of concentration in the inner parts of bays and close to stormwater outlets. However, the trace element concentrations dramatically declined toward the mouths of the bays and along the edges and shoreline because the sand percentages increased at these locations (Figure 4.14 in chapter 4).

Generally, the trace element concentrations in surface sediments in the Port Hacking embayments (Figures 5.16-5.22) had lower concentrations compared with Botany Bay (Figures 5.1-5.7). This is because some catchments in Port Hacking drain national park areas free from residential development and stormwater discharge points. In addition, Port Hacking had higher percentages of sand and low percentages of mud (Figures 4.14 and 4.15) than the studied embayments in Botany Bay.

The highest concentrations of trace elements were found to be situated in the inner parts of bays and around discharge points in the surface samples, such as GU21, GU25, GU40, GU45 and GU55 in Gunnamatta Bay, GY1, GY2, GY5, GY8, GY9, GY12 and GY13 in Gympie Bay, SWA 17 in the South West Arm, NWA1, NWA3, NWA4 and NWA5 in the North West Arm, YO4, YO5, YO8, YO11, YO17, YO18, YO19, YO20 and YO21 in Yowie Bay and gh18, gh25 and gh35 in Burraneer Bay. This is because these locations contained many boats and are surrounded by residential areas, as well as the presence of several stormwater discharge points close to the samples.

Also, fine to very fine particles are concentrated (80% - 100% of mud) in the middle of the bays (Figure 4.15 in chapter 4), where depths are >1 m (Figure 4.16 in chapter 4). In these areas waves, currents and tidal activity do not disturb the surface sediments. The concentration of Rb at these sites is also increased (Figure 5.23 and Appendix 3.1), which is correlated to the abundance of clay minerals such as kaolinite and illite.

Furthermore, organic matter is also concentrated in the inner parts of the bays, where there was a high concentration of Br (Figure 5.24 and Appendix 3.1) ranging between 100 ppm and 500 ppm at the various sites. The presence of clay minerals and organic matter caused greater amounts of trace elements to accumulate at these sites (Clark et al., 1998; Morrissey et al., 2000; Swales et al., 2002; Zhu et al., 2012). The concentrations of trace elements declined towards the edges of the bay that exhibited very high percentages of sand (Alyazichi et al., 2015c; Figure 4.14 in chapter 4).

However, the lowest concentrations of trace elements occurred in the South West Arm, Hacking River and at the mouths of the bays and represent lower contamination compared with other sites in the Port Hacking area. This is due to the lack of watercraft, boatyards, residential areas or municipal waste discharge points in these areas. Moreover, most sediment fractions in the South West Arm and Hacking River are dominated by sand, which comprised more than 75% of the sediment (Figure 4.14). Also fluvial and tidal currents and waves become more active toward the mouths of the bays and in the rivers. In these situations the muddy particles are disturbed and moved by the waves and currents to be deposited in deeper areas that have less disturbance. As a result, trace elements were dominant in the middle parts of the bays that have the highest percentages of mud (Alyazichi et al., 2014a; Figure 4.15 and Appendix 3.1).

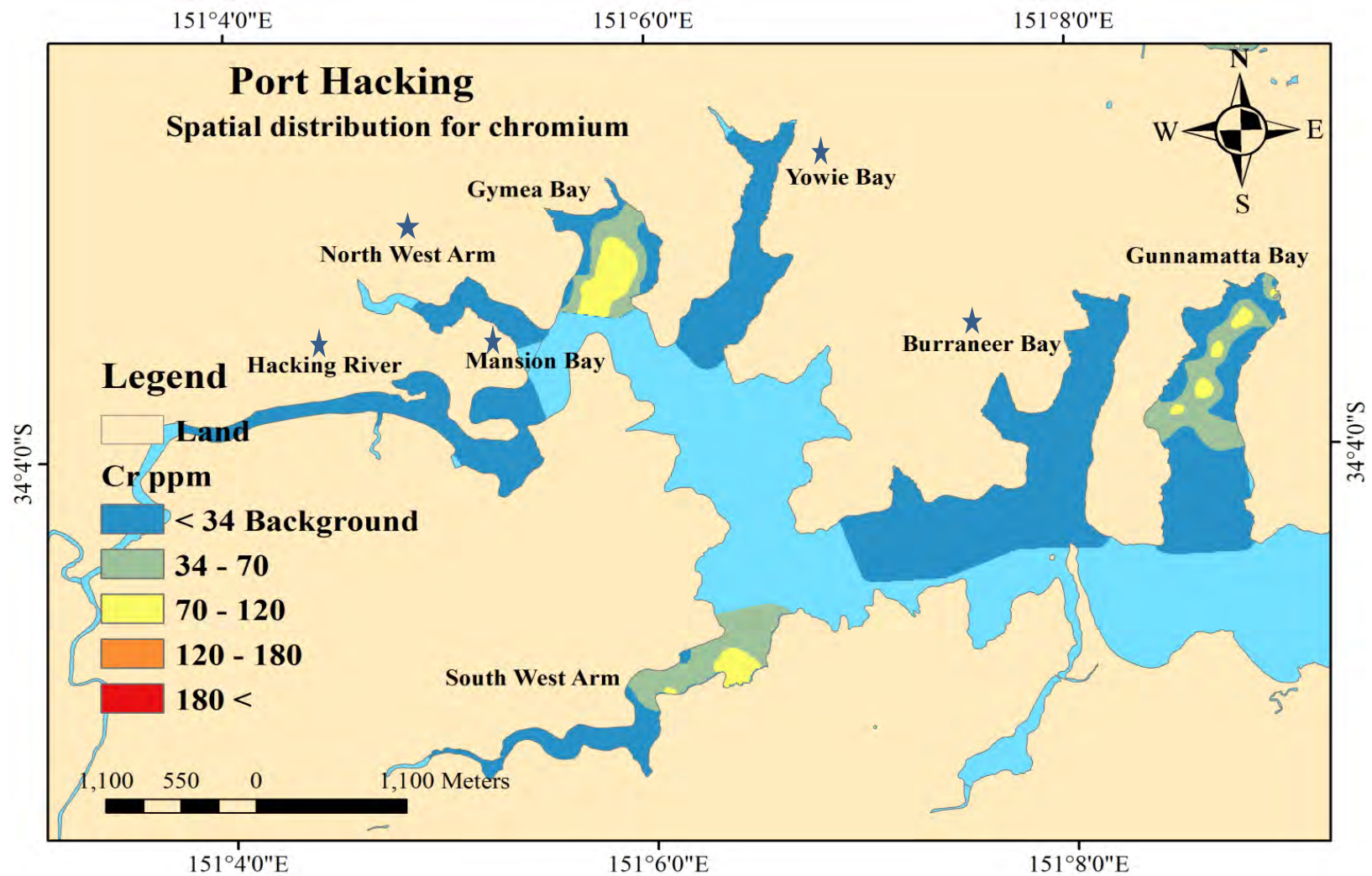


Figure 5.16: Spatial distribution of Cr (ppm) in surface sediments within embayments in Port Hacking.

Where: ★ not determined because samples were crushed by chrome steel Tema had extreme values of chromium.

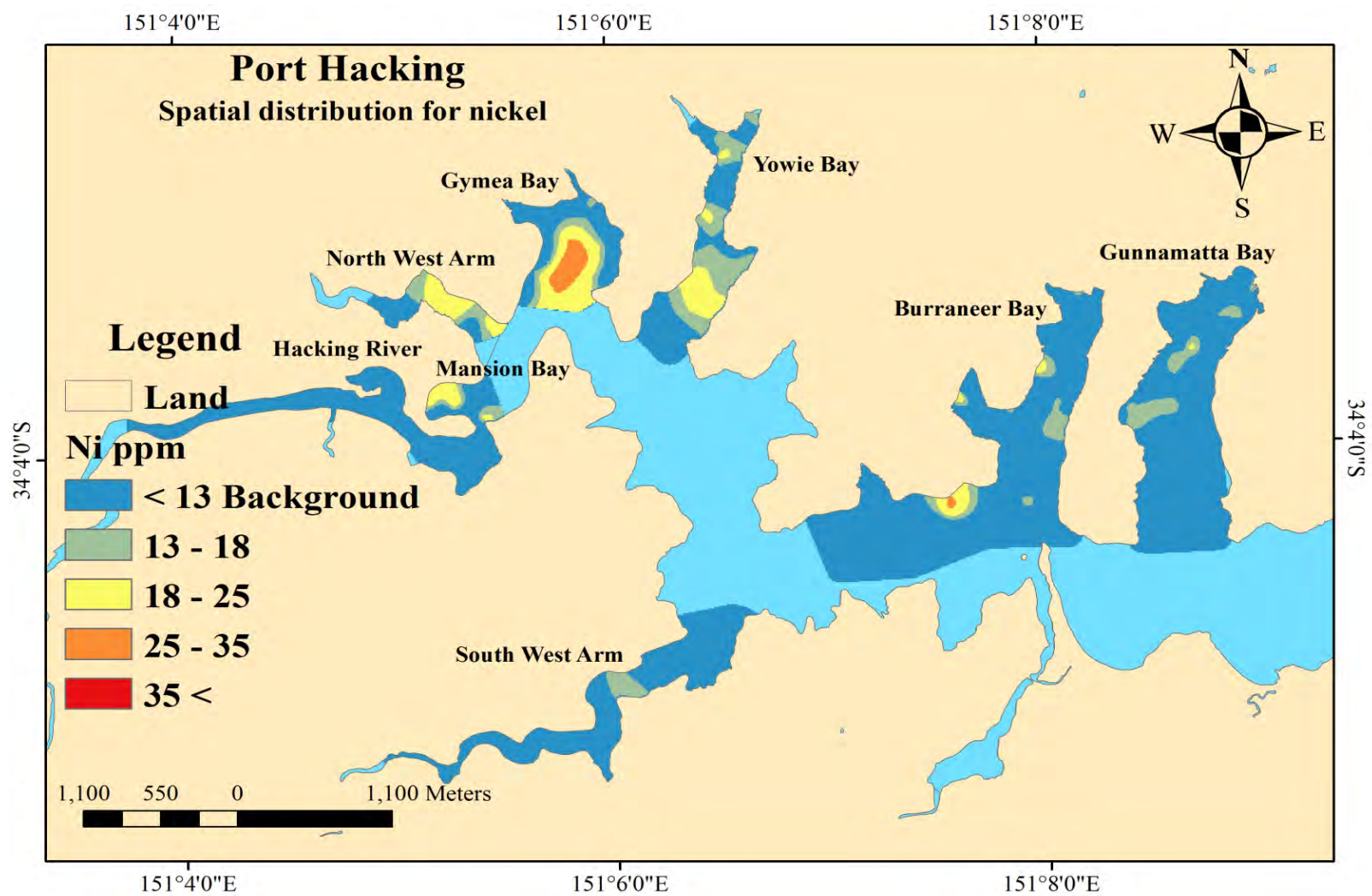


Figure 5.17: Spatial distribution of Ni (ppm) in surface sediments within embayments in Port Hacking.

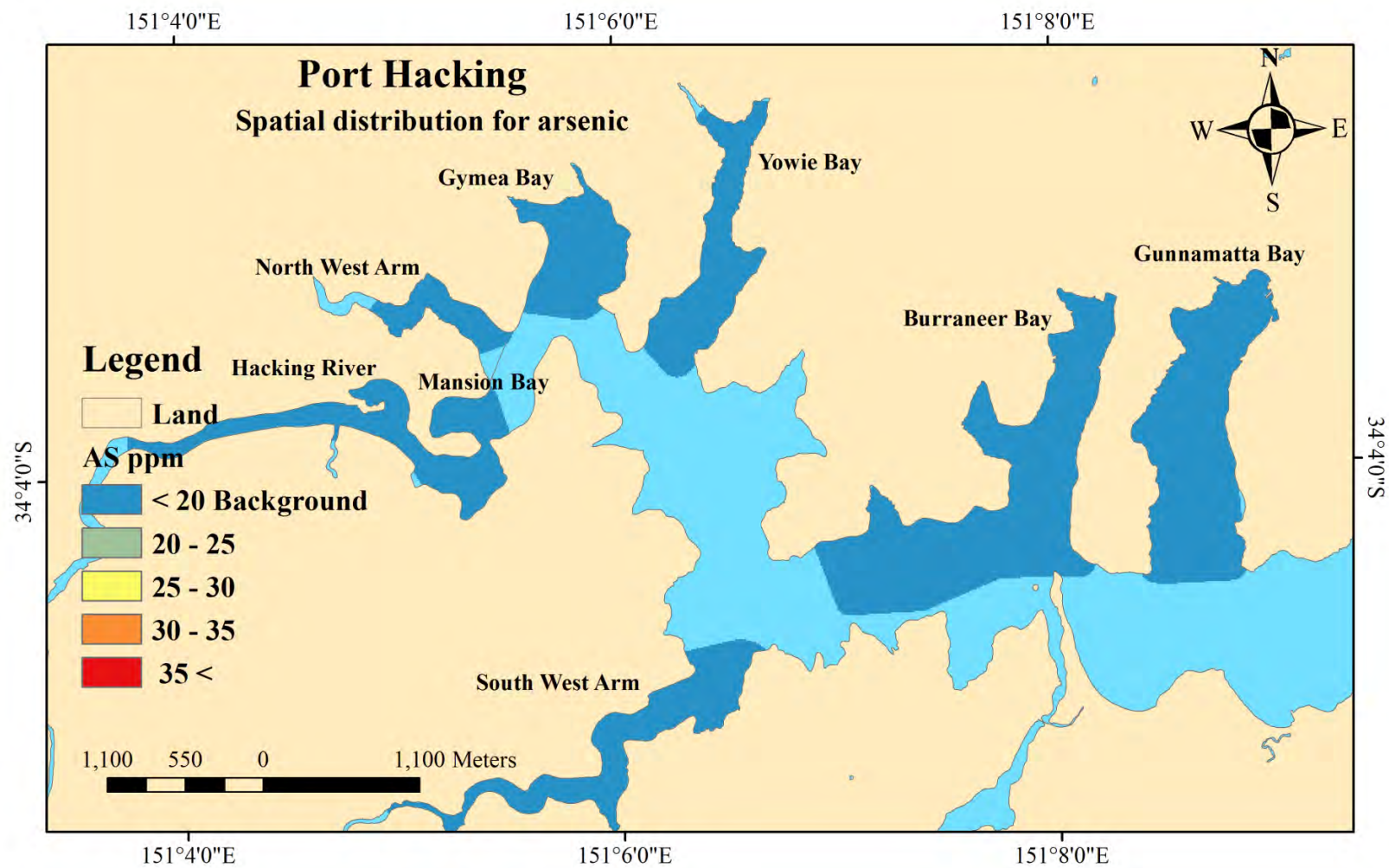


Figure 5.18: Spatial distribution of As (ppm) in surface sediments within embayments in Port Hacking.

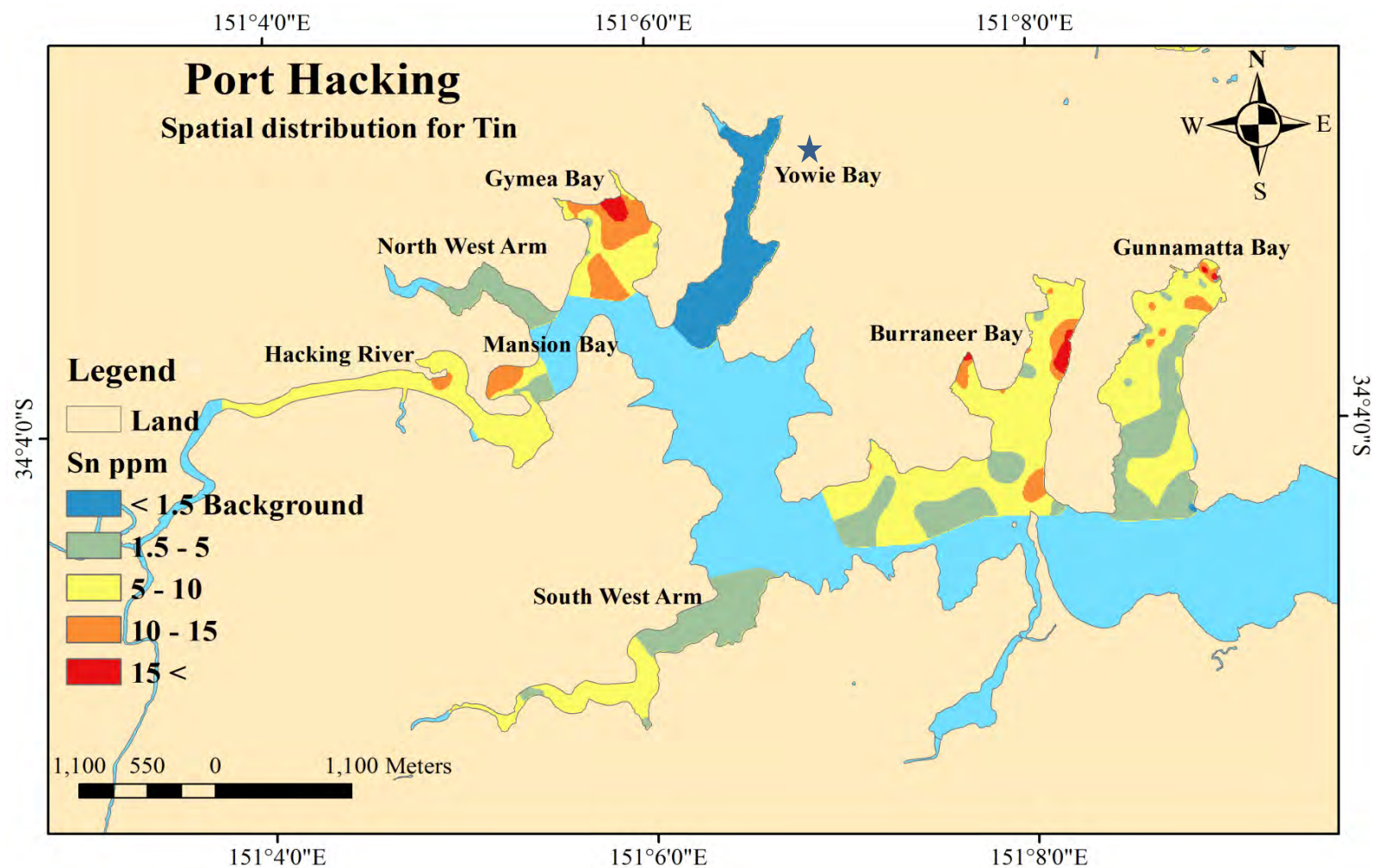


Figure 5.19: Spatial distribution of Sn (ppm) in surface sediments within embayments in Port Hacking.
Where: ★ data not available.

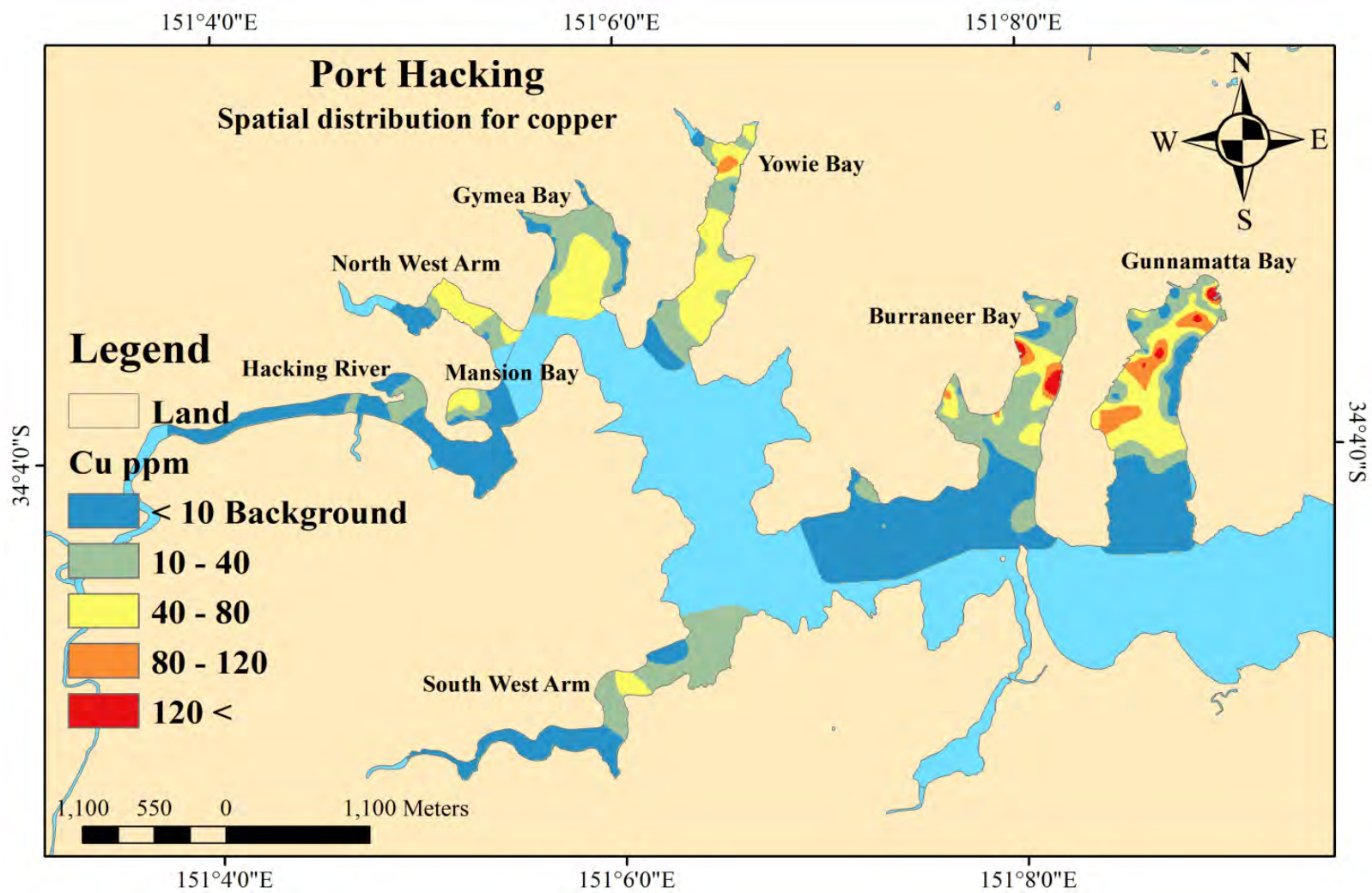


Figure 5.20: Spatial distribution of Cu (ppm) in surface sediments within embayments in Port Hacking.

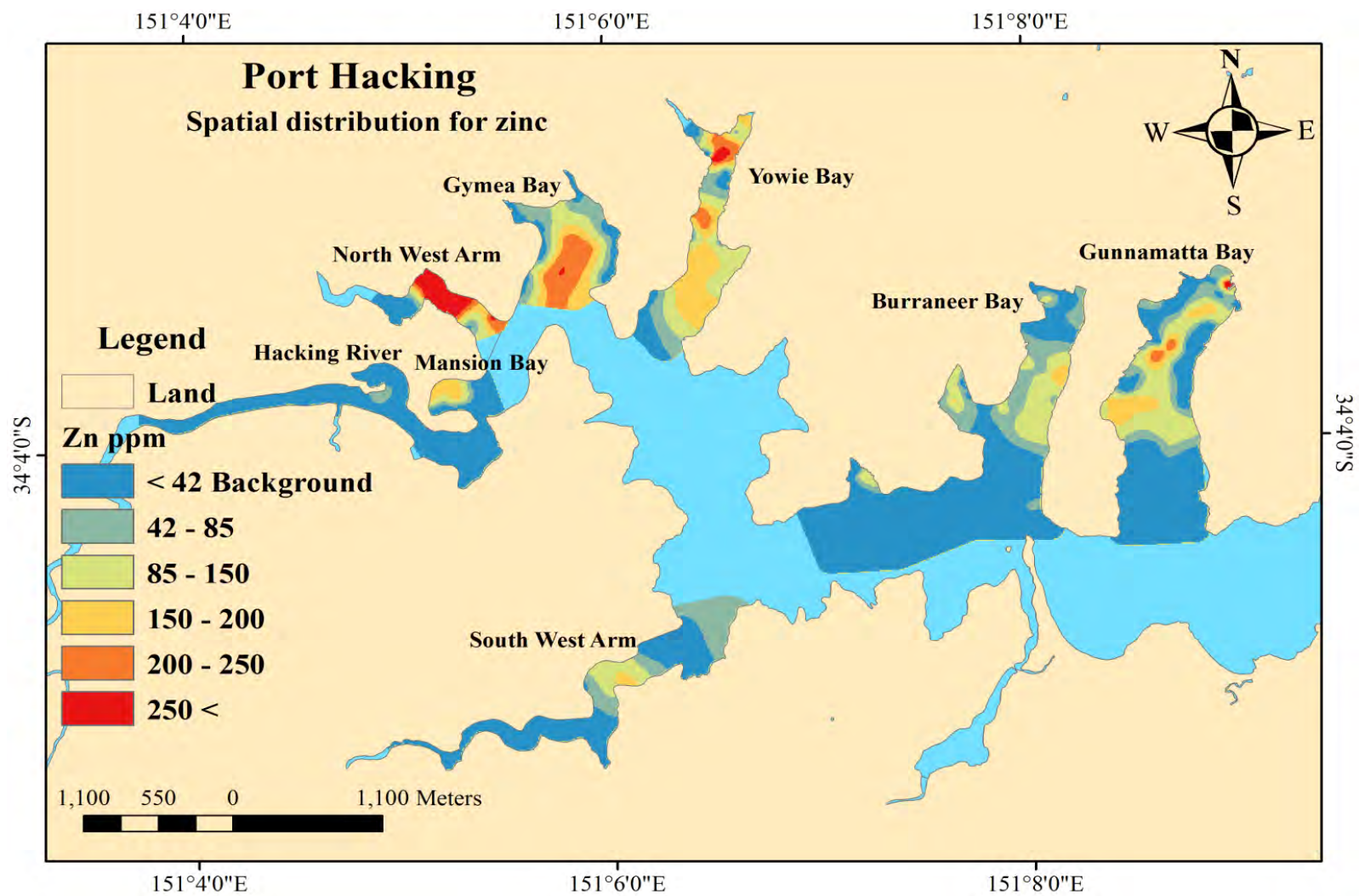


Figure 5.21: Spatial distribution of Zn (ppm) in surface sediments within embayments in Port Hacking.

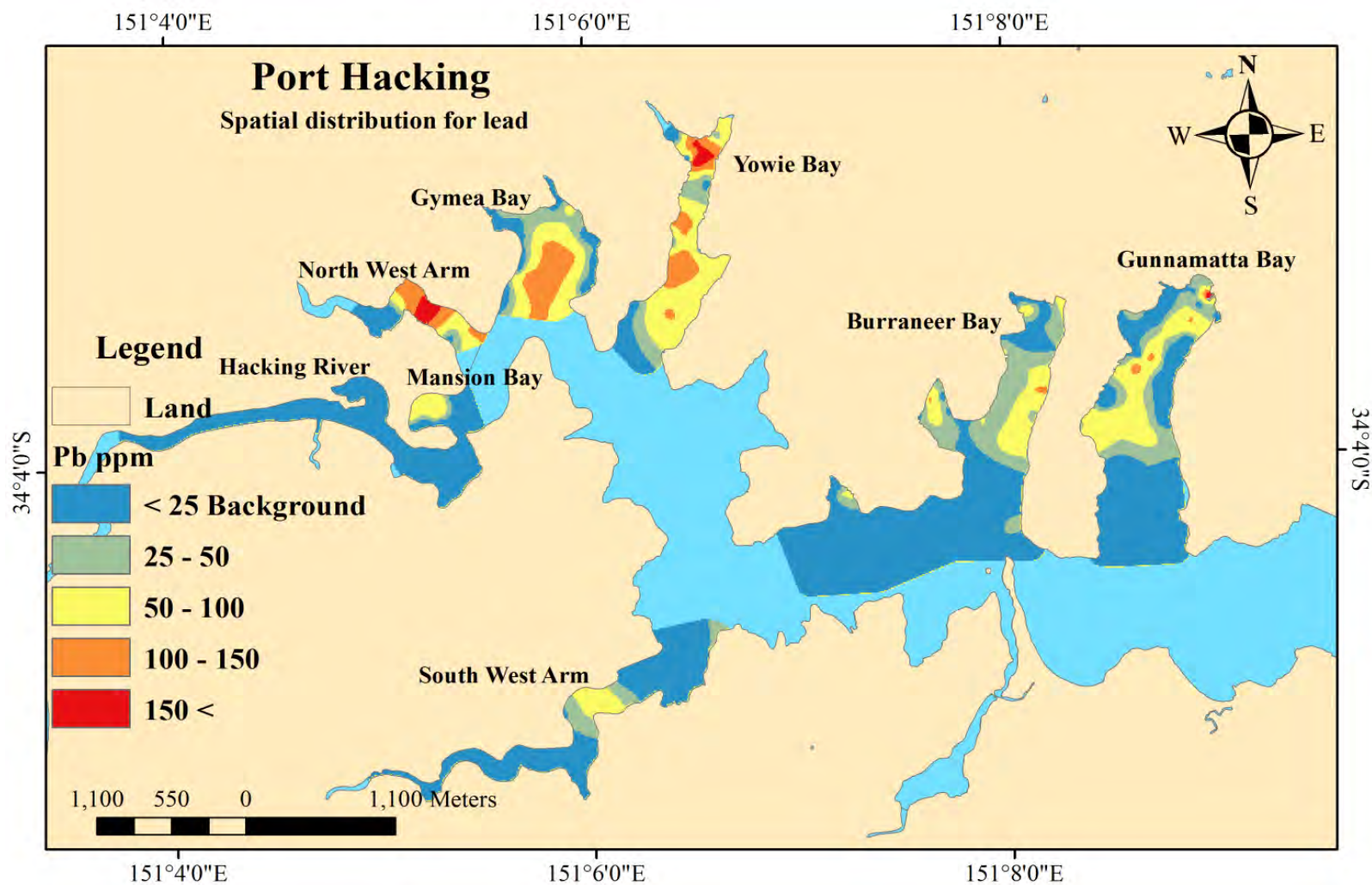


Figure 5.22: Spatial distribution of Pb (ppm) in surface sediments within embayments in Port Hacking.

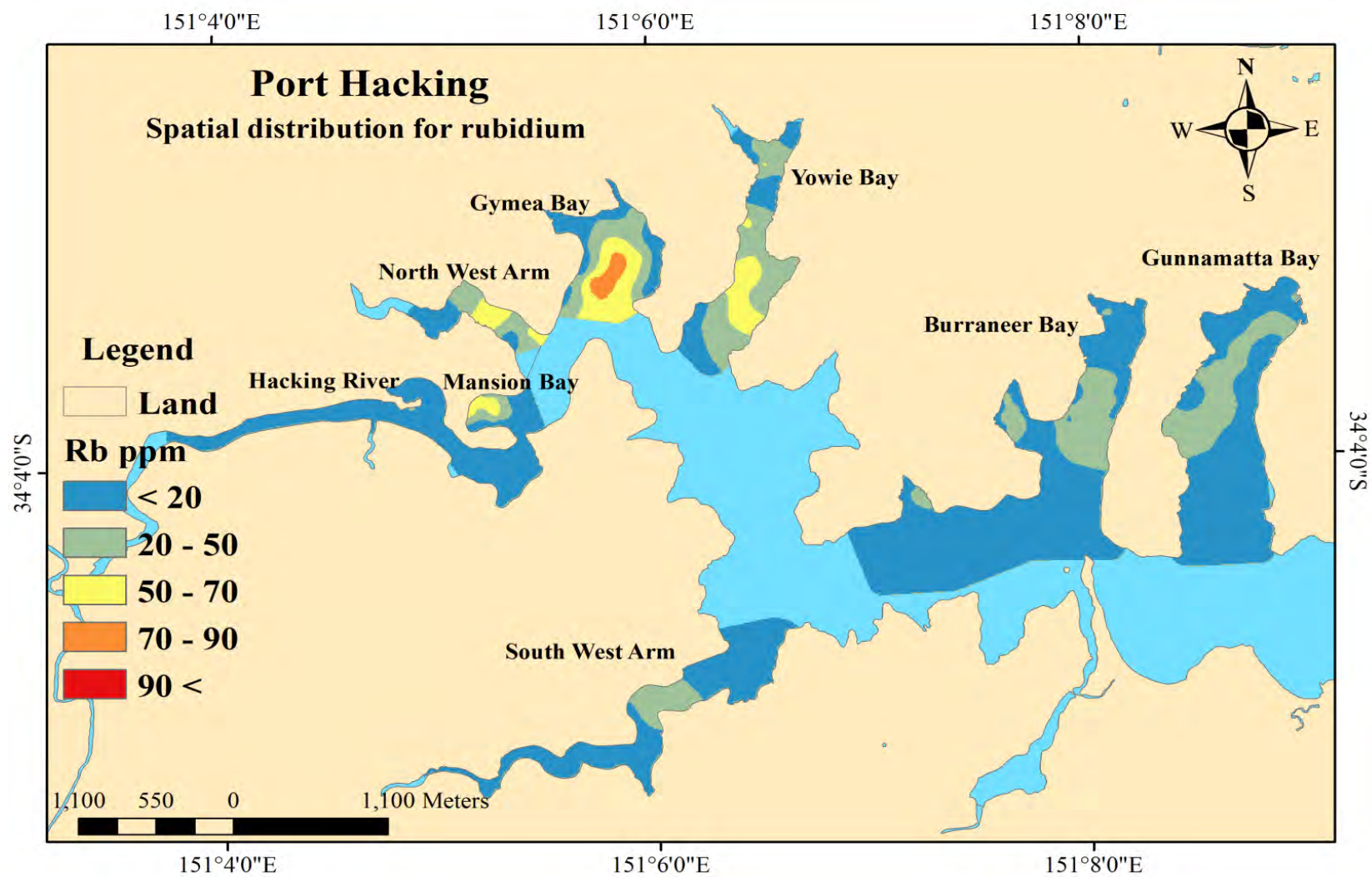


Figure 5.23: Spatial distribution of Rb (ppm) in surface sediments within embayments in Port Hacking.

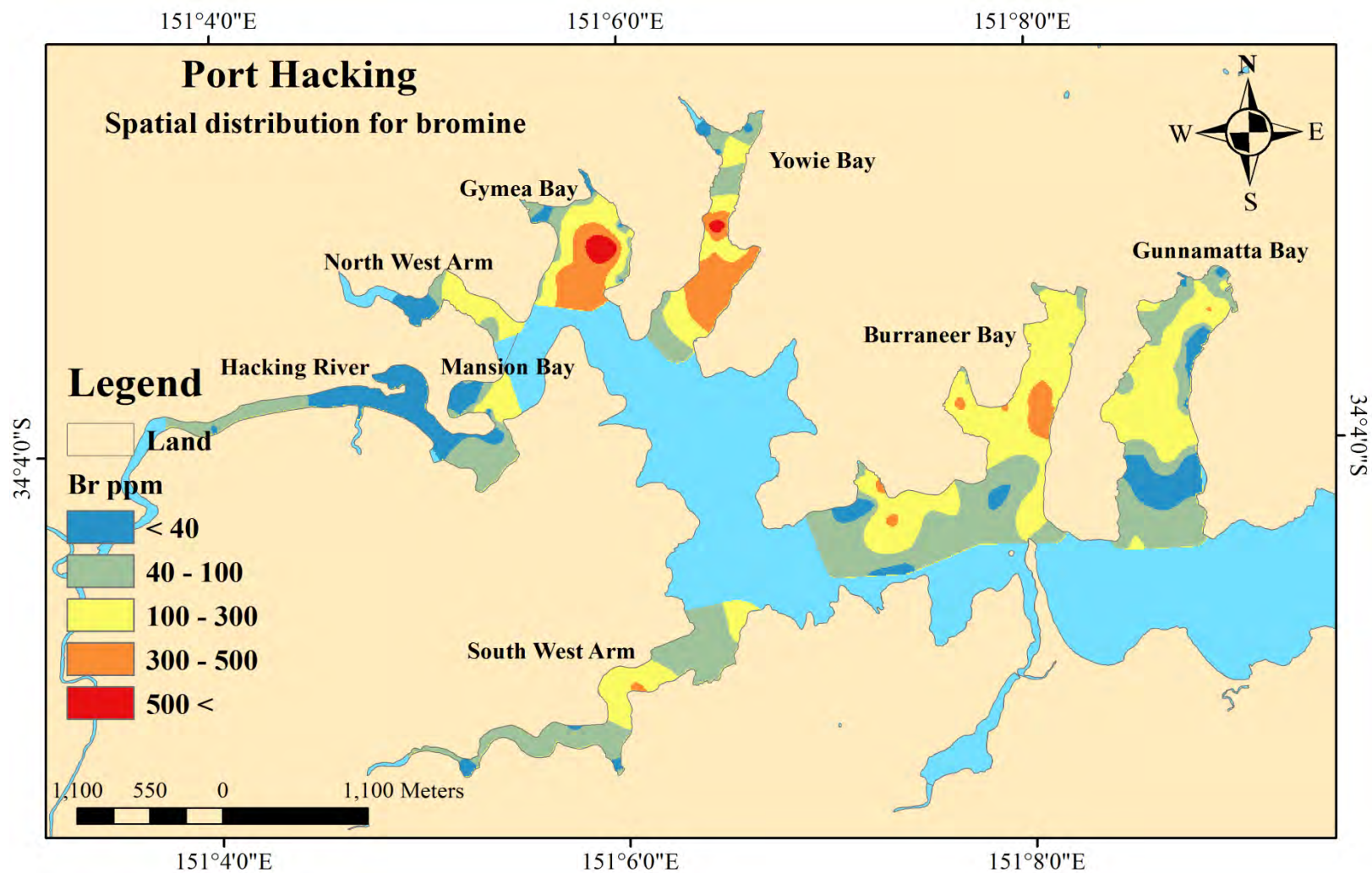


Figure 5.24: Spatial distribution of Br (ppm) in surface sediments within embayments in Port Hacking.

5.5.2 Temporal background concentrations for trace elements

Subsurface sediment samples were also collected to show the variation of trace elements with depth. The background concentrations for Port Hacking were obtained from local sediment cores (i.e. Gunnamatta Bay), which was located at the site of the highest concentration of trace elements in the north-east of the bay (Figures 3.13 and 3.15). Cores were not taken from other sites in Port Hacking due to rocky substrates and/or areas dominated by high sand percentages.

Figure 5.25 a displays the relationship between sediment depths and trace elements such as Cr, Cu, Zn and Pb (Appendix 3.2). The top 0-5 cm of surface sediments from Gunnamatta Bay core had highest concentrations of the trace elements Cr, Cu, Zn and Pb, ranging between 66 -71 ppm, 838-1058 ppm, 538-625 ppm and 180-193 ppm, respectively (Figure 5.25a). Trace elements, except for Pb, decrease sharply with increasing sediments depth below 10 cm, which indicates recent contamination released from stormwater and human activities, such as boatyards and watercraft, at this site.

The Cu and Zn concentrations decline with depth in the core, while Pb decreases moderately with increasing sediment depth, then increases to a peak of 238 ppm at 20 cm, before decreasing significantly again. This is due to high percentages of clay minerals, sulfur (pyrite) and organic matter (total carbon) at 20 cm, which play an important role as a trap for trace elements, and reflect accumulation of trace elements since European settlement around these areas. The low concentration of Cr fluctuates slightly with sediment depth, which may not be related to human activities. The Cr may be sourced from heavy minerals in sediments such as hematite, goethite and clay minerals (Johnston and Chrysochoou, 2014).

Although the trace elements decline slightly with increasing sediment depth in Mansion Bay, the subsurface sediments had very low concentrations of trace elements (Figure 5.25b), due to the high percentages of sand (about 83%) at this site, the shallow depth (< 1 m) and the distance from sources of pollution. Figure 5.25b shows the relationship between sediment depth and the trace elements Cu, Zn and Pb (Appendix 3.2).

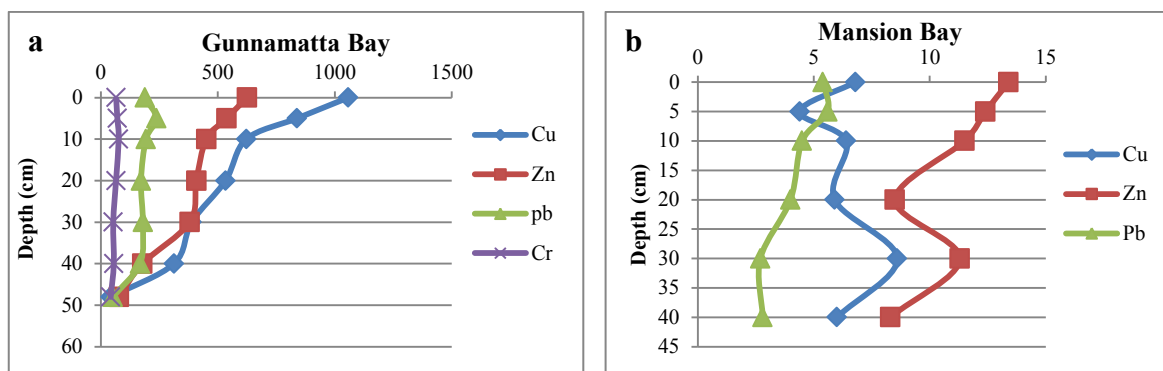


Figure 5.25: Variation of trace elements (ppm) in cores a- Gunnamatta Bay and b- Mansion Bay in Port Hacking.

5.5.3 Assessment of sediment contamination

Results of evaluation of surface sediment contamination by trace elements for Port Hacking, including the potential load index, modified degree of contamination and contamination factor, are shown in Attached Appendix 4.2. The results show that the values of these three factors varied between the surface sediment samples in the same bay, whereas they show generally similar patterns in all the studied bays in Port Hacking. One highly polluted and very high contaminated site was sample GU55 in Gunnamatta Bay, which is located in the north of bay close to a discharge point, as well as boatyards and moored boats that could release large amounts of trace elements that have accumulated in nearby sediment in the bay (Figures 5.26-5.30).

Figures 5.26 to 5.30 illustrate the PLI, mC_d and CF for the trace elements Cu, Zn and Pb within the embayments in Port Hacking. Sites classified as being considerably to highly polluted/contaminated are situated in the inner parts of the bays, such as GY1, GY2, GY9 and GY12 in Gynea Bay, MA21, MA22 and MA25 from Mansion Bay and YO8 and YO11 in Yowie Bay. Factors such as distance from source of pollution, types of sediment particles and mineralogy of the sediments can have an effect on the amount of sediment contamination. These contaminated sediments also contained high percentages of mud particles and organic matter, in accordance with the findings of Li et al. (2013).

In contrast, unpolluted to weakly contaminated sediment samples are located in the South West Arm, Hacking River, and at the mouths of the bays. This is because they have few sources of pollution from catchment areas, they are surrounded by non-residential areas, the sediment fractions consist of sand with low percentages of organic matter (Figure 5.24) and currents are more active allowing transportation of fine particles into deeper

areas (Figures 5.26-5.30). Based on the mean CF values, rank of the trace elements were found to be ordered Cu > Zn > Pb.

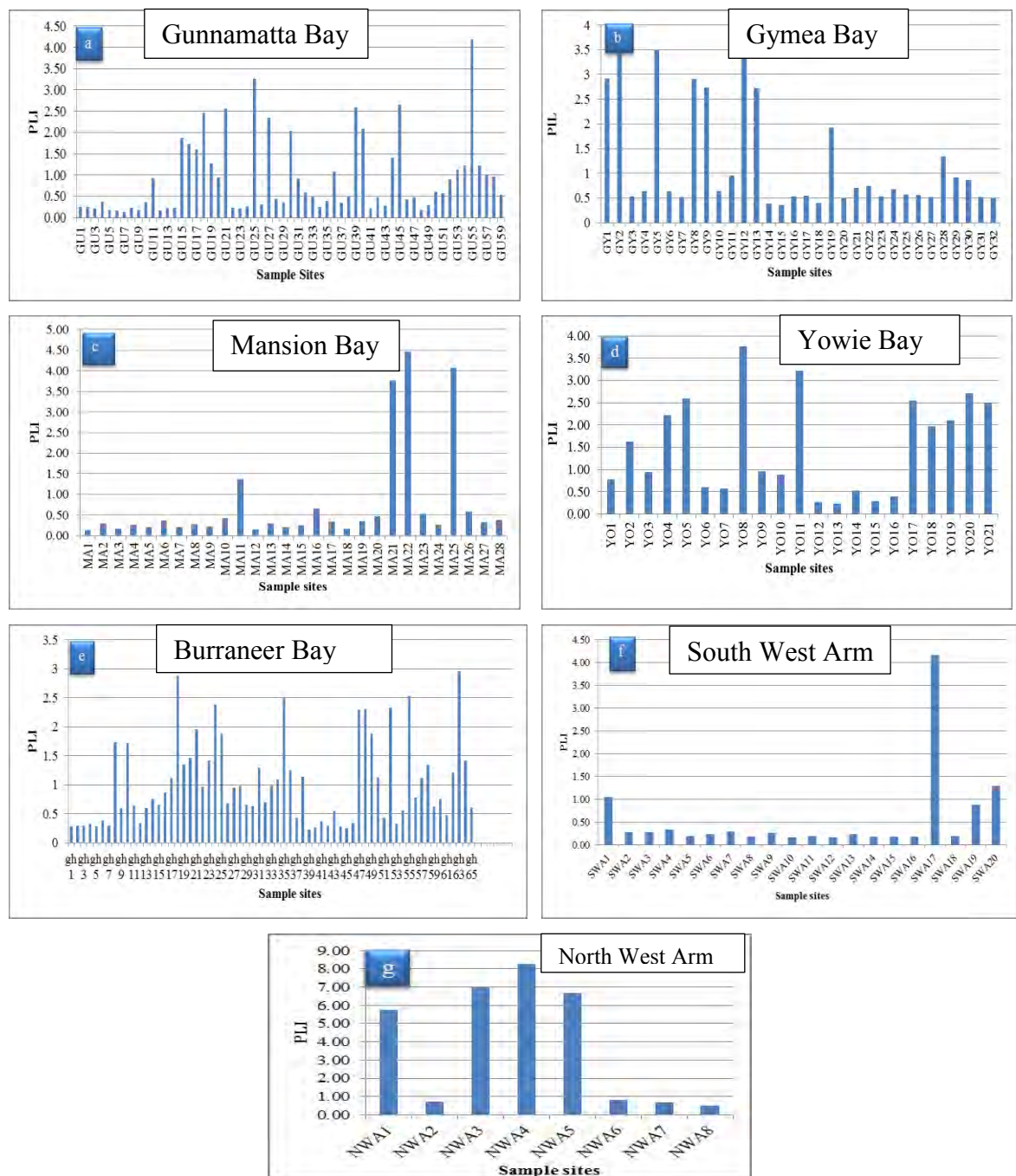


Figure 5.26: Potential load index a- Gunnamatta Bay, b- Gymea Bay, c- Mansion Bay and d- Yowie, e- Burraneer Bay, f- South West Arm and g- North West Arm in Port Hacking.

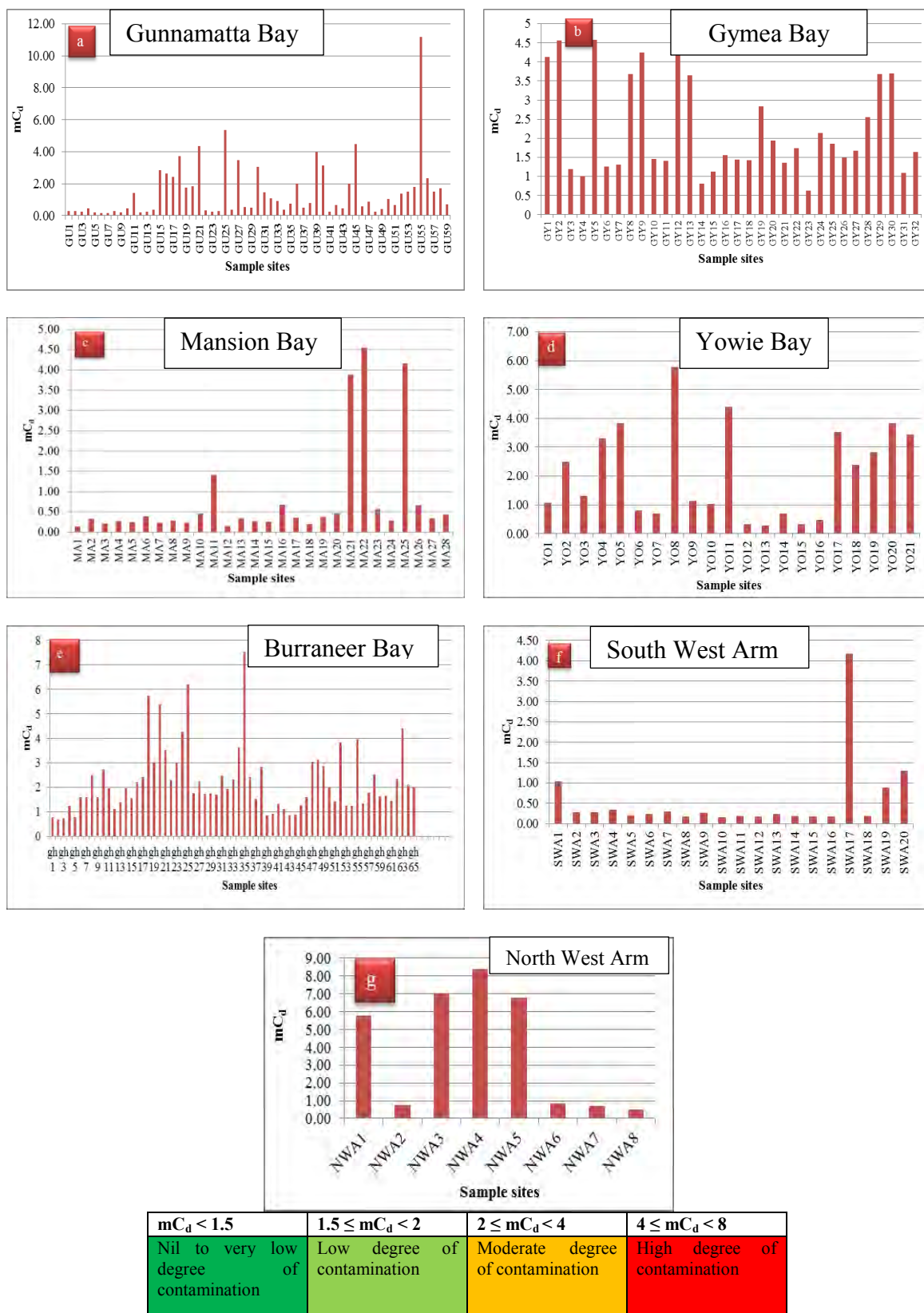


Figure 5.27: Modified degree of contamination a- Gunnamatta Bay, b- Gymea Bay, c- Mansion Bay d- Yowie Bay, e- Burraneer Bay, f- South West Arm and g- North West Arm in Port Hacking.

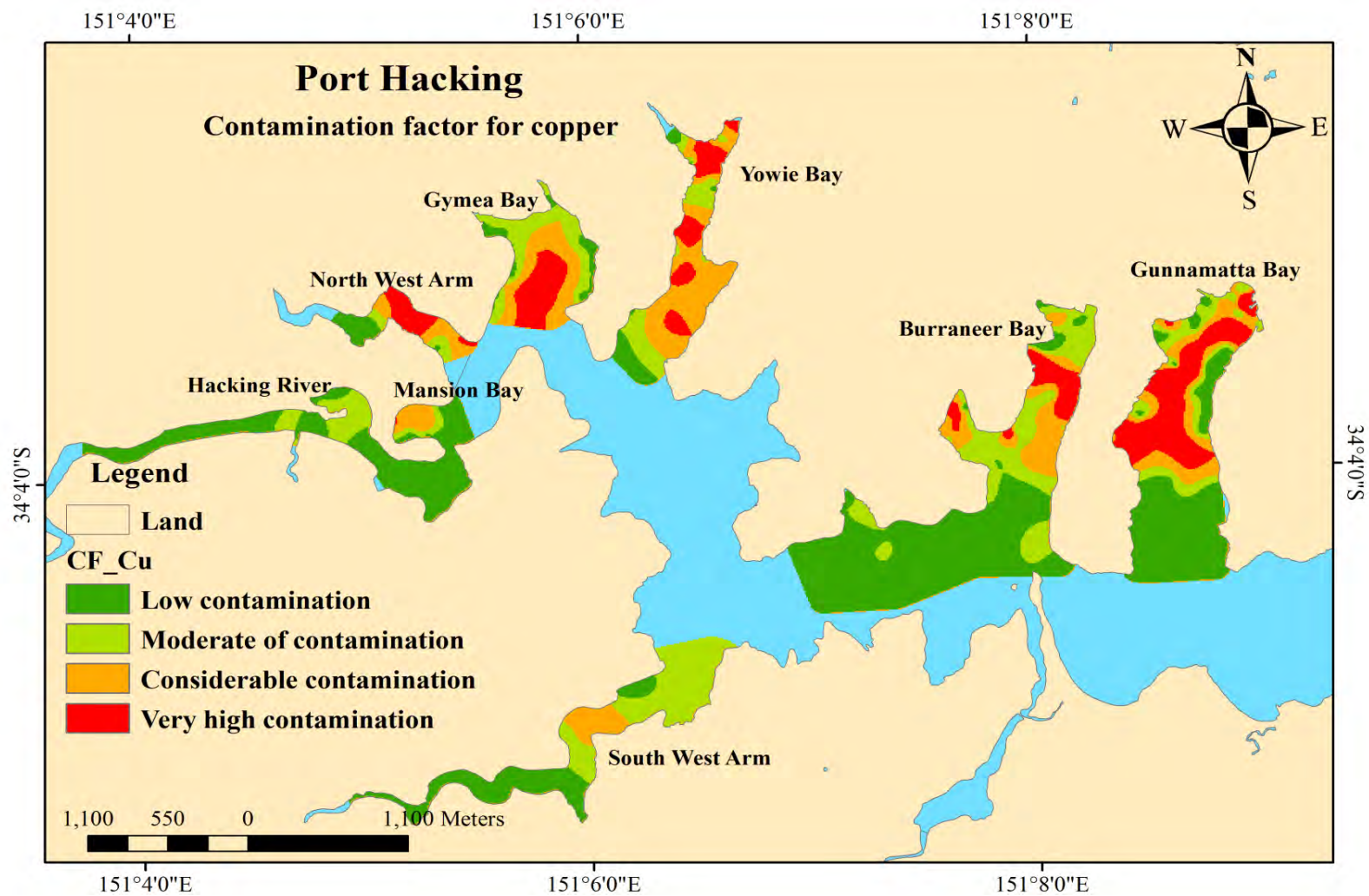


Figure 5.28: Contamination factor for Cu within embayments in Port Hacking.

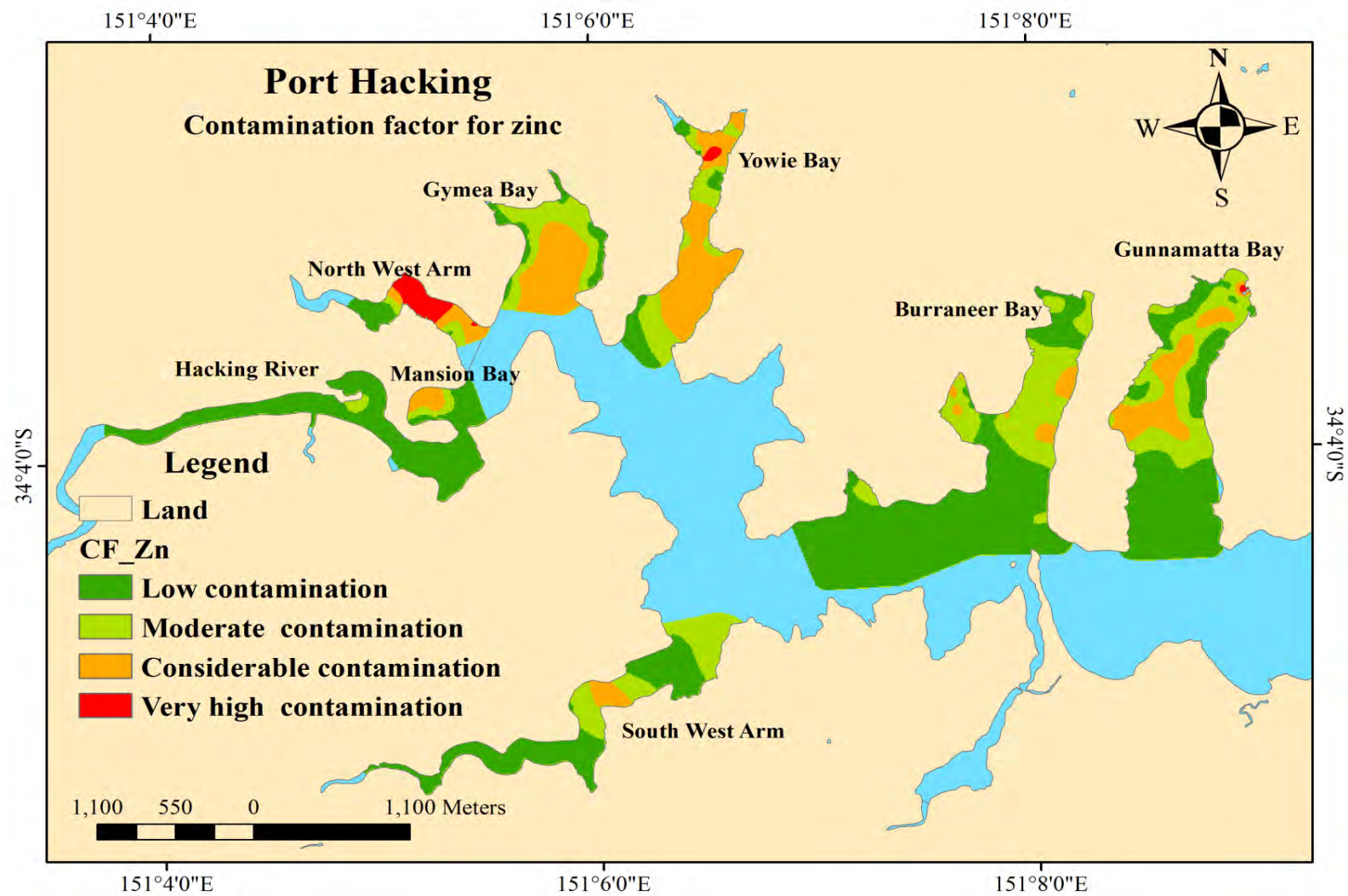


Figure 5.29: Contamination factor for Zn within embayments in Port Hacking.

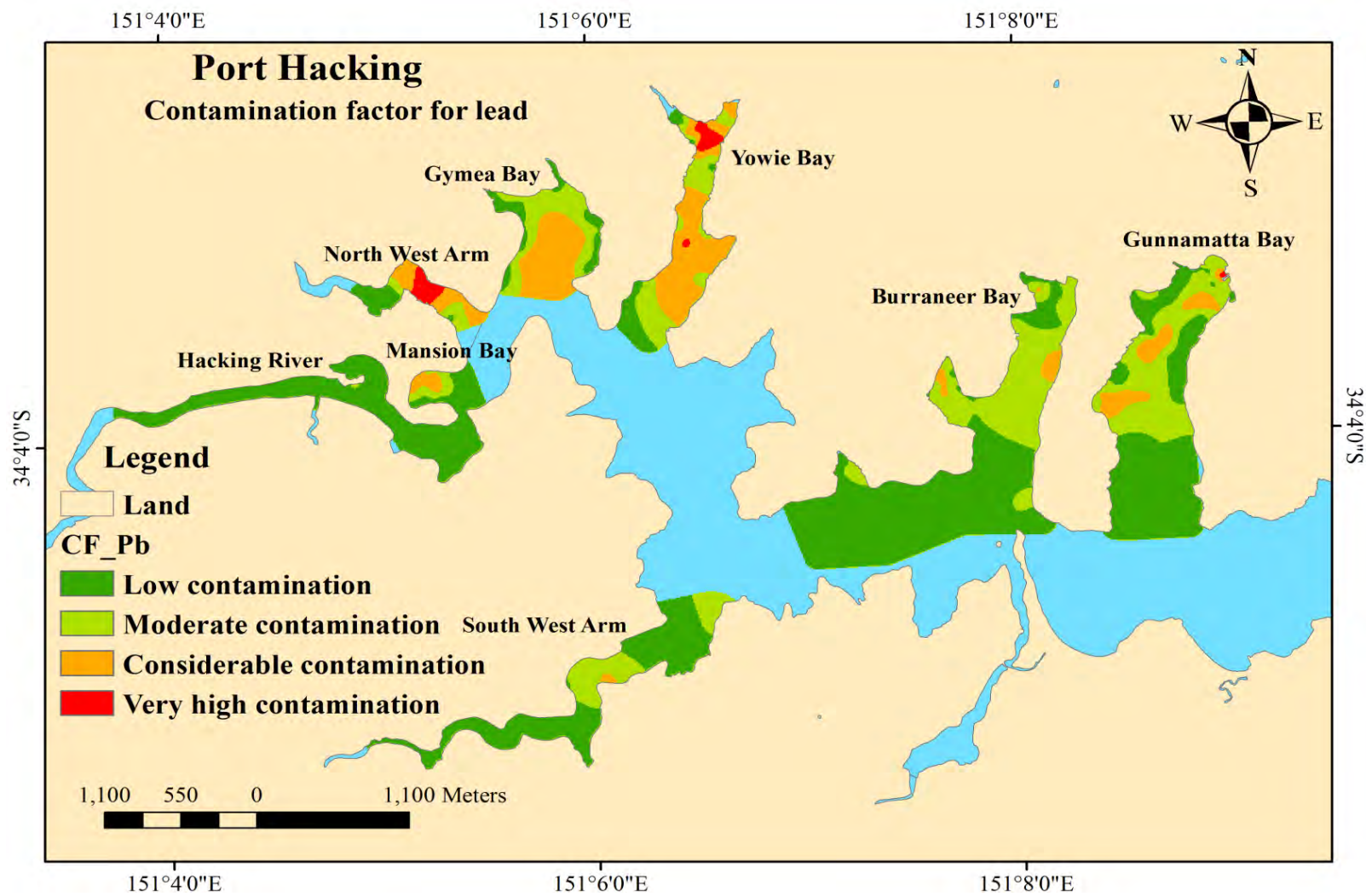


Figure 5.30: Contamination factor for Pb within embayments in Port Hacking.

5.6 Lead source and apportionment

Signature techniques for lead isotopes were determined in the surface and subsurface sediment samples from the study areas since no previous data on lead isotopes had been reported in these areas. Pb isotopic composition can lead to assessment of contributions from Pb-containing products such as gasoline-fumes, leaded pesticides and leaded paints (Flament et al., 2002; Vallelonga and Mather, 2003; Cheng and Hu, 2010). The main objective of investigating $^{204}\text{Pb}/^{206}\text{Pb}$ is to support a source apportionment and historic record of lead pollution in the study areas. Surface sediment samples were selected from areas with the highest concentrations of Pb (Appendix 3.3) that were close to discharge points from catchment areas in both Botany Bay and Port Hacking (Figures 5.31 and 5.32). Other sediment samples were collected from cores at 40 cm depth to represent more natural background compositions. The ratio of lead isotopes in subsurface samples, expressed as $^{206}\text{Pb}/^{204}\text{Pb}$, ranged from 17.6 to 18.4. It was fairly constant below 30 cm depth (Figure 5.33), but fluctuated at a depth of 40 cm, depending on each site. The concentration of lead at these sediment depths was stable at about 15 ppm (Alyazichi et al., 2014b).

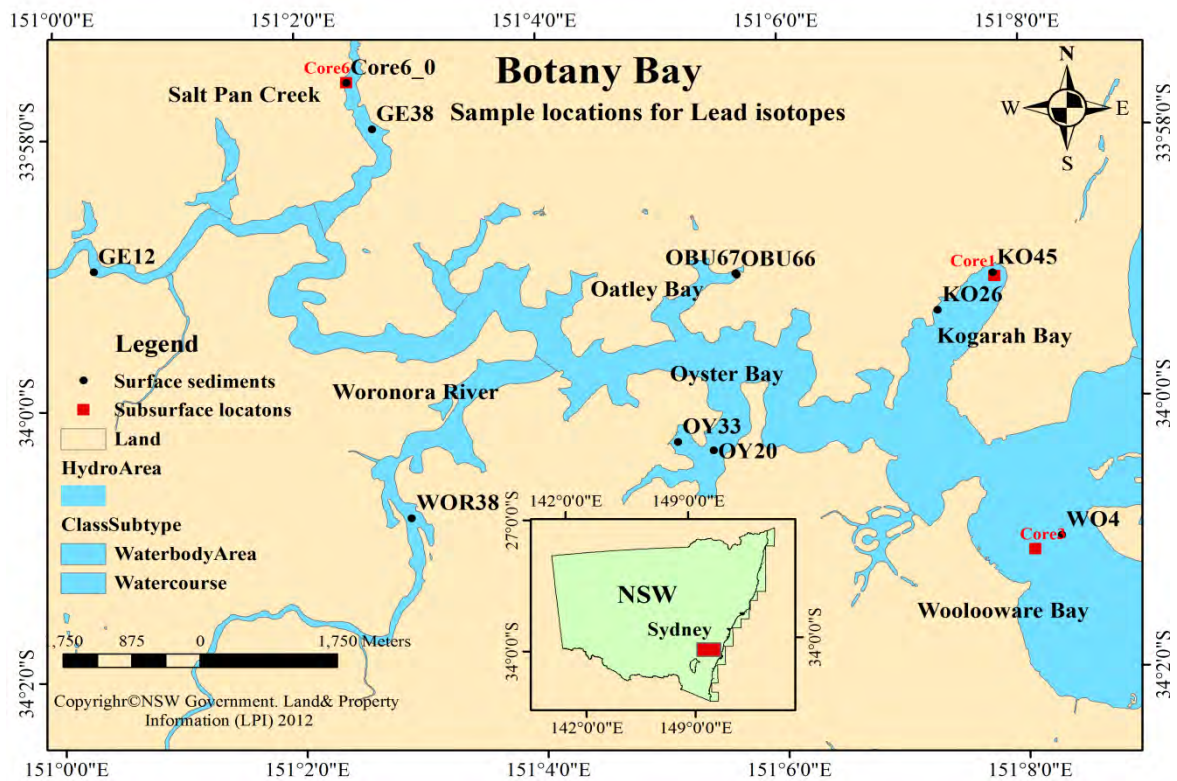


Figure 5.31: Sample locations for lead isotopes in Botany Bay.

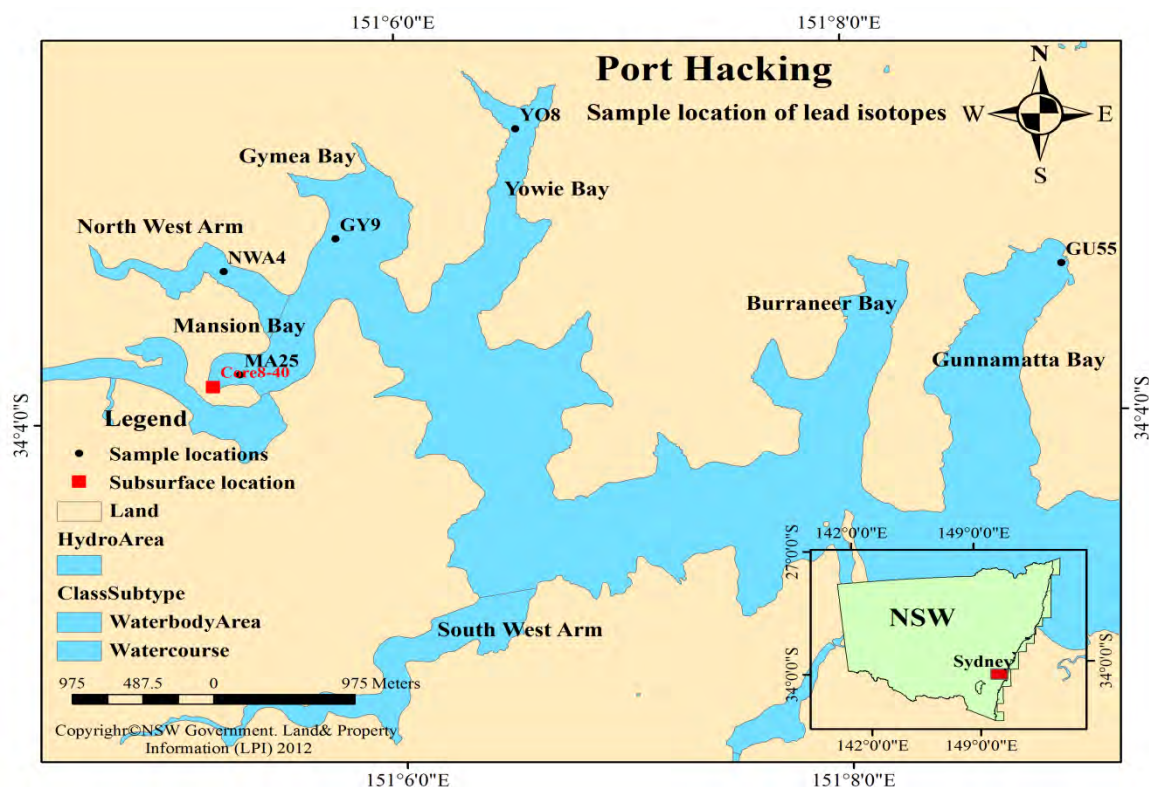


Figure 5.32: Sample locations for lead isotopes in the Port Hacking.

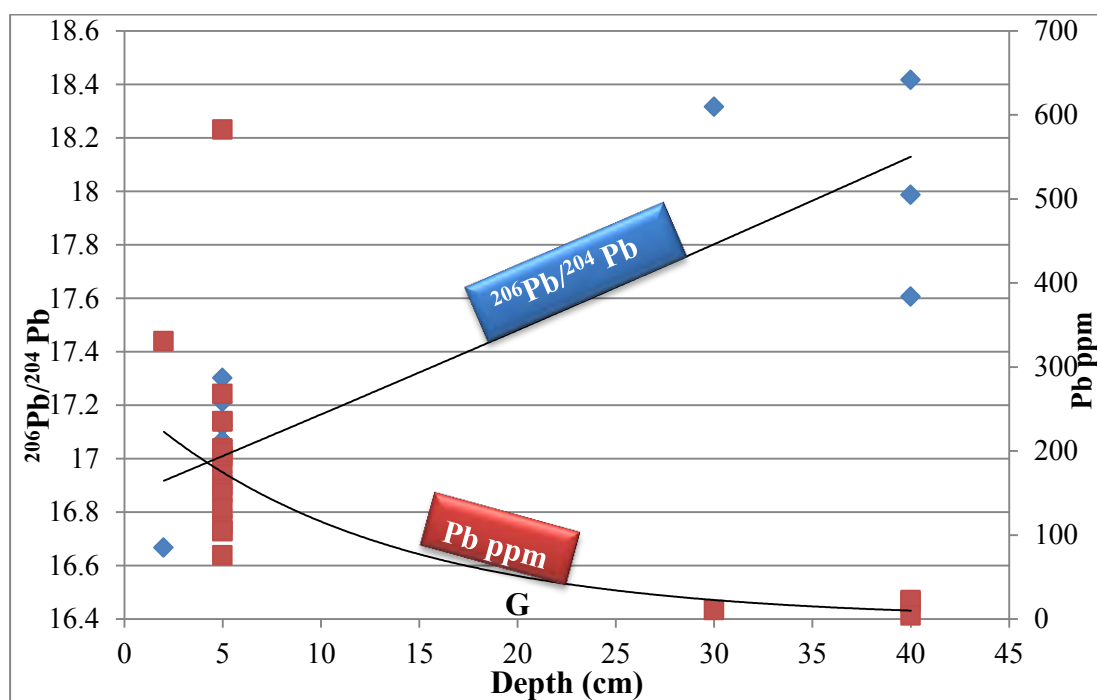


Figure 5.33: Pb concentration and variations of $^{206}\text{Pb}/^{204}\text{Pb}$ ratio with sediment depth in the study areas. G represents the time of introduction of lead gasoline-fumes.

The composition of lead isotopes in subsurface sediments, below at least 30 cm depth, represents the natural background (pre-European settlement) isotopic signature or a very minor introduction of Pb (Figure 5.33). This was reinforced by equivalent lead isotope ratios measured in pre-industrial sediment in the cores from Lake Illawarra (Chenhall et al., 1995; Chiaradia et al., 1997). Between 10 and 25 cm, the $^{206}\text{Pb}/^{204}\text{Pb}$ ratio demonstrated a decline towards the current surface sediment assuming that the natural background source of Pb remains the same in terms of both isotopic signature and accumulation rate of Pb from the source. In addition, the decline in $^{206}\text{Pb}/^{204}\text{Pb}$ suggests a rise in the contribution of old lead to the sediment, mainly from gasoline fumes (car and boat exhausts). This modification of isotopic composition corresponds to a progressive increase in the concentration of lead in the upper sedimentary layers. While the $^{206}\text{Pb}/^{204}\text{Pb}$ rose rapidly from a depth of 5 cm and reached a maximum value of 18.4 at 40 cm depth; conversely, the Pb concentration increased from 4 ppm at a depth of 40 cm to 582 ppm in the upper 5 cm of the sediment layers (Figure 5.33). The isotopic ratio changed depending on the amount of contamination by old Pb, with concentrations between 75 ppm and 582 ppm, at the sample sites in the bays.

Nonetheless, the isotopic composition of the lead between 2 cm and 40 cm in the sediments declined significantly with decreasing depth (Figure 5.33 and Appendix 3.3). The decline of $^{206}\text{Pb}/^{204}\text{Pb}$ can be attributed to an increased contribution to the load of sediment Pb from paint flakes or air, i.e. gasoline fumes (Figure 5.34), which corresponds very well with findings from both roof dust and contaminated sediments from the Illawarra region, with background $^{206}\text{Pb}/^{204}\text{Pb}$ ratios in Lake Illawarra of about 18.7%. Table 5.1 represents lead isotopes, lead concentrations in marine sediments, and contribution of the lead from air emissions (i.e. gasoline fumes), which are sourced from vehicles and boats exhausted, as well as industries.

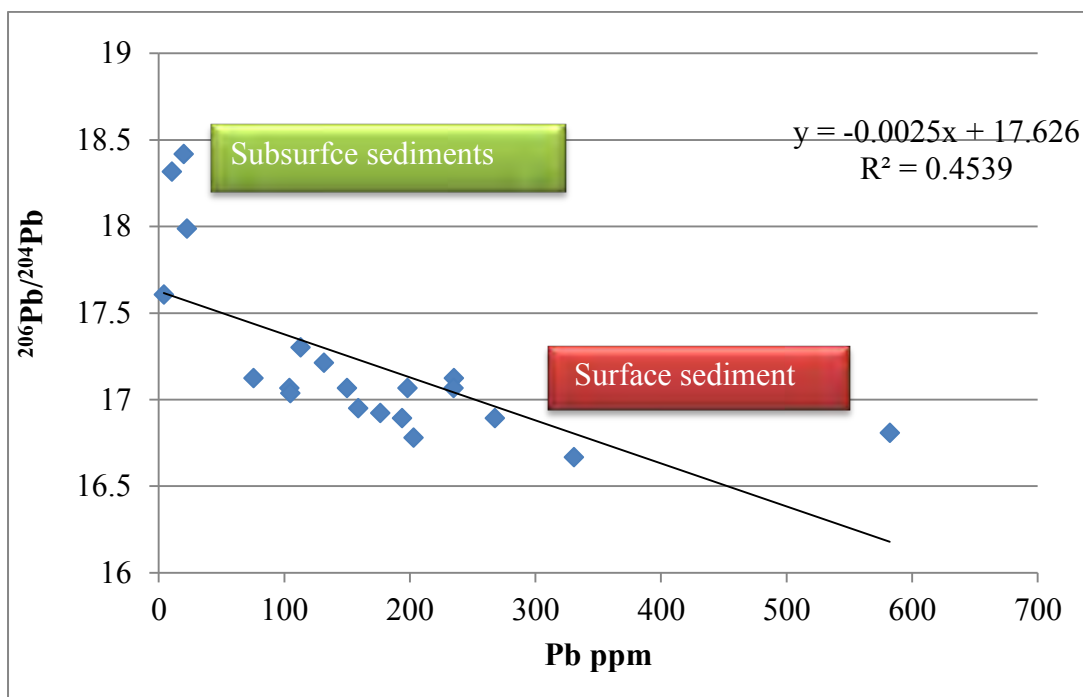


Figure 5.34: Pb concentrations vs. $^{206}\text{Pb}/^{204}\text{Pb}$ plot for surface and subsurface sediment samples from Botany Bay and Port Hacking indicate that the isotopic ratio is dependent on the Pb concentrations.

Table 5.1: Lead isotope data and percentage contributions from air (i.e. gasoline fume) in this study.

Sample No.	Depth(cm)	Pb ppm	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{206}\text{Pb}$	$^{206}\text{Pb}/^{204}\text{Pb}$	Pb air%
OB67U	5	582.2	0.921	2.173	16.81	82.32
GE38	5	267.6	0.918	2.174	16.89	78.61
KO26	5	235.2	0.912	2.168	17.12	68.55
OBU66	5	234.9	0.913	2.168	17.06	71.09
Core 6	2	330.7	0.931	2.188	16.67	88.41
GU55	5	203	0.925	2.175	16.78	83.54
OY20	5	198.2	0.909	2.163	17.06	71.09
KO45	5	193.7	0.916	2.17	16.89	78.61
YO8	5	176.5	0.914	2.168	16.92	77.37
NWA4	5	158.8	0.914	2.168	16.95	76.12
OY33	5	149.9	0.91	2.164	17.06	71.09
GE12	5	131.6	0.906	2.158	17.21	64.71
GY9	5	113	0.91	2.163	17.30	60.82
WOR38	5	104.9	0.907	2.156	17.04	72.36
WO4	5	104.1	0.905	2.159	17.06	71.09
MA25	5	75.6	0.901	2.157	17.12	68.55
Core 6-40cm	40	22.5	0.866	2.113	17.99	31.06
Core 1-40cm	40	20	0.848	2.096	18.42	12.34
Core 3-30cm	30	10.5	0.85	2.102	18.32	16.74

The lead isotope ratios in the Botany Bay and Port Hacking sediment samples are represented by $^{207}\text{Pb}/^{206}\text{Pb}$ vs $^{208}\text{Pb}/^{206}\text{Pb}$ in (Figure 5.35; Alyazichi et al., 2014b). The surface samples lie within and above some samples of roof dust in Port Kembla (Chiaradia et al., 1997), and below Broken Hill and Mt Isa (old lead deposits in Australia used in the production of leaded petrol), and leaded gasoline fumes. The subsurface sediment samples (background) from the study areas were below other samples, except for the samples from Lake Illawarra, with isotope ratios of 2.1 and 0.85 for $^{208}\text{Pb}/^{206}\text{Pb}$ and $^{207}\text{Pb}/^{206}\text{Pb}$, respectively (Figure 5.35).

The concentration of Pb in subsurface sediments in the study areas ranged between 4-20 ppm and the isotopic composition seemed to represent natural background sediment from a Palaeozoic source (Chiaradia et al., 1997). The lead concentration increased over time towards the surface sediment as a result of anthropogenic contributions. As can be seen in Figure 5.35, isotope modelling demonstrated that the lead concentrations in surface sediments were derived from anthropogenic pollution, especially gasoline fumes from both cars and boats.

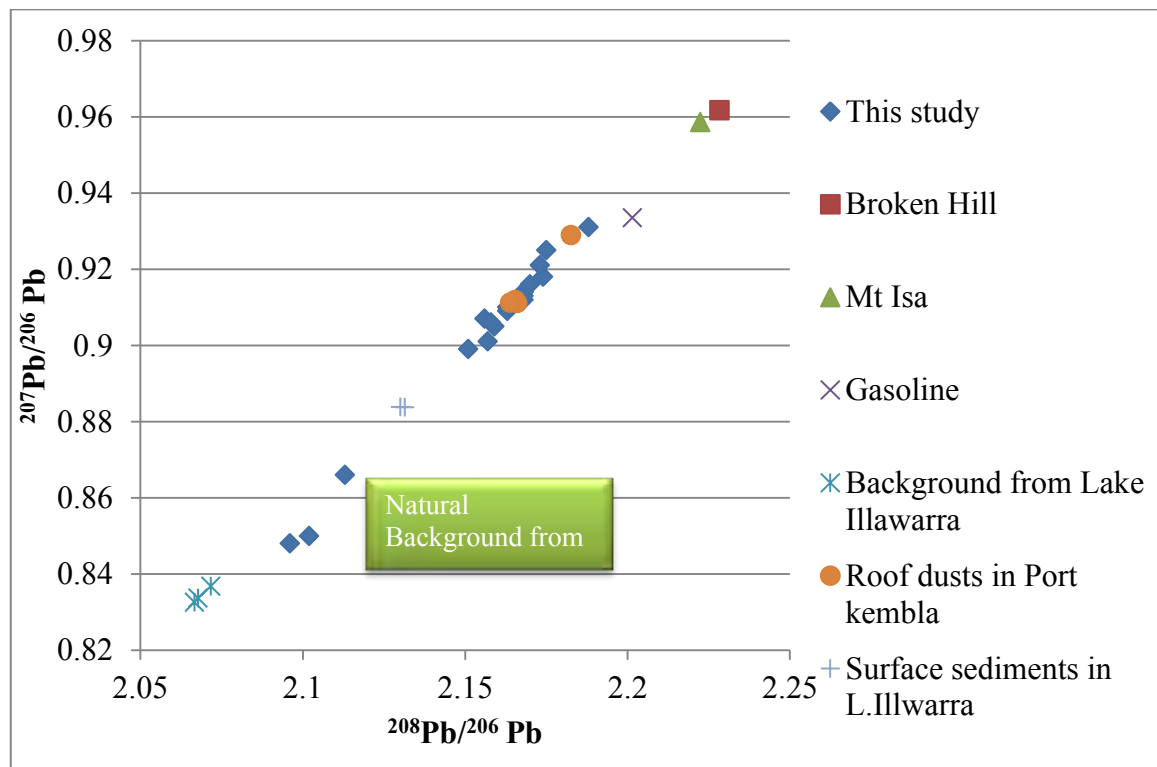


Figure 5.35: Comparison between $^{207}\text{Pb}/^{206}\text{Pb}$ vs. $^{208}\text{Pb}/^{206}\text{Pb}$ within different sites.

5.7 Conclusions

The trace element concentrations were concentrated in the bays of the study areas in particular sites, such as close to discharge points, stormwater outlets, moorings, and within the inner and middle parts of bays that contained high percentages of clay minerals, pyrite and organic matter. The results of the risk assessment for contamination of sediments showed that some sites, such as in Salt Pan Creek and GU55 in Gunnamatta Bay, had a high to very high degree of contamination. However, surface sediments in the South West Arm and Hacking River, as well as samples taken from the shoreline at other sites, had nil to a very low degree of contamination because the sediment fractions are almost pure sand. Furthermore, the South West Arm and Hacking River sites were away from residential areas and stormwater runoffs. The trace elements declined with increasing sediment depth, which indicated that human activity since European settlement in these areas had caused the additional contamination. In summary, the lead isotope ratios exhibit that the lead concentrations in surface sediments within the study areas were derived from anthropogenic pollution, especially petrol fumes (including the exhaust from both vehicles and boats).

Chapter 6

Hydrodynamic observations

6.1 Introduction

This chapter provides an initial evaluation of the hydrodynamic processes (current track and tide activity) within selected bays in the study areas, in order to determine the spatial distribution of sediments particles and trace element pollution pathways under ebb tidal flows within the bays.

6.2 Field measurements

In the present research, the current patterns and tide track velocity were recorded for selected bays in the study area by using specially designed drogues (Figure 3.20). Three drogues (Figure 6.1) were deployed in each of Kogarah Bay, Oyster Bay, Salt Pan Creek, Gunnamatta Bay, GyMEA Bay and Yowie Bay just after high tide in order to capture typical ebb tidal flow patterns and velocities for the larger tides associated with spring tidal ranges. Drogues were also deployed at discharge points and stormwater outlets for the catchment areas as well as in the middle of bays. Main freshwater discharge points for the systems are shown in Figure 6.2a and b, which shows model segments and flow directions determined by Sydney Water. Drogues were also deployed along Salt Pan Creek because of its narrow channel.



Figure 6.1: Current and tidal track velocities recorded by drogue in the study areas.

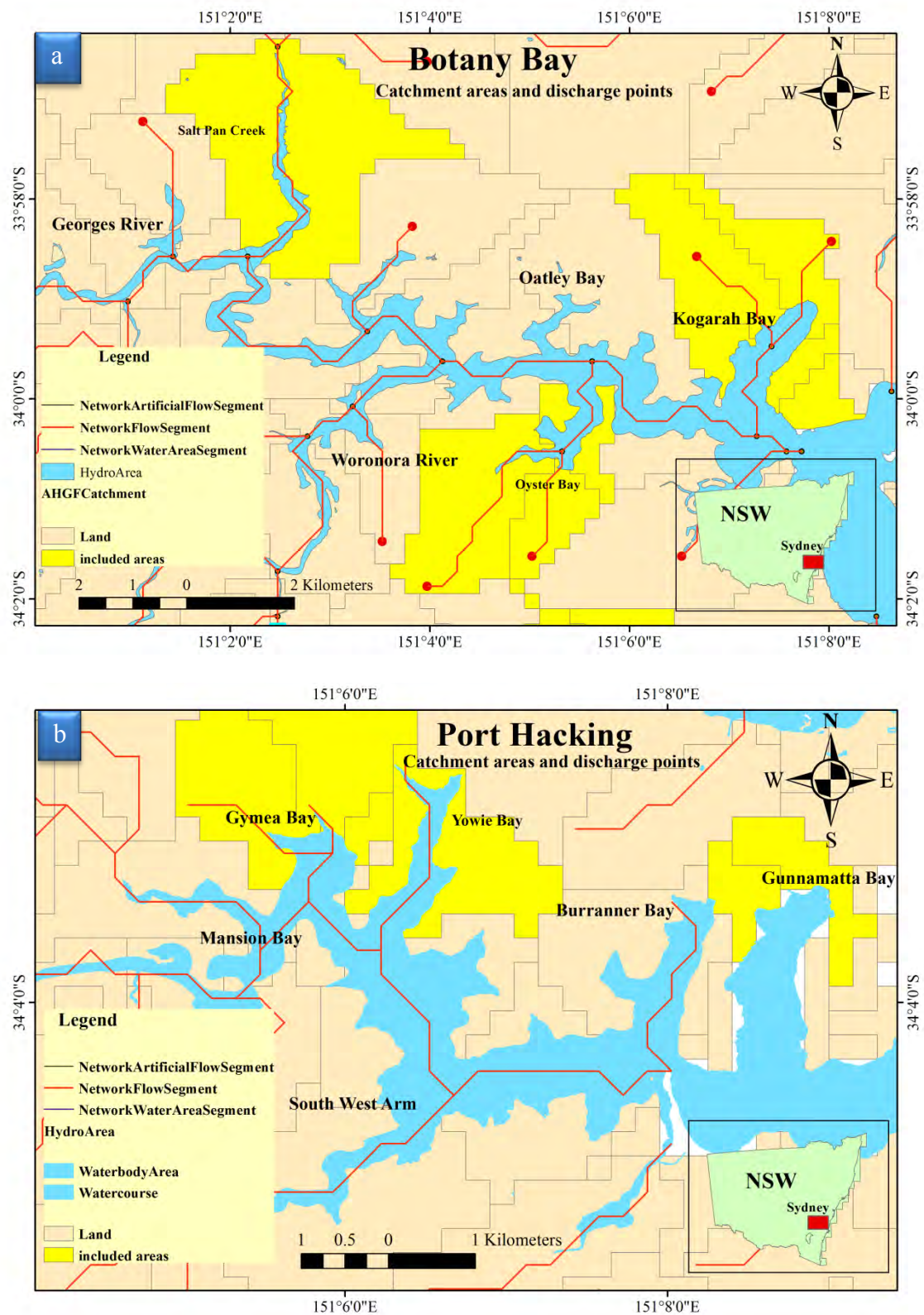


Figure 6.2: Catchment areas and discharge points for a- Botany Bay and b- Port Hacking.

Tidal data was obtained from the Office of Environment, NSW, for water level gauges in the area (Table 6.1). Field methodology was designed so that the current track and velocity data would be compatible with both the descriptive explanation of pollutant movement and the data needs of any future hydrodynamic modelling.

Table 6.1: Tide time table in the study area (Botany Bay).

Date	Time	High Tide	Time	Low Tide
3/12/13	11am	1.93m	16.30pm	0.16m
6/12/13	14.30pm	1.6m	21.30pm	0.35m
17/12/13	10.30am	1.74m	16.40pm	0.37m
18/12/13	10.30am	1.75m	17.15pm	0.36m

6.3 Typical early to mid-tide ebb tracks and velocities

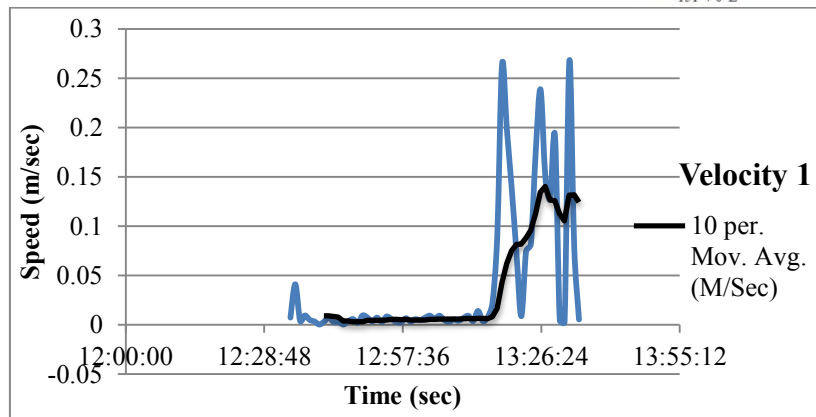
The main purpose of measuring ebb tracks and velocities was to provide a robust framework in order to understand the distribution and dynamics of both sediment particles and trace element pollution in the study areas (Alyazichi et al., 2015c).

Where the intertidal area is large, currents and tides have the capability to transport sediment particles into and within bays and rivers during ebb flows (high to low tide, Table 6.1). The tidal asymmetry and the estuarine gravitational circulation also may have an influence on the movement of fine sediments Shi, (2010). Due to the shortening of the flood tide, this normally results in a net sediment inflow into a bay. For the bays selected, tidal asymmetry effects are regarded as minor and sediment distribution will be dominated by catchment flow associated with ebb tidal flows (Simpson et al., 1990; Burchard et al., 2004; Stacey et al., 2008). Additionally, there are other significant physical processes that will affect settling behaviour, such as flocculation, erosion and consolidation (Dyer et al., 2002; Shi, 2010).

The tide and currents track have been driven by the ocean tide via both Botany Bay and Port Hacking. Three drogues were deployed and collected at each site at about the same time (with a difference of only a few minutes between deployment and collection of the three drogues). Drogues deployed in the middle of the bay had a faster speed compared with others because of increased current velocities due to a larger tidal storage above these locations (Attached Appendix 3; Alyazichi et al., 2015c).

In the Kogarah Bay open area (non-shelter environment) the three drogues were deflected to the western edge because of the prevailing wind direction on the day, indicating that wind speed and direction had a significant affect in this area, especially on the observation day when wind speed increased and ranged between 40-55 km/h.

Current speeds in all the bays had enough capability to transport the fine and very fine particles including trace elements from the edges and shoreline and then gradually deposit them in deeper areas. This accords with the observations of Mantovanelli et al. (2004) and Gong et al. (2014).



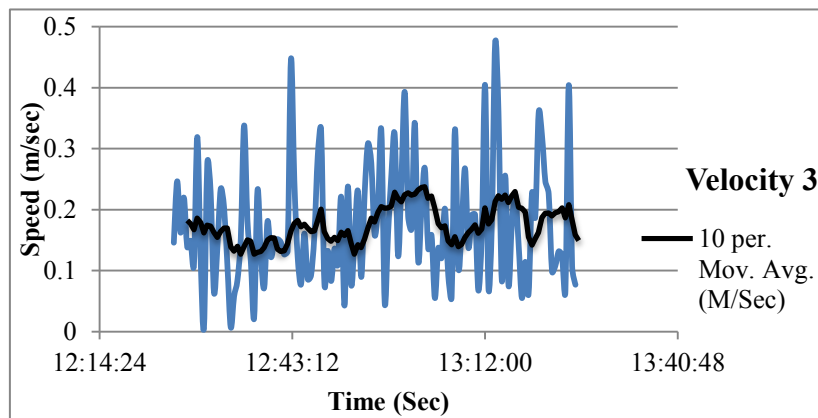
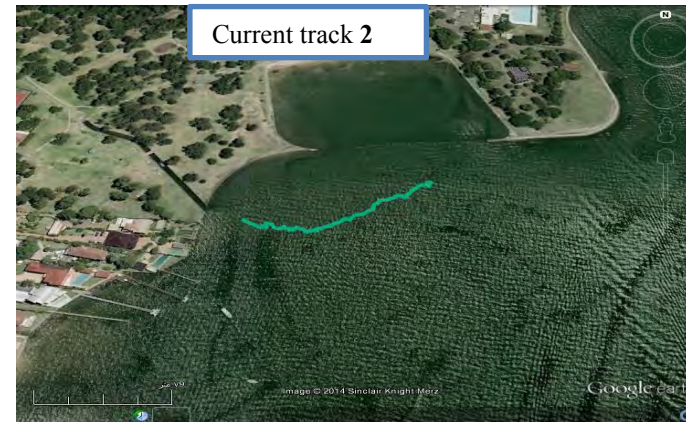
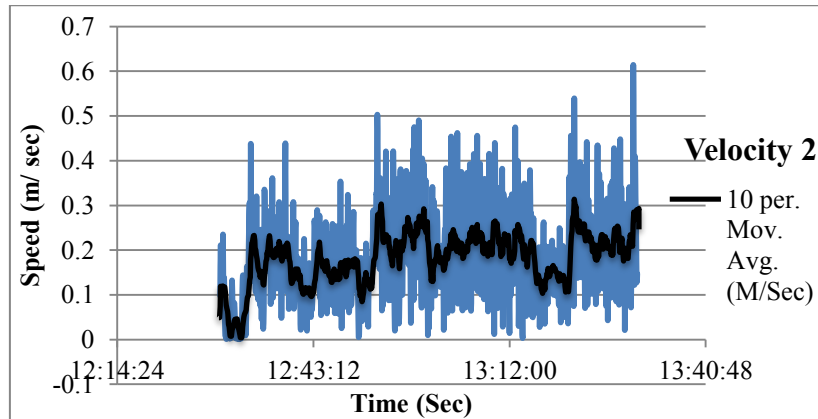
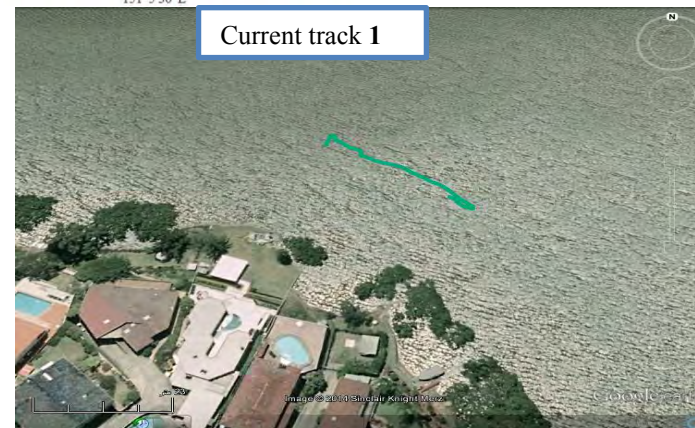
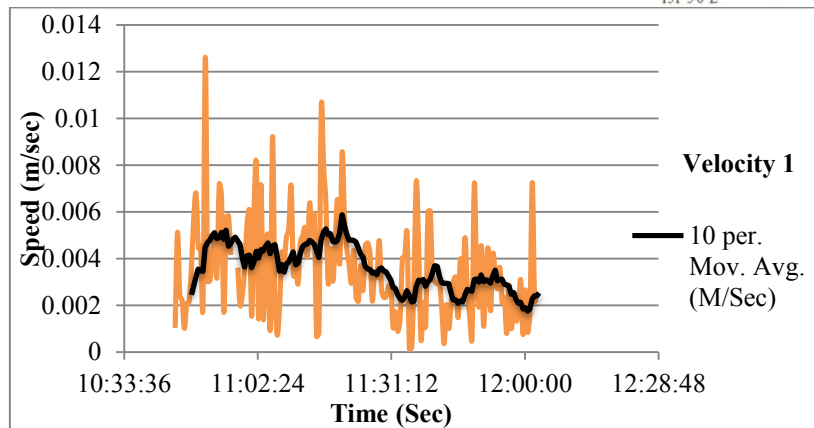


Figure 6.3: Current track velocities for three drogues in Kogarah Bay.

Three drogues were deployed in Kogarah Bay; the first and second drogues were close to discharge points. Drogue 1 moved slightly slower compared to drogues 2 and 3, due to the larger upstream tidal volume at these latter locations. The first and third drogues were slower at the beginning <0.05 m/sec then moved faster (about 0.1 m/sec; Figure 6.3) because the wind speeds increased, reaching 30-35 km/h, which led to increasing wave and current speeds.



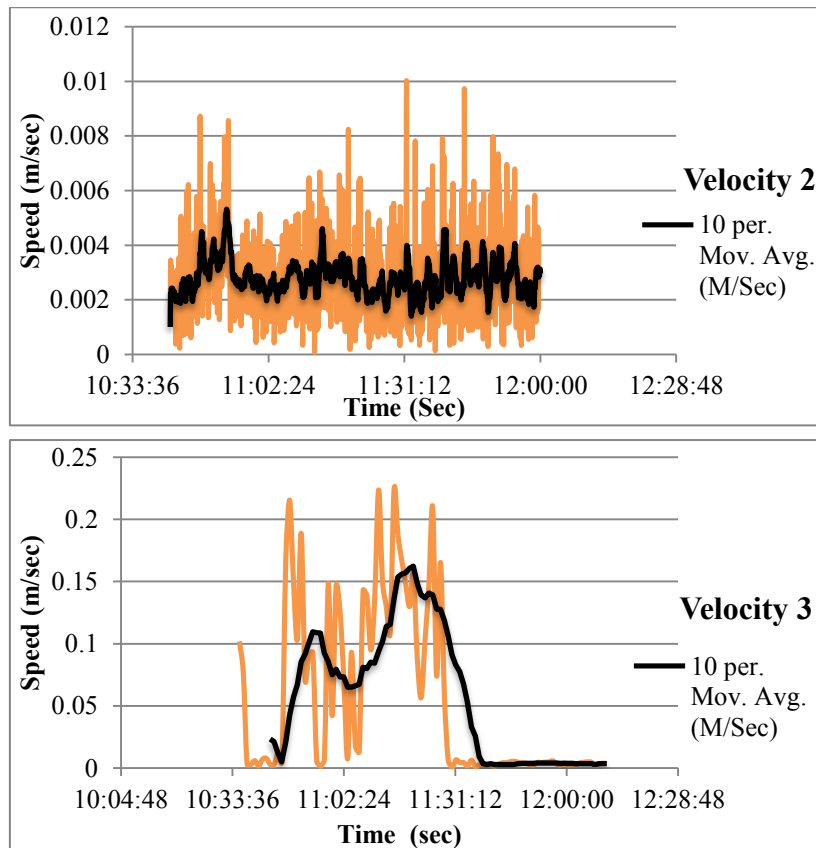
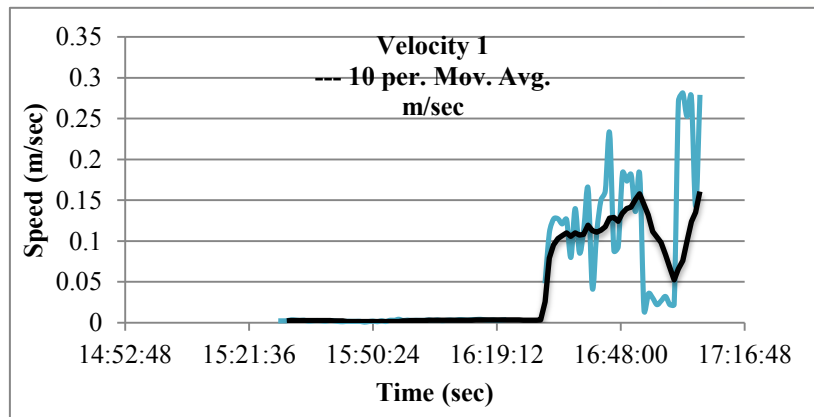


Figure 6.4: Current track velocities for three drogues in Oyster Bay.

Number one and two drogues were deployed in the vicinity of stormwater outlets at the head of Oyster Bay and the third drogue was placed in the inner bay. Overall Oyster Bay was deemed to be a protected (sheltered) environment protected from the high wind and the track velocities were very slow as shown in Figure 6.4 (current tracks 1 and 2). Therefore, fine particles and trace element pollution would be precipitated around the sites where the velocities dropped close to zero. Although, track number three had a faster current due to the increased tidal volume at this site, it was caught in shallow water in the bay causing it to essentially stop moving (Figure 6.4 current track 3).



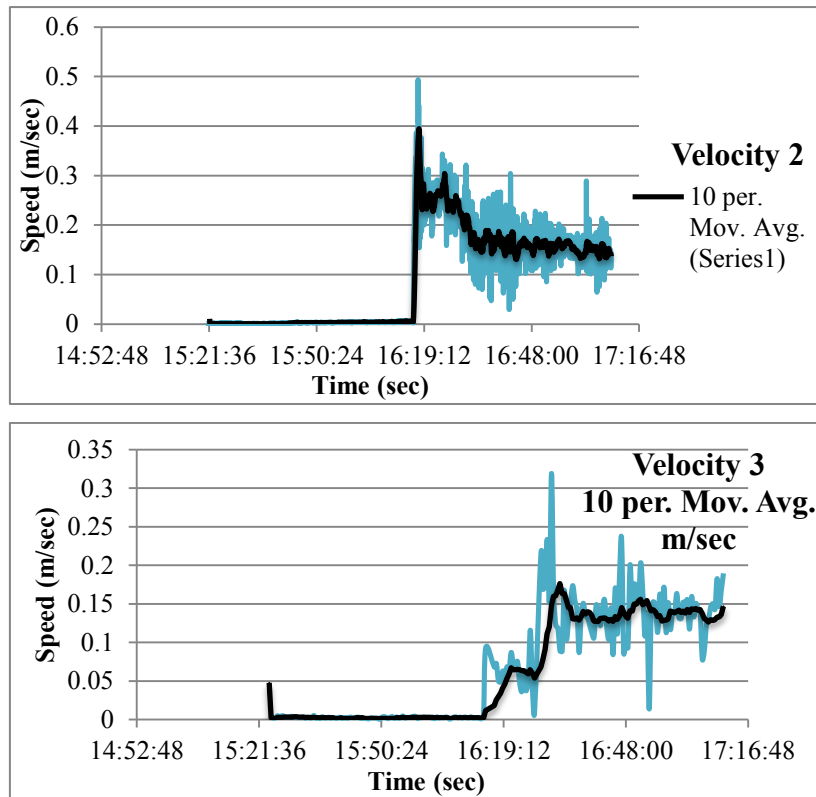
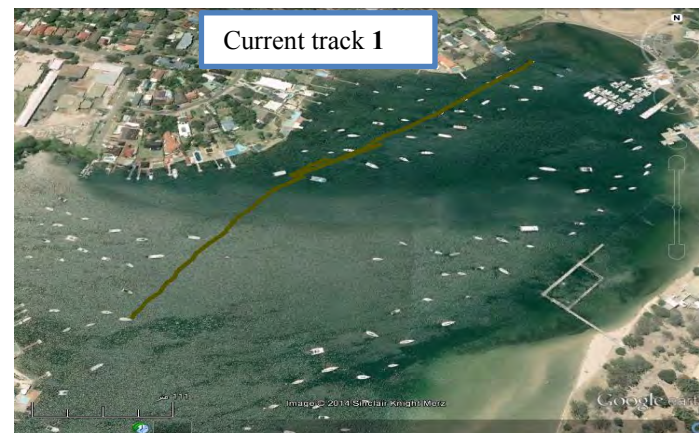
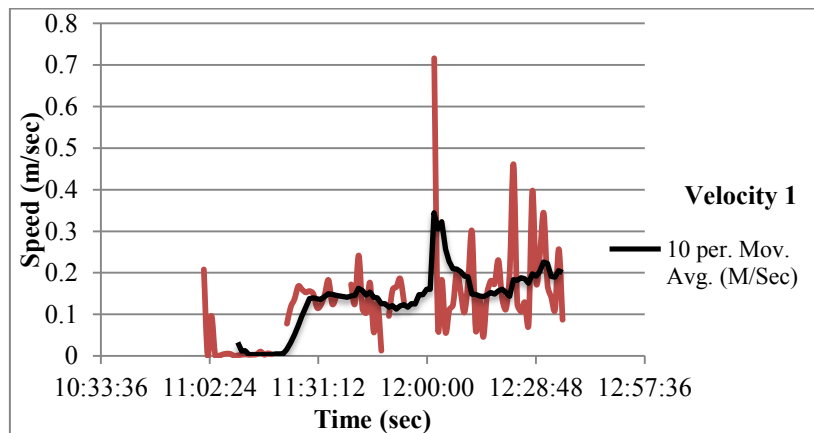
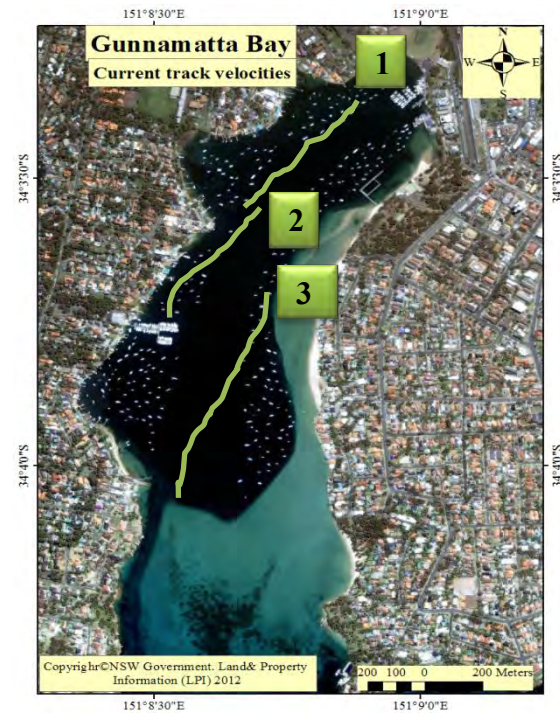


Figure 6.5: Current track velocities for three drogues in Salt Pan Creek.

The three drogues were deployed in Salt Pan Creek. The current track velocities in the beginning were zero because the drogues were dropped at high tide one hour before the ebb flow started. Then after that current velocities were fast, ranging between 0.2 and 0.3 m/sec as the tide started falling. Generally, the current track velocities were faster in this creek compared to other bays except at Gunnamatta Bay, which had a similar current speed. This was largely because the creek has a narrow, elongated channel. As a result, the current and tidal velocities were concentrated at these sites (Figure 6.5).



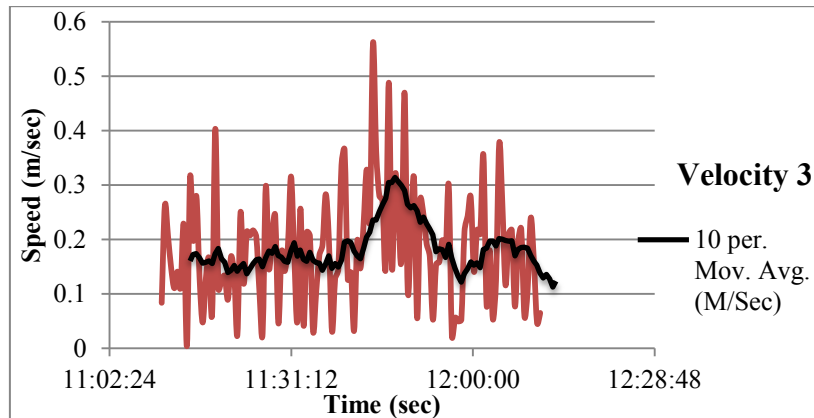
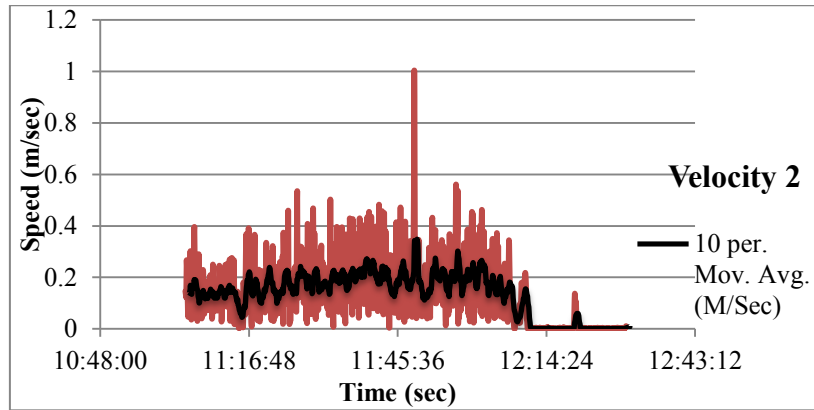
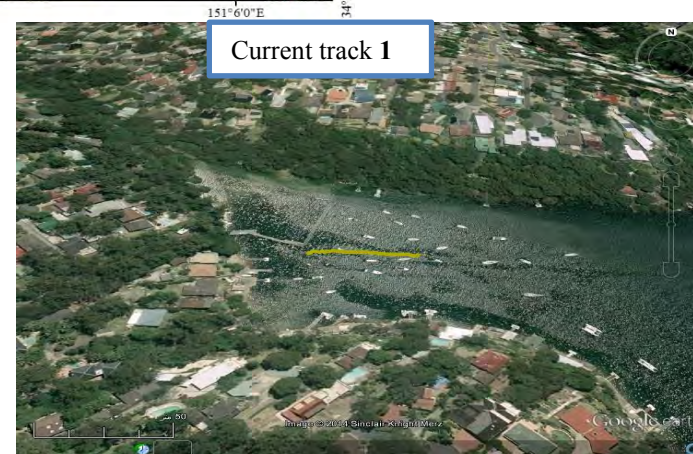
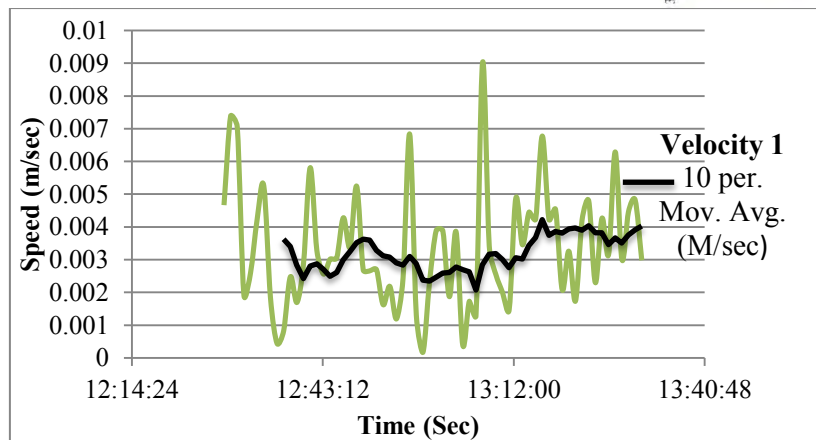


Figure 6.6: Current track velocities for three drogues in Gunnamatta Bay.

Three drogues were deployed in Gunnamatta Bay; the first and second drogues were at the head of the bay. Number three was in the middle of the bay. As observed in Figure 6.6 (velocities 1, 2 and 3) have peaks in velocity; this is because of the effects of boats moving past during measurement. Generally, the drogues moved faster than in other bays except Salt Pan Creek. This may be attributed to the narrow channel at the mouth of Gunnamatta Bay that causes the tidal currents to become more concentrated. Furthermore, drogue number three moved faster compared to other two since it was influenced by a greater tidal volume (Figure 6.6).



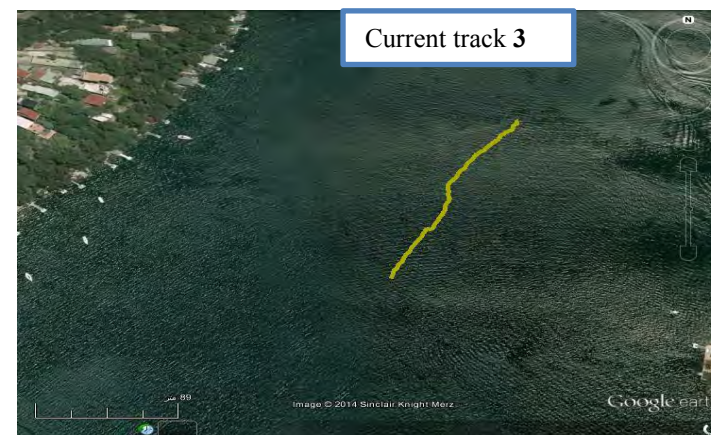
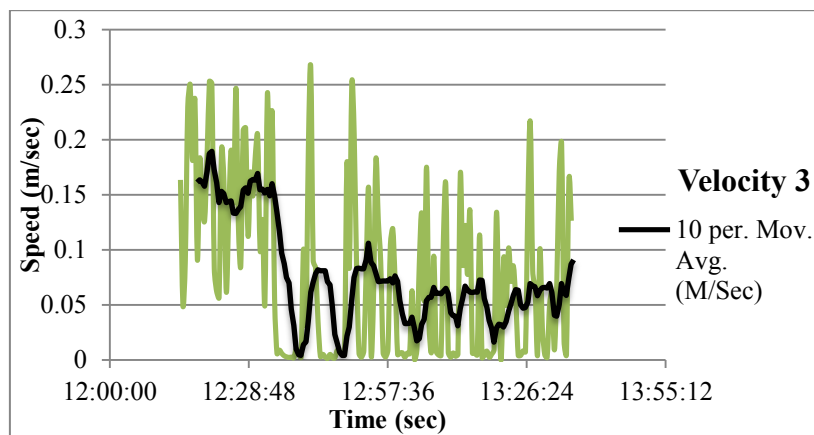
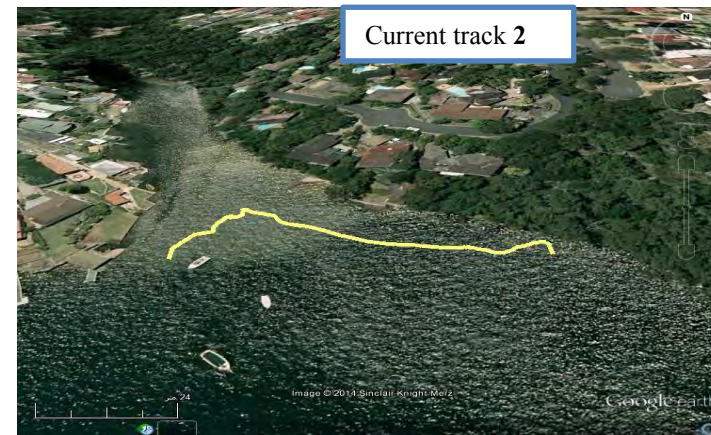
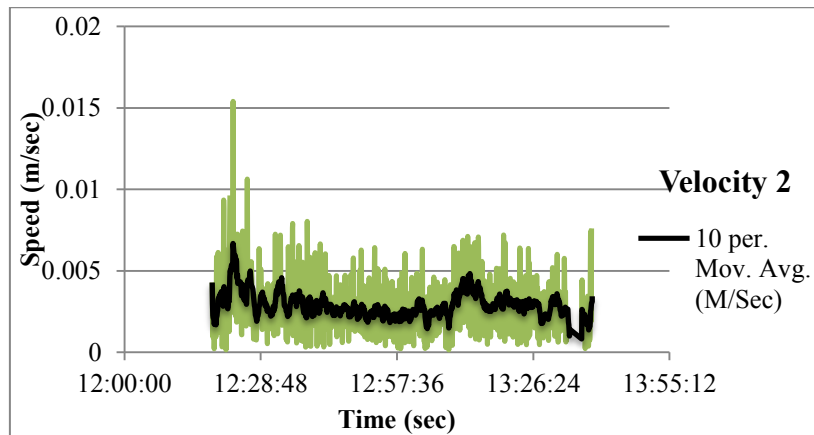
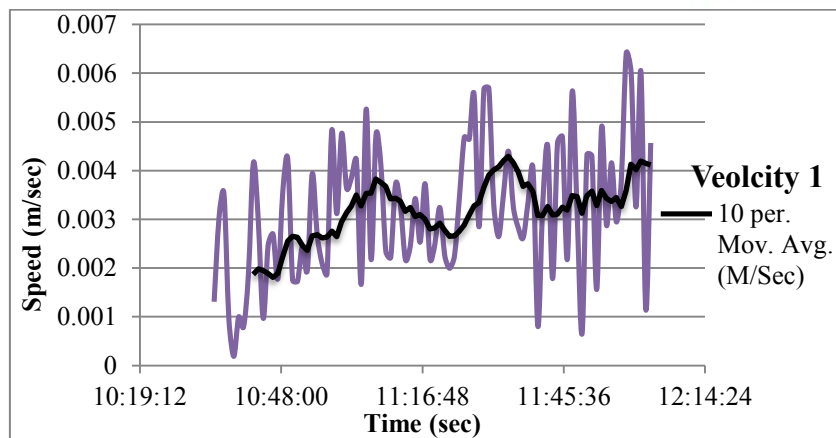


Figure 6.7: Current track velocities for three drogues in Gymea Bay.

In Gymea Bay, two drogues were deployed close to discharge points and the third was placed in the inner bay. The current tracks showed that the drogues 1 and 2 had low velocities, less than 0.005m/sec, compared to number three, which had a faster velocity. This is due to the upstream tidal storage at these locations. In addition, in the third current track, velocity has the capability to transport fine particles and trace element pollution (Figure 6.7).



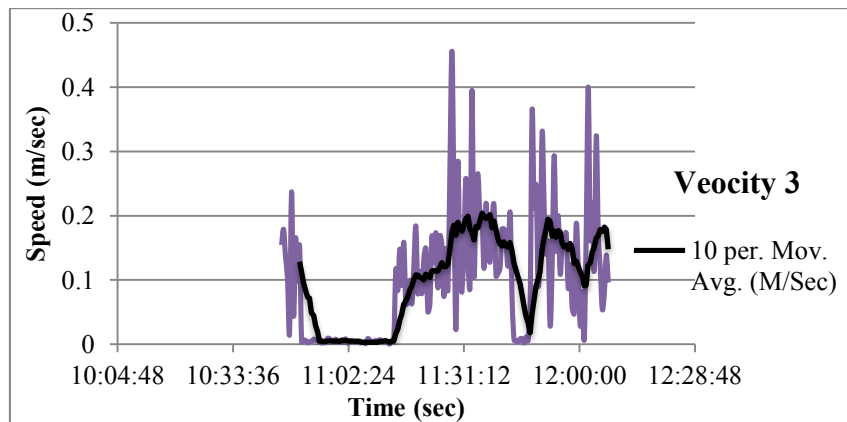
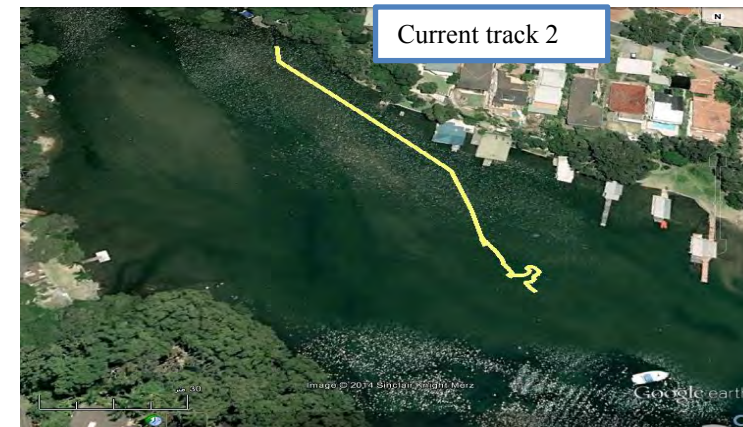
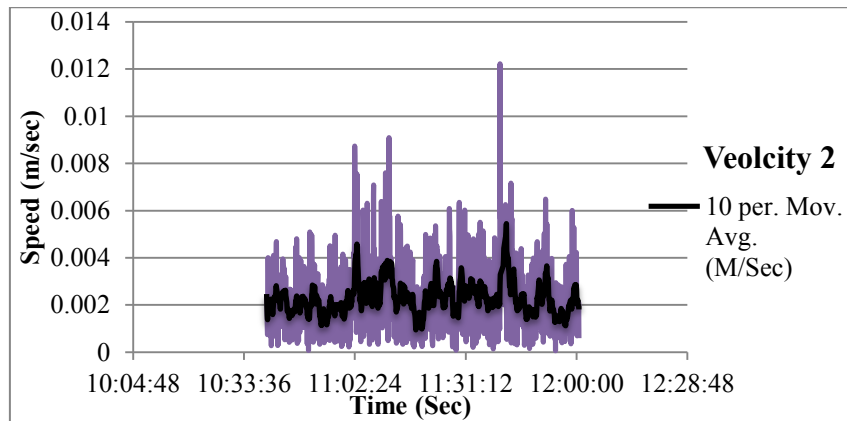
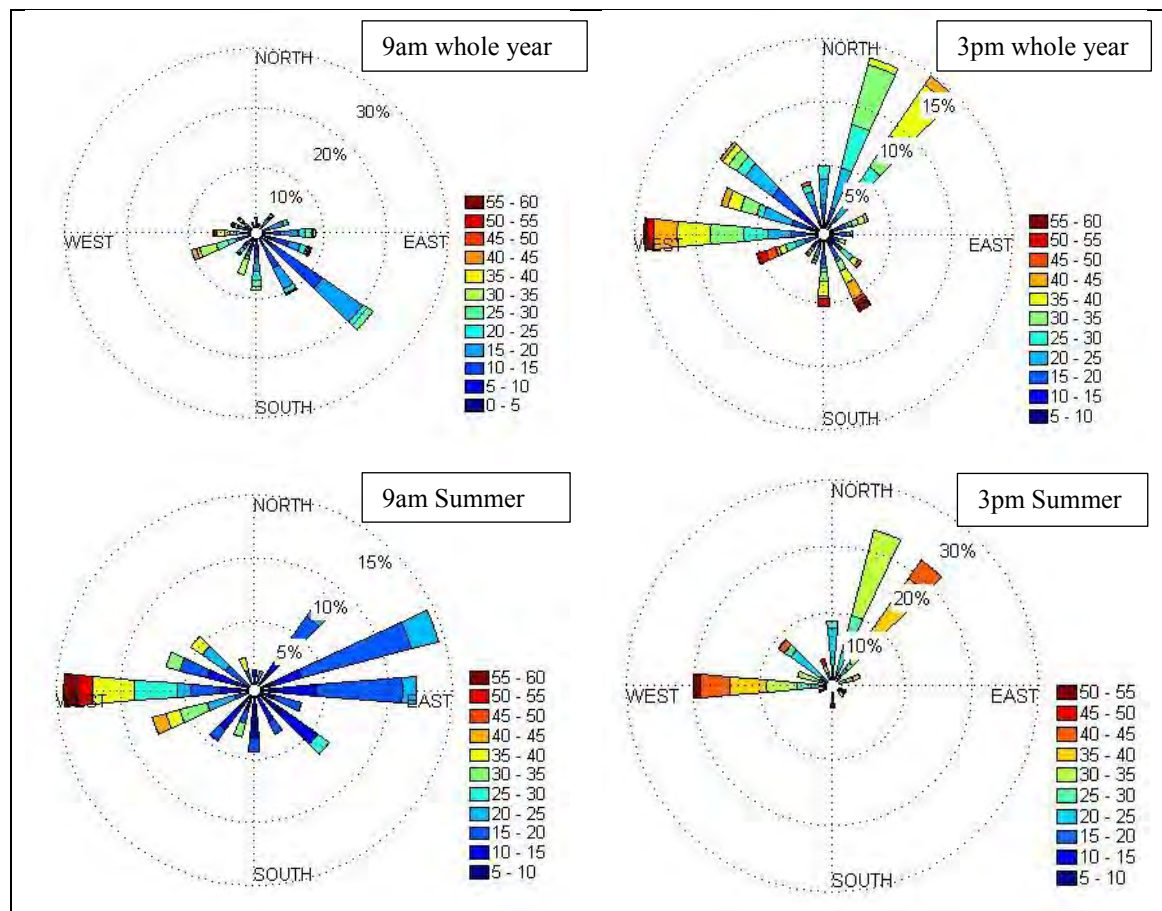


Figure 6.8: Current track velocities for three drogues in Yowie Bay.

In Yowie Bay, two drogues were deployed close to discharge points and the third was placed in the inner bay. Generally, the current speed shown in the three figures had peaks, because boats were moving at the time of measurement (Figure 6.8). The current tracks showed that the drogues 1 and 2 had low velocities compared to number three, which had a faster velocity. As for other bays, this is related to the upstream tidal volume at these locations. In addition, the third current track velocity had the capability to transport fine particles and trace element pollution.

6.4 Wind Data

Estuaries are typically regarded as mixed systems controlled by the combined influences of tides and catchment flows. Nonetheless, many aspects of their dynamics are influenced by wind forcing. Because wind is inherently variable, determining conventions that apply commonly is a challenge for estuarine physicists (Babanin and Makin, 2008; O’Callaghan and Stevens, 2011). Wind waves reflect wind stress at the air-sea interface and can influence the current tracks by producing secondary effects, which can deflect the current track and cause re-suspension and transportation of fine sediments (Shi et al., 2008). Figure 6.9 illustrates wind speed and direction in the study area at 9am and 3pm for the whole year 2013 and seasonally (the complete wind data is displayed in Attached Appendix 2). Overall, the wind direction trends southwest to southeast at 9am, changing to west-northwest with increased wind speed at 3pm. Generally, in the summer period, when currents were measured, the wind directions were trending west-southwest and northeast.



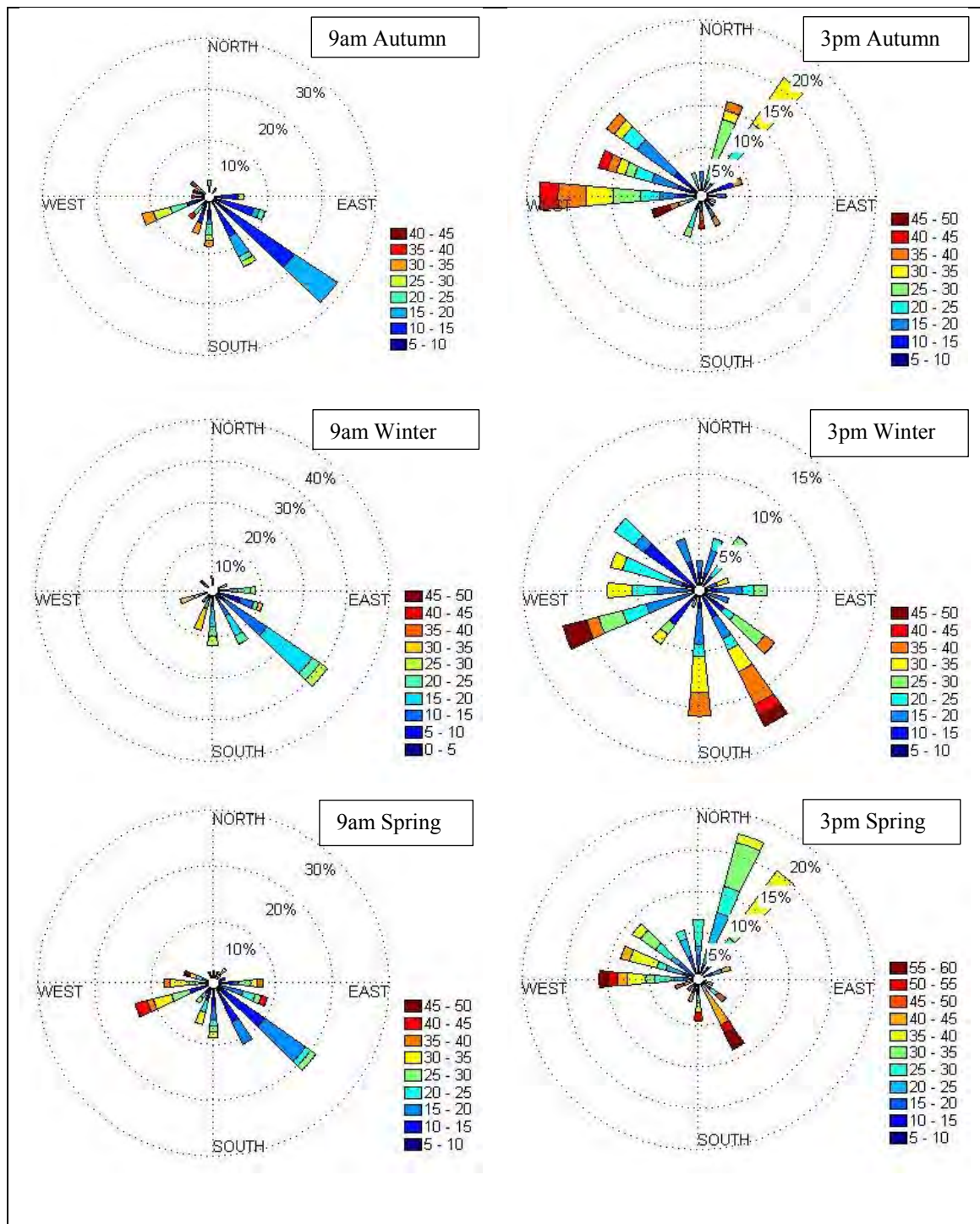


Figure 6.9: Wind data (speed and directions) at 9am and 3pm from Botany Bay station in the study area.

6.5 Hydrodynamic circulation

Hydrodynamic circulation in estuaries is controlled by several factors such as catchment area flows, entry points, wind effects (speed and direction) and tidal velocities (McLean and Hinwood, 2000; McLean et al., 2002; Shi et al., 2008; McLean and Hinwood, 2010a).

The suspended particles (fine to very fine silt and clay size) are derived from the catchment areas through the transport of soil and sediments into the estuary via discharge points on the estuary shoreline (Gong et al., 2014). In the study areas, there are three types of bay that can be used to illustrate typical hydrodynamic circulation. Kogarah and Oyster Bays are typical of the shallow bays with wide entrance whereas Gunnamatta Bay has marine sand deposits across the entrance that concentrate inflows and outflows through a narrower entrance section. The third type is an elongated, narrow estuarine tributary, represented by Salt Pan Creek in this study. The circulation patterns are controlled by factors such as tidal velocities and catchment flows, interacting with the different estuarine geometries. Wind waves are influential in the re-suspension and carriage of fine particles along shallow estuarine margins in the wider bays (McLean and Hinwood, 2007).

6.5.1. Shallow Bays with wide open mouth

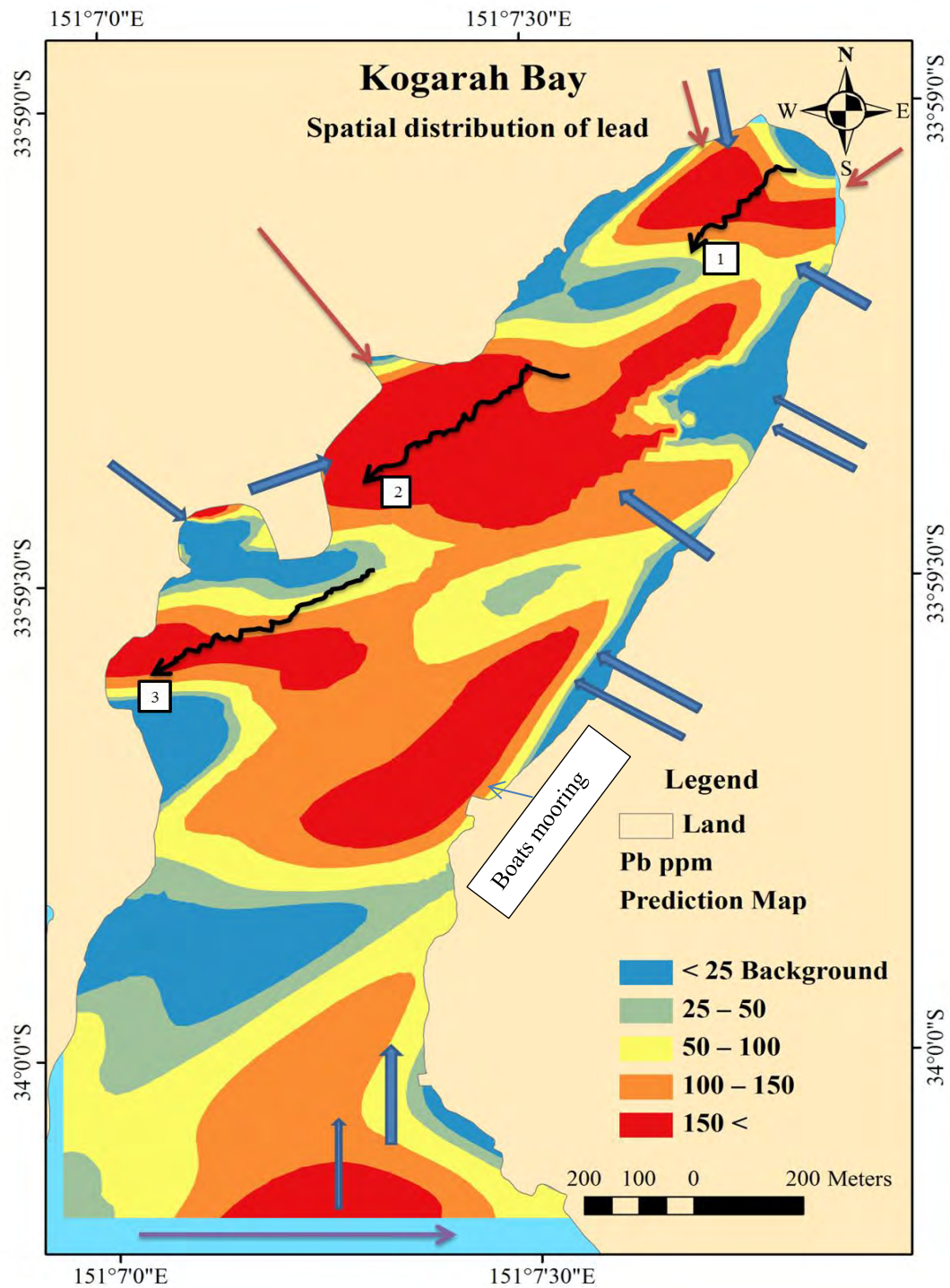
The main discharge points carry materials from catchment areas, which are pushed into the bays. The sediment pathway into the bay is in the form of a jet since water velocity decreases gradually when entering the bay, causing deposition of coarse materials close to discharge points and then finer particles farther into the bay (Fujiwara et al., 1994; Lee et al., 2011). The major mechanism for transport of trace elements away from discharge points is the tidally-driven circulation with ebb-currents being the most important.

Local waves become more active in the shallow waters close to the discharge points leading to re-suspension and transport of fine particles into deeper sites, where the current and waves become less active and cannot disturb the bottom sediments. Examples of this phenomenon were observed in Kogarah Bay (Figure 6.10) and Oyster Bay (Figure 6.11). The current velocities illustrated in Figures 6.10 and 6.11 are able to transport fine particles for some distance away from the discharge points.

Another important factor is wind speed and direction, which can affect the distribution of sediments and trace elements. Winds coming into the bay can deflect tidal current paths and produce set-up, resulting in return-flows which in shallow bays trend along the bay margins. Thus, waves in shallow bays can produce circulations which trend towards the bay margins.

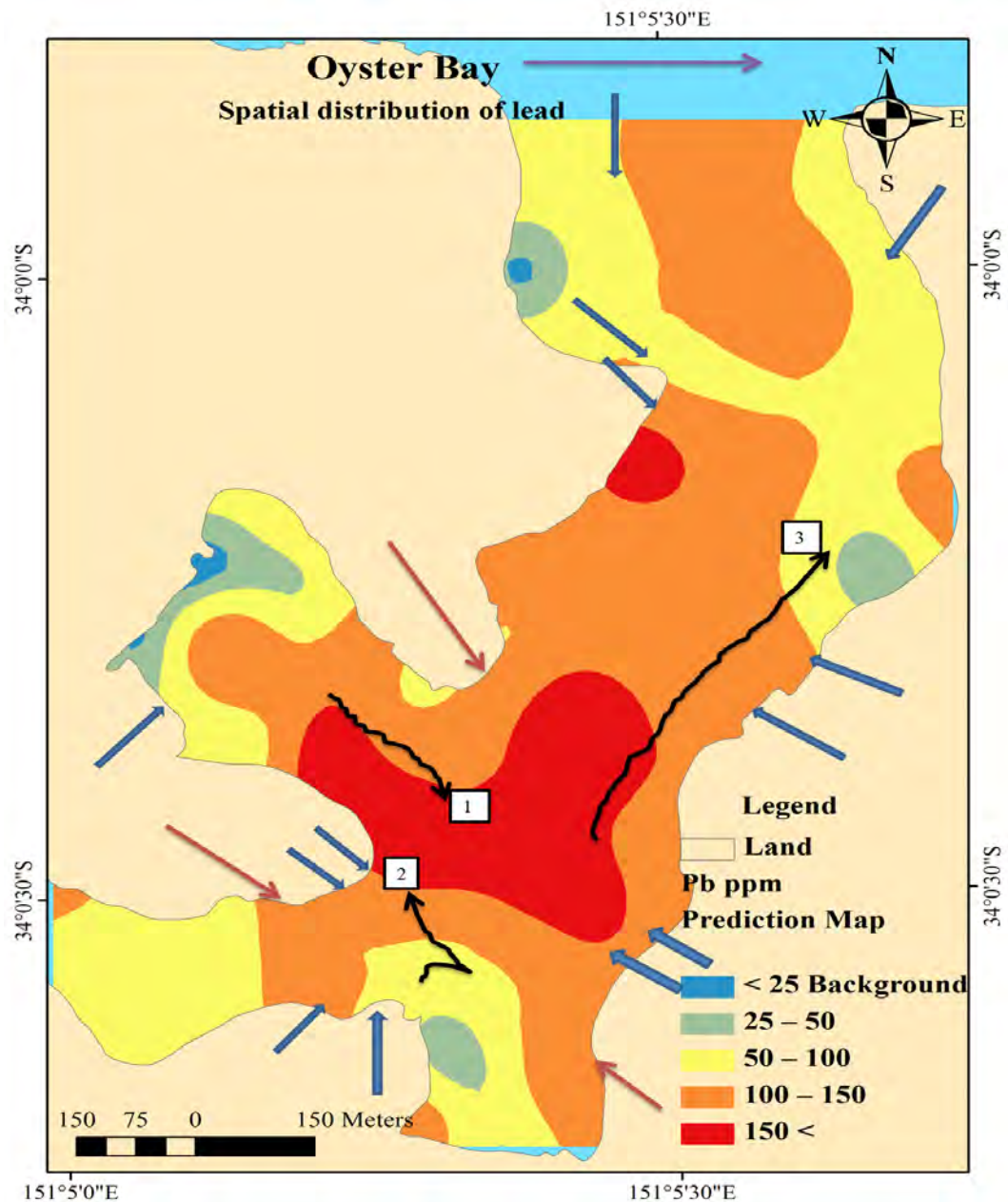
In the study areas, current track and velocities were measured during the summer period, and general wind directions were west to north east, with speeds ranging between 25-55 km/h. Figure 6.10 shows the wind affect on the track velocities (drogues) pushing them towards the western edge of the Kogarah Bay, which is generally considered to be an open estuary (unsheltered) and therefore impacted by wind. Therefore, the main direction of wind into the west of the bay pushes drogues into the western edges when moderate to strong winds occur. Because of the low tidal current speed in the study areas, these bays can be considered to be significantly affected by wind, with ebb current tracks being deflected towards the lee shores, depending on wind direction at the time. Kogarah Bay is more exposed than Oyster Bay where wind deflection appears to be minor.

Thus, movement and subsequent settling of trace elements and suspended sediment particles from the catchments will be a result of ebb tidal drainage and dominant wind directions during catchment events.



Where: Discharge points and stormwaters, Wind - deflected ebb current directions, Wind directions and Georges River main channel.

Figure 6.10: Sketch of main processes controlling the distribution of fine sediments and trace elements (e.g. Pb ppm) in Kogarah Bay.



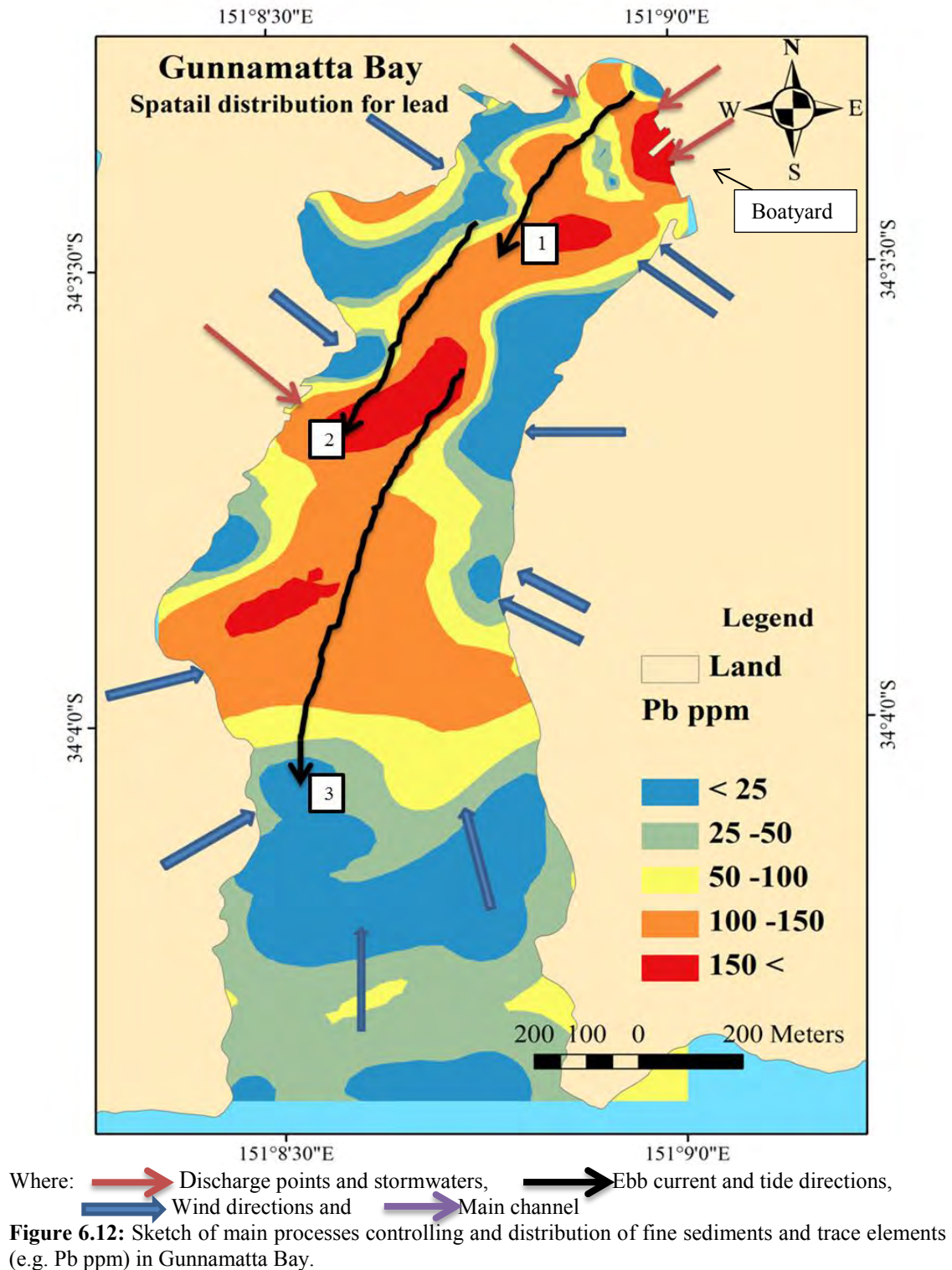
Where:  Discharge points for stormwater,  Ebb current and tide trajectory,  Wind directions and  Main channel.

Figure 6.11: Sketch of main processes controlling and distribution of fine sediments and trace elements (e.g. Pb ppm) in Oyster Bay.

6.5.2 Bays with an entrance constriction

The current track velocities in other bays (e.g. Gunnamatta Bay; Figure 6.12 and Salt Pan Creek; Figure 6.13) which had a narrow channel at the mouth of the bay exhibited higher current speeds than experienced in the open bays (Figures 6.12 and 6.13). The main ebb current pathway is along the same side of the bay as the location of the narrow entrance

channel. Consequently, this is the main pathway for fine particles and trace elements with most deposition being in deeper sites in the bay. Some evidence for wind wave resuspended sediments and re-deposition on lee shores is present for the upper sections of Gunnamatta Bay.



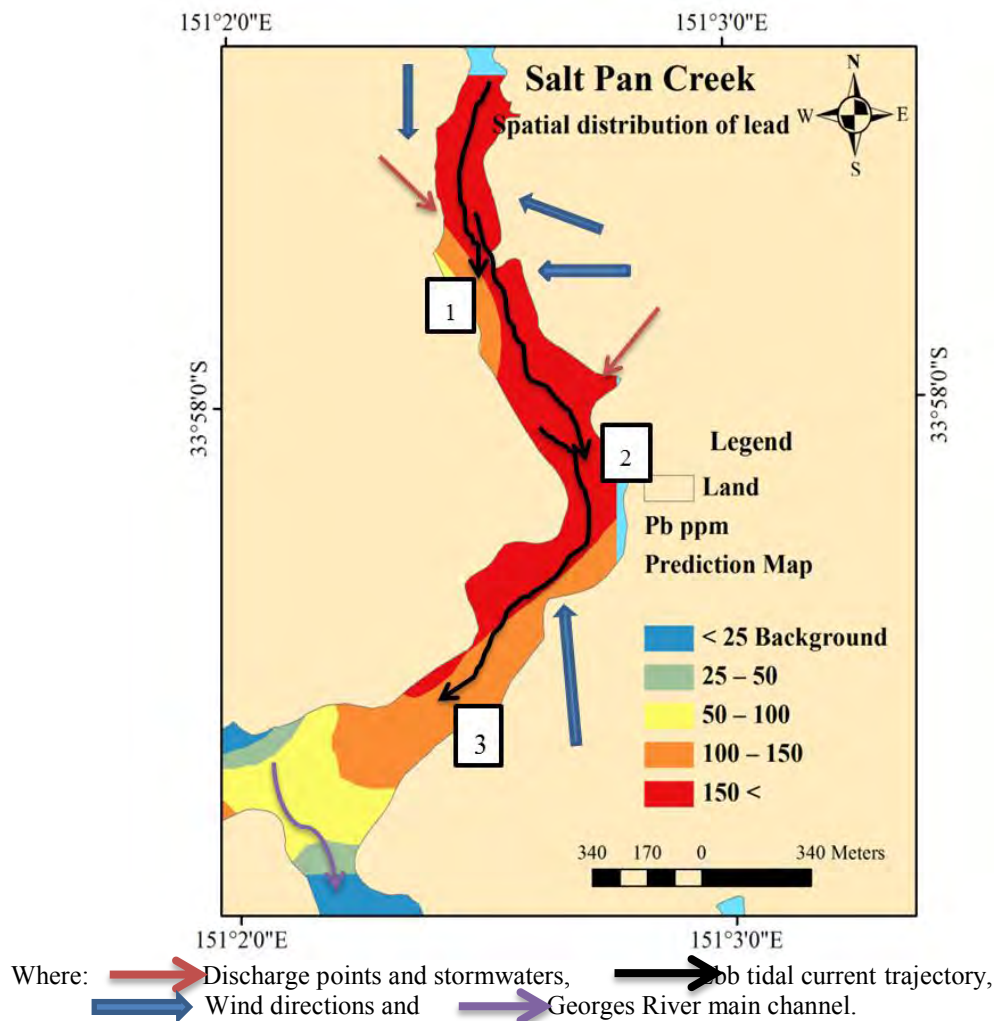


Figure 6.13: Sketch of main processes controlling and distribution of fine sediments and trace elements (e.g. Pb ppm) in Salt Pan Creek.

6.6 Conclusions

Measuring hydrodynamic activity provides a practical method to gain insight into the distribution of sediments and trace elements in the study areas. For several reasons, drogues were used to determine current track velocities. They are cost-effective; the materials to construct drogues are commonly available and simple GPS tracking instruments are widely available and easily used. Thus this methodology is available for use in isolated areas where local current maps and other more complex methods are not available or technically unsuitable. A portable XRF may be used for a first-order evaluation of trace element composition and, with the mapping of current velocities; inferences can be made about the distribution of trace elements as well as the forces effecting this distribution.

Chapter 7

Discussion of trace elements distribution models

7.1 Introduction

This chapter discusses, through statistical analysis, the features of the trace elements and sediments in both Botany Bay and Port Hacking. Sources of contamination are also discussed as well as the effects of hydrodynamic activities on the distribution of trace elements. Further, the extent of anthropogenic pollution is evaluated by comparison of the results with standard values such as Australian and New Zealand guidelines and the concentrations of trace elements in other estuaries which have similar geological conditions. Also, it discusses ecological risk assessment for culturing oysters in the study areas. In addition, possible management option treatments for discharge points have been addressed.

7.2 Sediment quality

7.2.1 Current study and published literature in estuaries worldwide

Most estuaries and embayments around the world are typically polluted by trace elements derived from different sources such as illegal discharges, waste dumps, sewage flows, road dust and atmospheric deposition from gasoline fumes and industrial activities. The results of trace element concentrations are summarized in Table 7.1.

As shown in Table 7.1, there is considerable variation between trace element concentrations in the study areas and trace elements in the estuaries around the world. This is because of several reasons; the sediment types, chemistry, physical, hydrology characteristics of the water, the sources and amounts of pollution discharged into the bays (e.g. industrial activities, farming, fishing and transportation as well as residential, commercial and agricultural), background concentrations of trace elements and possibly the use of different analytical methods to estimate the concentrations of trace elements. As a result, the behaviour of trace elements is varied in many estuaries and bays around the world. The different concentrations of trace elements in the various countries in Table 7.1 reflects differing industrial and other use concentrations in areas with varying concentrations of developments, as well as pollutant control measures.

Table 7.1: Comparison of trace elements in sediments with various other coastal regions around the world.

Sites	Country	Cr ppm	Co ppm	Ni ppm	Cu ppm	Zn ppm	Cd ppm	Pb ppm	References
Tyne Estuary	UK	46	11	34	92	421	2.2	187	(Bryan and Langston, 1992)
Humber Estuary	UK	77	16	39	54	252	0.5	113	(Bryan and Langston, 1992)
Bremen Bay	Germany	131	NA	60	87	790	NA	122	(Hamer and Karius, 2002)
Gulf of Naples	Italy	NA	NA	6.93	27.2	602	0.57	221	(Romano et al., 2004)
Coastal Bohai Bay	China	NA	NA	NA	38.5	131.1	0.22	34.7	(Gao and Chen, 2012)
Fanga'uta Lagoon	Tonga	NA	NA	11-14	7-15	13-38	<0.1-0.1	3-8	(Morrison and Brown, 2003)
Bengal Bay	India	194.8	8.1	38.6	506.2	126.8	6.6	32.3	(Raj and Jayaprakash, 2008)
Mannar Gulf	India	177	15	24	57	73	0.16	16	(Jonathan et al., 2004)
Tokyo Bay	Japan	77.3	NA	32.6	53.4	322	0.99	50.7	(Fukushima et al., 1992)
Masan Bay	Korea	67.1	NA	28.8	43.3	206.3	NA	44	(Hyun et al., 2007)
New York Harbor	USA	175	NA	33-40	105-131	188-244	1-2	109-136	(USEPA et al., 1999)
Estero Salado, Ecuador	South America	94.5	20.8	82.2	253.8	678.3	1.9	81.3	(Fernández-Cadena et al., 2014)
Jurujuba sound	Brazil	89	NA	48	51	158	NA	61	(Baptista Neto et al., 2000)
Gorgan Bay	Iran	32	NA	29.2	18	42.1	NA	11.5	(Bastami et al., 2012)
Izmit Bay	Turkey	74.3	NA	NA	67.6	930	NA	102	(Pekey, 2006b)
Red Sea	Egypt	NA	14.1	22	108	NA	1.8	25	(El-Said and Youssef, 2013)
Botany Bay									
Range	Australia	3-126	0.1-28	0.7-38	2-138	7-788	0.1-2	3-267	
Mean		39±27	8±5	13±8	30±23	157±127	1±1	67±56	Present study
Port Hacking									
Range	Australia	ND	0.8-94	0.4-27	2-398	2-417	0.1-14.4	0.3-203	
Mean			5±9	6±6	26±41	64±84	2.9±3	32±42	

NA= Not available and ND= Not determined (some sample were crushed using Cr-Tema giving extreme values).

7.2.2 Sediment Quality Guidelines

In this study the range and mean values of the trace element concentrations in marine sediment samples were compared with the ANZECC and NHMRC (1992) and ANZECC and ARMCAZ (2000) Sediment and Water Quality Guidelines. This comparison determined whether the trace elements were within acceptable ranges (low risk), between low and high triggers values, or exceeded the high trigger values that require further investigation according to the national guidelines. The main objective of this study was to find base line information on the health of embayments in Botany Bay and Port Hacking, in order to facilitate future evaluations of these and other estuaries. Adverse biological effects of trace elements are occasionally detected between the low and high values in the ANZECC and ARMCAZ (2000) guidelines.

According to ANZECC and ARMCAZ (2000) protocols, the anthropogenic pollution of trace elements such as Cr, Ni, Cu, Zn, As, Cd, Hg and Pb within the sediments of the study areas were generally below the interim sediment quality guideline values (ISQG-low) except for metals like Pb in Kogarah Bay, Oyster Bay, Salt Pan Creek, North West Arm and Yowie Bay; Cu and Ni in Salt Pan Creek; Zn in Oyster Bay and Salt Pan Creek; as well as Cd and Hg in Salt Pan Creek, Mansion Bay and Gynea Bay (Table 7.4). Furthermore, the trace element concentrations were noted to be between the ISQG-low and high values at some sites in all bays. These concentrations depend on the sources and discharge points as well as boatyards and watercraft. However, Zn in Salt Pan Creek exceeded the ISQG-high value. In addition, trace element concentrations, especially Cu, Zn and Pb, exceeded the ISQG-high values in some samples from the study areas, such as KO45, GU55 and GE38 (Table 7.4).

Salt Pan Creek, which is considered to be the most highly polluted by trace elements in the study areas, shows adverse biological effects on many organisms and micro-organisms. The trace element contents in this creek can be correlated with both water depth and muddy particles (silt and clay, Table 7.2), but they have the highest concentrations in the study areas. The reason for this fact is attributed to dumping waste into the creek, for example a chemical industry (i.e. oil refinery) close to the creek discharged waste within it.

Table 7.2: Correlation coefficient of sediment and trace elements in Salt Pan Creek.

Correlations															
	Depth	Sand	Silt	Clay	Cr	Ni	Cu	Zn	As	Br	Rb	Sr	Sn	Ba	Pb
Depth	1.0000	-0.4979	0.3698	0.7686	-0.1856	-0.2702	-0.5218	-0.7024	0.3530	-0.1631	0.4641	-0.5783	-0.8182	-0.4253	-0.0373
Sand	-0.4979	1.0000	-0.9806	-0.7720	0.3779	0.4887	0.6461	0.6974	-0.3585	0.0928	-0.5302	0.0585	0.3872	0.2063	-0.2545
Silt	0.3698	-0.9806	1.0000	0.6325	-0.4651	-0.5773	-0.6883	-0.6868	0.3346	-0.0224	0.4421	0.1053	-0.2943	-0.0766	0.3092
Clay	0.7686	-0.7720	0.6325	1.0000	0.0149	-0.0590	-0.3213	-0.5290	0.3317	-0.2945	0.6618	-0.5731	-0.5760	-0.5669	0.0030
Cr	-0.1856	0.3779	-0.4651	0.0149	1.0000	0.9584	0.8569	0.6209	-0.6425	-0.0268	-0.0424	-0.4815	0.1222	-0.4769	-0.7431
Ni	-0.2702	0.4887	-0.5773	-0.0590	0.9584	1.0000	0.9261	0.7543	-0.5764	0.0484	-0.0321	-0.3882	0.3000	-0.3741	-0.6227
Cu	-0.5218	0.6461	-0.6883	-0.3213	0.8569	0.9261	1.0000	0.8012	-0.4822	-0.0028	-0.1879	-0.2056	0.4656	-0.1383	-0.4479
Zn	-0.7024	0.6974	-0.6868	-0.5290	0.6209	0.7543	0.8012	1.0000	-0.5843	0.2097	-0.3913	0.1156	0.6695	0.0160	-0.3572
As	0.3530	-0.3585	0.3346	0.3317	-0.6425	-0.5764	-0.4822	-0.5843	1.0000	-0.5083	0.4428	-0.1443	-0.2051	0.4002	0.8810
Br	-0.1631	0.0928	-0.0224	-0.2945	-0.0268	0.0484	-0.0028	0.2097	-0.5083	1.0000	-0.0958	0.6253	0.4270	0.1464	-0.2507
Rb	0.4641	-0.5302	0.4421	0.6618	-0.0424	-0.0321	-0.1879	-0.3913	0.4428	-0.0958	1.0000	-0.2622	-0.0194	-0.0086	0.3063
Sr	-0.5783	0.0585	0.1053	-0.5731	-0.4815	-0.3882	-0.2056	0.1156	-0.1443	0.6253	-0.2622	1.0000	0.6232	0.4964	0.2690
Sn	-0.8182	0.3872	-0.2943	-0.5760	0.1222	0.3000	0.4656	0.6695	-0.2051	0.4270	-0.0194	0.6232	1.0000	0.5374	0.2043
Ba	-0.4253	0.2063	-0.0766	-0.5669	-0.4769	-0.3741	-0.1383	0.0160	0.4002	0.1464	-0.0086	0.4964	0.5374	1.0000	0.7072
Pb	-0.0373	-0.2545	0.3092	0.0030	-0.7431	-0.6227	-0.4479	-0.3572	0.8810	-0.2507	0.3063	0.2690	0.2043	0.7072	1.0000

The South West Arm and Hacking River in Mansion Bay have the lowest concentrations of trace elements compared with other sites in the study areas (Table 7.4). This is because of several facts: firstly, the South West Arm and Hacking River are considered to be natural ecosystems, in the other words they are free from residential areas and discharge points. Secondly, they are a less attractive area with very low numbers of watercraft. Finally, the sediment fractions in these areas are dominated by sand particles. Therefore, they have the lowest concentration of trace elements since the trace elements have positive relationships with muddy particles (Table 7.3 and Attached Appendix 4.3).

Table 7.3: Correlation coefficient of sediment and trace elements in South West Arm.

Correlations														
	Depth	Sand	Silt	Clay	Ni	Cu	Zn	As	Br	Rb	Sr	Sn	Ba	Pb
Depth	1.0000	-0.7463	0.7385	0.7981	0.4873	0.4432	0.4847	0.6125	0.5014	0.5084	0.9121	-0.3973	0.5567	0.5276
Sand	-0.7463	1.0000	-0.9998	-0.9880	-0.8748	-0.8880	-0.9118	-0.9325	-0.8995	-0.9179	-0.9172	0.4685	-0.8915	-0.9373
Silt	0.7385	-0.9998	1.0000	0.9848	0.8762	0.8922	0.9153	0.9326	0.9033	0.9207	0.9112	-0.4630	0.8915	0.9406
Clay	0.7981	-0.9880	0.9848	1.0000	0.8513	0.8419	0.8717	0.9187	0.8569	0.8829	0.9522	-0.5052	0.8789	0.8980
Ni	0.4873	-0.8748	0.8762	0.8513	1.0000	0.9359	0.9182	0.9207	0.8812	0.8688	0.7079	-0.4091	0.7932	0.9111
Cu	0.4432	-0.8880	0.8922	0.8419	0.9359	1.0000	0.9903	0.9585	0.9687	0.9487	0.6610	-0.3887	0.8561	0.9841
Zn	0.4847	-0.9118	0.9153	0.8717	0.9182	0.9903	1.0000	0.9663	0.9686	0.9764	0.7080	-0.4728	0.8892	0.9952
As	0.6125	-0.9325	0.9326	0.9187	0.9207	0.9585	0.9663	1.0000	0.9285	0.9394	0.7988	-0.5070	0.9093	0.9645
Br	0.5014	-0.8995	0.9033	0.8569	0.8812	0.9687	0.9686	0.9285	1.0000	0.9244	0.6867	-0.3490	0.8268	0.9755
Rb	0.5084	-0.9179	0.9207	0.8829	0.8688	0.9487	0.9764	0.9394	0.9244	1.0000	0.7391	-0.5385	0.9215	0.9797
Sr	0.9121	-0.9172	0.9112	0.9522	0.7079	0.6610	0.7080	0.7988	0.6867	0.7391	1.0000	-0.5403	0.7907	0.7443
Sn	-0.3973	0.4685	-0.4630	-0.5052	-0.4091	-0.3887	-0.4728	-0.5070	-0.3490	-0.5385	-0.5403	1.0000	-0.5661	-0.4638
Ba	0.5567	-0.8915	0.8915	0.8789	0.7932	0.8561	0.8892	0.9093	0.8268	0.9215	0.7907	-0.5661	1.0000	0.8957
Pb	0.5276	-0.9373	0.9406	0.8980	0.9111	0.9841	0.9952	0.9645	0.9755	0.9797	0.7443	-0.4638	0.8957	1.0000

7.2.3 Comparison with other Australian estuaries

The trace element concentrations in the study areas were also compared with selected polluted and non-polluted estuaries in Australia and with two previously studied bays in the same study areas. The results have been addressed in Table 7.4.

Table 7.4: Comparison of sedimentary trace element concentrations in the study areas with previous studies in Australian estuaries and Interim Sediment Quality Guideline values. **1** (Birch et al., 1996), **2** (Pease, 2007), **3** (Aljawi, 2010), **4** (Irvine and Birch, 1998), **5** (Jones et al., 2003a), **6** (Jafari, 2009), **7** (Crawford et al., 1976), **8** (Roy and Crawford, 1984), **9** (Killian, 1999), and **10** (Birch et al., 1997), **11** (Batley and Chenhall, 1994) and **12** (ANZECC and NHMRC, 2000).

Trace elements Sites	Cr ppm	Co ppm	Ni ppm	Cu ppm	Zn ppm	As ppm	Cd ppm	Hg ppm	Pb ppm
Kogarah Bay *									
Range	7-91	3-21	1-28	5-100	11-433	2-28	0.1-2	0.3-1	5.4-235
Mean ±SD	33±24	7±4	12±7	37±24	158±99	12±8	1.2±0.8	0.8 ± 0.3	87±60
Woolooware Bay *									
Range	6-99	3-20	1.1-26	9-58	8-314	1.2-22	0.1-2	0.3-2.2	3.3-104
Mean ±SD	43±24	9±5	12±7	21±2	116±74	11±6	1.3±0.7	0.9 ± 0.3	37±24
Oyster Bay *									
Range	9-127	3-28	7-39	10-63	43-386	1.9-26	0.1-2	0.3-3	14-198
Mean ±SD	51±32	10±6	19±7	35±13	204±84	15±6	1.2±0.8	1 ± 0.4	98±48
Botany Bay 1									
Range	NA	NA	NA	<50->200	<200->1500	NA	NA	NA	<100->400
Oatley Bay 2									
Range	7.9-130	4.4-20	6.6-30	7-156.6	38-915	6-42	2-2		14-582.2
Mean ± SD	40 ± 22	11 ± 5	14.5 ± 5	40 ± 25	196 ±134	23 ± 8	2 ± 2	NA	117 ± 81
Background values 2	33.5	NA	12.6	9.1	42	19.5	<1	NA	23.4
Woronora River *									
Range	4-84	25	0.7-24	3-55	9-329	1-19	0.1-2	0.3-1.3	4-105
Mean ±SD	33± 25	6± 5	10±7	19±16	92±87	6±5	1.3±0.7	0.8 ± 0.3	30±28
Georges River *									
Range	4-68	0.7-17	1.3-27	3-60	11-431	2-20	0.1-2	0.3-1	4-154
Mean ±SD	27±19	6±4	10±7	23±17	132±113	8±6	1.3±0.8	0.9 ± 0.3	48±54
Salt Pan Creek *									
Range	24-86	6-16	17-30	74-138	349-789	11-26	0.1-2	0.3-1	138-268
Mean ± SD	57±23	10±3	23±5	102±21	556±144	16±4	2±0.7	0.7±0.3	188±38
Gunnamatta Bay *									
Range	4-107	3-15	0.4-20	3-398	6-413	1-12	0.1-3	0.4-3	2-203
Mean ± SD	27±27	5±2	6±5	41±59	65±77	4±3.1	1.4±0.7	1.2 ± 0.7	32±37
Gymea Bay *									
Range	6-94	2-33	2-25	4-61	11-224	1-14	0.2-2	0.3-95	5-113
Mean ± SD	29±27	7±7	8±8	19±20	65±72	6±4	1.5±0.6	4 ± 16.6	34±38
Burraneer Bay 3									
Range	ND	3	0.4-27.2	2-232	5-179	1.6-13	0.1-53	0.3-17.2	1.4-101
Mean ± SD		3 ± 3	5.1 ± 6	24± 37	46 ± 43	5 ± 3	8.6 ± 12	0.9 ± 2.1	27 ± 23
South West Arm *									
Range	2-70	3-5	0.8-16	2-50	3-164	1-13	0.2-7	0.4-2.5	0.3-73
Mean ±SD	15±22	3-0.5	5±3	8±10	18±37	3±3	2±2	1.1 ± 0.5	8±17
Mansion Bay - Hacking River *									
Range	ND	0.8-95	1-24	2-53	6-177	1-18	0.1-7.3	0.3-1	2-85
Mean ± SD		9±20	6±7	10±14	30-48	4±5	2±2	1 ± 0.2	13±23
North West Arm *									
Range	ND	8-9	1.6-23	4.2-77	27-417	2.2-14	8-14	0.5-2.3	11-159
Mean ± SD		5±2	13±9	36±32	186±168	8±5	10±5	1±1	74±67
Yowie Bay *									
Range	ND	3-11	2-20	5-107	15-304	2-17	6-12	0.5-3	6-177
Mean ± SD		4±2	10±7	35±29	110±87	8±4	9±2	1.4 ± 0.8	65±53
Sydney Harbour 4									
Range	7-698	3-60	17-86	13-1078	46-2246	NA	NA	NA	44-1319
Mean	118	19	38	124	548				268
Derwent estuary 5									
Range	<5-183	8-95	<2-35	<2-1182	<2-22593	1-657	<10-180	<6-36	4-3866
Mean ±SD	63±33	32±15	16±1	106±184	2103±3897	51±97	14±33	6±8	580±763

Huon River 5									
Range	50-80	15-35	<2-28	7-32	<2-66	4-25	<10	<5	<2-48
Mean± SD	71± 8	25± 7	20± 6	17± 6	40± 18	16± 6	<10	<5	25± 12
Port Kembla 6									
Mean	58	NA	16	324	358	9	12	NA	115
Macquarie Lake 7									
Range	NA	NA	NA	<5-2250	40-1500	NA	<2-1700	NA	<5-4250
Cockle Creek 8									
Maximum	NA	NA	NA	305	6250	NA	600	NA	6000
Burrill Lake 9									
Range	NA	1-24	3-20	5-80	3-82	2.9-22	NA	NA	0-32
Mean± SD		9±1.6	11±4	32±24	29±23	11±6			13±9
Port Hunter 10									
	21-167	14-41	44-156	19-283	32-5161	NA	<0.1-8	NA	25-843
Griffins Bay 11									
				25-40	300-500		NA	NA	60-70
ISQG / Low 12									
	80	NA	21	65	200	20	1.5	0.15	50
ISQG / High 12									
	370	NA	52	270	410	70	10	1	220

ND= Not determined (samples were crushed by Cr steal Tema and had extreme values of chromium), NA= Not available and * study area sites.

The mean values of trace element pollution for Cu, Zn and Pb in the surface sediments of the study areas, except the samples from the South West Arm, Mansion Bay and Hacking River, had high concentrations compared with both the Huon estuary and Burrill Lake (Killian, 1999; Jones et al., 2003a). This is because the surface sediments in both the Huon estuary and Burrill Lake were dominated by clean fine to medium sand fractions (high proportion of sand), low percentages of organic matter, and their catchment areas are non-industrialised and relatively free of concentrated urban development (Killian, 1999; Jones et al., 2003a). Moreover, the results of these metals in the current study are slightly higher in comparison with a previous study in Botany Bay (Birch et al., 1996). Surface sediments in both South West Arm and Hacking River had lower concentrations of trace elements compared with the Huon estuary and Lake Burrill. As discussed above (sediment quality guideline) the South West Arm and Hacking River are considered to represent a natural background. Trace element concentrations for Cr, Co, Ni, Cd and As in surface sediments from the Huon River were high compared with all study areas, except for Ni in Salt Pan Creek and As in Oatley Bay (Table 7.4). This is because of the large amount of dolerite in the source rock in the Huon River releasing metals as it weathers.

Furthermore, surface sediments in Salt Pan Creek were extremely concentrated in trace elements compared with the Huon estuary and Burrill Lake (e.g. 3x times for Cu, 14x times for Zn and 7x times for Pb). This was caused by dumping waste from a chemical industry (i.e. oil refinery), and for this reason Salt Pan Creek is markedly more polluted compared to other sites in the study areas. However, the values of trace elements in

surface sediments from the study areas had low concentrations in comparison to previous studies in Sydney Harbour, Derwent River, Macquarie Lake, Cockle Creek, Port Kembla, Port Hunter and Griffins Bay, except for Zn and Pb in Salt Pan Creek. This is because of many reasons: firstly, surface sediments in Sydney Harbour (Irvine and Birch, 1998) and Derwent River (Jones et al., 2003a), have been subject to large amounts of contamination from urban, industrial and commercial activities, such as a zinc refinery, stormwater runoff, mine discharges, sewage effluent and watercraft, as well as leaching from reclamation areas. Lake Macquarie and Cockle Creek (Crawford et al., 1976; Roy and Crawford, 1984) have received trace element pollutants from a lead-zinc smelter, galvanized iron roofs, copper water pipes, vehicles exhausts, and discharge from sewerage treatments. Moreover, the sources of trace elements in Lake Illawarra emerged from industrial discharges (especially the copper refinery), atmospheric deposition, leaching of sediments and other terrestrial deposits, which eroded from sediments and in runoff from roads and freeways (Batley and Chenhall, 1994).

Secondly, sediment texture, which usually concentrates high percentages of mud particles in the deeper sites. In other words, fine and very fine particles can absorb and accumulate the trace elements by several processes such as absorption and ion exchange and they contain high proportions of pyrites, which indicated anoxic conditions that favour trapping of trace elements. Finally, the higher wave energy conditions near the shoreline transport fine material from the coast toward deeper areas (Matthai and Birch, 2000; Birch et al., 2001; Birch and Rochford, 2010).

7.3 Characteristics and depositional environments of sediments in the study areas

The present study was designed to determine the effect of trace element pollution on estuarine environments. The complete results of these statistical analyses are shown in (Appendix 4 and Attached Appendix 4.3). Figure 7.1 illustrates the results of Q-mode statistical analysis (HCA and PCA) for Gunnamatta Bay as an example (all the other sites are given in Appendix 4). The results of the Q-mode analyses are represented by maps in order to allow ease of interpretation and discussion (Figures 7.2, 7.3 and 7.4a-m). Also, the mean and standard deviation for the classification of each element for each cluster in all the study areas are illustrated in Tables 7.5 and 7.6.

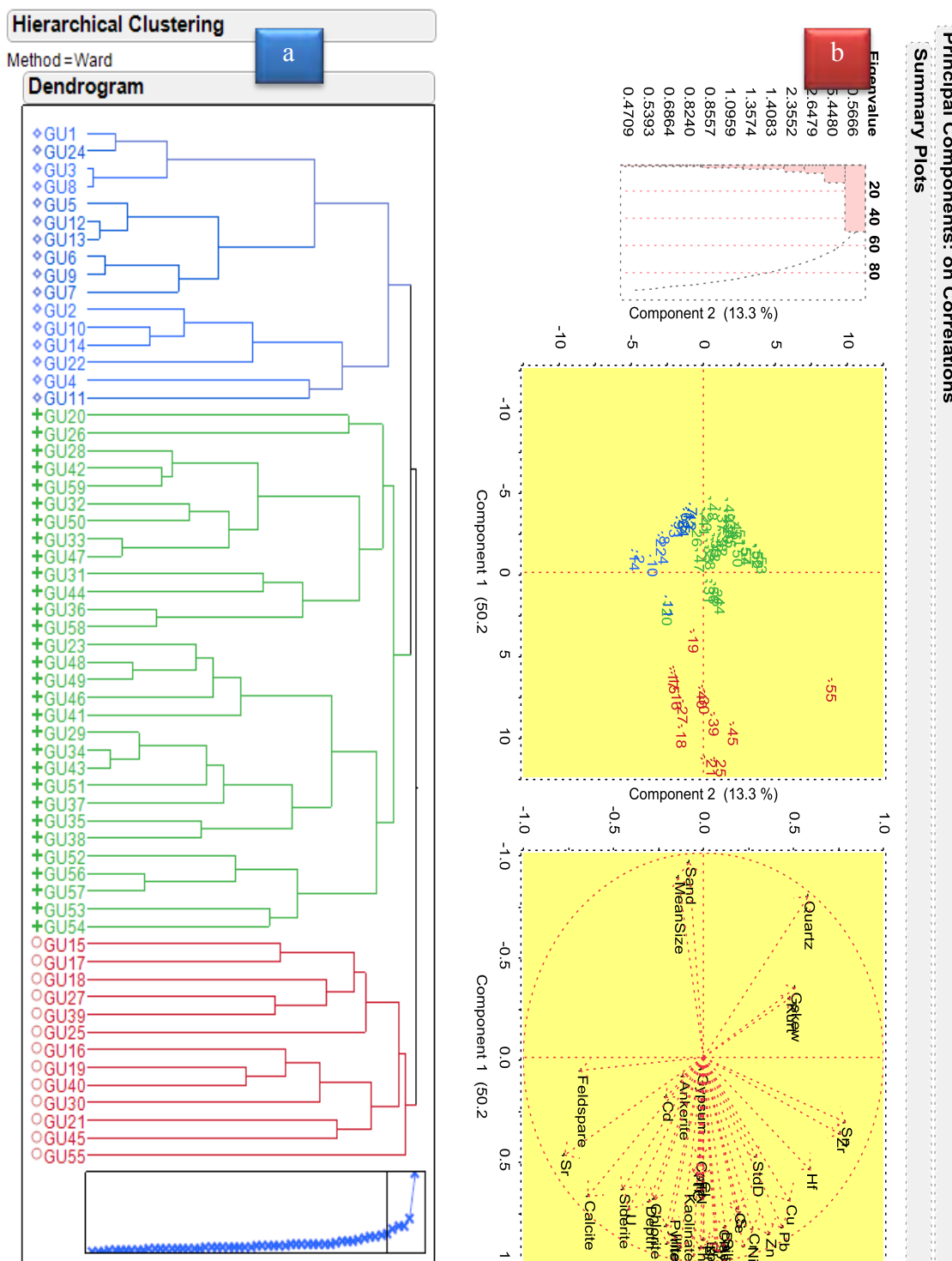


Figure 7.1: Statistical analysis of Q-mode a- hierarchical cluster analysis (HCA) and b principle components analysis (PCA) in (e.g. Gunnamatta Bay).

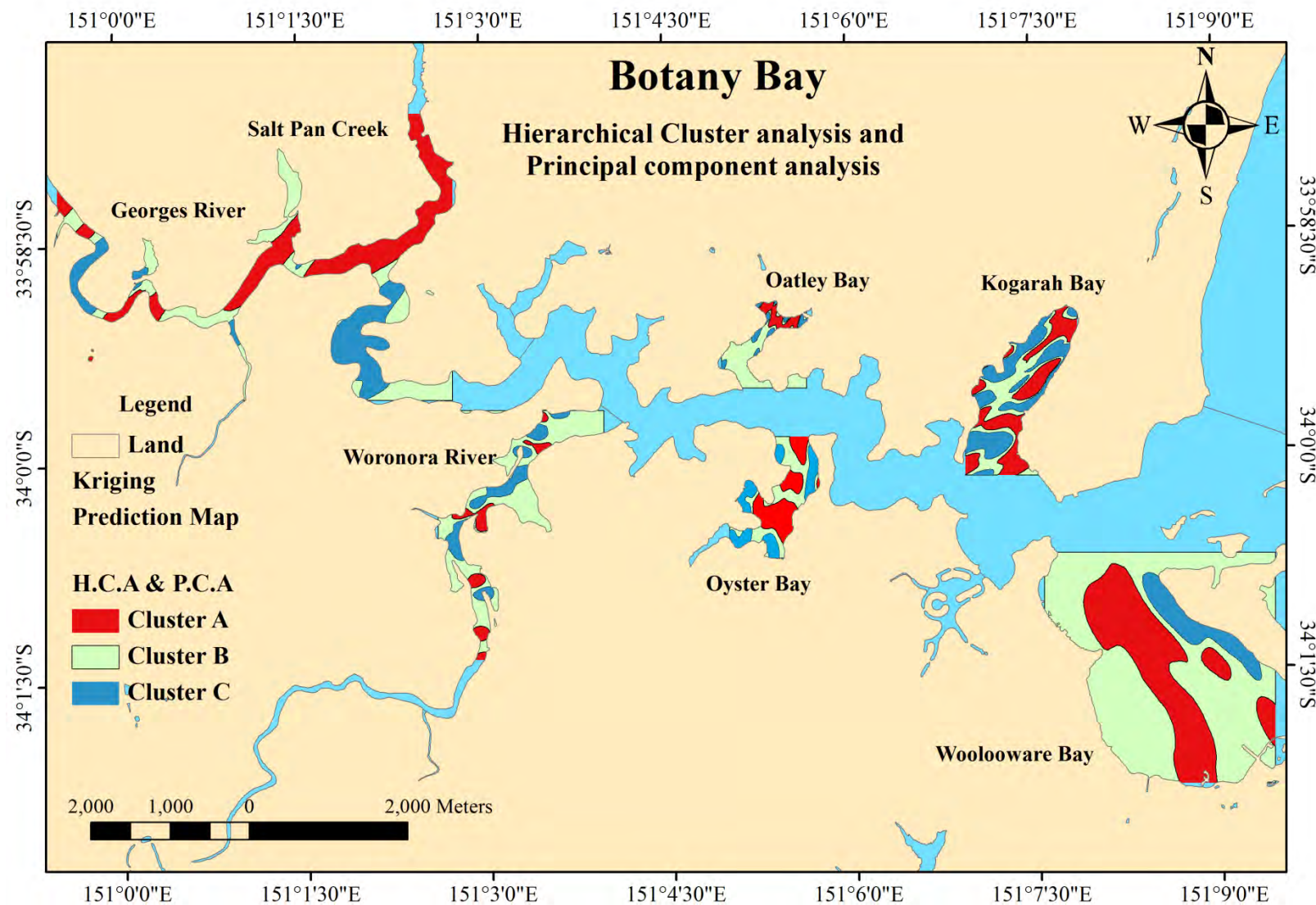


Figure 7.2: Q-mode statistical analysis (HCA and PCA) within embayments in Botany Bay.

Table 7.5: Mean and standard deviation of the variables in the clusters from Botany Bay computed by hierarchical cluster analysis.

	Kogarah Bay			Oatley Bay			Woolooware Bay			Oyster Bay			Woronora River			Georges River		
	Cluster A (22)*	Cluster B (19)	Cluster C (18)	Cluster A (18)	Cluster C (36)	Cluster C (11)	Cluster A (11)	Cluster B (28)	Cluster C (6)	Cluster A (16)	Cluster B (18)	Cluster C (21)	Cluster A (10)	Cluster B (23)	Cluster C (14)	Cluster A (24)	Cluster B (16)	Cluster C (14)
Depth																		
Mean	2.3	3.1	1.1	1.78	1.57	0.95	2.6	1.7	1.0	1.1	1.0	0.7	1.4	1.2	1.6	3.9	6.8	4.2
SD	1.0	0.9	0.5				0.9	0.5	0.2	0.6	0.4	0.4	1.3	1.2	1.2	3.4	4.5	3.7
Sand																		
Mean	23.9	7.1	81.6	6.5	18.1	57.6	15.8	38.0	90.7	7.1	9.3	36.9	15.1	55.3	92.1	10.2	49.8	92.7
SD	20.6	7.5	16.5	4.9	10.1	13.5	4.0	15.8	7.7	6.7	8.4	17.5	10.0	13.3	4.9	5.5	19.9	6.4
Silt																		
Mean	61.7	74.6	14.9	83.9	69.8	37.3	70.8	51.3	8.0	75.3	74.1	50.3	70.5	35.4	6.5	74.4	39.9	6.0
SD	16.7	7.0	12.8	5.3	9.1	11.8	4.5	13.3	6.7	5.9	6.8	14.3	10.5	10.9	3.9	5.5	16.6	5.2
Clay																		
Mean	14.3	18.3	3.5	9.6	12.0	5.1	13.3	10.6	1.3	17.6	16.6	12.8	14.4	9.3	1.4	15.4	10.3	1.3
SD	4.9	2.4	3.7	1.7	1.9	2.0	1.3	2.9	1.0	2.2	2.3	3.5	4.3	2.8	1.0	2.6	4.0	1.3
V																		
Mean	72.6	38.4	15.7	--	--	--	80.1	46.9	1.3	29.3	93.1	51.3	99.3	29.1	4.4	60.9	38.9	7.3
SD	33.0	24.4	14.1	--	--	--	33.9	22.5	0.6	12.8	30.4	23.3	13.6	15.6	2.8	28.7	19.4	4.7
Cr																		
Mean	55.7	21.4	17.6	38.2	37.8	41.9	61.9	43.9	7.3	18.6	76.3	55.1	72.8	44.9	7.6	41.9	38.0	8.7
SD	18.4	18.3	8.6	27.8	21.2	11.3	28.4	15.7	1.4	8.8	30.4	22.2	6.6	64.2	2.9	24.2	14.1	4.7
Co																		
Mean	8.7	7.1	4.9	--	--	--	9.8	9.2	4.2	13.0	10.0	7.1	12.7	4.3	3.2	9.6	4.8	3.2
SD	4.3	2.1	4.1	--	--	--	4.7	5.2	1.2	8.3	4.0	3.2	6.1	1.8	1.6	3.9	2.4	1.1
Ni																		
Mean	16.1	15.3	4.3	19.9	12.9	8.8	19.6	11.0	2.9	14.6	24.9	16.0	20.7	9.2	2.4	19.7	11.0	2.5
SD	5.3	3.7	2.3	2.5	2.3	1.9	5.2	4.2	2.1	2.6	6.4	6.3	2.7	4.0	1.9	5.7	4.9	0.9
Cu																		
Mean	51.8	41.1	13.9	63.0	28.2	22.4	33.7	19.7	4.4	31.9	47.6	25.4	45.1	15.0	5.2	64.4	20.1	5.1
SD	22.9	18.1	11.4	15.1	6.0	9.5	7.6	9.2	1.4	4.4	9.4	9.5	8.4	6.1	1.7	33.1	10.2	2.5
Zn																		
Mean	210.7	206.5	42.7	298.9	142.2	99.7	209.6	102.5	10.4	186.0	290.8	144.0	232.7	70.0	15.1	369.7	108.8	23.0
SD	84.2	60.1	31.8	69.1	35.2	47.1	53.0	41.1	3.1	36.8	60.7	63.5	61.2	34.7	4.7	181.0	62.1	10.4
As																		
Mean	12.4	21.0	3.3	29.0	23.4	12.0	18.3	9.8	1.5	22.0	17.3	8.5	15.5	5.4	1.7	15.1	6.6	2.8
SD	4.5	3.3	1.7	5.2	5.5	5.4	3.6	3.5	0.4	3.0	1.9	3.8	2.2	2.2	0.5	3.8	2.9	0.9
Br																		
Mean	200.7	148.9	50.4	152.2	97.7	71.3	315.0	128.3	46.8	131.5	185.9	98.9	235.6	63.3	40.3	169.9	64.5	34.5
SD	111.4	39.0	37.2	38.4	19.0	26.9	100.7	47.3	23.3	23.7	40.9	50.4	110.0	24.2	11.6	61.4	28.0	12.3
Rb																		
Mean	51.5	77.2	14.5	75.6	52.6	24.0	69.4	38.0	12.9	72.6	75.2	34.0	68.6	21.1	9.4	71.6	28.4	11.1
SD	17.4	7.6	6.9	6.7	13.8	5.1	12.1	13.6	2.3	5.4	9.6	14.2	12.4	9.0	2.3	9.9	12.3	2.6
Sr																		
Mean	127.6	137.6	44.2	119.7	92.8	69.8	200.6	155.4	19.1	122.7	122.2	64.5	124.8	39.8	20.6	119.8	64.5	21.5
SD	65.9	17.4	29.7	7.6	31.7	25.2	65.9	129.5	2.7	5.1	9.1	20.5	23.7	14.2	6.9	12.9	62.1	5.4
Cd																		
Mean	1.1	1.4	1.3	--	--	--	1.9	1.3	0.8	1.1	1.2	1.2	1.5	1.2	1.4	1.5	1.1	1.3
SD	0.8	0.8	0.7	--	--	--	0.5	0.7	0.7	0.9	0.8	0.6	0.8	0.7	0.8	0.7	0.8	0.8
Sn																		
Mean	11.3	12.4	10.5	--	--	--	9.3	8.7	6.6	12.3	12.2	9.9	10.8	8.9	7.2	13.2	9.0	7.5
SD	2.6	1.4	4.8	--	--	--	2.0	2.2	1.1	1.4	1.6	1.2	2.1	1.3	1.0	2.6	1.5	1.6
Ba																		
Mean	146.3	187.3	71.2	--	--	--	146.3	103.3	71.5	188.2	177.2	96.8	143.9	59.9	42.1	197.6	94.1	52.7
SD	67.9	12.5	39.9	--	--	--	18.5	25.3	7.5	15.8	16.4	31.7	22.9	16.2	9.2	23.0	31.4	8.3
Ce																		
Mean	49.7	72.6	10.5	--	--	--	64.3	34.6	8.7	72.5	69.6	34.5	61.1	28.7	12.2	61.4	32.9	14.6
SD	23.8	16.0	15.3	--	--	--	17.0	25.0	13.8	24.6	11.9	18.7	7.5	18.6	10.2	22.5	23.6	11.1
Pb																		
Mean	85.2	142.2	20.5	174.2	94.4	45.0	69.3	31.1	4.1	149.8	109.7	47.3	76.9	23.8	6.1	135.8	30.4	7.9
SD	34.6	47.7	12.7	28.1	38.2	24.9	15.4	10.8	0.7	28.3	16.2	19.5	18.8	11.3	1.5	51.1	15.5	4.2

*Number of sample.

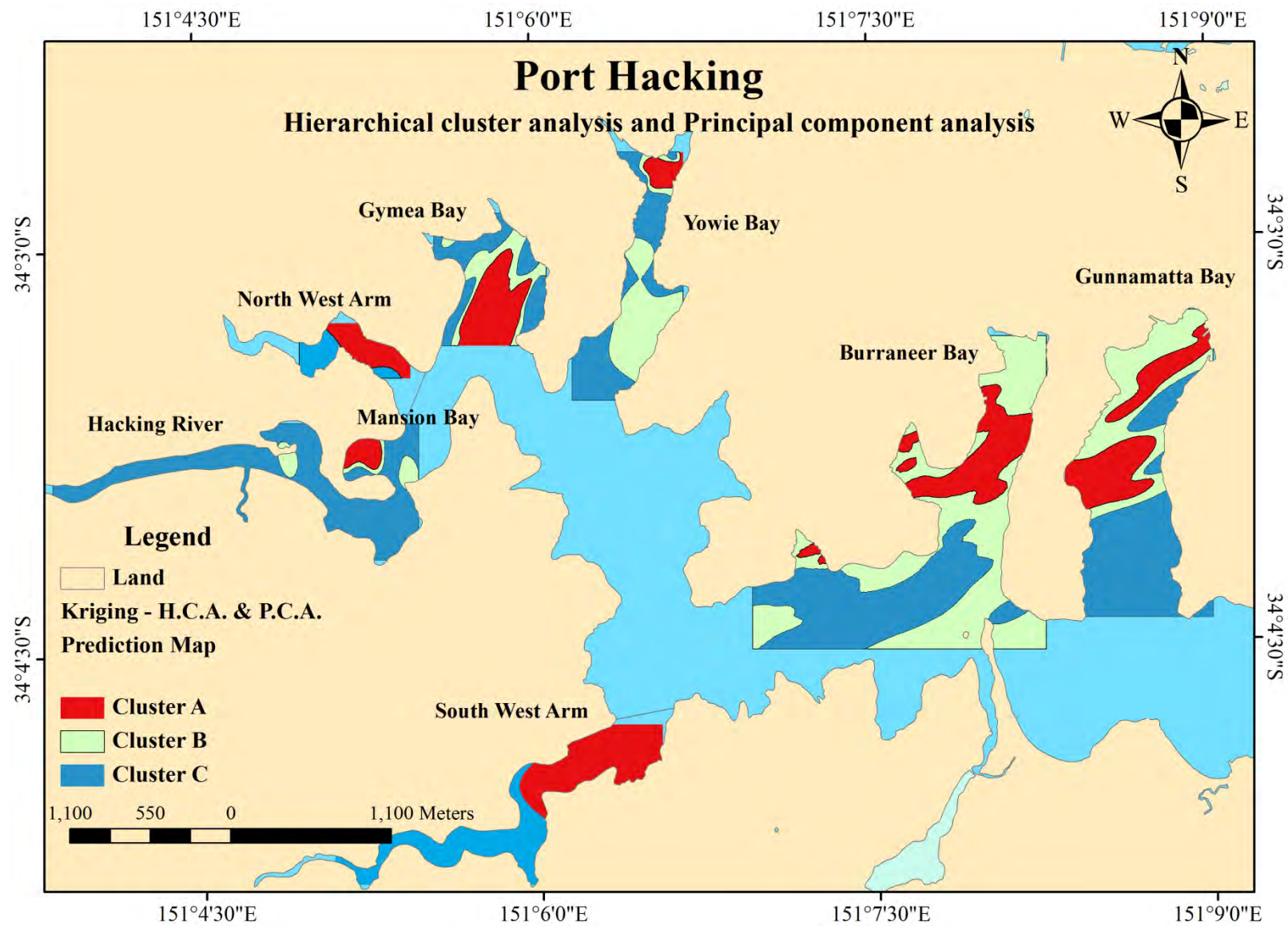
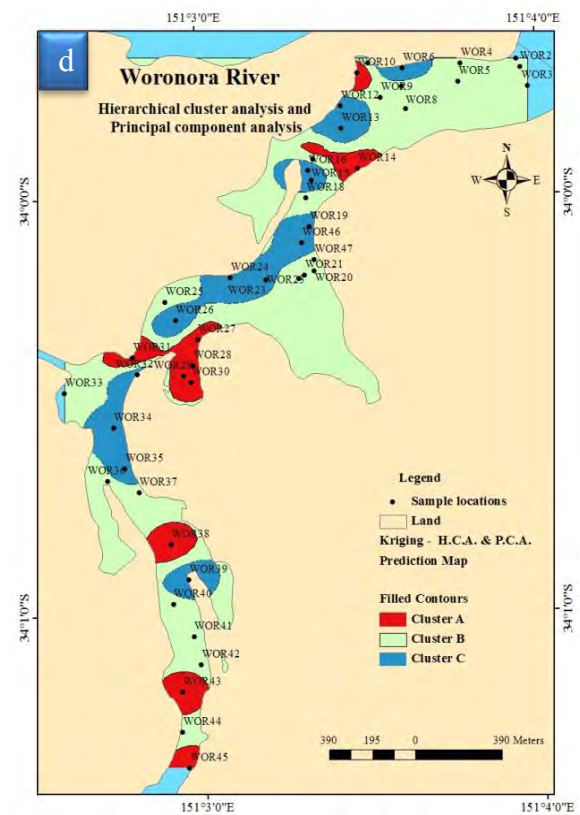
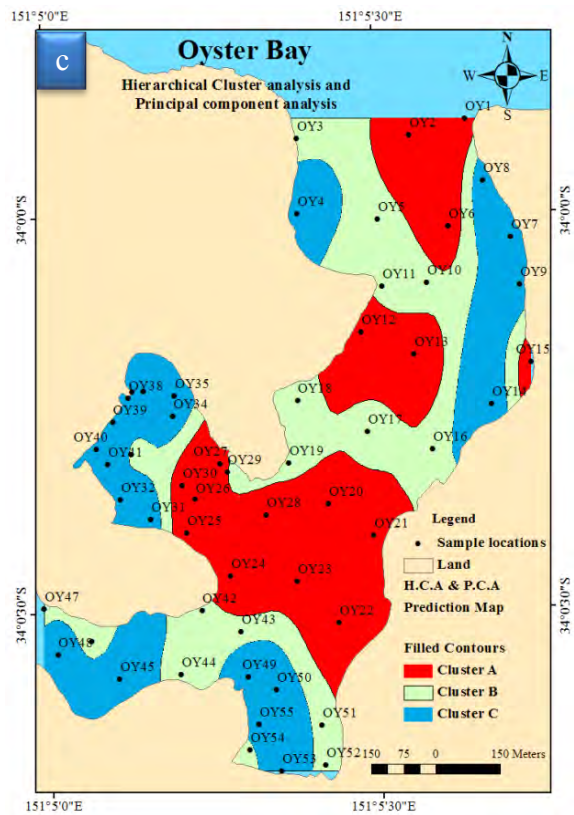
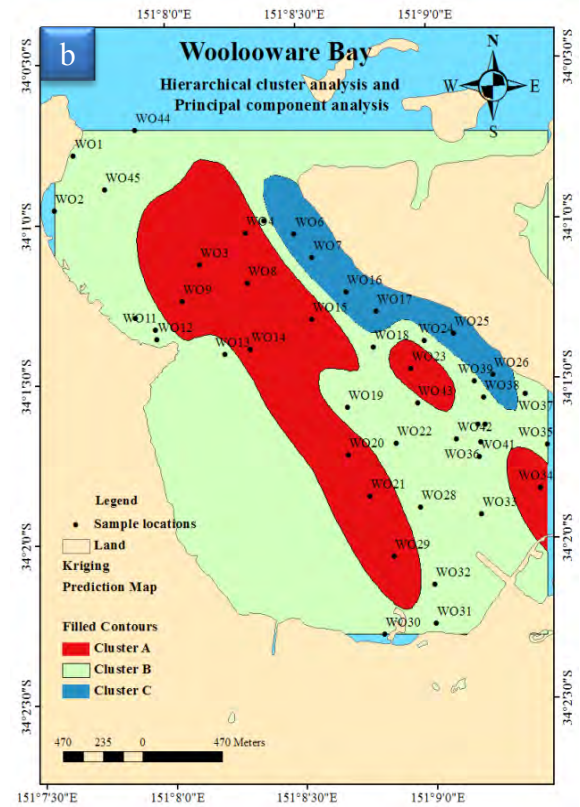
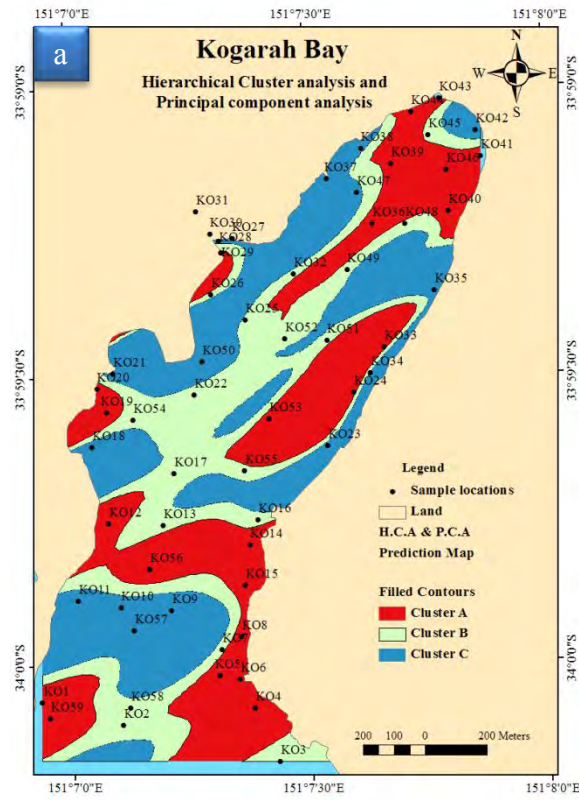


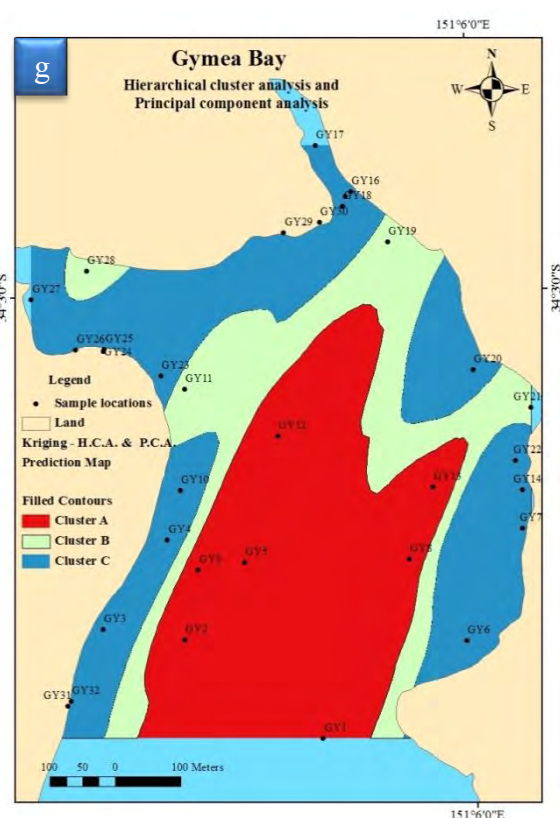
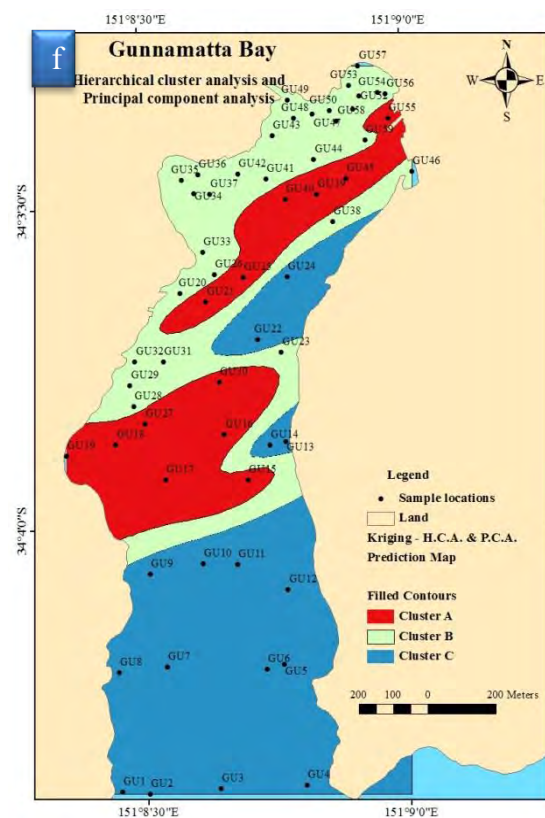
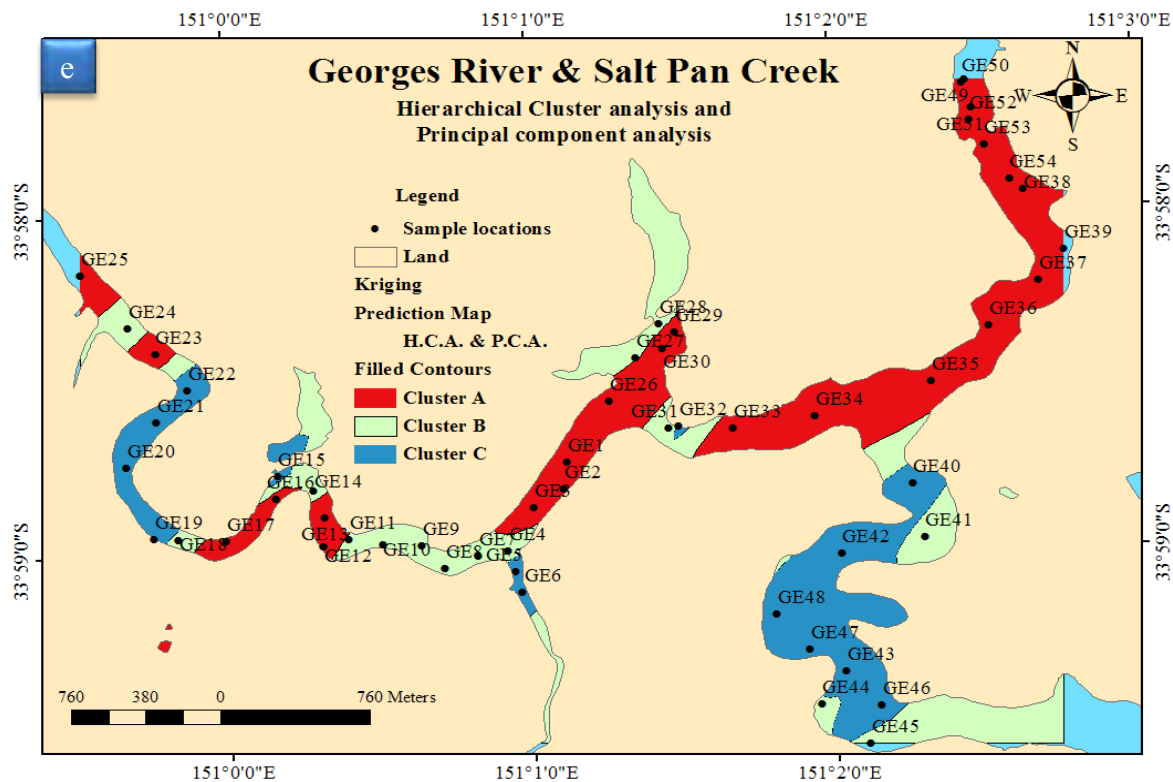
Figure 7.3: Q-mode statistical analysis (HCA and PCA) within embayments in Port Hacking.

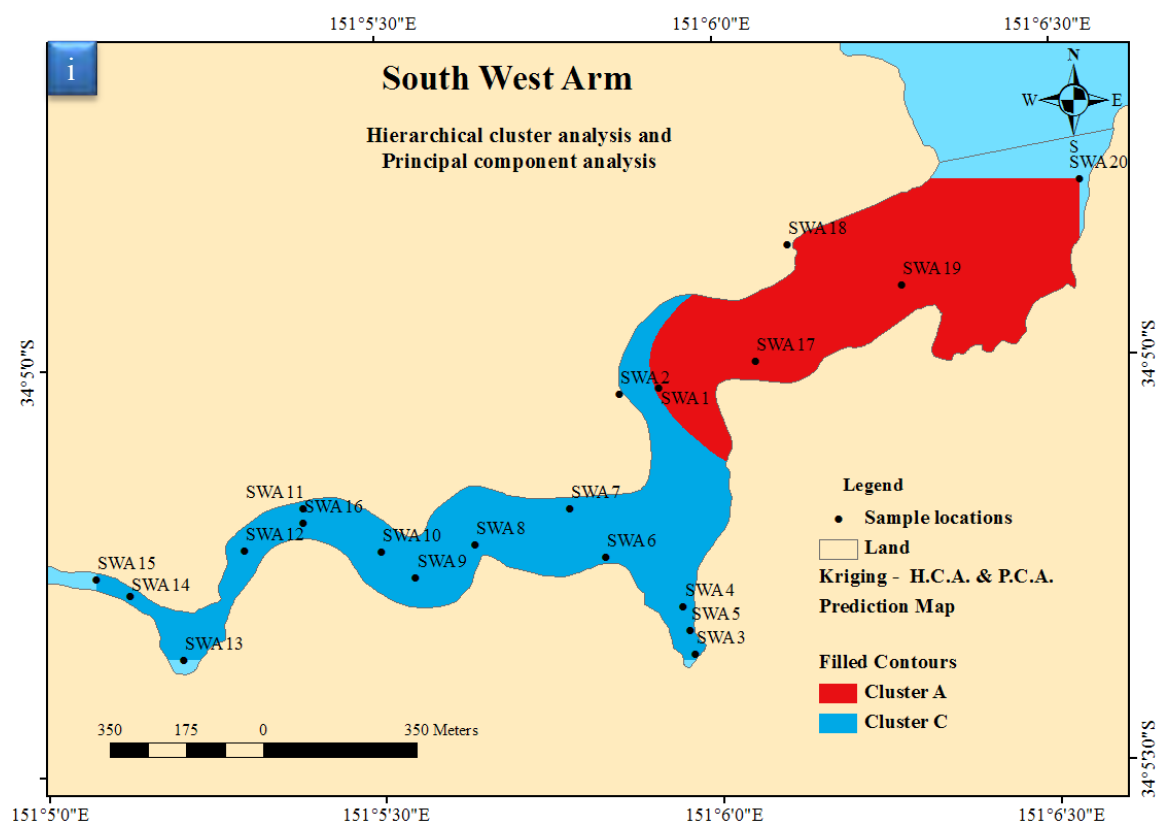
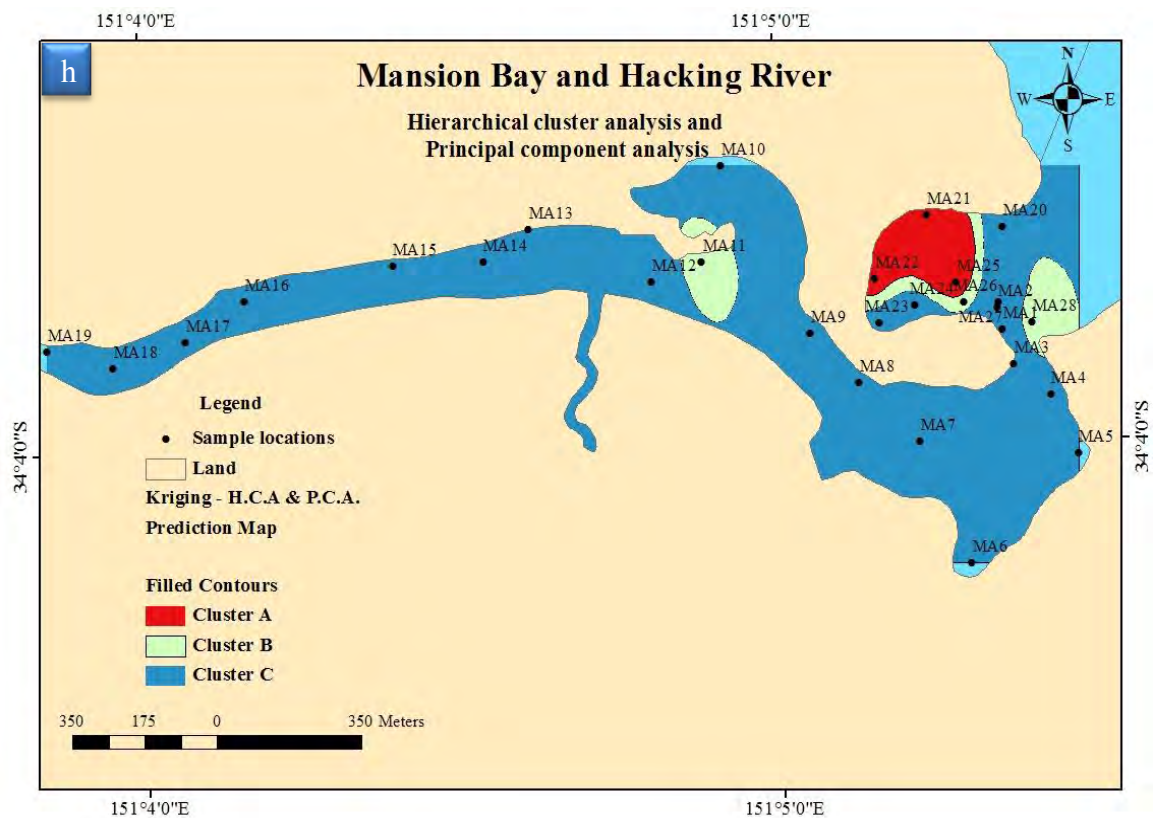
Table 7.6: Mean and standard deviation of the variables of the clusters from Port Hacking computed by hierarchical cluster analysis.

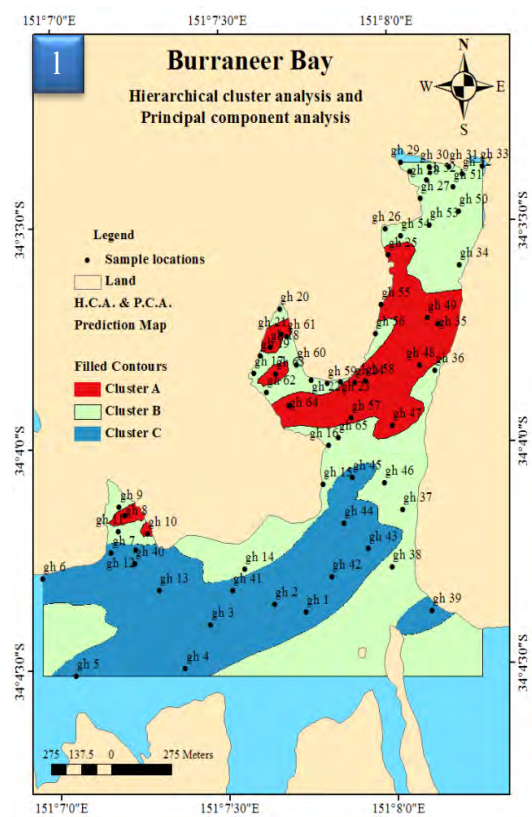
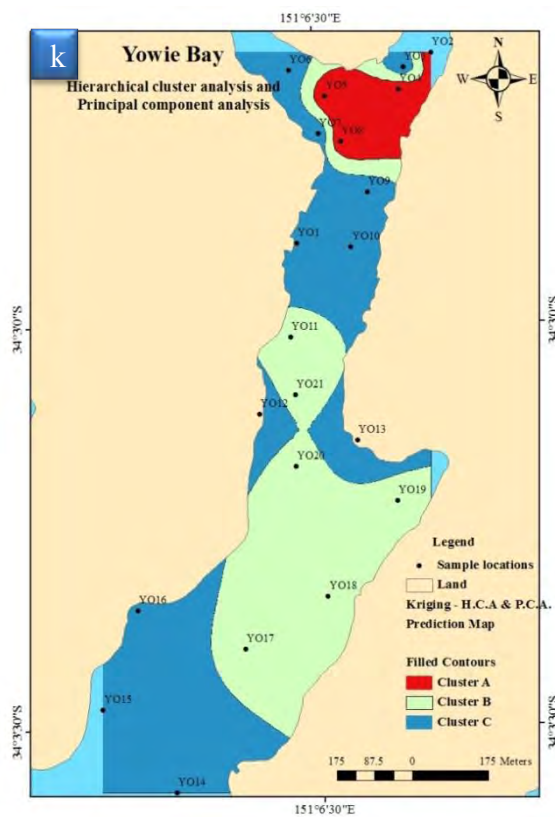
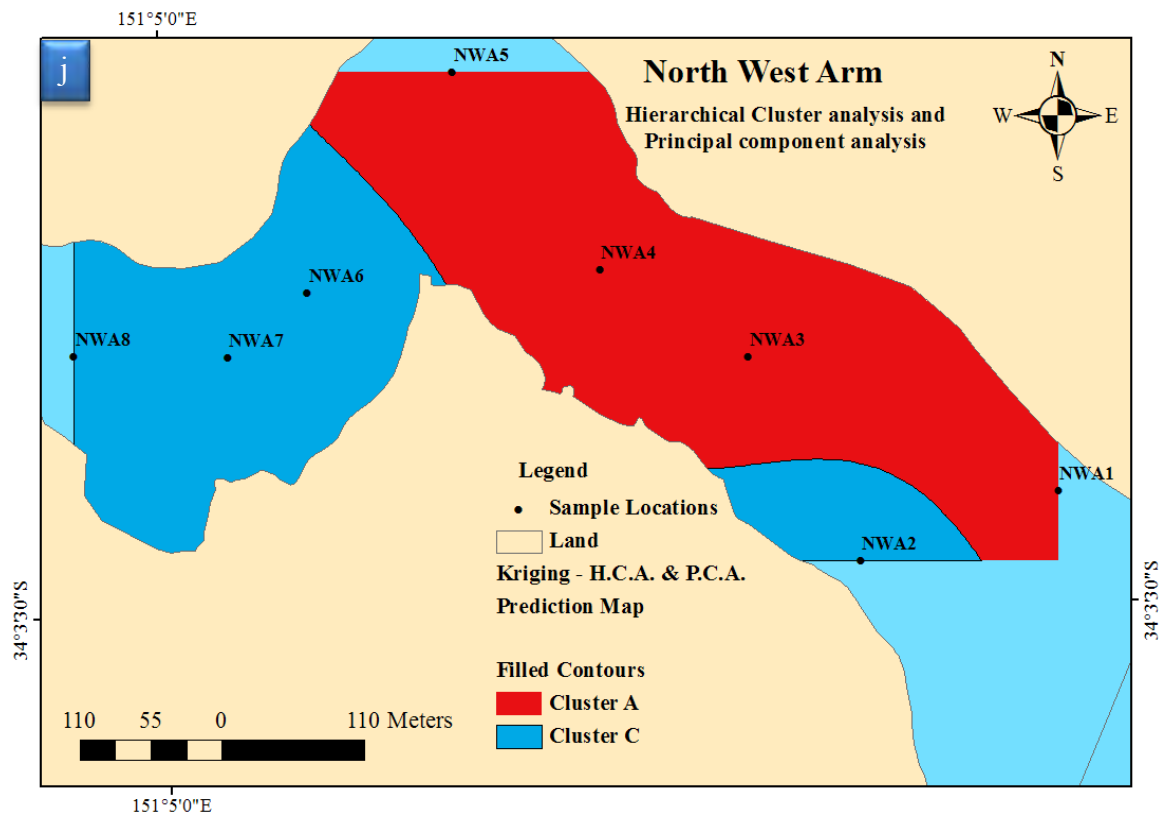
	Gunnamatta Bay			Burraneer Bay			Gymea Bay			South West Arm		Mansion Bay			North West Arm		Yowie Bay		
	Cluster A (13)*	Cluster B (30)	Cluster C (16)	Cluster A (16)	Cluster B (32)	Cluster C (17)	Cluster A (7)	Cluster B (4)	Cluster C (21)	Cluster A (4)	Cluster C (16)	Cluster A (3)	Cluster B (3)	Cluster C (22)	Cluster A (4)	Cluster C (4)	Cluster A (4)	Cluster B (6)	Cluster C (11)
Depth																			
Mean	9.6	4.1	3.5	7.1	3.5	3.4	17.7	8.3	3.3	11.6	1.2	4.8	1.7	1.8	11.1	2.1	4.7	17.8	4.8
SD	2.7	2.9	2.5	4.8	3.5	3.6	1.2	2.3	3.5	4.9	1.8	0.4	2.1	1.4	2.9	3.0	3.5	2.0	4.0
Sand																			
Mean	26.1	81.4	97.9	41.5	74.4	97.3	5.3	39.4	93.5	51.3	96.4	20.6	72.1	90.8	14.5	89.7	39.3	10.0	85.8
SD	14.5	13.1	6.5	12.8	21.9	4.0	3.8	26.4	3.6	16.9	3.3	10.8	16.6	7.4	8.8	4.1	20.8	4.4	8.7
Silt																			
Mean	63.3	15.9	1.9	52.4	23.3	2.6	82.8	52.2	5.9	43.2	3.3	68.9	24.3	8.2	72.3	9.4	51.8	76.1	11.9
SD	12.8	10.9	5.6	12.0	19.4	3.8	4.3	23.2	3.2	15.5	3.1	9.1	14.3	6.3	6.9	3.5	17.9	3.7	6.8
Clay																			
Mean	10.6	2.6	0.2	6.1	2.3	0.1	12.0	8.5	0.6	5.5	0.2	10.5	3.6	1.0	13.1	1.0	8.9	13.9	2.2
SD	2.7	2.3	0.9	2.0	2.9	0.2	1.6	3.3	0.5	1.4	0.3	1.7	2.3	1.1	1.9	0.8	3.0	1.1	2.0
V																			
Mean	--	--	--	--	--	--	--	--	--	40.8	2.7	100.1	27.0	6.7	107.8	11.8	58.4	89.4	16.3
SD	--	--	--	--	--	--	--	--	--	32.4	2.3	11.4	16.7	5.4	22.2	3.8	29.9	18.2	6.3
Cr																			
Mean	68.3	18.3	10.1	--	--	--	72.6	33.5	13.4	--	--	--	--	--	--	--	--	--	--
SD	25.1	14.7	4.7	--	--	--	21.9	17.9	4.4	--	--	--	--	--	--	--	--	--	--
Co																			
Mean	6.6	3.8	4.8	--	--	--	17.4	3.0	3.6	3.8	3.2	6.2	4.5	5.7	6.4	3.2	3.0	7.2	3.3
SD	3.9	0.8	1.8	--	--	--	8.6	0.0	1.1	0.6	0.4	2.4	1.4	12.6	2.5	0.2	0.0	2.6	0.5
Ni																			
Mean	13.2	3.9	2.6	8.2	5.4	1.7	21.6	7.1	3.7	9.3	3.3	21.5	13.2	2.8	21.4	5.4	14.2	17.0	4.5
SD	3.3	1.9	1.6	5.6	6.7	3.5	2.6	4.5	1.1	4.8	1.2	2.3	3.9	1.0	2.5	4.1	4.1	2.3	2.6
Cu																			
Mean	114.3	26.6	7.4	64.3	15.1	4.1	53.7	15.5	7.5	22.3	4.4	49.9	11.6	4.5	64.9	6.8	67.0	57.4	11.6
SD	90.2	17.9	8.8	57.4	8.1	2.0	5.4	8.0	3.7	18.7	1.2	2.3	5.2	1.7	8.4	2.6	27.6	14.0	5.6
Zn																			
Mean	183.1	39.9	15.5	107.7	33.0	11.1	193.7	52.0	24.9	70.4	5.1	162.6	30.2	11.6	337.5	34.4	205.5	180.9	36.1
SD	82.1	28.3	16.5	37.5	17.7	7.1	19.8	26.9	15.9	62.8	2.4	14.3	22.6	5.3	66.7	6.1	70.4	35.7	20.8
As																			
Mean	9.3	3.1	2.2	9.2	3.4	3.8	12.1	6.9	3.2	6.9	1.5	16.3	5.1	2.5	12.9	3.4	9.9	12.4	4.3
SD	1.7	1.5	1.1	2.2	1.5	1.2	1.3	1.6	2.3	4.0	0.6	1.5	2.3	1.1	1.6	1.6	3.9	2.4	2.1
Br																			
Mean	214.3	76.6	62.3	257.2	123.9	86.3	416.1	122.2	53.0	156.3	46.4	184.1	40.6	39.7	191.7	36.8	97.5	380.5	46.7
SD	41.4	36.9	39.8	95.3	44.5	72.9	143.0	77.3	22.5	102.9	10.9	18.8	13.2	17.8	63.1	4.9	56.8	113.4	15.0
Rb																			
Mean	31.0	8.7	11.2	26.1	9.1	11.1	61.1	15.3	7.1	21.5	3.3	52.3	10.7	5.8	54.1	8.2	29.5	48.8	11.9
SD	11.8	4.3	2.9	9.2	3.3	4.3	4.4	5.8	3.4	15.0	2.5	5.6	8.1	2.8	9.7	2.9	14.3	7.6	4.6
Sr																			
Mean	764.1	335.9	707.0	633.1	282.9	647.2	311.6	186.4	181.8	721.8	44.1	175.0	45.7	28.8	188.9	50.1	123.8	487.8	188.9
SD	226.3	219.4	368.1	318.2	256.3	353.0	18.7	65.0	207.6	103.0	64.5	7.0	26.5	11.1	40.4	41.4	60.7	95.2	165.1
Cd																			
Mean	1.6	1.3	1.5	6.3	7.9	12.1	1.7	1.8	1.4	4.6	1.5	1.2	5.0	1.4	13.2	6.7	11.6	8.5	8.0
SD	0.8	0.7	0.7	8.2	11.2	14.3	0.7	0.5	0.6	2.2	1.0	0.8	4.0	1.1	1.6	5.0	0.8	2.0	1.5
Sn																			
Mean	9.0	7.2	3.8	9.3	8.7	5.4	10.2	8.0	8.6	3.9	5.8	12.0	5.9	7.6	3.0	3.0	--	--	--
SD	4.0	3.3	1.5	3.7	4.0	2.1	2.2	2.7	4.9	1.8	1.4	0.8	5.1	1.6	0.0	0.0	--	--	--
Ba																			
Mean	133.5	57.6	73.2	103.6	59.1	72.6	202.7	71.9	45.0	74.8	24.8	192.9	60.5	38.1	4.0	34.0	--	--	--
SD	27.1	24.1	12.2	24.3	18.1	23.4	18.4	21.1	14.1	33.1	11.1	22.0	38.0	7.6	0.0	21.0	--	--	--
Ce																			
Mean	33.7	13.3	6.4	--	--	--	51.6	37.3	19.8	31.6	13.0	52.5	32.3	11.6	26.8	8.5	28.2	20.9	13.9
SD	11.1	9.5	6.0	--	--	--	23.8	7.9	18.5	21.0	13.1	4.8	5.9	13.7	4.4	8.7	8.2	9.5	9.8
Pb																			
Mean	85.5	23.1	6.7	58.8	21.2	6.3	102.4	33.3	11.0	33.2	1.6	75.7	12.4	4.6	135.6	13.1	126.2	103.0	22.7
SD	41.9	15.8	5.7	20.6	10.5	4.8	7.9	17.0	5.3	26.5	1.3	9.3	10.1	2.6	19.3	2.6	45.7	29.0	13.9

*Number of samples









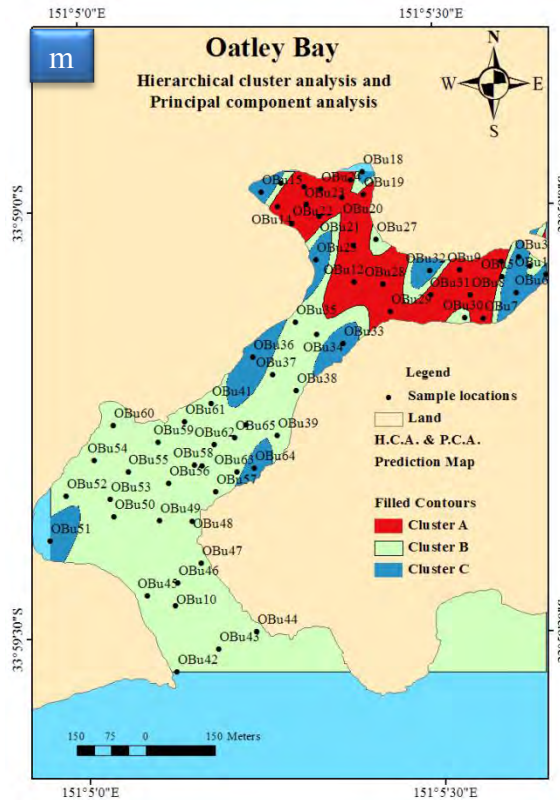


Figure 7.4: Sample classifications using hierarchical cluster analysis and principal component analysis: a- Kogarah Bay, b- Woollooware Bay, c- Oyster Bay, d- Woronora River, e- Georges River, f- Gunnamatta Bay, g- Gymea Bay, h- Mansion Bay, i- South West Arm j- North West Arm, k- Yowie Bay, l- Burraneer Bay and m- Oatley Bay.

Depending on the results from both HCA and PCA, as exhibited in Appendix 4, the surface sediment samples of each bay, river and arm of the study area were categorised into three clusters. Overall, the first cluster (red colour) is broadly distinguished by samples from deep water, with low percentages of sand, high proportions of mud (silt and clay); poorly to very poorly sorted sediments with high concentrations of trace elements. The samples in this cluster also had low percentages of quartz, high percentages of clay minerals (kaolinite, chlorite and illite), and high percentages of carbonate minerals (calcite, siderite and ankerite), high percentages of pyrite and organic matter (Table 7.8). Sediment samples in the red group were located predominantly close to discharge points, and in the inner and middle of the bays where there was a significant presence of boats. These environments act as sinks for fine to very fine silt and clay particles, which can contain and accumulate high concentrations of trace elements.

The environment for the red group is considered to be anoxic because the abundant organic matter in these fine-grained sediments. Current and wave velocities rarely disturb the sediments at these sites, as indicated by the presence of poorly to very poorly sorted very fine-grained sediment (Folk, 1974; Packwood, 1999; Jones et al., 2003b). These red group environments are considered to represent more highly contaminated sites within the study area (Figure 7.4a-m).

The green group from the cluster analysis was found to have high percentages of sand, low percentages of mud (silt and clay) and low percentages of clay minerals (Table 7.8). Also, it has lower concentrations of trace elements in most of the study areas compared with the red group. It is present in Woollooware Bay, Woronora River, Oatley Bay, Georges River, Gunnamatta Bay, GyMEA Bay, South West Arm, North West Arm, Mansion Bay, Yowie Bay and Burraneer Bay. However, the green group in Kogarah Bay and Oyster Bay was found to have slightly higher percentages of mud particles and nearly the same concentrations of trace elements as the red group. This is because the green group samples had similar percentages of mud particles to the red group, but the high percentages of mud in the samples do not necessarily reflect the amount of clay minerals since they may also contain high percentages of silt and clay-sized quartz and carbonate (Jones et al., 2003a). On the other hand, two locations in the South West Arm and North West Arm in the Port Hacking study areas did not have this green group of variables, but had only red and blue groups. This is because the sediment particles had high proportions of sand and very low concentrations of trace elements in the South West Arm (Figures 4.14 Chapter 4 and 5.16-5.22 Chapter 5) or low to moderate percentages of mud particles in the North West Arm (Figure 4.15 and Appendix 4).

The main characteristics of the final cluster, the blue group, were found to be shallow water depth, high sand proportion, low percentages of mud (silt and clay), very low concentrations of trace elements, high percentages of quartz, and low percentages of clay minerals (kaolinite, chlorite and illite) and pyrite (Table 7.8 and Appendix 4). Moreover, the surface sediment samples in this cluster were located predominantly along the edges and shorelines of the study areas which were away from discharge points of contamination. These sediments were found to be well to slightly poorly sorted and composed of coarser grains (Appendix 4, HCA and PCA), which indicate that the

deposited sediments have been exposed to significant wave action and current velocities which possibly disturbed the fine to very fine particles, and gradually moved them to deeper water. Therefore, these environments represent oxic conditions, which have very low concentrations of trace elements, and are considered to be much less contaminated sites compared with other sites (Figures 7.2, 7.3 and 7.4a-m).

The results also revealed the low concentrations and percentages of all trace element variables in both the red and blue groups in the South West Arm (Figure 7.4i and Appendix 4), except for Sr (721 ppm) and Ba (74 ppm), which may be attributed to the presence of shell particles (Gillikin et al., 2006; Ito and Forester, 2009; Yang et al., 2014b). This finding, while preliminary, suggests that surface sediment samples within the South West Arm reflect a natural non-anthropogenic environment, as the catchment area is almost free of residential and industrial activity (Figure 3.16; Chapter 3).

7.4 Correlation coefficients of variables in the study areas

The correlation coefficients (R-mode) among all variables (water depth, sediment fractions and trace elements) in individual and all the study areas together have been produced (Attached Appendix 4.3). The results showed a significant positive relationship between trace elements and fine particles (silt and clay), water depth and organic matter (Br), while trace elements have a negative correlation with sand in all bays and rivers in the study area. For example, the correlation coefficient of water depth, sediment fraction and trace elements for samples at Gunnamatta Bay (Table 7.7), showed that muddy particles (silt and clay) have a positive relationship with water depth, while sand is negatively correlated with water depth. This is because the fine and very fine particles around the edges of the bay are disturbed by currents and waves and they are transported into areas where the currents and wave activity become less effective (McLean et al., 2002; McLean and Hinwood, 2010b; Alyazichi et al., 2015c). They are deposited gradually through flocculation within deeper areas. Furthermore, muddy particles have a positive relationship with trace elements, whereas sand particles have a negative relationship with trace elements (Table 7.7). This is due to the clay minerals ($<4\mu\text{m}$), such as kaolinite; illite and chlorite, being dominant in muddy particles, which can absorb the trace elements by ion exchange or absorption onto charged surfaces. The chemical compositions of the clay minerals are aluminosilicate, with two crystal structures

(tetrahedral and octahedral). In comparison sand (> 63 µm) has minerals such as quartz that does not accumulate trace elements (Jones et al., 2003b; Jones et al., 2003a; Al-Juboury, 2009b; Turan et al., 2011).

Moreover, the organic matter in Botany Bay and Port Hacking, represented by bromine (Br; Figures 5.9 and 5.24), has a positive relationship with trace elements in deeper areas. The results of the R-mode analysis are comparable with the Q-mode analysis (HCA) and these indicate that the trace elements are concentrated in the inner parts of bays, with greater water depth where waves and currents have less effect on bottom sediments, and muddy particles and organic matter also increased. However, as water depth diminishes toward the edges and sediments become coarser (sandy), currents and waves become more active, which can resuspend the fine particles, and the trace element contents decline.

Table 7.7: Correction coefficients between water depth, sediment fractions and trace elements in Gunnamatta Bay.

Correlations															
	Depth	Sand	Silt	Clay	Cr	Ni	Cu	Zn	As	Br	Rb	Sr	Sn	Ba	Pb
Depth	1.0000	-0.7256	0.7169	0.7504	0.4979	0.5514	0.2416	0.4072	0.6932	0.6939	0.5608	0.5669	-0.0436	0.3575	0.3767
Sand	-0.7256	1.0000	-0.9991	-0.9710	-0.8016	-0.8817	-0.6197	-0.7979	-0.9209	-0.9157	-0.8361	-0.3586	-0.3414	-0.7151	-0.7736
Silt	0.7169	-0.9991	1.0000	0.9601	0.8042	0.8847	0.6269	0.8039	0.9206	0.9184	0.8386	0.3605	0.3436	0.7202	0.7777
Clay	0.7504	-0.9710	0.9601	1.0000	0.7600	0.8345	0.5578	0.7367	0.8914	0.8694	0.7935	0.3358	0.3176	0.6620	0.7241
Cr	0.4979	-0.8016	0.8042	0.7600	1.0000	0.8556	0.7726	0.8662	0.8278	0.7661	0.7385	0.2081	0.4401	0.7881	0.8483
Ni	0.5514	-0.8817	0.8847	0.8345	0.8556	1.0000	0.7384	0.8910	0.9242	0.8245	0.8921	0.2088	0.4897	0.8866	0.8723
Cu	0.2416	-0.6197	0.6269	0.5578	0.7726	0.7384	1.0000	0.9449	0.6505	0.6358	0.6193	0.0611	0.6036	0.7453	0.9500
Zn	0.4072	-0.7979	0.8039	0.7367	0.8662	0.8910	0.9449	1.0000	0.8268	0.7755	0.7863	0.1777	0.5755	0.8573	0.9843
As	0.6932	-0.9209	0.9206	0.8914	0.8278	0.9242	0.6505	0.8268	1.0000	0.8528	0.8656	0.3737	0.3759	0.7964	0.8121
Br	0.6939	-0.9157	0.9184	0.8694	0.7661	0.8245	0.6358	0.7755	0.8528	1.0000	0.7943	0.4878	0.2533	0.7039	0.7474
Rb	0.5608	-0.8361	0.8386	0.7935	0.7385	0.8921	0.6193	0.7863	0.8656	0.7943	1.0000	0.3693	0.3464	0.8737	0.7635
Sr	0.5669	-0.3586	0.3605	0.3358	0.2081	0.2088	0.0611	0.1777	0.3737	0.4878	0.3693	1.0000	-0.4856	0.2798	0.1099
Sn	-0.0436	-0.3414	0.3436	0.3176	0.4401	0.4897	0.6036	0.5755	0.3759	0.2533	0.3464	-0.4856	1.0000	0.4426	0.6431
Ba	0.3575	-0.7151	0.7202	0.6620	0.7881	0.8866	0.7453	0.8573	0.7964	0.7039	0.8737	0.2798	0.4426	1.0000	0.8461
Pb	0.3767	-0.7736	0.7777	0.7241	0.8483	0.8723	0.9500	0.9843	0.8121	0.7474	0.7635	0.1099	0.6431	0.8461	1.0000

7.5 Relationships between all variables in the study areas

All individual surface sediment samples in the study areas (bays and rivers) are combined together by using both Q and R mode analyses in order to provide information on the environment of deposition and relationships between sediment fractions and trace element pollution. Surface sediment samples in group A (red group) contain low percentages of

sand, high percentages of mud particles (silt and clay), and high concentrations in trace element concentrations (Table 7.8). The surface samples in this group were present at some locations in all the study areas, except for samples in the Hacking River and South West Arm. This is because the latter areas are free from urban development and are composed of sandy particles. The second cluster (green group) has high sand percentages, low muddy percentages, and lower concentrations of trace elements compared with the red group.

Finally, cluster C (blue group) consisted of very high percentages of sand particles, very low percentages of mud, and very low concentrations of trace elements. Most of the sediments are located on the edges and shorelines of bays such as KO9, KO10, WO5, WO6, WOR3, WOR4, GE40, GE41, GU5, GU, GY6, G10, SWA6, SWA7, MA10, MA11, YO5, YO6, GH2 and GH3. In addition, most of sediment samples in South West Arm and Hacking River are classified in this group for the same reason as given in previous discussion (Figure 7.7).

Table 7.8: Mean and standard deviation of the variables in the clusters from all samples in the study areas hierarchical cluster analysis.

Variables	Depth	Sand	Silt	Clay	Co	Ni	Cu	Zn	As	Sn	Pb	QZ	CM	Pyrite
Clusters	(m)	(%)	(%)	(%)	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%	%
ISQG/low*	---	---	---	---	NA	21	65	200	20	NA	50	---	---	---
Group A														
Mean	3.5	20.1	66.8	13.2	9	16	45	202	16	9	95	53	11	1.7
SD.	4.3	16.6	14.4	4.0	6	5.7	34	107	7	4	51	10.5	7	0.6
Group B														
Mean	5.8	64.1	32.1	3.7	3	6	24	53	9	8	30	66	7	1.1
SD.	4.3	26.2	23.2	3.3	0	6	23	44	3	3	23	20.6	4	0.8
Group C														
Mean	2.7	85.4	12.2	2.3	4	4	11	29	3	7	14	90	1.2	0.3
SD.	3	14.3	11.6	2.8	2	3	12	25	2	4	12	2.2	0.09	0.1

*Interim Sediment Quality Guidelines (ANZECC and NHMRC, 2000).

QZ= Quartz and CM= Clay minerals.

7.6 Significant trace elements in sediment samples

The distribution of trace elements in sediment samples in the study areas was related to both the lithology of the catchment areas and anthropogenic activities. Botany Bay and Port Hacking catchment areas are dominated by Hawkesbury Sandstone, a quartz sandstone with very minor feldspar, lithic grains, mica and kaolinite, as well as the Narrabeen Group, Wianamatta Group and Illawarra Coal Measures that consist mostly of lithic grains with minor quartz, feldspar and mica. The results of diagenetic alteration of

these source rocks include authigenic quartz, clay minerals, feldspar, pyrite and carbonate and iron oxide cements (Rust and Jones, 1987; Jones, 1990; Herbert, 1995; Al Gahtani, 2012).

Inadequate information about the background concentrations, mineral percentages, and current and tide velocity led to complications for assessing trace element pollution effects in the surface sediments in the study areas. Previous research on the study areas by Pease (2007) and Aljawi (2010) did not establish any information about the identity and percentages of minerals and organic matter, which play an important role in the accumulation of trace elements over time. However, the study conducted by Pease (2007) in Oatley Bay did provide background concentrations of trace elements in subsurface sediments. In order to evaluate the amount of anthropogenic activities and its environmental impacts, therefore, pre-anthropogenic background concentrations of trace elements in the soils and sediments were established. There are two ways to determine pre-industrialised background of concentrations of trace elements; it can be obtained either by measuring down core data (Birch et al., 1998) or by analysing soils from source regions of the area (Gillis and Birch, 2006).

In the current study, eight short subsurface sediment cores were collected from sites, which had the highest concentrations of trace elements in the more polluted bays. Samples from down the cores show a progressive decrease towards background values and these were compared with the average background values derived from 1.5 m to 3.5 m beneath the sediment surface in four cores from Oatley Bay. According to Damiani et al. (1986), background trace element contents reflect the lithology, morphology and hydrology of the drainage catchment area. Therefore, the background concentration of trace elements in the sediments of estuaries draining catchments of similar geology, such as Botany Bay and Port Hacking, should show a degree of similarity (Table 7.9). Variations in individual background concentrations depend on the sand: mud ratios.

Table 7.9 compares concentrations of Cr, Ni, Co, Cu, Zn and Pb in the surface sediments with their background concentrations from subsurface sediments extracted from the study areas, as well as from other areas in the Sydney Basin. The mean concentration of trace elements in the surface sediments in most areas was found to be high compared with the background values, except for the Woronora River and Mansion Bay. This indicates that

the concentration of these trace elements within the study areas has certainly emerged from anthropogenic pollution, such as urban runoff, stormwater outlets, boat activities, moored water craft, agricultural waste, fallout emissions and sewerage sludge.

According to the results from X-ray fluorescence analysis, the concentrations of Rb and Br (where Rb relates to muddy sediments and Br relates to organic carbon content) also varied in each site in Botany Bay (Figures 5.8 and 5.9 and Appendix 3.1) and in Port Hacking (Figures 5.23 and 5.24). The highest concentrations of Rb and Br occur in samples located in deeper portions of the study areas, which had high percentages of mud and organic matter (Figures 5.8, 5.9 in Botany Bay and 5.23 and 5.24 in Port Hacking for spatial distributions of both Rb and Br). Conversely, the lowest concentrations of Rb and Br were along the edges and shorelines of bays and rivers where the quartz sand content was highest. Moreover, the Woronora River in Botany Bay and the South West Arm and Hacking River showed the lowest concentrations of both Rb and Br compared with other sites in the study areas (Figures 5.8, 5.9, 5.23 and 5.24 in Chapter 5). Higher Br concentrations at some sites in the study areas could be due to two reasons: firstly, discharge points, channels and stormwater runoff from the vicinity of residential areas may release large amounts of organic matter; secondly, some of the bays contain large areas of seagrass beds.

Table 7.9: Comparison of surface sediment traces metal concentrations with background trace element concentrations in the study areas **1**(Pease, 2007), **2** (Aljawi, 2010) **3** (Irvine and Birch, 1998), **4** (Chenhall et al., 2004), **5** (Packwood, 1999) and **6** (Birch et al., 1998).

Sites	Cr ppm	Ni ppm	Co ppm	Cu ppm	Zn ppm	Pb ppm
Botany Bay 1						
Background Values	33.5	12.9	NA	9.1	42	23.4
Kogarah Bay *						
Surficial Mean (Range)	33 (7-91)	12 (1-28)	7 (3-21)	37 (5-100)	158 (11-433)	87 (5-235)
Local Background	81	18.1	3.6	12.8	60.8	20.9
Woolooware Bay *						
Surficial Mean (Range)	43 (6-99)	12 (1-26)	9 (3-20)	21 (9-58)	116 (8-314)	37 (3.3-104)
Local Background	51	11	5	6	33	10
Oatley Bay 1						
Surficial Mean (Range)	40 (7.9-130)	14.5 (7-30)	NA	40 (7-156.6)	196 (38-915)	117 (14-582.2)
Background	33.5	12.9		9.1	42	23.4
Oyster Bay *						
Surficial Mean (Range)	51 (9-127)	19 (7-39)	10 (3-28)	35 (10-63)	204 (43-386)	98 (14-198)
Local Background	62	18	--	10	53	20
Woronora River *						
Surficial Mean (Range)	33 (4-48)	10 (0.7-24)	6 (0.2-25)	19 (3-55)	92 (9-329)	30 (4-105)
Local Background	ND	7	--	10	35	8
Georges River *						
Surficial Mean (Range)	32 (4-86)	13 (1-30)	7 (0.7-17)	36 (3-138)	203 (11-789)	71 (4-268)
Local Background	52	15	9	18	68	26
Gunnamatta Bay *						
Surficial Mean (Range)	27 (4-107)	6 (0.4-20)	5 (3-15)	41 (3-398)	65 (6-413)	32 (2-203)
Local Background	42	--	--	42	78	52
Gymea Bay *						

Surficial Mean (Range)	29 (6-94)	8 (2-25)	7 (2-33)	19 (4-61)	65 (11-224)	34 (5-113)
Local Background	NA	NA	NA	NA	NA	NA
South West Arm *						
Surficial Mean (Range)	15 (2-70)	5 (0.8-16)	3 (3-5)	8 (2-50)	18 (3-164)	8 (0.3-73)
Local Background	NA	NA	NA	NA	NA	NA
Mansion Bay *						
Surficial Mean (Range)	ND	6 (1-24)	9 (0.8-95)	10 (2-53)	30 (6-177)	13 (2-85)
Local Background	ND	5	3	6	8	2
North West Arm *						
Surficial Mean (Range)	ND	13 (1.6-23)	5 (8-9)	36 (4.2-77)	186 (27-417)	74 (11-159)
Local Background	NA	NA	NA	NA	NA	NA
Yowie Bay *						
Surficial Mean (Range)	ND	10 (2-20)	4 (3-11)	35 (5-107)	110 (15-304)	65 (6-177)
Local Background	NA	NA	NA	NA	NA	NA
Burraneer Bay 2						
Surficial Mean (Range)	ND	5 (0.4-27)	NA	24 (2-232)	46 (5-179)	27 (1-101)
Local Background	NA	NA	NA	NA	NA	NA
Sydney Harbour 3						
Surficial Mean (Range)	118 (7-698)	38 (17-86)	19 (3-60)	124 (13-1078)	548 (46-2246)	268 (44-1319)
Background	51	26	16	10	47	33
Lake Illawarra 4						
Surficial Mean (Range)	NA	NA	---	60	170	60
Background			20	37	84	18
Lake Conjola 5						
Surficial Mean (Range)	NA		NA			
Background		16		25	88	17
Hawkesbury River 6						
Surficial maximum	NA	NA	NA	200	270	175
Background				20-30	90-120	30-40

ND: not determine (because the samples were crushed using a Cr steal-Tema), **NA:** not available and * study area sites.

7.7 Explanations from hydrodynamic activities

Various field measurements have been used to calibrate mathematical hydrodynamic models of estuaries around the world. In the present study, the current and tide track method has been applied rather than flow volume measuring or tidal range variation because within bays (as explained in Chapter 2, literature review) volume and range, do not provide data to adequately calibrate the models. In bays like the study areas current tracking and speed measuring are the usual data collected for model calibration. While catchment events provide the main influx of pollutants, the distribution of these pollutants is also dependant on the tidal circulation within the bays.

This study has recorded only the ebb tidal velocities, as catchment flow from discharge points are quickly dissipated within the bays and the flow pathways are predominantly controlled by ebb tidal circulation. Wind effects can also be important and have been discussed in general terms.

The current track velocities recorded in the study areas had the capability to transport fine particles and trace element pollution within the bays. As a result, the hydrodynamic activities were applied in this study to support and help explain the distribution of

sedimentary particles and geochemical materials. Details and discussion of these results have been presented in Chapter 6 (Hydrodynamic observations).

This method could also be used in remote areas and developing countries since it is cost effective. This is because the materials to build drogues are universally available and simple GPS tracking equipment is cheap and generally obtainable. It is important that any field measurement of hydrodynamic properties be sufficient to use both in basic explanation and potential hydrodynamic model development.

7.7.1 Summary of the differences between bays

The distribution pattern of sediment particles and trace elements in the different bays in this study appears to be related to different bay morphologies and their interactions with catchment and tidal flows.

Firstly, wide bays with wide-open mouths such as Kogarah Bay and Oyster Bay (Figures 6.10 and 6.11). Deposition of trace elements generally follows the current and tide trajectories, with secondary concentrations in boatyards and under moored boats where leaching, anti-fouling and fuel spillages add to the pollutant sources.

Secondly, wide bays with an entrance constriction such as Gunnamatta Bay (Figure 6.12). The high concentrations of trace elements are accumulated in the inner-middle parts of these bays, close to discharge points and drainage outlets, with further distribution coinciding with the main ebb current pathway. For sediments in general in Gunnamatta Bay, sand particles (size $\geq 63 \mu\text{m}$) are deposited in the vicinity of discharge points and/or within channels, but the fine to fine particles are transported by waves and current and deposited gradually farther from the stormwater outlets as well as in the inner parts of the bay. In addition, current and tide speeds in all the bays have enough capability to transport the trace element pollution and fine to very fine particles from the edges and shoreline, gradually depositing them in deeper areas (Figure 6.12). These observations correspond with previous work in different places around the world (e.g. Mantovanelli et al., (2004), and Gong et al., (2014).

Thirdly, linear and elongated bays. These usually have a single major point source for water and thus pollutant flows show trace element distributions that are constrained by the narrow bay form (Figure 6.13). Trace element pollution is concentrated in Salt Pan Creek,

which has the highest concentrations of trace elements along the creek, with the concentrations significantly declining when the creek joins with the main Georges River channel. The current and tide track velocities were faster in this creek compared to other bays except at Gunnamatta Bay, which had a similar current speed. This was largely because the creek has a narrow, elongated channel (Figure 6.13).

7.8 Potential anthropogenic sources of trace elements

There are many sources and types of pollutants around the world, including urban, agricultural, commercial, atmospheric deposition and industrial developments from the catchment areas, as well as using antifouling products, anticorrosive paints and metallurgical processing to repairs boats (boatyards). All of these are considered to be important sources of trace element pollution in estuaries and lakes. For example, agricultural and rural activities are considered to be a major source for phosphorous and nitrogen. Numerous studies have attempted to explain the source of trace elements in marine sediments (Attia et al., 2012; Tarique et al., 2012; Zhang et al., 2012b; Karageorgis et al., 2012). The soils and sediments within industrial and surrounding areas undergo various types of direct and indirect contamination (Table 2.3 in Chapter 2). The main sources of pollution in sediments have been noted by ANZECC and NHMRC (2000).

Natural activities, such as erosion, weathering of sediments and soils, and flood cycles (hurricanes) can increase sediment inflows. Moreover, the clearing and deforestation of areas can cause increased erosion and weathering of soils and increase the sedimentation rate in both terrestrial and coastal marine systems (Chenhall et al., 1995; Hosono et al., 2011).

In the study areas trace element pollution carried out into the estuary is attributed to both point and non-point sources. Large amounts of pollution are dispersed into Botany Bay from 786 discharge points, marine moorings and stormwater outlets, which account for approximately 95% of the total pollutant discharge into the study areas (PAB, 1992). Secondly, point sources also include waste dumps and large numbers of watercraft and boatyards. Natural runoff provides a minor amount of non-point source pollution.

According to Irvine (1980), the highest concentrations of trace elements such as Cu, Zn and Pb can be found in stormwater particulate matter, at 0.2%, 1-2% and >1.25%, respectively. This is because the trace elements in stormwater discharges are derived from residential catchment areas, which include road surfaces, aerosol emissions, roof runoff, industrial activities, soil erosion, polluted sites and sewage overflows, as well as illegal historical and modern discharges (Birch and Taylor, 1999a; McPherson et al., 2005).

The results of the present investigation confirm the previous suggestions by Taylor and Birch (1996), Birch and Taylor (1999a), Taylor (2000), Barry et al. (2000), Rochford (2008) and Birch and Rochford (2010) that the trace element concentrations show remarkable decreases with increasing distance from discharge outlets, which tend to be located at the head of some bays, such as Kogarah, Oatley and Oyster Bays in Botany Bay and Gunnamatta and Yowie Bays in Port Hacking (Figures 5.1-5.7 and 5.16-5.22, for spatial distribution of trace elements in Chapter 5).

The main source of lead was found to be in stormwater outlet particulate matter, which was derived from Pb-based paint and fallout emissions from car exhaust onto stable soil and road particle material. Moreover, slipways, moored boats, as well as settled aerosol dust, galvanized iron roofs and plumbing, are considered to be sources of both zinc and copper pollution (Fujita et al., 2014; Song et al., 2014; Huang et al., 2014).

The trace element distribution in bays and estuaries corresponds with a suggestion by Batley et al. (1991) that this is due firstly to water flow losing velocity away from discharge points, causing precipitation of large particles; and secondly, the currents and waves become more active close to the shoreline, which leads to re-suspension of fine particles. At some sites, which had large numbers of boating activities and boatyards, boats are painted to prevent them from fouling. As a consequence, the concentration of trace elements such as Cu, Zn, Sn and Pb increase remarkably. For instance, surface sediment samples KO5, KO14, KO16, KO25, KO41, KO46 and KO49 at Kogarah Bay, from sites which have large numbers of moored boats, had much higher concentrations of trace elements compared to sediment samples KO27, KO28, KO31 and KO32 in the vicinity of stormwater outlets and sewage overflows (Figures 3.6 and 5.1-5.7 for spatial distribution of trace elements). Moreover, the correlation coefficient for Sn (from tributyltin antifouling) at sites such as Salt Pan Creek and Gunnamatta Bay has a positive

relationship with the other trace elements (Tables 7.2 and 7.7). This is because of the number of watercraft and boatyards in these bays. However, Sn has a negative relationship with other trace elements in surface sediments in South West Arm (Table 7.3). This is due to the absence of watercraft and boatyards. For more details see correlation coefficients in Attached Appendix 4.3.

A similar situation was found in Yowie Bay. The samples in the red group were located at shallow depths (≤ 4.7 m) and contained high fine sand percentages, but also had high concentrations of trace elements (205ppm for Zn, 67ppm for Cu and 126ppm for Pb) compared to the samples in the green group (180ppm for Zn, 57ppm for Cu and 103ppm for Pb), which were located at deeper sites (up to 17.8 m) and had higher percentages of mud. This is attributed to the large number of boats in the shallow areas, as well as their close proximity to discharge points (Figure 7.4k and Appendix 4.11).

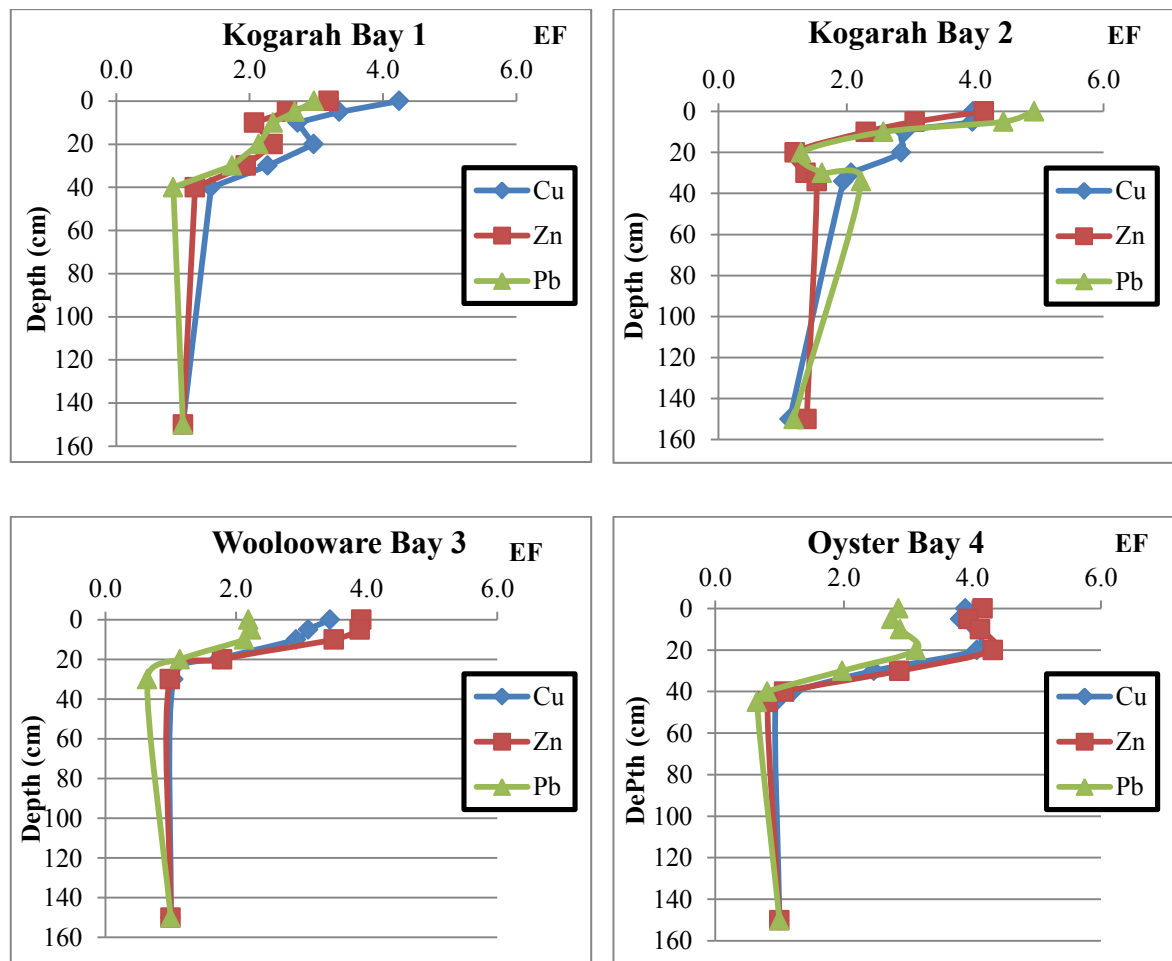
Legislation was instituted by former the State Pollution Control Commission (SPCC) prohibiting the use of tributyltin-based (TBT) products, which are compounds containing organic derivatives of tin ($(C_4H_9)_3Sn$) used as antifouling paint to prevent growth of organisms on boats (Andersen, 2004). Banning the use of this compound to paint boats has led to the use of paints containing higher concentrations of copper (Batley et al., 1991). In addition, wastes from manufacturing were in the past legally discharged into Salt Pan Creek in Botany Bay (Batley et al., 1991; Batley et al., 1992).

However, the monitoring programs introduced by New South Wales Environmental Protection Authority (EPA), industry and the Councils of associated municipalities (New South Wales State Pollution Control Commission), provided new legislation in the form of the Clean Waterways Act in 1972 to prohibit discharge of industrial waste into Salt Pan Creek (Batley et al., 1992). Because of this legislation, the concentrations of trace elements (and their enrichment factors) declined markedly from 20 cm depth in cores (where they reached a peak) to the surface sediments (Figure 7.5, Salt Pan Creek 6).

Background from previous data (Oatley Bay) was used to determine the enrichment factors in the study areas because background values from Oatley Bay were stable between 2.0-2.5 m depth in cores (excavated from the delta area where the sediments consist of alternating sand and mud reflecting flood pulses; Figure 7.5, core 9). The

enrichment factors for trace elements in cores dramatically increased in surface sediments at Kogarah Bay, Woollooware Bay and Oyster Bay (Figure 7.5, cores 1, 2, 3 and 4) over the time since European settlement of these areas. Furthermore, the enrichment factor in a Gunnamatta Bay core rose sharply from 40 cm to surface sediments, and this is due to the location of the core being close to boatyards (Figure 7.5, core 7).

In comparison, enrichment factors for trace elements in subsurface sediments in both the Woronora River and Mansion Bay-Hacking River did not show any significant change or showed negative enrichment (Figure 7.5, cores 5 and 8). This is due to the sediment fractions for these cores being dominantly fine sand (Attached Appendix 4.4).



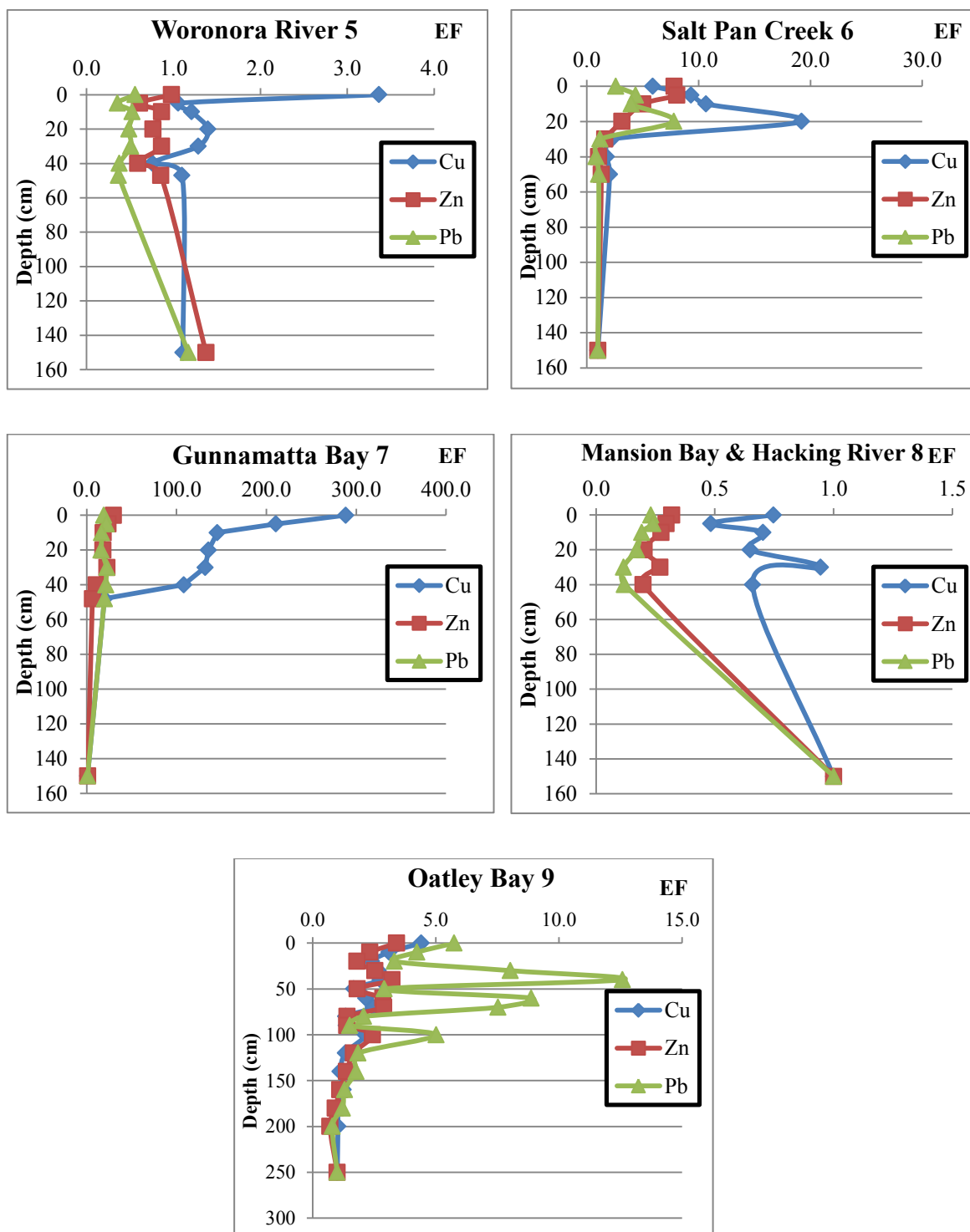


Figure 7.5: Variations of enrichment factor with core depth (cm) in the study areas.

Overall, the concentration of trace elements such as Cr, Ni, Cu, Zn, As, Sn and Pb in surface sediments in Botany Bay was found to be higher than in Port Hacking (Table 7.10 and Appendix 3.1). This is because the catchment areas of Botany Bay are a combination of more intense residential and commercial areas with chemical industries (i.e. ICI

Australia and Australian Paper Manufacturers Pty Ltd), Sydney Airport, as well as the shellfish and fishing industries. As a result, it has a larger number of stormwater and channel discharge outlets into the bays than in Port Hacking estuary.

Moreover, the sediments in Botany Bay contained lower percentages of sand and higher percentages of mud, which were reflected by Rb, and higher percentages of organic matter, indicated by Br, compared with sediments in Port Hacking (Tables 7.10 and 7.11). Furthermore, the clay minerals such as kaolinite, chlorite and illite in the Botany Bay had higher percentages compared with Port Hacking Table 7.11.

Table 7.10: Comparison of trace elements in the study areas.

Locations	Cr ppm	Ni ppm	Cu ppm	Zn ppm	As ppm	Sn ppm	Pb ppm	Rb ppm	Br ppm
Botany Bay									
Range	3-126	0.7-38	2-138	7-788	0.8-27	2-24	3-267	3-92	10-566
Mean± SD.	39±27	13±8	30±23	157±127	11±7	10±3	67±56	45±27	127±89
Port Hacking									
Range	2-106	0.4-27	2-398	2-417	0.7-18	0.6-21	0.3-203	1.6-68	17-703
Mean± SD	25±27	6±6	26±41	64±84	4±4	7±4	32±42	16±17	105-111

Table 7.11: Comparison of sediment fractions and mineral compositions in the study areas.

Locations	Sand%	Silt%	Clay%	Muddy%	Clay minerals %
Botany Bay					
Range	0-100	0-89	0-22	0-100	0.3-61
Mean± SD.	35±31	54±26	11±6	64±31	23±17
Port Hacking					
Range	0.8-100	0-88	0-15	0-99	0.9-51
Mean± SD.	72±31	24±26	4±4	27±31	11±14

Botany Bay:

89 sample sand

236 sample mud

Port Hacking:

184 sample sand

49 sample mud

Clay minerals such as kaolinite, chlorite and illite, as well as pyrite, can play an important role in the accumulation of trace elements, which can be incorporated into surface layers of these minerals (Gunawardana et al., 2014). The highest concentrations of trace elements were observed in Salt Pan Creek in Botany Bay, which had been widely adopted as a large waste dump (PAB, 1992).

7.9 Risk assessments

7.9.1 Potential ecological risk

The potential ecological risk index (RI) is the most popular method used in order to evaluate the hazards of the trace elements for both human and environmental ecosystems. It indicates the concentration of trace elements that may cause adverse effects in biological toxicology, environmental chemistry and ecology (Table 7.12; Guo et al., 2010; Yang et al., 2014a; Jiang et al., 2014).

On the one hand, the results of RI values indicate some sites in the study areas have considerable to very high risk (exceeding and/or slightly less than 120 RI; Appendix 3.4), for example sites located in Kogarah Bay, Oyster Bay, Salt Pan Creek, Oatley Bay and Yowie Bay. This is because these sites are close to discharge points; watercraft and boatyards as well as having sediment types that are dominated by muddy particles. Moreover, RI values exceeding 120 occurred at some sites in north-eastern Gunnamatta Bay (RI about 284) and Salt Pan Creek where the pollution was caused by boatyards when compared with other nearby sites in the study areas (Table 7.12 and Figures 7.6 and 7.7). On the other hand, low risk sites are also indicated in the study areas, located around the edges and mouths of the bays (Figures 7.6 and 7.7), where the sediment fractions are dominated by coarse particles (sand and/ or coarse silt) and current and waves are more active in these sites, leading to transportation of fine particles and trace elements toward deeper areas.

Other intermediate sites have been indicated as moderate risk with RI values between low and very high risk. They are comprised of muddy fine particles, but with low trace element concentrations compared with sites located in the vicinity of discharge points. The moderate risk sites are located farther from stormwater outlets (Table 7.12; Figures 7.6 and 7.7 and Appendix 3.4).

Table 7.12: Indices and potential ecological risk of trace elements pollution.

RI value	Potential ecological risk
$RI < 30$	Low risk
$30 \leq RI < 60$	Moderate risk
$60 \leq RI < 120$	Considerable risk
$RI \geq 120$	Very high risk

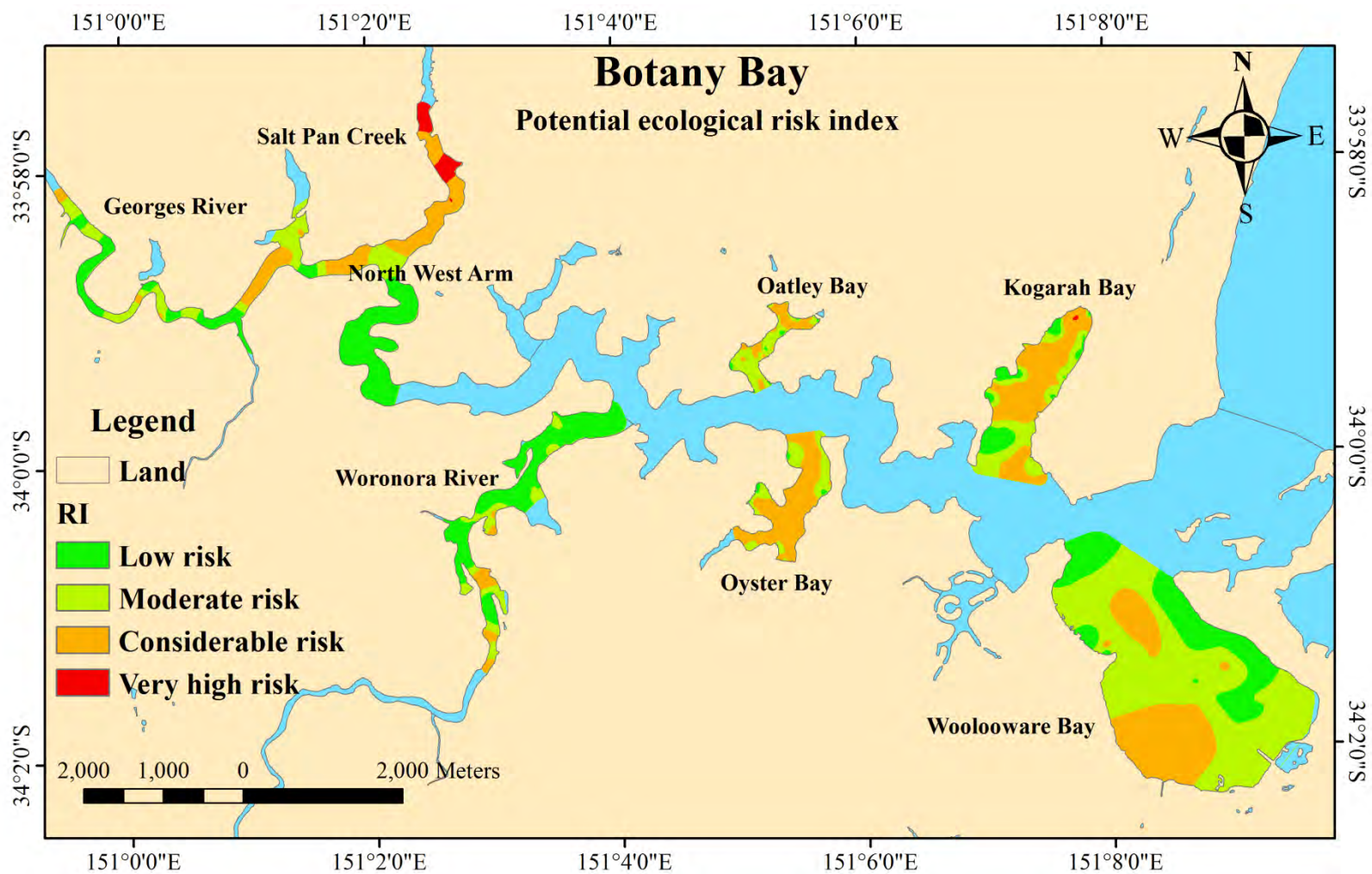


Figure 7.6: Potential ecological risk index within embayments in Botany Bay.

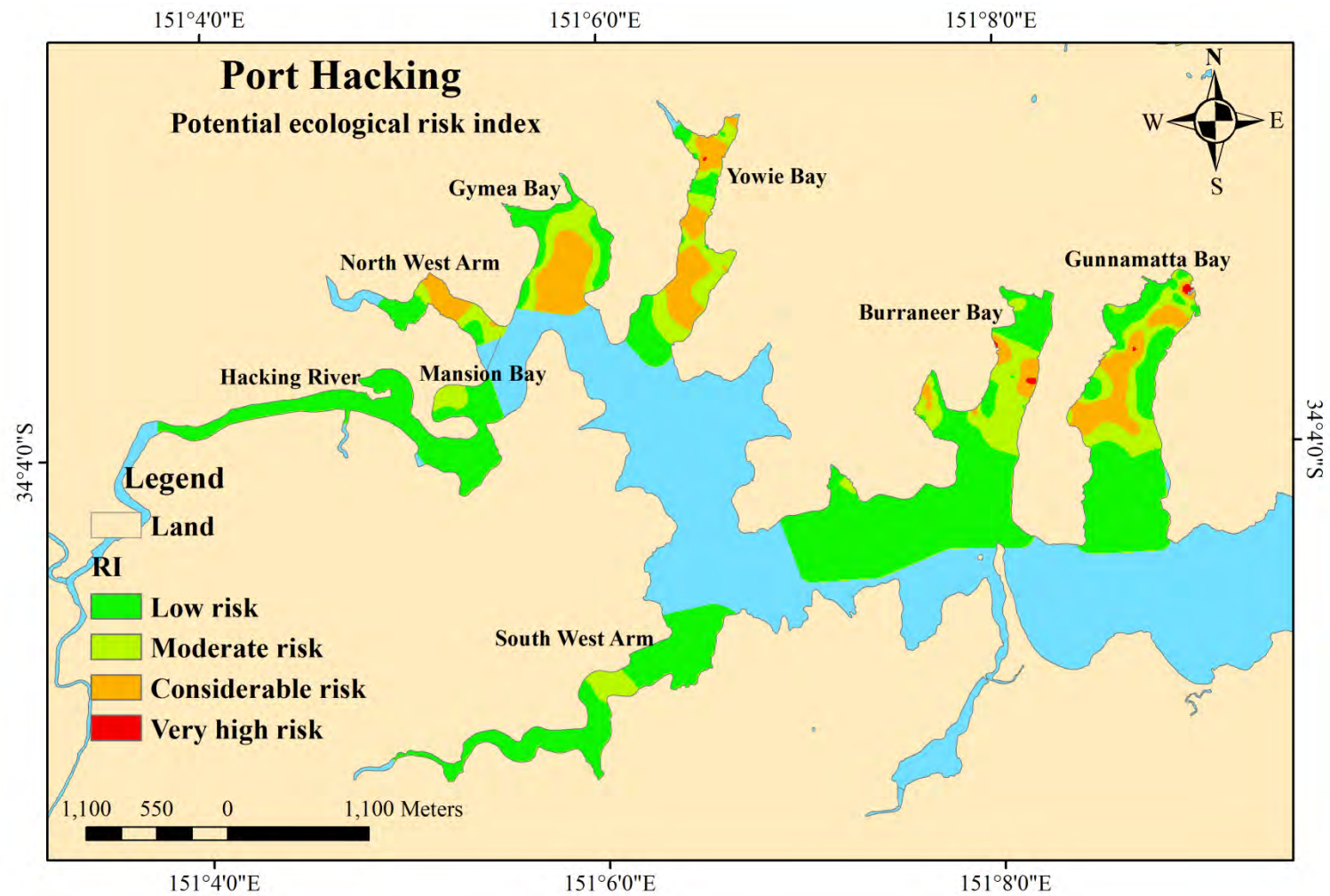


Figure 7.7: Potential ecological risk index within embayments in Port Hacking.

7.9.2 Evaluation of trace element bioavailability to humans

The trace elements in the aquatic environments may become toxic and have deleterious effects on aquatic organisms such as fish and oysters for two reasons: when they exceed normal concentrations and if the trace element is bioavailable. Oysters are considered to be a popular seafood for consumption in Australia and other countries around the world, which raises concern about the acceptable range of trace elements contained in their tissues (Hayes et al., 1998; Shulkin et al., 2003; Spooner et al., 2003; Bragigand et al., 2004; Birch et al., 2014). Many standards have been proposed for safety of human consumption of trace elements in oysters. As a consequence, the seafood is considered unhealthy for human consumptions if the trace elements exceed the acceptable concentrations for shellfish (Environmental Health Criteria, 1998, 2001; Rezaian and Jozi, 2012).

An aquaculture industry of oyster farming is an important industry in Woollooware Bay in Botany Bay. Therefore, the trace element concentrations in Woollooware Bay were compared with the deleterious biological effect concentrations in marine sediments (Table 7.13). According to the National Oceanic and Atmospheric Administration guideline, (NOAA; Long et al., 1995; MacDonald et al., 2000a; Ligerio et al., 2002; Bakan and Özkoç, 2007), the biological effect values ranged from effect range low (ERL) to effect range median (ERM).

Table 7.13: Basic statistic range and mean concentrations of trace elements (ppm) in Woollooware Bay compared with effect range low (ERL) and effect range median (ERM) values.

Trace elements (ppm)	Cr	Ni	Cu	Zn	As	Pb
Woollooware Bay						
Range	6-99	1.1-26	9-58	8-314	1.2-22	3.3-104
Mean \pm SD.	43 \pm 24	12 \pm 7	21 \pm 2	116 \pm 74	11 \pm 6	37 \pm 24
ERL	81(3)	20.9 (6)	34 (7)	150 (13)	8.2 (28)	46.7 (12)
ERM	270	51.6	270	410	70	218

(N): Numbers of samples exceeding ERL.

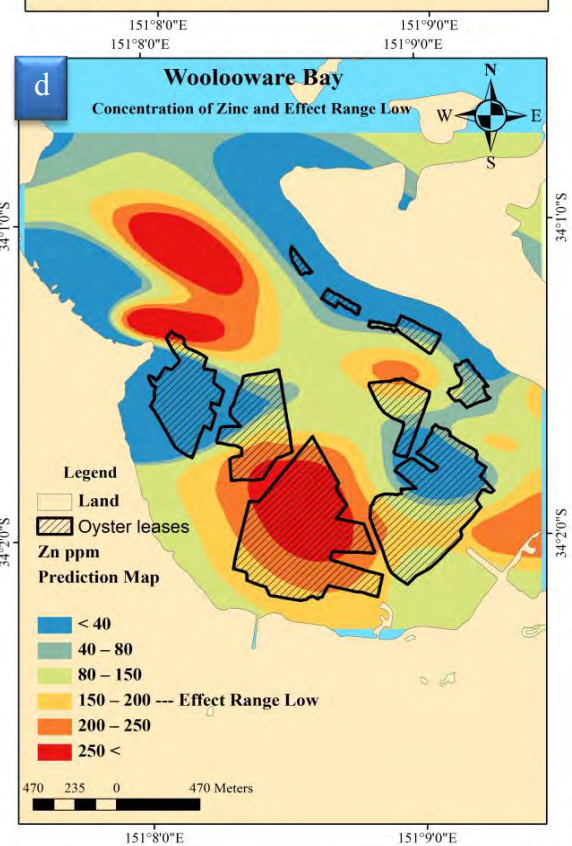
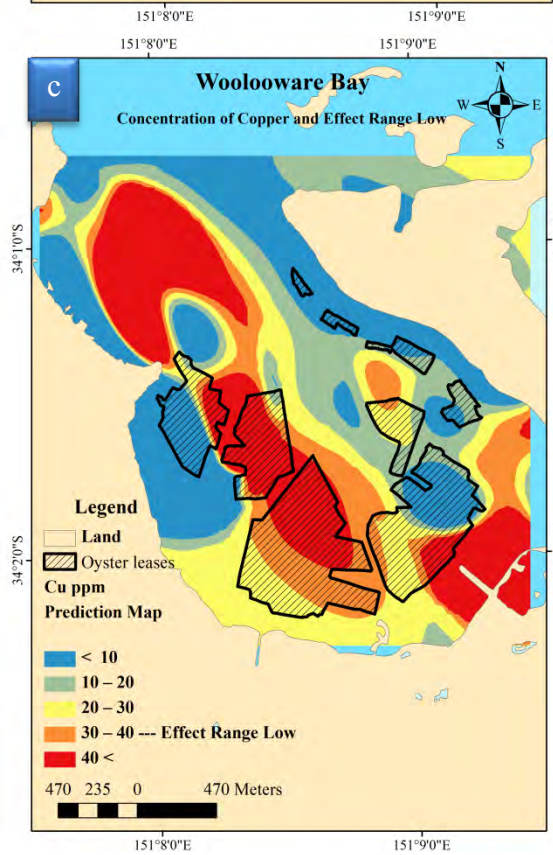
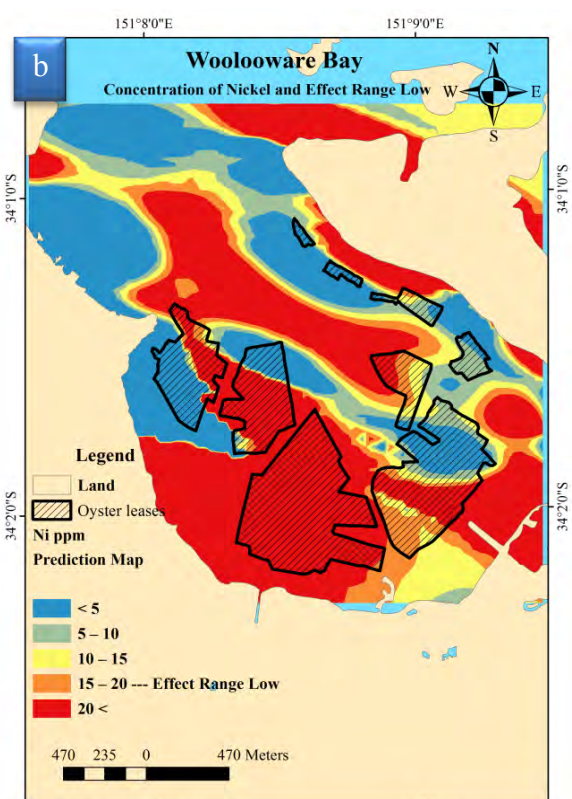
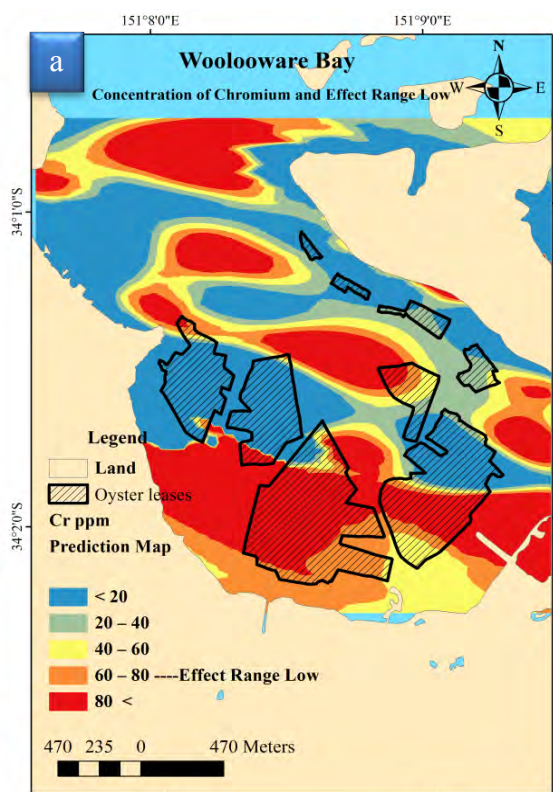
The mean results of trace elements such as Cr, Ni, Cu, Zn, As and Pb were found to be below ERL and ERM values within surface sediments in Woollooware Bay (Table 7.13). This is because most catchment areas around the bay are bushland with only a minor residential area, it is not an attractive bay (few boats) and it is subject to several monitoring programs

proposed by the New South Wales Department of Fisheries, the Environment Protection Authority (EPA) and Australian New Zealand Food Authority (2002) in order to protect the environmental ecosystem of the bay.

However, the trace element pollution at some sites in Woollooware Bay, which contains the oyster farming, were found to be above the Effect Range Low (ERL) values (Figure 7.8a-f) and require monitoring. One site in the southern part of the bay that contained oyster leases showed a potential ecological risk from trace elements that are classified as a considerable risk (Table 7.12 and Figure 7.6). Although, the concentrations of trace elements exceeded the effect range low (ERL) in some oyster leases, additional sampling through the oyster lease areas would be needed to more fully address this concern since data shown within the oyster leases is only derived by the kriging method. This is because of limitations of numbers of sediment samples in the oyster leases.

Increasing concentration of trace elements in some locations where oyster culturing occurs may affect population health and the ecological environment and cause harmful effects to micro-organisms and oysters. Trace element pollution can be deleterious to human bodies through consumption of oysters. This is because they can enter human bodies via the food chain, resulting in serious health problems such as brain damage, cancer and various other types of illness (Melegy et al., 2010; Alves et al., 2013; Huang et al., 2013; Alves et al., 2014; Cao et al., 2014; Mahmood and Malik, 2014; Zhao et al., 2014b).

Specific sites in the other bays within the study such as Kogarah Bay and Oyster Bay areas could be used for an aquaculture industry of oysters. This suggestion is based on concentrations of trace elements in surface sediments, water depth which is less than 2m (Figures 4.3 and 5.1-5.7), and potential ecological risk index classifications (Figures 7.6 and 7.7). Other sites in these bays may not be used for farming oysters due to containing high concentrations of trace elements, high RI and/or greater water depths (e.g. Salt Pan Creek, Gunnamatta Bay 5.2m and Yowie Bay 8.5m).



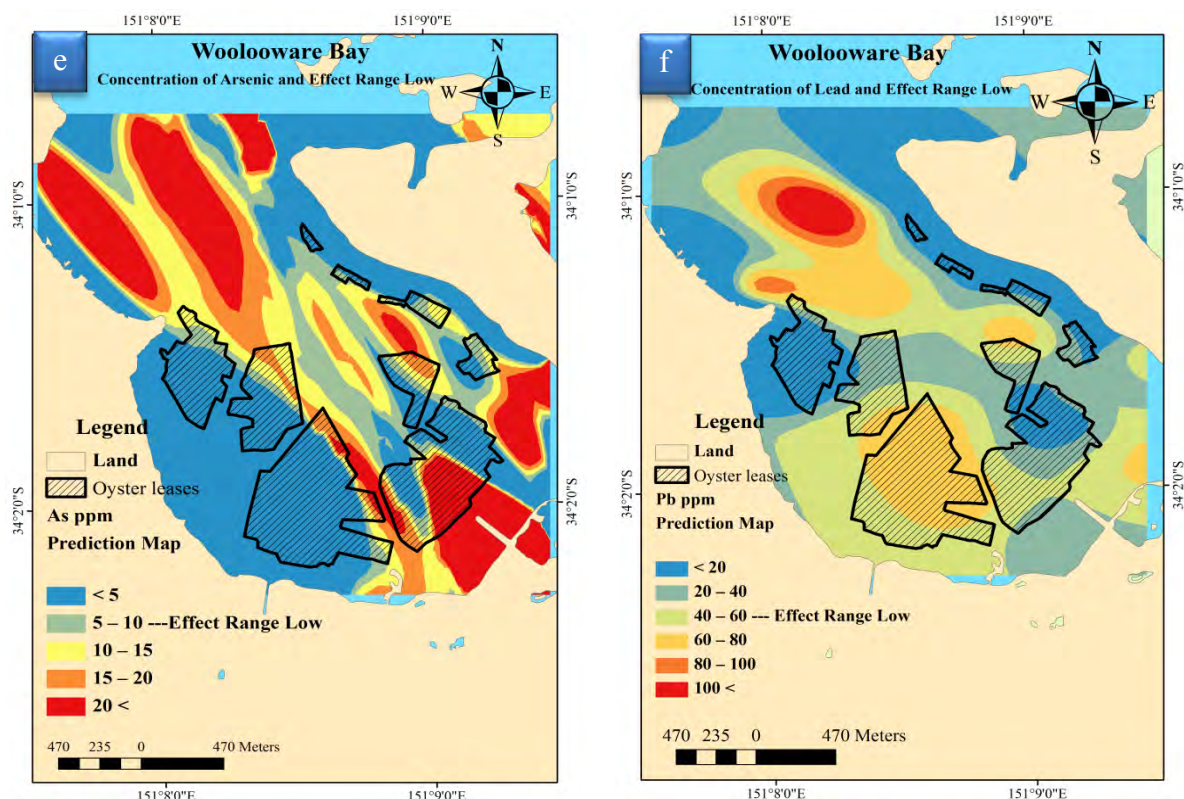


Figure 7.8: Effect range low of trace elements a-Cr; b-Ni; c-Cu; d-Zn; e-As and f-Pb in Woollooware Bay. Note: Numbers of sediment samples were limited because the Oyster leases.

The study conducted by Spooner et al. (2003) to evaluate the concentrations of trace elements in oyster tissues at Woollooware Bay, showed they had a significant concentration of trace elements compared with more pristine areas such as Jervis Bay and Batemans Bay (Table 7.14; Spooner et al., 2003). This is because the aquaculture of oysters in Woollooware Bay is located within an area containing high concentrations of trace elements. However, some other areas of Botany Bay had higher concentrations of trace elements and deeper sites.

Table 7.14: Trace element concentrations in $\mu\text{g/g}$ in oysters from Jervis Bay, Batemans Bay and Woollooware Bay from (Spooner et al., 2003).

Locations	Zn $\mu\text{g/g}$	Cu $\mu\text{g/g}$	As $\mu\text{g/g}$	Cd $\mu\text{g/g}$	Pb $\mu\text{g/g}$
Jervis Bay (1990)	980 \pm 400	33 \pm 11	ND	0.62 \pm 0.37	0.31 \pm 0.18
Jervis Bay (1997)	1015 \pm 506	22 \pm 14	ND	0.74 \pm 0.47	0.47 \pm 26
Clyde River, Batemans Bay (1987)	991 \pm 300	47 \pm 13	ND	0.96 \pm 0.22	ND
Clyde River, Batemans Bay (1994)	1547 \pm 487	64 \pm 17	ND	0.99 \pm 0.29	0.6 \pm 0.4
Woollooware Bay (Spooner et al., 2003)	2600 \pm 690	170 \pm 45	10 \pm 2	1.4 \pm 0.3	0.38 \pm 0.2

ND= no data.

7.10 Management options for wastewater outlets

7.10.1 Remediation

Stormwater and channel outlets, as well as boatyards (moored) have provided significant amounts of pollutants including trace elements, such as copper, zinc and lead into the embayments, where they are of major concern and a greater problem to environmental ecosystems. Moreover, the concentrations of trace element pollution in the dissolved phase are significantly increased within estuaries and bays resulting from remobilisation and remineralisation (Byrd et al., 1990). In order to protect environmental, economic and social values of estuaries from these contaminations, therefore, management option targets are considered to be an important issue in order to remove or reduce the amounts of pollutants.

According to Barry et al. (1999), Taylor (2000), Birch and Rochford (2010) and Birch (2011), trace element pollution from stormwater outlets is spread rapidly into the estuary under high-flow conditions when rainfall exceeds 50 mm during 24 hours and they are not precipitated in the sediments in the bays. However, they are deposited in the sediments in the inner bays under medium flow (ranged between 5 and 50mm rainfall in 24 hours; Rochford, 2008). Birch and Taylor (1999b) demonstrated that stratification of the sediments and soils in the bays occurred when rainfall ranged between 40 and 60 mm per day, and in embayments when rainfall precipitation exceeds 5 mm in 24 hours. Consequently, the potential risks in the estuaries have been certified within low-flow conditions (less than 5 mm of rainfall in a day). In addition, based on the current track velocities that were measured within these bays, the trace element pollutants are transported from discharge points and precipitated when the current speed diminishes at low tide.

7.10.2 Remediation methods

There are many potential remediation strategies to remove pollutants from stormwater outlets, which include physical, biological and chemical treatment methods. These methods for wastewater treatment were developed by a sponsor team from various disciplines including engineering, environment, sustainability, finance and project management (Hvitved-Jacobsen et al., 1994; Le Goffe, 1995; Miklas, 2006; Hardisty et al., 2013). The

best remediation to remove the trace element pollution from urban runoff involves a combination of physical, biological and chemical methods, such as filtration using sand with a sorbent like zeolite, alumina, dust and/or fly ash, which is cost-effective (Sivakumar et al., 1992; Sivakumar and Sidrak, 1992; Miklas, 2006; Ray et al., 2006; Vymazal and Kropfelova, 2008; Genç-Fuhrman et al., 2008; Zhu et al., 2012). This is due to the complex mixture of pollutants, which are discharged from catchment areas. The stormwater management plans should be required to integrate environmental and economic considerations in the decision making.

An arrangement both of direct and indirect options need to be considered to treat the pollution from drains. Direct management options include for example litter traps, constructed stormwater wetlands and vegetation planting. In addition, indirect management options involve: educational quantity, research, planning control and evaluation. The treatment procedures at sanitation and discharge points, has a benefit for environmental ecosystems and it also has beneficial environmental effects.

As a result, this study suggests and recommends the use of wastewater treatment plants (WWTPs) which comprise cost effective, applicable and utility strategies to treat the wastewater outlets. Pollution from some sewage and wastewater sources are now being treated by using wastewater treatment plants worldwide (Kuosmanen and Kortelainen, 2005; Molinos-Senante et al., 2014; Marti et al., 2014).

Furthermore, research conducted by Sansalone (1999), Deng et al. (2004) and Guittonny-Philippe et al. (2014) showed using filters to remove particulate bound metals and adsorption of dissolved phase metals as useful remediation strategies to reduce trace element contamination from stormwater outlets. Remediation procedures are commonly promoted by using sedimentation and settling of particulates to remove particulate bound trace elements from discharge points. The effectiveness of detention ponds and constructed wetlands in removing finer particulates and associated trace elements from urban stormwater outlets has also been demonstrated (Hvitved-Jacobsen et al., 1994; Birch et al., 2004; Birch et al., 2005). The results of using sand filtration to remove trace element pollution from channels has

displayed that more than 75% of suspended sediments can be removed following pre-management to remove coarse sediments and litter (EPA, 1997). Moreover, using a filter consisting of a mixture of sand and zeolite was found to be effective to remove trace elements, especially copper, zinc and lead, from discharge points (Ćurković et al., 1997; Pitcher et al., 2004; Birch et al., 2005; Hui et al., 2005; Magriotis et al., 2014). In addition, many sorbents including waste products can be efficiently used to remove trace element pollution from channels, such as dust, fly ash and red mud (Jamil et al., 2009; Ahmaruzzaman, 2011). However, the efficiency of removing trace element pollution from stormwater outlets varied between methods based on residence times in the wetland and the size of the wetland relative to the catchment area (Birch et al., 2004).

7.11 Summary

Marine sediments are estimated to be a sensitive indicator for both spatial and temporal trend monitoring of contaminants in the coastal marine environment. Marginal marine sediment contamination is considered to be one of the main environmental concerns for marine ecosystems.

Toxic pollutants, such as trace elements and organic matters originating from human activities like transport, industry, stormwater runoff drains, boatyards and watercraft, are continuing to be introduced to aquatic environments through rivers, waste dumping and emission processes. They are then deposited in marine sediments, which act as both a sink and source of pollution in the aquatic environment. As a consequence, trace element pollution is one of the largest problems in coastal marine ecosystems and can cause potential bio-accumulation and bio-magnification, resulting in potential long-term implications and can enter the human body via the food chain.

Sediments from Botany Bay are more polluted than sediments from Port Hacking estuary. This is because Botany Bay has more discharge points and industries as well as containing more muddy particles than Port Hacking. Furthermore, Salt Pan Creek in Botany Bay contains the highest concentrations of trace elements.

Measuring current paths and velocities using the current track method has been established in order to provide an explanation for the distribution of both sediment particles and trace element pollution in the estuaries. This method can be applied in developing and developed countries and is applicable to remote or low cost/technology countries or locations. The objectives are designed to satisfy scientific rigour, as well as provide the base for a cost effective methodology to apply in less financially affluent or remote areas. The advent of portable instruments to measure trace element concentrations in the field has also contributed to the development of lower cost and easily applied methodologies available for use in remote locations and low-cost economies.

This study provides useful information as far as management and future water quality planning are concerned. It is necessary to investigate the distribution and pollution degree of trace elements in order to protect environmental ecosystems from accumulating pollution and to provide basic information for coastal utilization and management.

Chapter 8

Conclusions and recommendations

The present research determined the effects of the spatial and temporal distribution of trace elements in marine sediments in Botany Bay and Port Hacking, NSW, Australia. Based on GIS maps and statistical analysis, the spatial distribution of trace elements such as Cr, Ni, Cu, Zn, As, Sn and Pb, as well as Rb and Br, were observed and significant trace elements were found to be concentrated in the inner bays and rivers.

Generally, Botany Bay contained higher concentrations of trace elements compared with Port Hacking because the catchment areas of Botany Bay are predominantly urbanised and light industry with many discharge points and stormwater outlets. In contrast, most catchment areas around Port Hacking consist of national park with more limited urban development. In the other words Port Hacking has fewer drainage and stormwater outlets. Moreover, Botany Bay has higher percentages of mud (fine particles) and lower percentages of sand, clay minerals and pyrite than the more sandy Port Hacking estuary.

In addition, concentrations of environmentally significant trace elements were found to be higher close to contamination sources such as discharge points and stormwater outlets, and they declined markedly toward the shoreline and mouths of bays and rivers. This is due to concentrations in deeper areas of fine and very fine-grained sediments, including kaolinite, illite and chlorite, which can accumulate trace elements by absorption and ion exchange. These clay minerals have a high affinity with Rb. Moreover, increasing percentages of pyrite and organic matter in deeper areas, which are reflected by the presence of high concentrations of Br, indicate anoxic conditions. Pyrite and organic matter can also play an important role in trapping trace elements.

Conversely, the presence of coarser quartz-rich sand around the edges, shoreline and mouths of many bays as the result of wave action explains their low concentrations of trace elements. Both Rb and Br also have their lowest concentrations in these areas. This is because the

waves and currents tend to be more active along the bay margins, which can disturb fine and very fine particles (and their associated trace elements) and transport them into deeper areas where they are gradually deposited since the wave and current activity have less effect on the deeper bottom sediments compared with the near surface sediments.

The highest concentrations of trace elements were found to be in Salt Pan Creek in Botany Bay. This is because of dumped waste and discharge points from previous industries, which have released trace elements into the creek. Also, the sediment fractions in the creek are mostly muddy particles, with clay mineral percentages of $92\pm3.2\%$, and high concentrations of pyrite, whereas the lowest concentrations of trace elements are found in the South West Arm and Hacking River in Port Hacking. This is because these sites are in non-residential areas, which means no waste has been discharged into them, and the sediments contain high average percentages ($90\pm13.2\%$) of sand particles.

The results of the lead isotope modelling in the surface sediments of the study areas indicated significant contributions from anthropogenic sources of lead from gasoline-fumes, including vehicle and boats exhausts. The $^{206}\text{Pb}/^{204}\text{Pb}$ varied between 16.6-17.3 indicating a high proportion of Broken Hill lead. However, subsurface sediments at or below 40 cm depth had higher lead isotopic records reflecting a much higher proportion of natural background (pre-industrial) Permian isotopic signature for $^{206}\text{Pb}/^{204}\text{Pb}$ of 18.7.

The negative correlation between the trace element concentrations and sediment depths in cores was notable in the study areas (8 cores). The trace elements in surface sediments increased remarkably to about 10 cm depth and then dropped sharply to the bottom of the cores except in Mansion Bay and the Woronora River, which indicates trace element pollution has accumulated over the time since Europeans settled around these areas but is now decreasing as a result of stricter Environmental Protection Authority regulations.

The spatial distribution of trace element pollution in the selected bays in the study area was qualitatively explained by the hydrodynamic data, including the tracking of current velocities and wind data (speed and direction). Fine and very fine particles, including their associated trace elements, can be remobilised from the edges and shoreline by local wind waves in all

these bays and are capable of being further transported by the measured current speeds, gradually being deposited in deeper sites. Currents in the middle of the bays had faster speeds compared to currents close to the head of the bay. This is because of accelerated current velocities due to larger tidal storage above these locations. The spatial distribution of trace elements in bays was in the form of decreasing concentrations away from stormwater outlets such as those at Kogarah Bay and Oyster Bay. This is because the water flow velocity diminishes away from discharge points. Wind directions can deflect the material causing deposition of fine particles and trace elements less related to the initial runoff discharge points. In the deeper bays, trace elements are concentrated in a line away from discharge points, such as Gunnamatta Bay, where current and wave activity cannot disturb deeper sediment particles.

The results of trace elements were evaluated using several risk assessment parameters and were compared with the ANZECC and NHMRC (2000) guidelines. The mean concentration of trace elements Cr, Ni, Cu, Zn, As, Cd, Hg and Pb in surface sediments from the present research did not exceed the high trigger value (ISQG-high), except for Zn at Salt Pan Creek, which also had the highest concentrations for Cr, Ni, Cu and Pb compared to other sites, due to previous waste dumps being located there. In addition, other sites such as KO45 in Kogarah Bay, Gu55 in Gunnamatta Bay, OY54 in Oyster Bay and NWA4 in North West Arm also had extreme values for Cu, Zn and Pb. Other surface sediments ranged between ISQG-low and high in the bays.

In contrast, nil to very low concentrations of trace elements, which did not exceed ISQG-low, were notable in the Woronora River in Botany Bay and in Burraneer Bay, South West Arm and Hacking River in Port Hacking, as well as some sandy sites located at the edges of most bays. Based on the results of trace element pollution in the study areas, the major sources were from residential areas, road dust, sewage runoff, boatyards and watercraft.

These findings of the spatial distribution of trace elements in both Botany Bay and Port Hacking have a number of important implications for further applications and investigation.

- Continued monitoring of trace element concentrations in both marine sediments and water, particularly close to discharge points, boatyards and watercraft is needed.
- Investigations of both sediments and water at the discharge points and stormwater outlets, which are considered to be important source of trace elements in Botany Bay and Port Hacking estuary, are required.
- Analysis of micro-organism shells, especially ostracoda carapaces (valves), from both surface and subsurface sediments is useful to reconstruct palaeo-environments of water chemical composition to reveal past episodes of trace element pollution.
- The areas containing significant total trace element concentrations should be targeted for a more detailed assessment of the bioavailability of the major contaminants. This would provide a better measure of the likely uptake of trace elements into the food chain, including fish.
- A further study should be conducted on oysters, to assess the concentrations of trace elements in oysters and find the best places (containing very low concentrations of metals) for seafood oyster culturing since they can be harmful to human health if contaminated.
- A stormwater outlet remediation device should be designed with the purpose of decreasing discharges into estuaries and efficiently removing dissolved toxic trace elements by using various filters and absorbents.
- Data about hydrodynamic activities (tide and current) collected from this study can be used to develop more complex and predictable mathematical models for channels or bays where geomorphology is complex in order to obtain a decision support tool for distribution of sediment particles and chemical pollution as well as to improve water quality.

Implication of incorporating hydrodynamic methods in determining the distribution of trace elements in low cost and remote areas

Although advanced hydrodynamic methods (two and three dimensional models) have been used in developed countries in order to build models for the distribution of sediment particles and trace element pollution, the simple method such current track velocity that was applied in this study could provide good prediction for distribution of sediment particles and trace elements in estuaries and bays. The application of the latter technique could be used in developing countries where more detailed analyses are difficult for both cost and technical reasons.

Current tracking designs are cost-effective because the materials are commonly available and simple GPS tracking instruments are widely available and easily used. Thus this methodology is available for use in isolated and remote areas where local hydrological maps and other methods are not available or technically unsuitable. A portable XRF may be used on sediment samples and, together with the mapping of current velocities, inferences can be made about the distribution of trace elements as well as the forces effecting their distribution.

However, it is important that any data collection for explanation of sediment and trace elements transport in these areas be upward-compatible with potential future modelling. Field data such as tidal levels, current track and wind speed and direction comprise such suitable data.

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Appendices

Appendix 1: Sample locations (surface and subsurface)

Botany Bay

(A): Kogarah Bay

Samples No	Easting	Northing
KO1	325974	6236128
KO2	326234	6236056
KO3	326740	6235940
KO4	326659	6236111
KO5	326546	6236216
KO6	326610	6236204
KO7	326552	6236300
KO8	326615	6236341
KO9	326389	6236425
KO10	326227	6236435
KO11	326088	6236456
KO12	326187	6236702
KO13	326362	6236698
KO14	326642	6236636
KO15	326627	6236506
KO16	326668	6236716
KO17	326398	6236866
KO18	326133	6236949
KO19	326179	6237061
KO20	326148	6237137
KO21	326200	6237186
KO22	326463	6237118
KO23	326893	6236955
KO24	326977	6237128
KO25	326626	6237360
KO26	326515	6237441
KO27	326584	6237621
KO28	326541	6237612
KO29	326548	6237574
KO30	326512	6237636
KO31	326466	6237707
KO32	326783	6237507
KO33	327074	6237274
KO34	327031	6237191

KO35	327236	6237457
KO36	327034	6237669
KO37	326888	6237814
KO38	326999	6237912
KO39	327096	6237863
KO40	327280	6237711
KO41	327384	6237888
KO42	327368	6237972
KO43	327251	6238074
KO44	327160	6238030
KO45	327215	6237954
KO46	327273	6237843
KO47	326986	6237770
KO48	327141	6237671
KO49	326955	6237522
KO50	326488	6237225
KO51	326890	6237294
KO52	326755	6237300
KO53	326703	6237042
KO54	326265	6237038
KO55	326625	6236874
KO56	326319	6236556
KO57	326270	6236359
KO58	326258	6236111
KO59	325999	6236077
Core 1	327239	6237907
Core 2	326586	6237504

(B): Woollooware Bay

Samples No	Easting	Northing
WO1	327087	6234817
WO2	326976	6234500
WO3	327830	6234191
WO4	328102	6234372
WO5	328214	6234445
WO6	328392	6234368
WO7	328498	6234232
WO8	328116	6234084
WO9	327728	6233977
WO10	327456	6233879
WO11	327571	6233812
WO12	327583	6233756
WO13	327984	6233673
WO14	328132	6233704
WO15	328497	6233877
WO16	328701	6234034
WO17	328879	6233921
WO18	328860	6233717
WO19	328708	6233366
WO20	328712	6233092
WO21	328839	6232856
WO22	328997	6233160
WO23	329083	6233594
WO24	329160	6233752
WO25	329337	6233794
WO26	329568	6233558
WO27	329480	6233269
WO28	329142	6232791
WO29	328986	6232509
WO30	328930	6232057
WO31	329234	6232122
WO32	329224	6232348
WO33	329502	6232755
WO34	329849	6232907
WO35	329892	6233156
WO36	329495	6233169
WO37	329760	6233447
WO38	329514	6233426
WO39	329460	6233519
WO40	329522	6233269
WO41	329489	6233086
WO42	329352	6233185
WO43	329122	6233392
WO44	327450	6234964
WO45	327271	6234620
Core 3	327765	6234183

(C): Oyster Bay

Samples No	Easting	Northing
OY1	323973	6236426
OY2	323843	6236387
OY3	323582	6236378
OY4	323584	6236202
OY5	323770	6236189
OY6	323934	6236174
OY7	324081	6236149
OY8	324015	6236281
OY9	324102	6236037
OY10	323886	6236042
OY11	323781	6236032
OY12	323732	6235925
OY13	323856	6235873
OY14	324037	6235758
OY15	324129	6235857
OY16	323899	6235651
OY17	323748	6235692
OY18	323585	6235764
OY19	323565	6235618
OY20	323656	6235523
OY21	323762	6235449
OY22	323681	6235244
OY23	323584	6235342
OY24	323429	6235353
OY25	323327	6235455
OY26	323346	6235533
OY27	323405	6235617
OY28	323512	6235497
OY29	323421	6235597
OY30	323316	6235566
OY31	323244	6235486
OY32	323173	6235531
OY33	323198	6235637
OY34	323295	6235728
OY35	323298	6235775
OY36	323227	6235785
OY37	323200	6235784
OY38	323191	6235769
OY39	323155	6235713

OY40	323117	6235650
OY41	323143	6235615
OY42	323363	6235273
OY43	323454	6235223
OY44	323314	6235123
OY45	323172	6235113
OY46	323107	6235200
OY47	322996	6235276
OY48	323028	6235168
OY49	323472	6235118
OY50	323536	6235088
OY51	323643	6235004
OY52	323651	6234911
OY53	323549	6234897
OY54	323475	6234947
OY55	323496	6235007
Core 4	323447	6235235

(D): Woronora River

Samples No	Easting	Northing
WOR1	321357	6236755
WOR2	321376	6236718
WOR3	321411	6236633
WOR4	321106	6236733
WOR5	321098	6236652
WOR6	320844	6236711
WOR7	320841	6236629
WOR8	320859	6236531
WOR9	320745	6236580
WOR10	320639	6236690
WOR11	320688	6236732
WOR12	320565	6236543
WOR13	320567	6236445
WOR14	320642	6236267
WOR15	320432	6236214
WOR16	320418	6236256
WOR17	320439	6236306
WOR18	320409	6236135
WOR19	320424	6236008
WOR20	320445	6235812
WOR21	320402	6235792
WOR22	320376	6235778
WOR23	320227	6235772
WOR24	320066	6235781
WOR25	319771	6235670
WOR26	319818	6235590
WOR27	319918	6235506
WOR28	319898	6235391
WOR29	319854	6235345
WOR30	319889	6235316
WOR31	319624	6235424
WOR32	319645	6235349
WOR33	319315	6235267
WOR34	319538	6235112

WOR35	319590	6234932
WOR36	319511	6234877
WOR37	319653	6234828
WOR38	319797	6234596
WOR39	319878	6234442
WOR40	319809	6234331
WOR41	319902	6234187
WOR42	319936	6234064
WOR43	319851	6233942
WOR44	319850	6233766
WOR45	319882	6233606
WOR46	320391	6235935
WOR47	320447	6235861
Core 5	319837	6235569

(E) Georges River and Salt Pan Creek

Samples No	Easting	Northing
GE1	316969	6238411
GE2	316952	6238269
GE3	316802	6238163
GE4	316672	6237927
GE5	316715	6237817
GE6	316749	6237704
GE7	316521	6237902
GE8	316353	6237834
GE9	316235	6237959
GE10	316036	6237965
GE11	315863	6237993
GE12	315737	6237954
GE13	315741	6238111
GE14	315686	6238253
GE15	315501	6238334
GE16	315494	6238213
GE17	315239	6237978
GE18	315000	6237986
GE19	314875	6237991
GE20	314734	6238381
GE21	314887	6238624
GE22	315045	6238803
GE23	314878	6238995
GE24	314742	6239137
GE25	314500	6239422
GE26	317186	6238744
GE27	317322	6238982

GE28	317438	6239166
GE29	317515	6239120
GE30	317457	6239034
GE31	317486	6238596
GE32	317538	6238612
GE33	317815	6238600
GE34	318229	6238664
GE35	318823	6238859
GE36	319112	6239161
GE37	319368	6239406
GE38	319290	6239903
GE39	319497	6239574
GE40	318728	6238298
GE41	318791	6238008
GE42	318369	6237917
GE43	318394	6237275
GE44	318267	6237098
GE45	318516	6236881
GE46	318574	6237090
GE47	318208	6237395
GE48	318042	6237585
GE49	318991	6240501
GE50	318972	6240481
GE51	319024	6240344
GE52	319012	6240282
GE53	319089	6240142
GE54	319218	6239960
Core 6	318957	6240539

Port Hacking
(A): Gunnamatta Bay

Samples No	Easting	Northing
GU1	328450	6228136
GU2	328532	6228131
GU3	328740	6228147
GU4	328991	6228156
GU5	328925	6228506
GU6	328875	6228492
GU7	328582	6228497
GU8	328440	6228481
GU9	328532	6228765
GU10	328687	6228796
GU11	328787	6228795
GU12	328936	6228722
GU13	328929	6229150
GU14	328882	6229140
GU15	328818	6229039
GU16	328748	6229170
GU17	328576	6229039
GU18	328429	6229140
GU19	328285	6229107
GU20	328618	6229577
GU21	328694	6229553
GU22	328846	6229444
GU23	328916	6229408
GU24	328933	6229626
GU25	328804	6229625
GU26	328719	6229632
GU27	328515	6229200
GU28	328483	6229250
GU29	328472	6229312
GU30	328733	6229321

GU31	328569	6229380
GU32	328486	6229379
GU33	328685	6229697
GU34	328658	6229867
GU35	328622	6229904
GU36	328671	6229921
GU37	328705	6229865
GU38	329066	6229785
GU39	329019	6229864
GU40	328927	6229851
GU41	328871	6229908
GU42	328787	6229922
GU43	328888	6230033
GU44	329011	6229966
GU45	329105	6229910
GU46	329299	6229930
GU47	329007	6230097
GU48	328952	6230084
GU49	328934	6230137
GU50	329057	6230106
GU51	329126	6230111
GU52	329144	6230148
GU53	329113	6230180
GU54	329198	6230159
GU55	329228	6230085
GU56	329221	6230155
GU57	329140	6230236
GU58	329077	6230077
GU59	329161	6230022
Core 7	329231	6230128

(B) South West Arm

Samples No	Easting	Northing
SWA1	324511	6226904
SWA2	324482	6226899
SWA3	324656	6226306
SWA4	324628	6226415
SWA5	324643	6226360
SWA6	324451	6226526
SWA7	324369	6226638
SWA8	324153	6226556
SWA9	324018	6226479
SWA10	323940	6226539
SWA11	323762	6226637
SWA12	323627	6226542
SWA13	323489	6226292
SWA14	323366	6226437
SWA15	323289	6226475
SWA16	323762	6226604
SWA17	324791	6226973
SWA18	324864	6227238
SWA19	325125	6227148
SWA20	325532	6227389

(C) Gynea Bay

Samples No	Easting	Northing
GY1	324412	6229986
GY2	324199	6230137
GY3	324074	6230153
GY4	324173	6230290
GY5	324291	6230255
GY6	324632	6230136
GY7	324718	6230308
GY8	324544	6230261
GY9	324220	6230244
GY10	324193	6230365
GY11	324199	6230520
GY12	324342	6230449
GY13	324580	6230371
GY14	324718	6230366
GY15	324446	6230814
GY16	324454	6230822
GY17	324400	6230892
GY18	324442	6230800
GY19	324511	6230745
GY20	324642	6230550
GY21	324731	6230492
GY22	324707	6230411
GY23	324163	6230540
GY24	324074	6230578
GY25	324076	6230581
GY26	324032	6230580
GY27	323964	6230657
GY28	324049	6230700
GY29	324351	6230759
GY30	324406	6230775
GY31	324020	6230036
GY32	324025	6230043

(D) Mansion Bay & Hacking River

Samples No	Easting	Northing
MA1	323673	6229064
MA2	323661	6229117
MA3	323700	6228984
MA4	323791	6228911
MA5	323857	6228774
MA6	323600	6228516
MA7	323474	6228802
MA8	323326	6228940
MA9	323208	6229056
MA10	322990	6229449
MA11	322944	6229223
MA12	322822	6229177
MA13	322524	6229299
MA14	322414	6229223
MA15	322194	6229212
MA16	321835	6229128
MA17	321693	6229032
MA18	321517	6228972
MA19	321356	6229011
MA20	323674	6229306
MA21	323488	6229333
MA22	323363	6229183
MA23	323374	6229080
MA24	323460	6229122
MA25	323559	6229176
MA26	323580	6229129
MA27	323663	6229130
MA28	323744	6229083
Core 8	323462	6229100

(E): North West Arm

Samples No	Easting	Northing
NWA1	323802	6229817
NWA2	323649	6229763
NWA3	323562	6229920
NWA4	323447	6229987
NWA5	323354	6230105
NWA6	323221	6229969
NWA7	323159	6229919
NWA8	323087	6229868

(F) Yowie Bay

Samples No	Easting	Northing
YO1	325359	6230872
YO2	325668	6231311
YO3	325604	6231278
YO4	325593	6231227
YO5	325423	6231211
YO6	325339	6231270
YO7	325409	6231125
YO8	325459	6231107
YO9	325521	6230990
YO10	325484	6230864
YO11	325345	6230657
YO12	325272	6230480
YO13	325499	6230421
YO14	325082	6229610
YO15	324911	6229800
YO16	324991	6230028
YO17	325240	6229940
YO18	325431	6230062
YO19	325592	6230282
YO20	325357	6230361
YO21	325355	6230525

Appendix 2: Sedimentary results

2.1: Grain Size Distribution (GSD)

A: Botany Bay/ Kogarah Bay

Sample No	Depth (m)	Sand %	Silt %	Clay %	Muddy %	Clay2µm	Mode	Mode2	Mean (micron)	Mean	StdD	GsKew	Kurt
KO1	3.7	37.24	49.03	13.73	62.76	5.42	320.928	8.69	31.18	5	2.72	-0.17	0.66
KO2	4.9	4	75.12	20.87	95.99	8.12	9.207	0	9.49	6.72	1.59	0	1.07
KO3	5.4	7.48	70.06	22.47	92.53	9.84	8.988	0	9.9	6.66	1.81	-0.02	1.1
KO4	2.4	35.66	50.44	13.9	64.34	5.06	422.677	8.5	32.16	4.96	2.91	-0.32	0.61
KO5	4.2	6.67	76.5	16.83	93.33	6.13	9.697	0	11.23	6.48	1.6	-0.05	1.06
KO6	2	10.85	71.16	17.98	89.14	6.54	9.095	432	11.55	6.44	2.03	-0.21	1.42
KO7	4	3.85	76.69	19.46	96.15	7.65	9.464	0	9.89	6.66	1.57	0.02	1.07
KO8	3	9.63	72.4	17.97	90.37	7.09	9.406	313.09	11.58	6.43	1.89	-0.13	1.24
KO9	2.4	52.69	37.11	10.21	47.32	3.4	365.858	8.19	78.93	3.66	2.76	0.62	0.59
KO10	1.3	77.46	18.68	3.86	22.54	1.11	400.795	8.9	138.76	2.85	2.38	0.75	2.47
KO11	0.9	91.97	6.4	1.63	8.03	0.37	365.93	7.74	340.33	1.55	1.2	0.39	2.93
KO12	2.3	15.52	67.89	16.59	84.48	6.36	9.108	328.06	14.2	6.14	2.03	-0.17	1.07
KO13	3.2	4.95	78.42	16.63	95.05	6.33	9.611	0	11.24	6.48	1.57	-0.01	1.03
KO14	2.3	13.93	66.29	19.78	86.07	8.26	8.953	353.26	12.18	6.36	2.2	-0.2	1.34
KO15	2.1	24.93	61.54	13.52	75.06	5.06	9.617	305.56	24.55	5.35	2.53	-0.28	0.96
KO16	2.5	0.19	82.74	17.07	99.81	6.29	10.089	0	9.32	6.74	1.3	0.09	1.07
KO17	3.2	3.43	77.34	19.23	96.57	7.62	9.371	0	9.77	6.68	1.54	0.02	1.09
KO18	1.1	91.7	6.94	1.35	8.29	0.28	390.297	8.73	346.27	1.53	1.35	0.35	2.14
KO19	2.5	28.84	56.31	14.86	71.17	5.99	9.181	320.64	25.5	5.29	2.65	-0.25	0.83
KO20	1.2	20.35	69.13	10.52	79.65	3.56	11.178	0.86	19.47	5.68	1.98	-0.16	1
KO21	1	93.52	5.35	1.12	6.47	0.2	322.992	7.84	303.93	1.72	1.23	0.28	1.86
KO22	3.1	2.63	77.52	19.84	97.36	7.65	9.084	0	9.43	6.73	1.51	0.02	1.07
KO23	1.2	64.08	28.11	7.82	35.93	2.9	301.076	8.59	83.92	3.57	2.59	0.59	0.7
KO24	2	28.47	60.99	10.54	71.53	3.46	10.389	349.83	29.36	5.09	2.53	-0.29	0.83
KO25	2.9	3.02	78.89	18.09	96.98	6.65	9.23	0	9.58	6.71	1.45	0	1.11
KO26	3.1	3.16	79.19	17.64	96.83	6.91	9.97	0	9.71	6.69	1.45	0.04	1.14
KO27	0.5	99.26	0.74	0	0.74	0	734.265	0	687.7	0.54	0.76	0.06	0.94
KO28	0.7	94.16	5.49	0.36	5.85	0	361.696	29.49	372.37	1.43	1.32	0.16	1.31
KO29	1.1	40.35	51.04	8.61	59.65	3.13	12.367	54.28	41.62	4.59	2.54	-0.06	0.81
KO30	1	89.08	9.91	1.01	10.92	0.19	580.326	69.31	467.52	1.1	1.5	0.42	2.09
KO31	0.9	94.62	4.98	0.4	5.38	0.01	536.465	62.74	503.39	0.99	1.05	0.27	1.7
KO32	2.8	22.98	62.39	14.62	77.01	5.61	9.686	368.26	22.09	5.5	2.53	-0.29	1.04
KO33	1.7	16.71	67.23	16.06	83.29	6.72	10.676	383.29	15.37	6.02	2.24	-0.2	1.28
KO34	1.4	48.78	40.58	10.64	51.22	4.13	411.863	9.59	51.69	4.27	2.84	0.05	0.64
KO35	0.5	92.83	6.12	1.05	7.17	0.16	346.222	8.28	308.66	1.7	1.23	0.32	1.89
KO36	2.5	21.73	61.09	17.18	78.27	7.29	9.424	318.58	19.16	5.71	2.54	-0.24	1.1
KO37	0.7	94.02	5.29	0.7	5.99	0.07	480.67	10.14	404.09	1.31	1.2	0.31	1.6
KO38	0.8	76.11	19.13	4.76	23.89	1.63	444.389	8.48	137.43	2.86	2.52	0.6	1.14
KO39	2.7	2.26	84.7	13.04	97.74	4	10.616	0	10.47	6.58	1.25	0.02	1.08
KO40	1.5	2.58	79.24	18.18	97.42	6.35	9.546	0	9.78	6.68	1.45	0.02	1.05
KO41	1.8	17.35	70.74	11.91	82.65	4.33	11.251	409.09	17.32	5.85	2.03	-0.19	1.16
KO42	1.1	85.92	11.7	2.38	14.08	0.75	418.754	9.64	302.65	1.72	1.64	0.46	2.08
KO43	1.2	93.09	6.12	0.79	6.91	0.12	815.1	12.6	643.34	0.64	1.38	0.39	1.95
KO44	0.8	56.12	37.9	5.99	43.89	2.16	129.385	11.65	59.62	4.07	2.36	0.26	0.85
KO45	2.3	5.65	81.19	13.16	94.35	4.57	11.445	0	12.11	6.37	1.46	-0.01	1.08
KO46	1.6	26.6	57.51	15.88	73.39	6.38	9.279	336.82	23.42	5.42	2.65	-0.27	0.9
KO47	1.4	80.82	15.14	4.04	19.18	1.35	360.56	8.29	156.48	2.68	2.22	0.66	2.2
KO48	1.9	11.84	69.19	18.96	88.15	7.95	9.52	340.78	11.8	6.41	2.05	-0.15	1.31
KO49	2.3	1.54	78.35	20.1	98.45	7.87	9.028	0	9.29	6.75	1.51	0.02	1.08
KO50	1.5	90.48	7.77	1.75	9.52	0.45	406.546	8.43	370.28	1.43	1.34	0.38	2.62
KO51	2.9	4.26	77.18	18.56	95.74	6.75	8.985	0	9.81	6.67	1.52	-0.02	1.1
KO52	3	7.25	74.38	18.38	92.76	7.41	9.487	411.64	10.88	6.52	1.69	-0.04	1.11
KO53	3.1	5.47	72.88	21.65	94.53	8.56	8.156	188.71	9.67	6.69	1.68	-0.04	1.06
KO54	2.7	4.29	77.95	17.76	95.71	6.56	9.268	0	10.18	6.62	1.52	-0.02	1.09
KO55	2.8	1.38	79.66	18.96	98.62	7.41	9.586	0	9.26	6.75	1.43	0.06	1.1
KO56	2.5	31.94	53.25	14.81	68.06	5.71	8.704	356.65	27.82	5.17	2.79	-0.32	0.65
KO57	2.1	52.2	37.88	9.92	47.8	3.31	348.314	8.3	75.23	3.73	2.72	0.59	0.6
KO58	3.5	14	64.14	21.86	86	9.43	8.495	430.67	11.86	6.4	2.25	-0.19	1.25
KO59	5	9.41	70.55	20.04	90.59	7.88	8.906	369.89	10.56	6.56	1.88	-0.14	1.27
Min	0.5	0.19	0.74	0	0.74	0	8.156	0	9.26	0.54	0.76	-0.32	0.59
Max	5.4	99.26	84.7	22.47	99.81	9.84	815.1	432	68.7	6.75	2.91	0.75	2.93

Woollooware Bay

Sample No	Depth (m)	Sand %	Silt %	Clay %	Muddy%	Clay2µm	Mode	Mode2	Mean (micron)	Mean	StdD	GsKew	Kurt
WO1	1.4	71.55	23.07	5.38	28.45	1.91	346.111	9.22	115.48	3.11	2.49	0.65	0.85
WO2	2.4	46.28	43.64	10.08	53.72	3.9	329.099	10.11	45.38	4.46	2.66	0.03	0.66
WO3	3.8	15.77	69.32	14.9	84.22	5.94	11.064	0	15.54	6.01	1.97	-0.09	1.04
WO4	4.2	19.95	66.03	14.01	80.04	5.75	11.341	362.01	18.27	5.77	2.23	-0.17	1.12
WO5	1.9	57.55	35.57	6.88	42.45	2.11	356.063	9.62	91.31	3.45	2.59	0.66	0.62
WO6	1.2	93.12	5.91	0.98	6.89	0.09	295.423	7.76	284.71	1.81	0.92	0.37	2.86
WO7	0.7	97.78	1.88	0.34	2.22	0	339.424	8.49	333.56	1.58	0.48	0.03	0.99
WO8	3.1	19.09	69.28	11.64	80.92	4	10.762	375.21	18.34	5.77	2.12	-0.23	1.14
WO9	2.4	16.41	68.48	15.11	83.59	5.85	10.229	281.37	15.45	6.02	2.07	-0.16	1.12
WO10	1	56.18	34.76	9.06	43.82	3.23	298.894	8.09	67.68	3.89	2.58	0.49	0.67
WO11	2	13.33	69.9	16.77	86.67	6.36	9.488	321.26	13.06	6.26	2.04	-0.19	1.27
WO12	0.6	54.96	38.08	6.96	45.04	2.05	311.761	9.4	78.87	3.66	2.54	0.59	0.62
WO13	1.4	22.94	62.45	14.62	77.07	5.49	9.754	334.84	21.98	5.51	2.49	-0.28	1.03
WO14	2.4	16.92	69.37	13.71	83.08	4.77	9.817	380.11	16	5.97	2.06	-0.2	1.12
WO15	3.1	23.94	62.76	13.3	76.06	5.3	10.681	408.9	21.66	5.53	2.39	-0.21	1.04
WO16	0.8	95.8	3.74	0.46	4.2	0	312.986	39.58	306.09	1.71	0.47	0.08	1.07
WO17	1.1	88.86	9.16	1.99	11.15	0.44	341.18	8.17	310.18	1.69	1.22	0.43	3.32
WO18	2.8	31.98	57.03	10.99	68.02	4.02	10.707	336.28	31.48	4.99	2.59	-0.24	0.72
WO19	2.5	49.23	41.27	9.5	50.77	3.53	333.599	9.56	51.2	4.29	2.67	0.12	0.63
WO20	1.7	12.6	73.12	14.28	87.4	5.17	10.414	0	13.95	6.16	1.84	-0.14	1.13
WO21	2.5	12.49	73.86	13.66	87.52	4.86	11.006	378.11	14.08	6.15	1.92	-0.17	1.28
WO22	1.9	44.3	46.64	9.07	55.71	3.27	406.104	10.39	47.09	4.41	2.72	-0.07	0.64
WO23	2.7	14.82	72.22	12.96	85.18	4.8	11.238	407.97	15.88	5.98	1.85	-0.09	1.03
WO24	1.8	30.41	57.1	12.49	69.59	4.32	9.74	353.81	29.49	5.08	2.68	-0.3	0.7
WO25	1.1	92.5	6.59	0.91	7.5	0.09	339.439	40.67	320.03	1.64	0.99	0.37	2.69
WO26	0.9	76.27	20.74	2.99	23.73	0.89	318.014	10.82	135.23	2.89	2.07	0.71	2.05
WO27	1.3	32.96	55.45	11.59	67.04	3.63	316.127	9.29	30.82	5.02	2.64	-0.28	0.63
WO28	1.7	29.19	59.86	10.96	70.82	3.68	10.048	310.79	28.78	5.12	2.48	-0.23	0.85
WO29	1.7	11.88	76.33	11.79	88.12	4.05	11.803	386.67	14.88	6.07	1.73	-0.11	1.13
WO30	1.4	18.85	70.42	10.73	81.15	3.82	12.09	315.71	19.07	5.71	2.02	-0.16	1.11
WO31	1.5	33.27	56.91	9.82	66.73	3.56	12.033	319.72	34.24	4.87	2.55	-0.2	0.73
WO32	1.5	33.29	57.87	8.84	66.71	2.96	11.853	335.82	35.14	4.83	2.5	-0.21	0.72
WO33	1.6	20.6	66.6	12.8	79.4	4.54	11.199	310.23	19.26	5.7	2.18	-0.18	1.07
WO34	1.4	10.42	78.53	11.05	89.58	3.71	11.662	335.23	14.08	6.15	1.73	-0.16	1.31
WO35	1.5	27.73	61.6	10.67	72.27	3.8	11.791	329.84	28.8	5.12	2.48	-0.25	0.91
WO36	1.5	18.38	64.3	17.32	81.62	6.28	8.729	332.43	16.08	5.96	2.32	-0.26	1.14
WO37	1.4	35.58	51.2	13.22	64.42	4.77	327.982	9.21	31.58	4.99	2.72	-0.22	0.64
WO38	1.3	54.46	37.88	7.66	45.54	2.24	318.075	9.09	78.79	3.67	2.58	0.6	0.62
WO39	1.5	38.86	49.72	11.43	61.15	3.57	332.108	8.78	34.66	4.85	2.7	-0.23	0.61
WO40	1.5	24.54	62.65	12.81	75.46	3.69	9.183	315.41	25.41	5.3	2.57	-0.37	0.96
WO41	1.6	47.66	43.33	9.01	52.34	3.12	326.133	10.22	48.95	4.35	2.63	0.05	0.64
WO42	1.6	32.75	55.03	12.22	67.25	3.99	320.157	9.09	30.2	5.05	2.66	-0.28	0.64
WO43	2.2	24.3	64.45	11.25	75.7	4.09	10.938	320.22	22.54	5.47	2.26	-0.21	0.99
WO44	2.9	74.64	19.84	5.52	25.36	2.11	334.32	8.7	133.47	2.91	2.68	0.56	1.04
WO45	2.6	39.37	50.09	10.54	60.63	3.78	299.188	9.94	35.2	4.83	2.59	-0.15	0.66
Min	0.6	10.42	1.88	0.34	2.22	0	8.729	0	13.06	1.58	0.47	-0.37	0.61
Max	4.2	97.8	78.5	17.3	89.6	6.4	406.1	408.9	333.6	6.3	2.72	0.71	3.32

Oyster Bay

Sample Name	Depth (m)	Sand %	Silt %	Clay %	Muddy%	Clay2µm	Mode	Mode2	Mean (micron)	Mean	StdD	GSkew	Kurt
OY1	2.4	6.17	71.12	22.71	93.83	9.14	8.42	302.39	9.17	6.77	1.71	-0.04	1.15
OY2	1.8	25.2	59.45	15.36	74.81	6.01	9.071	85.7	18.6	5.75	2.26	-0.17	0.88
OY3	1.2	18.67	68.27	13.06	81.33	4.52	9.742	0	16.79	5.9	1.97	-0.18	0.96
OY4	1	57.27	33.8	8.92	42.72	3.35	431.037	8.72	93.1	3.43	2.87	0.54	0.64
OY5	1.7	16.87	68.98	14.15	83.13	5.11	9.505	60.07	15.76	5.99	1.89	-0.12	0.9
OY6	1.8	11.96	71.15	16.89	88.04	6.64	9.122	0	12.98	6.27	1.84	-0.1	1.01
OY7	1.4	26.42	59.15	14.42	73.57	5.58	9.34	358.29	25.08	5.32	2.67	-0.32	0.91
OY8	1.8	28.9	56.08	15.02	71.1	6.05	9.243	399.36	27.73	5.17	2.84	-0.33	0.69
OY9	1.5	36.78	49.46	13.76	63.22	5.67	399.491	8.97	32.94	4.92	2.86	-0.23	0.65
OY10	1.7	13.72	68.52	17.76	86.28	7.2	8.788	405.93	13.38	6.22	1.94	-0.1	0.98
OY11	1.2	19.59	66.25	14.15	80.4	5.4	9.496	392.86	17.19	5.86	2.22	-0.23	1.11
OY12	1.2	4.61	77.07	18.32	95.39	6.92	8.954	0	10.44	6.58	1.58	-0.03	1.05
OY13	1.5	5.78	76.99	17.23	94.22	6.37	9.093	0	10.93	6.52	1.59	-0.05	1.06
OY14	0.8	51.35	38.18	10.47	48.65	3.91	417.582	8.74	71.88	3.8	2.85	0.42	0.61
OY15	1.4	11.89	70.04	18.07	88.11	7.24	9.038	376.22	11.99	6.38	2.09	-0.2	1.38
OY16	1.1	28.88	57.94	13.18	71.12	4.97	9.283	383.23	29.02	5.11	2.74	-0.33	0.67
OY17	1.4	5.39	74.91	19.69	94.6	8.43	9.68	0	10.46	6.58	1.68	0.02	1.07
OY18	1	1.95	81.6	16.45	98.05	5.97	9.65	0	10.2	6.62	1.41	0.02	1.06
OY19	1.1	6.32	74.98	18.7	93.68	7.43	9.422	0	9.98	6.65	1.63	-0.04	1.21
OY20	1.2	16.73	67.67	15.59	83.26	6.02	9.452	385.84	14.98	6.06	2.22	-0.28	1.33
OY21	0.7	2.44	78.69	18.87	97.56	7.19	9.135	0	9.72	6.68	1.5	0.03	1.06
OY22	0.5	0.14	80.32	19.54	99.86	6.43	8.393	0	8.09	6.95	1.24	0.05	1.1
OY23	0.9	7.63	78.51	13.85	92.36	4.34	9.688	352.94	10.69	6.55	1.73	-0.22	1.68
OY24	0.8	7.12	78.38	14.5	92.88	5.32	10.61	349.27	11.7	6.42	1.58	-0.06	1.17
OY25	0.6	0.63	79.74	19.64	99.38	6.91	8.592	0	8.42	6.89	1.32	0.04	1.11
OY26	0.6	0.52	81.52	17.97	99.49	5.93	8.785	0	8.56	6.87	1.25	0.04	1.11
OY27	0.5	6.16	75.71	18.14	93.85	6.91	9.579	294.45	9.72	6.68	1.58	-0.05	1.28
OY28	0.7	6.03	77.61	16.35	93.96	6.18	10.276	376.13	10.53	6.57	1.56	-0.04	1.22
OY29	0.9	0.76	79.9	19.35	99.25	6.39	8.591	0	8.13	6.94	1.25	0.05	1.12
OY30	0.9	0.26	80.73	19	99.73	5.75	8.335	0	8.02	6.96	1.19	0.04	1.09
OY31	0.6	4.82	77.24	17.93	95.17	6.39	9.037	524.04	9.47	6.72	1.47	-0.04	1.19
OY32	0.5	20.78	64.24	14.98	79.22	5.11	8.711	392.64	19.17	5.71	2.45	-0.38	1.16
OY33	0.7	0	80.65	19.35	100	6.25	8.637	0	7.8	7	1.15	0.1	1.08
OY34	0.6	40.17	46.28	13.56	59.84	5.13	427.981	8.3	33.49	4.9	2.92	-0.3	0.61
OY35	0.7	25.05	63.42	11.53	74.95	3.59	9.355	390.15	22.44	5.48	2.38	-0.34	0.95
OY36	0.3	39.58	47.04	13.38	60.42	4.84	420.307	8.1	34.29	4.87	2.87	-0.24	0.63
OY37	0.3	55.22	34.92	9.86	44.78	3.56	451.632	8.21	76.81	3.7	2.9	0.39	0.62
OY38	0.4	72.74	22.48	4.78	27.26	1.72	512.192	9.66	147.07	2.77	2.65	0.64	0.84
OY39	0.4	46.12	42.97	10.91	53.88	3.89	494.219	8.73	46.15	4.44	2.91	-0.12	0.6
OY40	0.4	57.82	34.47	7.71	42.18	2.79	421.289	9.24	75.1	3.74	2.72	0.34	0.66
OY41	0.5	14.75	65.72	19.52	85.24	7.13	7.97	445.06	11.73	6.41	2.19	-0.31	1.53
OY42	0.9	2.86	80.83	16.3	97.13	5.31	9.201	0	9.69	6.69	1.36	-0.02	1.11
OY43	1	9.45	72.98	17.57	90.55	7.12	9.563	0	11.34	6.46	1.8	-0.1	1.23
OY44	0.8	0.11	84.72	15.17	99.89	4.97	10.374	0	9.42	6.73	1.19	0.09	1.05
OY45	0.6	21.07	63.62	15.31	78.93	5.77	9.27	404.56	20.7	5.59	2.57	-0.37	1.19
OY46	0.5	7.05	75.93	17.02	92.95	6.12	9.243	639.61	10.61	6.56	1.6	-0.08	1.17
OY47	0.7	10.13	74.09	15.79	89.88	5.68	9.768	461.22	11.91	6.39	1.77	-0.15	1.25
OY48	0.4	11.14	72.34	16.52	88.86	5.1	8.436	520.73	10.34	6.6	1.95	-0.3	1.81
OY49	0.8	50.35	39.64	10.01	49.65	3.84	476.247	9.03	60.58	4.04	2.93	0.11	0.62
OY50	0.7	32.63	53.25	14.13	67.38	5.27	8.719	465.21	30.77	5.02	2.94	-0.37	0.64
OY51	0.6	5.12	77.79	17.1	94.89	6.03	9.343	172.35	10.03	6.64	1.49	-0.04	1.15
OY52	0.5	1.68	78.93	19.39	98.32	6.26	8.231	0	8.34	6.91	1.3	0	1.13
OY53	0.4	47.64	41.33	11.03	52.36	4.15	377.308	8.34	46.85	4.42	2.77	0.05	0.63
OY54	1	18.96	67.23	13.81	81.04	4.77	9.69	358.16	17.1	5.87	2.2	-0.27	1.15
OY55	0.9	35.17	50.76	14.07	64.83	4.66	1239.32	7.88	41.87	4.58	3.44	-0.49	0.54
Min	0.3	0	22.48	4.78	27.26	1.72	7.97	0	7.8	2.77	1.15	-0.49	0.54
Max	2.40	72.74	84.72	22.71	100.00	9.14	1239.32	639.61	147.07	7.00	3.44	0.64	1.81

Woronora River

Sample No	Depth (m)	Sand %	Silt %	Clay %	Muddy%	Clay2µm	Mode	Mode2	Mean (micron)	Mean	StdD	GsKew	Kurt
WOR1	1.2	64.55	28.17	7.28	35.45	2.66	558.828	9.05	126.2	2.99	2.87	0.67	0.65
WOR2	2.3	68.69	24.55	6.76	31.31	2.31	539.857	8.5	134.95	2.89	2.81	0.78	0.64
WOR3	0.4	62.39	27.87	9.74	37.61	3.8	336.33	7.39	80.46	3.64	2.73	0.6	0.66
WOR4	3.4	73.18	20.67	6.15	26.82	2.28	620.435	8.69	165.77	2.59	2.87	0.75	0.76
WOR5	0.4	54.29	35.44	10.26	45.7	3.97	472.1	8.72	95.17	3.39	2.89	0.67	0.59
WOR6	3.5	95.55	3.67	0.78	4.45	0.11	600.291	11.01	598.29	0.74	0.5	0.05	1.1
WOR7	0.4	57.46	33.57	8.98	42.55	3.32	490.876	8.95	101.62	3.3	2.9	0.62	0.61
WOR8	0.5	70.86	22.79	6.35	29.14	2.24	510.231	8.44	136.23	2.88	2.75	0.76	0.7
WOR9	0.7	53.52	36.37	10.11	46.48	3.87	454.617	8.6	66.24	3.92	2.88	0.25	0.63
WOR10	0.5	7.55	70.58	21.87	92.45	8.75	8.205	0	9.9	6.66	1.76	-0.07	1.1
WOR11	0.5	61.89	29.01	9.1	38.11	3.42	439.29	7.95	96.63	3.37	2.83	0.62	0.64
WOR12	2.4	94.37	4.61	1.02	5.63	0.21	613.162	9.85	598.79	0.74	1.17	0.34	2.69
WOR13	1.4	94.49	4.6	0.91	5.51	0.15	483.584	9.63	469.2	1.09	0.91	0.32	2.36
WOR14	0.5	19.39	58.95	21.66	80.61	8.75	7.39	401.81	15.15	6.04	2.55	-0.31	1.15
WOR15	0.5	94.64	4.59	0.77	5.36	0.09	516.762	10.65	502.76	0.99	0.87	0.33	2.5
WOR16	0.4	84.7	12.05	3.24	15.29	1.1	486.296	8.77	367.71	1.44	1.59	0.56	3.06
WOR17	0.5	77.7	17.31	4.99	22.3	1.77	467.696	8.53	151.22	2.73	2.56	0.72	2.12
WOR18	0.2	66.82	27.14	6.04	33.18	1.9	522.003	8.94	132.37	2.92	2.75	0.78	0.62
WOR19	4	96.35	2.86	0.79	3.65	0.15	552.273	10.27	544.83	0.88	0.55	0.05	1.03
WOR20	0.4	46.1	41.28	12.63	53.91	4.98	275.716	8.05	39.54	4.66	2.71	0.05	0.66
WOR21	0.4	27.42	55.91	16.67	72.58	6.25	8.156	254.19	21.88	5.51	2.6	-0.31	0.79
WOR22	0.5	47.64	41.23	11.13	52.36	4.3	291.877	8.56	44.52	4.49	2.69	0.09	0.65
WOR23	1.8	89.02	9.22	1.76	10.98	0.43	479.006	9.62	418.83	1.26	1.41	0.41	2.68
WOR24	2.7	97.9	1.8	0.31	2.11	0	549.284	0	546.9	0.87	0.59	0.02	0.97
WOR25	0.4	70.96	22.83	6.22	29.05	2.28	389.939	8.49	114.66	3.12	2.59	0.69	0.78
WOR26	1.1	87.14	10.53	2.34	12.87	0.65	614.653	9.31	553.5	0.85	1.44	0.46	3.7
WOR27	0.4	27.63	58.55	13.82	72.37	5.06	9.325	307.61	23.45	5.41	2.5	-0.25	0.89
WOR28	0.4	16.86	70.39	12.75	83.14	4.56	10.504	0	16.56	5.92	1.98	-0.17	1.09
WOR29	0.4	6.12	80.39	13.49	93.88	4.79	11.758	0	12.59	6.31	1.52	0	1.04
WOR30	0.4	6.69	82.12	11.19	93.31	3.96	12.541	0.85	13.96	6.16	1.48	0.01	1.01
WOR31	1.6	29.03	57.29	13.68	70.97	4.9	9.268	206.1	23.41	5.42	2.48	-0.27	0.79
WOR32	0.4	93.39	5.69	0.92	6.61	0.13	491.172	10.97	470.22	1.09	1.02	0.39	3.24
WOR33	2.5	58.51	32.74	8.75	41.49	3.28	359.683	9.13	80.55	3.63	2.72	0.53	0.65
WOR34	0.5	86.01	11.55	2.44	13.99	0.84	593.544	10.37	506.38	0.98	1.51	0.48	3.15
WOR35	2.2	83.87	12.77	3.36	16.13	1.22	652.198	9.28	322.69	1.63	2.21	0.69	2.95
WOR36	0.4	57.26	34.89	7.85	42.74	2.88	349.832	9.26	78.51	3.67	2.67	0.46	0.66
WOR37	4.9	39.18	49.47	11.35	60.82	4.01	602.868	9.49	41.39	4.59	3.05	-0.33	0.57
WOR38	3.9	6.06	77.89	16.05	93.94	6.11	10.766	0	11.25	6.47	1.56	-0.01	1.11
WOR39	0.4	94.53	4.74	0.73	5.47	0.09	523.078	11.46	496.91	1.01	0.94	0.32	2.19
WOR40	1.3	48.11	42.43	9.46	51.89	3.61	480.8	10.4	54.53	4.2	2.85	0	0.63
WOR41	2	45.61	45.73	8.65	54.38	2.97	540.619	10.27	49.39	4.34	2.89	-0.21	0.57
WOR42	2.4	40.6	48.06	11.34	59.4	4.29	500.88	10.21	39.86	4.65	2.86	-0.2	0.67
WOR43	2	26.76	63.66	9.58	73.24	3.67	13.733	489.25	25.87	5.27	2.28	-0.18	1.04
WOR44	1.7	34.86	54.21	10.93	65.14	4.28	535.255	11.01	38.32	4.71	2.89	-0.3	0.65
WOR45	3.4	4.65	85.15	10.21	95.36	3.42	13.719	0	13.45	6.22	1.36	0.03	1.05
WOR46	1.5	97.31	2.16	0.53	2.69	0.03	473.61	9.39	466.15	1.1	0.62	0.04	0.98
WOR47	0.4	44.91	41.83	13.25	55.08	5.22	320.212	8.18	37.88	4.72	2.78	-0.04	0.63
Min	0.2	4.65	1.8	0.31	2.11	0	7.39	0	9.9	0.74	0.5	-0.33	0.57
Max	4.9	97.9	85.15	21.87	95.36	8.75	652.198	489.25	598.79	6.66	3.05	0.78	3.7

Georges River and Salt Pan Creek

Sample No	Depth (m)	Sand %	Silt %	Clay %	Muddy %	Clay2µm	Mode	Mode2	Mean (micron)	Mean	StdD	GsKew	Kurt
GE1	5.8	3.18	82.57	14.26	96.83	5.47	12.498	0	11.72	6.41	1.44	0.07	1.05
GE2	2	6.45	76.43	17.12	93.55	6.69	9.836	0	10.99	6.51	1.61	-0.03	1.11
GE3	8	12.18	69.22	18.6	87.82	8.09	10.157	352.84	11.87	6.4	2.08	-0.15	1.38
GE4	3.8	72.73	21.65	5.63	27.28	2.15	449.685	9.04	132.95	2.91	2.62	0.69	0.85
GE5	0.8	81.27	14.64	4.09	18.73	1.68	520.653	9.08	216.17	2.21	2.3	0.72	2.78
GE6	0.4	87.34	10.71	1.95	12.66	0.61	643.603	11.17	515.59	0.96	1.64	0.44	2.37
GE7	9.6	54.21	34.04	11.75	45.79	5.26	412.266	8.16	69.44	3.85	2.92	0.42	0.65
GE8	8.1	40.35	47.18	12.47	59.65	5.26	379.211	9.63	35.19	4.83	2.77	-0.16	0.67
GE9	15.4	46.16	38.67	15.17	53.84	6.51	544.31	7.76	40.51	4.63	3.14	-0.18	0.58
GE10	2.5	41.74	49.63	8.62	58.25	3.13	10.795	155.85	35.9	4.8	2.39	-0.04	0.75
GE11	9.2	95.88	3.42	0.7	4.12	0.08	472.295	8.95	454.63	1.14	0.64	0.09	1.06
GE12	1.5	11.09	73.02	15.89	88.91	6.69	11.109	0	13.11	6.25	1.81	-0.05	1.11
GE13	10.3	14.09	71.24	14.67	85.91	5.88	10.737	342.4	14.31	6.13	2.03	-0.18	1.3
GE14	6.2	29.24	53.12	17.64	70.76	7.71	440.12	9.15	27.16	5.2	3.01	-0.34	0.63
GE15	1	88.99	8.85	2.16	11.01	0.71	308.349	8	266.29	1.91	1.42	0.37	2.17
GE16	8.6	3.06	81.88	15.06	96.94	5.66	10.985	0	10.74	6.54	1.41	0.04	1.1
GE17	3.6	26.24	61.6	12.17	73.77	4.73	10.493	109.66	21.46	5.54	2.2	-0.17	0.88
GE18	12.4	47.9	40.59	11.52	52.11	5.03	767.342	9.55	60.86	4.04	3.24	-0.08	0.6
GE19	0.5	100	0	0	0	0	468.447	0	467.57	1.1	0.44	0	0.95
GE20	8.5	85.83	11.57	2.6	14.17	0.92	437.894	9.31	365.22	1.45	1.49	0.45	2.69
GE21	5.2	83.54	13.49	2.97	16.46	0.99	573.896	9.5	282.74	1.82	2.14	0.72	3.3
GE22	12.3	90.91	7.47	1.62	9.09	0.49	551.022	10.19	508.51	0.98	1.35	0.39	2.87
GE23	6.5	16.6	64.9	18.49	83.39	8.12	9.352	123.69	13.99	6.16	2.11	-0.14	1.07
GE24	6.5	57.27	34.25	8.47	42.72	3.67	219.473	9.95	62.41	4	2.53	0.4	0.73
GE25	4.4	11.78	73.2	15.02	88.22	6.27	11.31	510.62	13.5	6.21	1.83	-0.08	1.16
GE26	9.5	10.66	70.48	18.86	89.34	7.84	9.507	307.11	11.28	6.47	1.93	-0.13	1.29
GE27	14	37.58	51.67	10.75	62.42	4.19	101.314	9.79	27.87	5.17	2.15	0.1	0.77
GE28	1.6	19.23	67.57	13.21	80.78	5.09	10.507	0	17.45	5.84	2.07	-0.17	1.04
GE29	1.2	8.99	79.17	11.83	91	4.14	11.614	0	14.47	6.11	1.58	-0.02	0.98
GE30	1.3	11.13	74.48	14.39	88.87	5.23	10.088	0	13.62	6.2	1.72	-0.08	1.01
GE31	8.2	41.27	46.9	11.84	58.74	4.79	542.825	9.55	41.62	4.59	2.99	-0.23	0.62
GE32	0.5	100	0	0	0	0	509.525	0	510.78	0.97	0.44	0	0.95
GE33	8.2	10.5	68.27	21.22	89.49	9.38	9.27	0	10.6	6.56	1.94	-0.09	1.22
GE34	9.5	11.98	70.46	17.56	88.02	7.33	10.178	462.32	12.34	6.34	1.95	-0.12	1.25
GE35	2.7	12.5	72.54	14.96	87.5	5.84	10.597	0	13.53	6.21	1.82	-0.11	1.13
GE36	2.6	5.12	77.21	17.68	94.89	6.69	9.285	0	10.63	6.56	1.58	-0.02	1.07
GE37	2.2	6.72	77.98	15.3	93.28	6.32	11.689	0	12.62	6.31	1.63	0.04	1.03
GE38	1.8	7.91	77.62	14.47	92.09	5.96	11.828	0	13.43	6.22	1.65	0.03	1.01
GE39	2.1	4.46	80.47	15.07	95.54	6.1	11.661	0	11.84	6.4	1.53	0.05	1.05
GE40	4.1	98.8	1.09	0.11	1.2	0	560.976	0	567.01	0.82	0.53	-0.01	0.98
GE41	5.3	65.58	26.05	8.38	34.43	3.31	381.937	8.41	96.14	3.38	2.76	0.6	0.68
GE42	6.2	95.38	3.8	0.83	4.63	0.12	435.117	8.7	417.53	1.26	0.6	0.12	1.11
GE43	2.1	94.93	4.2	0.87	5.07	0.12	392.272	8.26	373.92	1.42	0.84	0.28	1.85
GE44	1.2	46.2	43.64	10.16	53.8	4.05	99.981	8.74	36.53	4.77	2.2	0.35	0.79
GE45	0.7	75.75	18.35	5.9	24.25	2.14	161.942	7.03	72.54	3.79	2.05	0.61	1.68
GE46	7.4	100	0	0	0	0	568.789	0	575.65	0.8	0.46	-0.02	0.96
GE47	7.6	94.38	4.64	0.98	5.62	0.18	527.278	10.33	508.07	0.98	1.03	0.37	2.94
GE48	2.8	96.55	2.84	0.61	3.45	0.05	426.003	9.3	411.05	1.28	0.58	0.07	1.01
GE49	0.3	29.48	61.16	9.36	70.52	3.74	14.133	596.7	28.18	5.15	2.36	-0.14	1.08
GE50	0.3	11.65	74.44	13.91	88.35	5.22	10.537	0	14.29	6.13	1.74	-0.06	1
GE51	0.4	12.28	74.33	13.39	87.72	5.5	12.274	480.77	15.25	6.04	1.76	-0.01	1.01
GE52	1.1	10.12	76.7	13.18	89.88	5.31	12.594	0	14.58	6.1	1.67	0.01	1.01
GE53	2.2	9.34	74.79	15.87	90.66	6.45	11.25	469.64	12.68	6.3	1.74	-0.03	1.09
GE54	0.5	3.33	84.16	12.51	96.67	4.53	11.948	0	12.45	6.33	1.41	0.04	1.02
Min	0.3	3.06	0	0	0	0	9.27	0	10.6	0.8	0.44	-0.34	0.58
Max	15.4	100	84.16	21.22	96.94	9.38	767.342	596.7	575.65	6.56	3.24	0.72	3.3

B- Port Hacking Gunnamatta Bay

Sample No	Depth (m)	Sand %	Silt %	Clay %	Muddy%	Clay2µm	Mode	Mode2	Mean (micron)	Mean	StdD	GsKew	Kurt
GU1	3.8	99.26	0.74	0	0.74	0	337.591	0	328.62	1.61	0.67	0.04	0.94
GU2	4	98.34	1.66	0	1.66	0	316.733	0	444.55	1.17	1.13	-0.06	0.84
GU3	3.3	99.15	0.85	0	0.85	0	353.707	0	345.31	1.53	0.66	0.03	0.95
GU4	2	99.12	0.88	0	0.88	0	264.043	0	258.69	1.95	0.63	0.03	0.94
GU5	1	100	0	0	0	0	344.004	0	345.25	1.53	0.51	0	0.95
GU6	1	100	0	0	0	0	359.581	0	363.87	1.46	0.53	-0.01	0.95
GU7	1.4	100	0	0	0	0	403.849	0	403.66	1.31	0.51	0	0.95
GU8	4	97.87	2.13	0	2.13	0	407.271	51.69	384.94	1.38	0.75	0.08	1
GU9	4.2	100	0	0	0	0	361.73	0	371.48	1.43	0.61	-0.03	0.96
GU10	8	100	0	0	0	0	328.151	0	324.91	1.62	0.48	0.01	0.97
GU11	7.5	73.56	22.97	3.47	26.44	1.69	327.098	59.27	139.33	2.84	1.99	0.46	1.03
GU12	0.8	100	0	0	0	0	362.889	0	365.08	1.45	0.5	0	0.95
GU13	0.8	100	0	0	0	0	612.98	0	561.09	0.83	0.52	0.08	0.91
GU14	6.5	98.97	1.03	0	1.03	0	489.008	0	495.38	1.01	0.75	0.01	0.95
GU15	10.8	37.95	52.4	9.65	62.05	4.11	11.939	357.45	37.31	4.74	2.55	-0.11	0.74
GU16	10.9	24.52	63.78	11.7	75.48	4.91	11.982	381.1	25.03	5.32	2.43	-0.23	1.05
GU17	11	29.3	62.35	8.35	70.7	3.09	129.025	14.43	25.79	5.28	1.93	-0.03	0.79
GU18	10	24.53	65.97	9.49	75.46	4.89	43.094	356.46	27.81	5.17	1.86	0.25	1.28
GU19	8.6	46.91	43.51	9.58	53.09	4.13	365.321	11.09	48.52	4.37	2.68	0.04	0.68
GU20	4.7	60.92	34.43	4.65	39.08	2.3	59.751	467.33	104.79	3.25	2.42	0.04	0.93
GU21	10.4	2.16	82.62	15.22	97.84	6.37	11.693	0.8	11.16	6.48	1.46	0.08	1.1
GU22	6.5	100	0	0	0	0	395.915	0	388.74	1.36	0.57	0.02	0.93
GU23	0.6	96.18	3.82	0	3.82	0	285.729	1169.07	257.7	1.96	0.99	0.07	2.32
GU24	1.2	99.35	0.65	0	0.65	0	377.24	0	374.94	1.42	0.61	0.01	0.94
GU25	12	13.67	73.06	13.27	86.33	5.86	13.4	338.22	15.44	6.02	1.98	-0.1	1.3
GU26	8.2	95.91	3.77	0.32	4.09	0.01	400.242	44.18	397.69	1.33	0.84	0.05	1.05
GU27	10.8	14.82	76.47	8.71	85.18	3.41	15.26	0.76	18.92	5.72	1.63	0	0.97
GU28	9.4	74.16	21.41	4.43	25.84	1.76	390.435	10.46	133.81	2.9	2.49	0.61	0.97
GU29	7	91.66	7.18	1.16	8.34	0.37	471.445	37.47	449.48	1.15	1.41	0.28	1.81
GU30	10.5	30.51	60.17	9.33	69.5	4.73	42.87	393.52	34.38	4.86	2.22	0.07	1.33
GU31	9	54.6	37.16	8.24	45.4	3.4	342.438	10.48	76.19	3.71	2.78	0.35	0.67
GU32	2.2	77.06	20.69	2.25	22.94	0.79	311.35	34.32	137.95	2.86	1.86	0.65	1.27
GU33	5.2	83.33	14.48	2.19	16.67	0.84	422.608	14.86	230.95	2.11	1.94	0.5	1.6
GU34	4.2	93.01	6.19	0.81	7	0.09	381.475	10.19	327.21	1.61	1.27	0.32	1.78
GU35	1.7	78.71	18.95	2.33	21.28	0.9	445.415	28.04	193.12	2.37	2.18	0.54	1.25
GU36	2.9	64.73	31.08	4.19	35.27	2	437.245	47.46	137.98	2.86	2.36	0.36	0.86
GU37	5.6	95.68	3.65	0.66	4.31	0.09	423.354	9.97	403.3	1.31	0.71	0.1	1.07
GU38	6.9	76.26	19.07	4.67	23.74	1.94	369.104	9.57	130.08	2.94	2.35	0.64	1.23
GU39	10.6	11.04	77.17	11.8	88.97	5.03	13.932	0.79	15.83	5.98	1.66	0.03	1.02
GU40	9.8	30.95	54.92	14.14	69.06	6.31	10.347	415.53	28.83	5.12	2.79	-0.26	0.79
GU41	8.2	95.35	4.04	0.61	4.65	0.05	564.327	10.23	538.41	0.89	0.99	0.23	1.53
GU42	5.6	80.33	16.13	3.54	19.67	1.43	509.573	10.22	201.66	2.31	2.48	0.55	1.51
GU43	2	91.51	7.85	0.64	8.49	0.02	486.038	13.6	422.93	1.24	1.32	0.35	1.98
GU44	8.3	45.98	45.12	8.9	54.02	4.38	370.264	32.25	54.52	4.2	2.6	0.02	0.78
GU45	9.1	19.61	68.75	11.65	80.4	5.9	38.751	0	22.8	5.45	1.92	0.24	1.17
GU46	5.7	89.4	8.59	2	10.59	0.69	380.836	8.55	336.88	1.57	1.31	0.41	2.75
GU47	2.5	75.68	21.3	3.02	24.32	1.14	492.519	14.01	181.12	2.46	2.45	0.56	0.99
GU48	2.7	95.55	4.11	0.33	4.44	0	540.972	63.95	517.22	0.95	0.94	0.22	1.49
GU49	1.2	91.09	8.13	0.77	8.9	0.08	490.432	12.38	430.27	1.22	1.31	0.37	2.22
GU50	1.5	73.99	23	3.01	26.01	1.15	405.324	47.15	150.39	2.73	2.24	0.6	0.94
GU51	4.2	84.5	12.79	2.71	15.5	1.02	410.685	9.62	247.29	2.02	1.8	0.54	1.99
GU52	1.9	83.87	14.02	2.11	16.13	0.8	322.465	17.01	197.9	2.34	1.71	0.46	1.56
GU53	0.4	87.81	11.14	1.05	12.19	0.33	305.427	0	203.97	2.29	1.36	0.32	1.23
GU54	0.5	87.66	11.19	1.15	12.34	0.26	326.968	0	245.51	2.03	1.42	0.41	1.75
GU55	1.2	53.74	41.16	5.1	46.26	2.59	69.489	0	66.3	3.91	2.01	0.13	1.22
GU56	0.4	84.98	13.49	1.53	15.02	0.49	329.459	0	208.31	2.26	1.58	0.48	1.61
GU57	0.3	91.98	7.1	0.92	8.02	0.21	306.728	0	259.03	1.95	1.16	0.3	1.56
GU58	4.6	62.59	30.73	6.68	37.41	2.75	407.561	10.51	97.54	3.36	2.64	0.55	0.69
GU59	7.3	77.96	17.8	4.24	22.04	1.71	497.142	10.27	173.95	2.52	2.56	0.63	1.6
Min	0.3	2.16	0	0	0	0	10.347	0	11.16	0.83	0.48	-0.26	0.67
Max	12	100	82.62	15.22	97.84	6.37	612.98	1169.07	561.09	6.48	2.79	0.65	2.75

South West Arm

Sample No	Depth (m)	Sand %	Silt %	Clay %	Muddy%	Clay2µm	Mode	Mode2	Mean (micron)	Mean	StdD	GSkew	Kurt
SWA1	13	60.17	35.58	4.25	39.83	1.67	401.026	17.84	99.14	3.33	2.43	0.44	0.7
SWA2	0.4	92.58	6.99	0.43	7.42	0.01	182.717	26.04	161.41	2.63	0.86	0.28	1.5
SWA3	5.2	92.2	7.35	0.45	7.8	0	469.282	66.98	397.72	1.33	1.23	0.35	1.84
SWA4	1	95.55	4.33	0.12	4.45	0	365.92	42.99	340.44	1.55	0.84	0.16	1.17
SWA5	0.4	97.58	2.42	0	2.42	0	525.84	62.88	521.54	0.94	0.65	0.03	1
SWA6	6.2	88.05	11.06	0.89	11.95	0.13	465.595	17.79	349.26	1.52	1.51	0.42	1.85
SWA7	1.6	93.46	6.33	0.21	6.54	0	391.492	42.68	362.65	1.46	1.01	0.3	1.83
SWA8	1.1	98.14	1.58	0.27	1.85	0	468.461	0	455.02	1.14	0.42	0.06	0.99
SWA9	0.4	95.78	3.49	0.73	4.22	0.12	351.443	9.08	301.15	1.73	0.74	0.19	1.08
SWA10	0.5	97.33	2.36	0.31	2.67	0	416.387	10.87	390.26	1.36	0.54	0.09	0.95
SWA11	0.4	97.54	2.46	0	2.46	0	531.085	65.18	528.06	0.92	0.59	0.03	1.02
SWA12	0.4	99.32	0.68	0	0.68	0	511.4	0	514.69	0.96	0.6	0	0.96
SWA13	0.4	98.64	1.36	0	1.36	0	507.162	0	512.53	0.96	0.68	0	0.97
SWA14	0.4	99.43	0.57	0	0.57	0	503.679	0	499.07	1	0.49	0.02	0.95
SWA15	0.2	99.16	0.84	0	0.84	0	517.649	0	522.5	0.94	0.64	0	0.95
SWA16	0.3	98.84	1.16	0	1.16	0	519.831	0	522.35	0.94	0.61	0.01	0.96
SWA17	8	26.89	65.6	7.5	73.1	3.3	24.391	0.78	27.74	5.17	1.93	0	1.01
SWA18	0.7	99.59	0.41	0	0.41	0	419.289	0	427.07	1.23	0.65	-0.01	0.95
SWA19	18	64.39	30.67	4.95	35.62	2.12	332.709	15.69	97.67	3.36	2.47	0.39	0.79
SWA20	7.5	53.8	40.96	5.25	46.21	2.17	236.012	16.63	65.82	3.93	2.36	0.23	0.75
Min	0.20	26.89	0.41	0.00	0.41	0.00	24.39	0.00	27.74	0.92	0.42	-0.01	0.70
Max	18	99.59	65.6	7.5	73.1	3.3	531.085	66.98	528.06	5.17	2.47	0.44	1.85

Gynea Bay

Sample No	Depth (m)	Sand %	Silt %	Clay %	Muddy %	Clay2µm	Mode	Mode2	Mean (micron)	Mean	StdD	GsKew	Kurt
GY1	20	12.28	76.94	10.79	87.73	4.43	15.182	0.81	16.55	5.92	1.69	-0.01	1.09
GY2	17	4.75	83.85	11.4	95.25	4.36	13.756	0.84	13.46	6.22	1.42	0.05	1.05
GY3	6.2	95.63	4.04	0.33	4.37	0	405.874	46.65	383.59	1.38	0.76	0.11	1.06
GY4	9.2	93.14	6.11	0.76	6.87	0.1	574.055	12.23	517.57	0.95	1.32	0.33	1.97
GY5	18	7.1	77.64	15.26	92.9	6.37	12.266	0	12.3	6.34	1.63	0.03	1.11
GY6	9.2	89.76	8.61	1.63	10.24	0.48	526.224	10.22	420.42	1.25	1.61	0.39	2
GY7	7.9	83.53	14.51	1.95	16.46	0.65	533.496	13.64	273.46	1.87	2.01	0.6	1.92
GY8	17	5.96	82.1	11.94	94.04	4.82	13.965	0.81	13.49	6.21	1.48	0.05	1.09
GY9	17	3.81	83.82	12.38	96.2	4.46	12.552	0	12.58	6.31	1.41	0.05	1.03
GY10	7	88.58	10.03	1.39	11.42	0.3	483.439	11.4	378.64	1.4	1.59	0.4	1.96
GY11	9.4	68.52	26.46	5.02	31.48	2.23	378.913	34.63	127.97	2.97	2.42	0.46	0.9
GY12	18	2	86.83	11.17	98	4.06	13.489	0	12.6	6.31	1.31	0.08	1.04
GY13	17	0.87	88.25	10.88	99.13	3.8	13.089	0	12.07	6.37	1.24	0.09	1.04
GY14	8.4	96.08	3.39	0.52	3.91	0.04	476.983	9.61	444.52	1.17	0.78	0.12	1.07
GY15	0.4	98.21	1.79	0	1.79	0	468.118	0	435.74	1.2	0.71	0.09	0.99
GY16	0.4	95.89	3.79	0.32	4.11	0	457.6	11.2	409.43	1.29	0.89	0.16	1.13
GY17	0.4	91.92	7.7	0.38	8.08	0	604.537	84.51	530.9	0.91	1.18	0.39	2.2
GY18	0.4	97.46	2.49	0.05	2.54	0	479.499	0	462.96	1.11	0.68	0.06	1
GY19	11	9.17	79.13	11.7	90.83	4.36	12.946	0	14.88	6.07	1.59	0.01	1
GY20	5.1	92.78	6.59	0.63	7.22	0.04	413.258	11.35	377.82	1.4	1.17	0.32	1.98
GY21	10	27.04	62.18	10.78	72.96	4.12	11.001	422.31	28.59	5.13	2.56	-0.31	0.97
GY22	6.3	91.09	7.96	0.96	8.92	0.16	456.539	12.35	360.93	1.47	1.47	0.36	1.75
GY23	5.8	91.19	7.91	0.9	8.81	0.16	476.762	12.11	428.57	1.22	1.33	0.35	2.15
GY24	0.4	97.65	2.33	0.02	2.35	0	372.448	0	367.24	1.45	0.57	0.03	0.98
GY25	0.4	96.24	3.6	0.16	3.76	0	449.478	48.43	433.36	1.21	0.7	0.08	1.04
GY26	0.4	95.3	4.42	0.28	4.7	0	389.444	45.96	374.93	1.42	0.64	0.11	1.12
GY27	0.4	95.19	4.48	0.33	4.81	0	492.931	12.44	458.29	1.13	0.96	0.24	1.53
GY28	5.2	52.72	40.86	6.42	47.28	2.51	199.85	13.16	52.75	4.24	2.19	0.32	0.77
GY29	0.8	91.11	8.15	0.74	8.89	0.1	453.323	45.65	399.15	1.33	1.27	0.35	2.07
GY30	0.4	97.53	2.44	0.02	2.46	0	478.757	58.03	468.23	1.09	0.61	0.05	0.99
GY31	0.4	93.37	6.15	0.47	6.62	0.01	394.984	36.23	365.08	1.45	1.14	0.28	1.76
GY32	0.4	90.89	8.39	0.72	9.11	0.07	415.048	13.45	363.95	1.46	1.32	0.34	1.95
Min	0.4	0.87	1.79	0	1.79	0	11.001	0	12.07	0.91	0.57	-0.31	0.77
Max	20.2	98.21	88.25	15.26	99.13	6.37	604.537	422.31	530.9	6.37	2.56	0.60	2.20

Mansion Bay and Hacking River

Sample No	Depth (m)	Sand %	Silt %	Clay %	Muddy %	Clay2µm	Mode	Mode2	Mean (micron)	Mean	StdD	GsKew	Kurt
MA1	0.3	96.8	3.05	0.15	3.2	0	414.432	0	394.91	1.34	0.74	0.07	0.99
MA2	0.4	96.35	3.43	0.22	3.65	0	408.793	10.86	379.04	1.4	0.81	0.1	1.02
MA3	0.4	97.72	2.25	0.02	2.27	0	447.439	0	433.11	1.21	0.62	0.05	0.98
MA4	3.9	89.81	9.14	1.05	10.19	0.19	503.648	12.9	419.84	1.25	1.38	0.4	2.23
MA5	3	97.36	2.44	0.19	2.63	0	488.854	0	476.25	1.07	0.63	0.05	0.99
MA6	1.1	80.73	16.89	2.39	19.28	0.82	441.648	14.77	202.16	2.31	2.04	0.65	1.98
MA7	1.5	94.33	5.24	0.43	5.67	0	460.321	11.44	439.75	1.19	0.92	0.32	2.17
MA8	2.8	92.42	6.87	0.71	7.58	0.03	528.679	12.31	494.66	1.02	1.17	0.38	2.82
MA9	3.4	89.55	9.33	1.12	10.45	0.19	515.548	12.49	465.15	1.1	1.29	0.41	2.88
MA10	0.5	84.55	13.88	1.56	15.44	0.32	471.651	13.36	268.59	1.9	1.82	0.56	1.91
MA11	0.5	53.3	40.46	6.24	46.7	2.35	117.274	12.91	53.56	4.22	2.24	0.27	0.85
MA12	1	96.57	3.26	0.17	3.43	0	553.475	12.37	540.53	0.89	0.65	0.07	1.03
MA13	0.5	96.99	2.87	0.14	3.01	0	551.05	66.71	540.06	0.89	0.65	0.06	1.01
MA14	1.3	96.27	3.47	0.25	3.72	0	610.903	13.55	602.52	0.73	0.66	0.07	1.08
MA15	2.4	96.25	3.48	0.26	3.74	0	618.346	13.07	612.92	0.71	0.63	0.06	1.08
MA16	2.9	72.29	23.6	4.12	27.72	1.53	400.506	12.5	135.11	2.89	2.4	0.67	0.85
MA17	2.5	81.52	16	2.48	18.48	0.81	414.168	11.46	194.29	2.36	2.04	0.68	2.4
MA18	1.1	96.98	2.88	0.14	3.02	0	544.328	68.42	542.62	0.88	0.6	0.03	1.04
MA19	3.5	78.88	18.67	2.46	21.13	0.85	718.269	15.85	253.34	1.98	2.5	0.7	2.11
MA20	5.3	88.1	10.27	1.63	11.9	0.43	281.397	27	243.77	2.04	1.34	0.37	2.08
MA21	4.5	29.28	61.51	9.2	70.71	3.45	13.061	372.51	27.59	5.18	2.25	-0.14	0.94
MA22	4.6	8.43	79.11	12.46	91.57	5.25	15.769	0	15.17	6.04	1.61	0.09	0.99
MA23	0.8	83.61	14.08	2.31	16.39	0.74	557.841	11.46	285.23	1.81	2.06	0.66	2.52
MA24	1.4	93.43	5.88	0.7	6.58	0.02	508.293	10.81	476.61	1.07	1.16	0.36	2.53
MA25	5.2	24.05	66.03	9.92	75.95	4.08	14.986	0	22.99	5.44	1.97	-0.01	0.96
MA26	0.5	78.19	19.21	2.6	21.81	0.91	479.504	14.06	182.71	2.45	2.24	0.65	1.18
MA27	0.5	96.57	3.23	0.2	3.43	0	396.014	10.1	375.32	1.41	0.79	0.07	1
MA28	4.2	84.9	13.24	1.85	15.09	0.57	563.462	13.02	316.76	1.66	1.89	0.65	2.68
Min	0.3	8.43	2.25	0.02	2.27	0	13.061	0	15.17	0.71	0.6	-0.14	0.85
Max	5.3	97.72	79.11	12.46	91.57	5.25	718.269	372.51	612.92	6.04	2.5	0.7	2.88

North West Arm

Sample No	Depth (m)	Sand %	Silt %	Clay %	Muddy%	Clay2µm	Mode	Mode2	Mean (micron)	Mean	StdD	GsKew	Kurt
NWA1	12.9	11.11	74.82	14.07	88.89	5.84	11.999	453.96	14.21	6.14	1.75	-0.02	1.07
NWA2	6.6	86.53	11.62	1.85	13.47	0.62	430.525	11.66	316.31	1.66	1.55	0.48	2.15
NWA3	13.3	6.79	78.23	14.98	93.21	6.32	12.427	0	12.62	6.31	1.62	0.04	1.07
NWA4	11.2	13.24	73.98	12.77	86.75	5.44	13.587	366.98	15.95	5.97	1.81	-0.02	1.08
NWA5	8	27.05	62.29	10.66	72.95	4.3	12.522	0	24.31	5.36	2.16	-0.07	0.94
NWA6	0.7	85.73	12.95	1.32	14.27	0.29	387.248	37.64	252.96	1.98	1.6	0.48	1.75
NWA7	0.5	92.36	7.25	0.39	7.64	0	425.476	48.54	371.73	1.43	1.14	0.34	1.86
NWA8	0.5	94.03	5.68	0.29	5.97	0	426.842	48.72	386.7	1.37	1.02	0.3	1.72
Min	0.5	6.79	5.68	0.29	5.97	0	11.999	0	12.62	1.37	1.02	-0.07	0.94
Max	13.3	94.03	78.23	14.98	93.21	6.32	430.525	453.96	386.7	6.31	2.16	0.48	2.15

Yowie Bay

Sample No	Depth (m)	Sand %	Silt %	Clay %	Muddy %	Clay2µm	Mode	Mode2	Mean (micron)	Mean	StdD	GSkew	Kurt
YO1	5.5	83.02	13.74	3.24	16.98	1.22	327.61	9.68	191.54	2.38	2.07	0.44	1.6
YO2	0.4	55.3	38.91	5.79	44.7	2.35	213.019	20.88	65.27	3.94	2.35	0.26	0.81
YO3	0.4	79.99	17.34	2.67	20.01	1.02	205.725	18.56	137.15	2.87	1.85	0.39	1.42
YO4	4.5	47.07	44.73	8.2	52.93	3.43	113.491	12.16	42.44	4.56	2.22	0.25	0.84
YO5	5	46.04	45.33	8.63	53.96	3.7	112.372	11.87	39.97	4.64	2.16	0.29	0.84
YO6	1	91.47	7.53	1	8.53	0.2	408.798	11.44	340.34	1.55	1.33	0.35	1.87
YO7	3	82.65	14.78	2.57	17.35	0.96	438.036	11.8	210.96	2.24	1.99	0.56	1.61
YO8	9	8.62	78.31	13.07	91.38	5.38	12.789	0	14.39	6.12	1.63	0.04	1
YO9	9	69.89	23.58	6.53	30.11	2.56	438.51	9.02	119.44	3.07	2.73	0.64	0.71
YO10	8.5	75.52	20.17	4.31	24.48	1.62	446.133	10.14	145.42	2.78	2.58	0.61	1.12
YO11	15.2	11.29	75.46	13.26	88.72	5.49	12.372	395.28	14.19	6.14	1.8	-0.08	1.22
YO12	0.5	96.76	3.09	0.15	3.24	0	501.949	57.47	489.77	1.03	0.66	0.06	1.01
YO13	0.5	97.68	2.31	0.01	2.32	0	540.221	0	510.2	0.97	0.8	0.07	0.99
YO14	12	85.53	12.01	2.46	14.47	0.94	320.863	10.89	255.26	1.97	1.72	0.37	1.83
YO15	6.5	89.43	9.55	1.02	10.57	0.18	539.031	14.48	398.17	1.33	1.58	0.42	1.83
YO16	6	92.35	7.18	0.47	7.65	0.01	449.922	48.62	409.57	1.29	1.16	0.33	2.02
YO17	19	4.33	81.48	14.19	95.67	6.12	13.398	0.84	12.53	6.32	1.53	0.1	1.07
YO18	20	15.08	72.87	12.05	84.92	5.11	14.688	486.05	17.32	5.85	1.84	0	1.05
YO19	16	14.11	72.01	13.88	85.89	5.82	12.045	434.52	15.14	6.05	2.05	-0.14	1.31
YO20	19.5	5.6	79.25	15.16	94.41	6.39	12.218	0.86	11.8	6.41	1.56	0.05	1.12
YO21	17	9.77	75.4	14.83	90.23	6.26	11.891	0	13.15	6.25	1.74	-0.03	1.14
Min	0.4	4.33	2.31	0.01	2.32	0	11.891	0	11.8	0.97	0.66	-0.14	0.71
Max	20	97.68	81.48	15.16	95.67	6.39	540.221	486.05	510.2	6.41	2.73	0.64	2.02

Previous data / A- Burraneer Bay

Sample No	Depth	Sand %	Silt %	Clay %	Muddy %	Mean (micron)	StdD	GsKew	Kurt
gh 1	0.2	97.67	2.24	0.09	2.33	1.97	0.64	0.04	0.98
gh 2	0.9	99.86	0.14	0	0.14	1.97	0.6	0	0.94
gh 3	1.8	100	0	0	0	1.85	0.52	-0.01	0.95
gh 4	0.4	97.4	2.53	0.07	2.6	1.92	0.62	0.04	0.98
gh 5	0.6	98.54	1.46	0	1.46	2.05	0.6	0.03	0.96
gh 6	2.5	97.39	2.59	0.02	2.61	1.58	0.76	0.03	0.99
gh 7	0.6	93.54	6.4	0.07	6.47	1.52	1.2	0.21	1.51
gh 8	2	51.73	44.44	3.83	48.27	4.12	1.96	0.2	0.88
gh 9	0.2	86.41	13	0.59	13.59	2.08	1.42	0.38	1.7
gh 10	0.8	46.96	45.76	7.28	53.04	4.31	2.48	0.03	0.72
gh 11	3	58.57	38.38	3.06	41.44	3.64	2.1	0.22	0.82
gh 12	1	87.91	11.69	0.4	12.09	2.1	1.42	0.33	1.32
gh 13	1.7	89.07	10.48	0.45	10.93	2.34	1.23	0.27	1.56
gh 14	1	91.81	7.9	0.29	8.19	2.15	1.2	0.17	1.65
gh 15	1.7	90.77	8.93	0.3	9.23	1.97	1.17	0.31	1.62
gh 16	2	43.03	53.54	3.43	56.97	4.26	2.12	-0.06	0.9
gh 17	0.8	93.81	5.93	0.26	6.19	1.38	1.07	0.26	1.68
gh 18	1	51.5	44.97	3.53	48.5	3.96	2.17	0.08	0.81
gh 19	0.7	79.56	18.31	2.14	20.45	3.04	1.93	0.47	1.55
gh 20	0.4	88.6	10.8	0.6	11.4	1.53	1.64	0.21	1.48
gh 21	4.5	52.11	43.13	4.76	47.89	3.99	2.42	0.1	0.81
gh 22	1.5	65.24	32.55	2.21	34.76	3.25	2.21	0.26	0.84
gh 23	2	86.41	12.89	0.7	13.59	1.05	1.95	0.63	1.28
gh 24	3	27.11	68.73	4.16	72.89	5.01	1.59	0.05	0.97
gh 25	1.2	28.92	66.05	5.03	71.08	5	1.94	-0.09	1.11
gh 26	1	95.48	4.41	0.11	4.52	1.58	0.92	0.15	1.17
gh 27	1.2	80.71	18.39	0.9	19.29	2.48	1.78	0.44	1.24
gh 28	0.8	73.37	24.9	1.73	26.63	2.14	2.51	0.4	0.75
gh 29	0.5	86.42	12.95	0.63	13.58	1.92	1.56	0.47	1.59
gh 30	1.2	83.55	15.04	1.4	16.44	2.38	1.78	0.38	1.45
gh 31	1	96.12	3.79	0.09	3.88	1.35	0.8	0.09	1.05
gh 32	1.5	95.39	4.59	0.02	4.61	0.82	1.36	0.44	0.94
gh 33	0.6	99.13	0.87	0	0.87	1.25	0.9	-0.11	1
gh 34	1.8	96.04	3.79	0.17	3.96	0.15	0.9	0.37	1.69
gh 35	2.3	34.92	60.65	4.44	65.09	4.79	1.95	-0.05	0.86
gh 36	1.9	64.1	34.2	1.7	35.9	3.02	2.37	0.31	0.74
gh 37	1.3	86.87	10.97	2.16	13.13	2.13	1.14	0.5	3.88
gh 38	1.8	23.38	71.51	5.11	76.62	5.37	1.72	-0.14	0.85
gh 39	6	100	0	0	0	0.74	0.54	-0.02	0.95
gh 40	4.5	100	0	0	0	0.96	0.4	-0.01	0.97
gh 41	5	100	0	0	0	1.48	0.46	-0.01	0.96
gh 42	4	100	0	0	0	1.32	0.45	-0.01	0.96
gh 43	3	100	0	0	0	1.65	0.7	-0.02	0.94
gh 44	2	100	0	0	0	1.54	0.6	0.01	0.94
gh 45	13	100	0	0	0	1.61	0.52	0	0.94
gh 46	7	82.94	15.87	1.2	17.07	2.5	2	0.54	1.67
gh 47	12	28.25	64.24	7.52	71.76	5.23	1.99	-0.07	0.88
gh 48	11	32.14	60.4	7.45	67.85	5.05	2.08	-0.04	0.87
gh 49	11	24.31	66.12	9.57	75.69	5.48	2.05	-0.17	0.92
gh 50	10	25.97	61.75	12.28	74.03	5.49	2.37	-0.31	0.88
gh 51	7	85.59	13	1.42	14.42	1.99	1.57	0.45	1.96
gh 52	6	66.32	29.94	3.74	33.68	2.39	2.88	0.59	0.67
gh 53	8	68.24	29.85	1.91	31.76	2.82	2.51	0.54	0.69
gh 54	10	81.22	16.99	1.78	18.77	1.94	2.47	0.56	1.18
gh 55	11	27.95	63.27	8.78	72.05	5.32	2.16	-0.22	0.84
gh 56	10	55.94	36.67	7.39	44.06	3.76	2.67	0.38	0.65
gh 57	12	46.64	44.41	8.95	53.36	4.56	2.47	0.09	0.68
gh 58	12	47.88	44.9	7.22	52.12	4.28	2.51	0.08	0.72
gh 59	10	23.52	68.05	8.43	76.48	5.38	2.03	-0.13	1.02
gh 60	8	65.2	31.44	3.36	34.8	3.24	2.45	0.49	0.73
gh 61	6	81.23	16.92	1.85	18.77	2.74	1.9	0.52	1.59
gh 62	7	46.32	46.34	7.34	53.68	4.48	2.51	-0.02	0.66
gh 63	12	39.55	54.21	6.24	60.45	4.7	2.11	0.05	0.84
gh 64	11	57.64	36.86	5.5	42.36	3.81	2.42	0.31	0.75
gh 65	10	93.15	6.51	0.34	6.85	2.07	1.07	0.25	1.62
Min	0.2	23.38	0	0	0	0.15	0.4	-0.31	0.65
Max	13	100	71.51	12.28	76.62	5.49	2.88	0.63	3.88

Oatley Bay

Sample No	Depth (m)	Sand%	Silt%	Clay%	Muddy%	Mean	StdD	GsKew	Kurt
OBu1	0.9	59.2	36.1	4.7	40.8	3.04	2.76	0.51	0.62
OBu2	1.2	38.5	53.7	7.8	61.5	4.43	2.85	-0.30	0.61
OBu3	1.35	52.3	42.1	5.6	47.7	3.64	2.81	0.13	0.60
OBu4	1.7	10.6	80.7	8.7	89.4	5.98	1.55	-0.10	1.05
OBu5	1.4	27.8	62.9	9.3	72.2	5.05	2.52	-0.30	0.95
OBu6	1.4	50.2	45.8	4.1	49.8	3.80	2.69	-0.05	0.67
OBu7	1.9	5.0	85.4	9.6	95.0	6.34	1.31	-0.09	1.04
OBu8	1.9	3.6	87.4	9.0	96.4	6.30	1.25	-0.03	1.02
OBu9	1.8	3.0	89.4	7.7	97.1	6.21	1.20	0.02	1.02
OBu10	2.3	18.2	66.8	15.0	81.8	5.98	1.93	-0.17	0.85
OBu11	1.9	9.9	78.2	11.9	90.1	6.15	1.61	-0.13	0.95
OBu12	2.2	3.5	83.1	13.4	96.5	6.42	1.39	-0.03	0.95
OBu13	2.2	4.2	87.7	8.1	95.8	6.27	1.24	-0.05	1.04
OBu14	1.65	13.7	77.3	9.0	86.3	5.87	1.64	-0.10	0.99
OBu15	0.82	88.9	10.1	1.0	11.1	1.08	1.35	0.47	2.68
OBu16	1.18	16.6	68.9	14.5	83.4	6.04	2.28	-0.35	1.40
OBu17	1.75	7.8	85.4	6.8	92.2	5.94	1.37	-0.04	0.99
OBu18	0.68	58.5	37.4	4.1	41.5	3.48	2.58	0.20	0.70
OBu19	1.6	11.2	79.2	9.6	88.8	6.00	1.60	-0.11	1.04
OBu20	2	6.8	79.9	13.4	93.3	6.47	1.47	-0.13	1.15
OBu21	2.25	2.7	87.2	10.2	97.3	6.45	1.22	-0.04	1.04
OBu22	1.65	6.3	84.7	9.0	93.7	6.13	1.38	-0.04	0.99
OBu23	1.83	13.4	76.6	10.0	86.6	5.97	1.66	-0.14	0.99
OBu24	1.7	17.7	71.6	10.7	82.3	5.83	2.03	-0.29	1.21
OBu25	1.1	51.4	41.8	6.8	48.6	3.85	2.76	0.10	0.61
OBu26	1.85	1.6	87.6	10.8	98.4	6.52	1.18	-0.02	1.02
OBu27	1.3	23.0	63.4	13.7	77.1	5.48	2.53	-0.36	1.04
OBu28	1.6	2.2	88.3	9.5	97.8	6.38	1.21	-0.03	1.00
OBu29	1.65	1.9	89.7	8.3	98.1	6.31	1.17	0.03	1.01
OBu30	1.4	35.8	55.4	8.8	64.2	4.65	2.77	-0.31	0.68
OBu31	1.7	1.2	89.8	9.0	98.8	6.45	1.11	0.02	1.02
OBu32	0.78	74.7	21.5	3.8	25.3	2.74	2.53	0.72	0.95
OBu33	0.75	45.3	47.9	6.9	54.8	4.14	2.72	-0.08	0.62
OBu34	1.65	7.7	80.7	11.6	92.3	6.11	1.53	-0.01	0.91
OBu35	1.22	9.7	77.4	12.9	90.3	6.19	1.65	-0.12	1.00
OBu36	0.4	46.3	46.2	7.5	53.7	4.16	2.83	-0.11	0.58
OBu37	1.58	10.2	77.1	12.7	89.8	6.11	1.64	-0.08	0.90
OBu38	0.55	27.8	63.5	8.7	72.2	4.89	2.48	-0.18	1.03
OBu39	0.6	13.1	76.0	11.0	86.9	5.93	1.83	-0.12	1.10
OBu40	1.15	13.8	74.4	11.9	86.3	5.92	1.84	-0.08	1.00
OBu41	0.85	5.4	79.8	14.8	94.6	6.37	1.51	-0.07	0.88
OBu42	2.15	40.7	48.9	10.4	59.3	4.58	2.90	-0.25	0.63
OBu43	2.3	17.5	67.0	15.5	82.5	6.05	1.92	-0.22	0.89
OBu44	1.7	34.1	55.6	10.3	65.9	4.85	2.72	-0.29	0.77
OBu45	2.45	37.1	52.6	10.3	62.9	5.11	2.32	-0.10	0.75
OBu46	2.2	22.5	64.8	12.7	77.5	5.79	1.90	-0.11	0.76
OBu47	1.2	27.6	60.2	12.3	72.5	5.42	2.31	-0.20	0.87
OBu48	1.3	19.6	70.1	10.3	80.4	5.66	1.92	-0.06	0.96
OBu49	2.3	10.5	77.4	12.1	89.5	6.09	1.62	-0.10	0.83
OBu50	2.1	16.2	69.8	14.1	83.8	6.00	1.86	-0.14	0.87
OBu51	0.9	60.6	34.9	4.5	39.5	3.20	2.61	0.54	0.64
OBu52	1.55	24.0	64.3	11.7	76.0	5.41	2.33	-0.19	1.02
OBu53	1.95	17.4	70.9	11.7	82.6	5.88	2.04	-0.23	1.10
OBu54	1.75	20.3	67.9	11.8	79.7	5.68	2.03	-0.08	0.98
OBu55	2	20.8	67.0	12.2	79.2	5.66	2.29	-0.31	1.10
OBu56	2.25	14.8	73.1	12.1	85.2	5.97	1.74	-0.11	0.87
OBu57	1.4	12.1	76.0	11.9	87.9	6.07	1.82	-0.18	1.13
OBu58	2.3	5.8	81.0	13.2	94.2	6.31	1.49	-0.07	0.91
OBu59	1.9	10.9	75.6	13.5	89.1	6.13	1.69	-0.09	0.89
OBu60	1.4	9.7	79.7	10.6	90.4	5.97	1.56	0.01	0.83
OBu61	1.8	8.8	76.1	15.1	91.2	6.31	1.65	-0.12	0.97
OBu62	2.2	6.3	80.4	13.3	93.7	6.26	1.51	-0.04	0.91
OBu63	1.45	4.5	83.9	11.6	95.5	6.28	1.41	-0.05	0.91
OBu64	1.1	46.0	46.3	7.7	54.0	4.17	2.83	-0.11	0.60
OBu65	1.75	13.7	73.7	12.6	86.3	5.99	1.85	-0.13	1.00
Min	0.4	1.2	10.1	1.0	11.1	1.08	1.11	-0.36	0.58
Max	2.45	88.9	89.8	15.5	98.8	6.52	2.90	0.72	2.68

2.2 X-ray Diffraction results (XRD) Percentages (%).

A- Botany Bay / Kogarah Bay.

Note: Sodium chloride removed from minerals contents in the study areas because the samples from sea water.

Sample No	Quartz	Feldspar minerals	Calcite	Ankerite	Siderite	Kaolinite	Chlorite	Illite	Pyrite	Gypsum	Sodium Chloride
KO1	68.3	4.7	1.5		0.2	9.8	4	9.8	0.6	1.1	2.2
KO2	50.9	5.3	2		0.4	18.9	2.1	15.6	1.3	3.1	10.6
KO3	40.9	11.4	2	0.1	0.3	17.3	2	20.8	1.9	3.3	7.9
KO4	77.7	5.7	1.2		0.4	7.1	0.2	5	0.7	1.9	2.4
KO5	36.6	5.6	9.8			20.7	2.5	22	1.2	1.5	16.1
KO6	72.1	0.6	1		0.3	5.1	6.5	12.4	0.5	1.4	3.4
KO7	41	6.6	7.5		0.4	19.2	4.4	19.3	1.1	0.5	8.9
KO8	69.7	2.6	0.4		0.1	11.9	1.3	11.4	0.9	1.7	4.4
KO9	88.9	3.9			0.1	3.4		3.1	0.4		2.3
KO10	89.4	4.3				1.6	1.3	0.4	0.1	2.9	1.3
KO11	90.4	5.4			0.4	1		0.5		1.5	0.9
KO12	40.3	8.3	0.5	0.6		21.7	4.7	20.9	1.7	1.2	9.4
KO13	43.1	9.3	2.6		0.5	19.6	3.9	17.9	1.8	1.5	5.8
KO14	67.3	2.2	0.3	0.3	0.1	13.8		12.5	0.7	2.7	4.1
KO15	69.1	7	0.1		0.2	9.2	2.5	8.8	0.3	2.2	2.6
KO16	47.8	5.5	0.3		0.5	20.8	3.8	17.6	3	1.5	5.4
KO17	44.6	7.1	1.1	0.3	0.3	18.9	2.3	19.9	1.3	3.8	5.3
KO18	92.1	3.7			0.2	1.1	0.3	0.7	0.1	0.4	1.5
KO19	50.6	10.2	0.3			15.4	2.2	16.8	1.5	3	4.7
KO20	82.2	3.2	1.3		0.4	5.2		3.7	0.7	2.5	9.8
KO21	95.1	1.1			0.2	0.5	0.2	1.5	0.1	1.2	1.2
KO22	49.4	6.6	0.8	0.2	0.6	12.4	4.8	21.5	1.5	1.4	7.8
KO23	92.4	1.6				3.1		2.2	0.3	0.2	2.2
KO24	69.6	3.4	1.2	0.5	0.3	10.7	0.1	9.9	0.8	3	4.4
KO25	51.7	5.6	0.4	0.3	0.2	19.6	2.3	16.6	0.9	2.7	7.8
KO26	43.1	8.2	0.6	0.1	0.4	22.1	0.9	18.4	2.7	3.4	6.2
KO27	91	3.8			0.2	0.9		2.5		0.9	0.8
KO28	93.7	4.5				0.3		0.7			0.8
KO29	67.1	15.4			0.1	6.2	1	6.5	0.3	3.4	3.1
KO30	82.2	6.9	7.3		0.2	0.2	1.9	0.4		0	0
KO31	77.9	15.1	0.3	0.6		1.3	0.1	0.2		3.4	1.1
KO32	57	7.6		0.4	0.7	13.6	5.1	12.3	1.7	1.6	6.2
KO33	72.2	6.8				8.9	1.2	9.5	0.6	0.7	5
KO34	89.8	0.2			0.3	4.8		4.2	0.5		3.2
KO35	90.2	4.8			0.5	1.1	1.3	0.2		1.2	0.7
KO36	67.6	2.1	0.6		0.4	11.8		13	1.8	2.6	3.3
KO37	92.1	3.1	1.4		0.1	0.8		0.2		1.4	0.9
KO38	91.7	5.1			0.2	1.5	0.9	0.2	0.1	0.2	1.1
KO39	35.4	7.6	0.5	0.3	0.4	24.4	5.4	21.7	1.3	2.4	18.7
KO40	88.7	1.6			0.3	4.4		3.9	0.6	0.6	4
KO41	47.6	4.9	0.7		0.4	19.1	3.5	19.4	1.8	2.7	8.4
KO42	84.5	9.6			0.3	1.5	1.6	0.3	0.2	2	2.5
KO43	69.1	11.7	4.9			4.2	1	8.4	0.6	2.2	1.9
KO44	69.8	13.4	4.3			5.2	4.4	0.3	1.2	1.4	4.1
KO45	43.1	5.9	1.2	0.3	0.6	21.5	2.5	20	2.1	2.9	7.1
KO46	53.5	10	0.5		0.4	12.9	1.2	14.7	1.6	3.3	2.9
KO47	89.7	4.5			0.1	1.5		0.4	0.1	3.1	0.6
KO48	49	10.5	0.5		0.5	14.6	4	16.7	2.4	1.3	0.5
KO49	56.2	5.5	1.6		0.4	15.7	2.1	14	1.2	3	0.3
KO50	89.4	7.8	0.1		0.7	1.6	0.8	0.2		0.8	0.7
KO51	41.5	10.7	1.1		0.5	18.2	4.1	18.7	1.6	3.5	0.1
KO52	67.7	2	0.5		0.5	11.7		15.6	1.1		0.7
KO53	52.7	8.5	2.1		0.3	13.8	2.7	14.1	1.4	3.7	4.7
KO54	39.8	11.6	0.6	0.4	0.7	22.4	2.3	20.1	1.3	1	4.9
KO55	39.6	9.3	0.3		0.5	19.7	3.7	22.8	1.2	2.3	4.4
KO56	80.1	3.7	0.5		0.4	7.8		6.4	0.7	1.2	3.1
KO57	78.3	13.1				4.1		0.2		3.4	0.9
KO58	38.7	10.6	1.9		0.7	19.3	3.8	20.9	1.7	1.6	1.9
KO59	54.5	12.2	5.4		0.1	11.3	3.2	11.3	1.3	0.7	4.4
Min	35.4	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0	0
Max	95.1	15.4	9.8	0.6	0.7	24.4	6.5	22.8	3	3.8	18.7

Woollooware Bay

Sample No	Quartz	Feldspar minerals	Calcite	Ankerite	Siderite	Kaolinite	Chlorite	Illite	Pyrite	Gypsum	Sodium Chloride
WO1	83.9	8.3	0.2		0.1	1.6	1.7	0.9	0.3	2.4	1.5
WO2	71.1	6.6	2.4		0.3	6.4	0.6	8.9	0.8	3	3
WO3	31.3	7	4.6	0.2	1.1	24.2	5.5	21.8	2.2	2.1	7.4
WO4	44.5	4.2	2		0.6	21.9	2.3	20.2	1.8	2.3	10.3
WO5	87.3	5.6				2.9		0.2	0.1	3.6	1.5
WO6	87.3	7			0.2	1.3		0.2	0.1	2.3	1.8
WO7	92.5	2.1	0.2		0.3	0.2	2.2	1.5			1.7
WO8	38.1	5.2	3.1	0.1	0.5	21.3	3.8	23.4	1.6	2.8	15.8
WO9	39.5	7.7	6.9	1.1	0.6	17.7	2.6	19.1	2.9	1.3	6.6
WO10	83.9	8.1			0.2	2.9	0.5	0.6	0.3	3.2	1.3
WO11	80.3	3.8	0.2		0.8	7.3		5.7	1.2		2.7
WO12	88.9	3.1			0.1	2.6	0.9	1.5	0.1	2.3	1.5
WO13	60.4	7.8	2.1		0.2	15.4		9.6	1.2	1.7	6.6
WO14	49.5	7.6	7.1		1.7	17.2	3.8	7.3	2.7	2.7	5.4
WO15	43.2	7.5	4.8	0.6	0.6	16.9	2.3	18.8	2.6	2.2	7.7
WO16	96.3	1.2			0.3	0.5		0.5		0.3	0.9
WO17	91.7	6.5				0.5		0.1	0.1		1.2
WO18	70.2	4.3	0.9			9.1		12.3	0.5	1.4	3.3
WO19	86.9	1.5	0.6	1.1	0.2	4	0.5	4.1	0.3	0.7	2.1
WO20	42.4	3.9	6.1			19.2	2.9	21.9	1.4	2.2	21.1
WO21	36.7	8.6	1.2		2.9	18.7	7.2	19.4	2.8	1.5	8
WO22	38.5	7.4	4.4		1.8	17.2	3.3	19.3	6.1	2.9	5.8
WO23	42.8	7.9	3.1		0.3	16.9	3.7	20.3	1.9	2.5	7.7
WO24	63.9	8.4	0.3	2.3	0.4	10.2	3	8.1	0.8	2.9	6.1
WO25	92.5	4.7			0.6	0.2	0.8	0.2	0.1	0.8	1.3
WO26	97.7					0.2		1.6	0.2		1.4
WO27	72.2	7.4	1		0.4	6.2		7.6	0.5	3.9	2.7
WO28	73.3	3.4	4		0.2	5.7		9.8	1.3	2.4	2.6
WO29	41	8.3	1.4	0.6	0.7	21.3	3.6	19.4	3.2	0.4	9.1
WO30	68.5	4	0.3			9	0.3	13.2	3.3	1.5	5
WO31	82.5	4.1			0.2	5.2		4.7	1.5	0.8	2.9
WO32	63.7	7.6	0.8	0.3	0.5	10.9	0.6	9.8	1.7	3.1	3.8
WO33	69.2	2.5	0.2		0.3	8.3		13.5	3.3	2.3	4.4
WO34	41.5	8.3	1.6		0.2	21.5	3	16.5	3.3	3.9	9.4
WO35	86.1	3.2				4.7		4.4	1.3	0.5	3
WO36	71	7.5	0.5		0.3	7.8	1.2	7.5	1.1	3.8	3.4
WO37	83.8	5.2	0.2		0.1	4.2		4.4	0.7	1.3	2.1
WO38	82.5	6.3	0.5		0.2	3.9	1.5	2.8	0.2	2.8	2.3
WO39	75.1	7.8	1.2		0.1	6.3		6.4	0.5	2.6	2
WO40	81.5	7.1	0.2		0.2	4.3	1.5	1.8	0.5	2.9	2.1
WO41	59.3	6.9	0.5		1.1	10.1	6.7	11.7	0.9	2.1	5.7
WO42	78.9	3.7	2.2		0.9	5		6.6	1.4	1.3	3.2
WO43	48.1	6.8	3.8		1.2	16.4		18.9	2.4	1.6	8.8
WO44	70.6	7.3	9.8		0.5	2.1	1.2	5.4	2.1	0.9	2.1
WO45	64.1	8.2	4.9		1.1	9	1.1	8.3	1.6	1.7	4
Min	31.3	1.2	0.2	0.1	0.1	0.2	0.3	0.1	0.1	0.3	0.9
Max	97.7	8.6	9.8	2.3	2.9	24.2	7.2	23.4	6.1	3.9	21.1

Oyster Bay

Sample No	Quartz	Feldspar minerals	Calcite	Ankerite	Siderite	Kaolinite	Chlorite	Illite	Pyrite	Gypsum	Sodium Chloride
OY1	61.9	2.4	0.4		0.2	15.3		14.3	3	3	5.7
OY2	47.3	6.6	1.3		0.4	18.3	3	15.5	3.2	3.5	8.9
OY3	68.7	2.8	0.8		0.3	11	1.2	12.5	0.8	2.4	3.4
OY4	78.8	5.8			0.3	5	1	5.2	0.1	3.5	2.3
OY5	45.4	6.2	1.3	0.1	0.4	21.3	2.9	18.7	2.3	1.8	10.6
OY6	49.5	5	0.4		0.3	19.9		21.6	0.7	2.3	19.2
OY7	81	4.9			0.3	6.1	1.1	2.6	0.5	3.5	3
OY8	64.5	5.6	0.4		0.2	12.1		16	0.8		2.8
OY9	84.9	2.3			0.1	5.3		7	0.4	0.8	3.1
OY10	60.3	2.9	0.3		0.2	14.2	0.4	19.1	1	1.5	4.1
OY11	47.8	7.9	0.3		0.6	19.5	2.6	17	0.9	3.8	5.8
OY12	41.9	7.9	1.5	0.4	0.6	22.2	2	21.1	0.7	1.2	23.5
OY13	53.3	4.9	0.1		0.3	17.2	2.6	19.1	0.8	2	8.4
OY14	79.7	6.3	0.1		0.3	5.3	1.2	5.3		1.6	3.1
OY15	46.6	5.4	0.2		0.2	22.2	3.2	18	0.7	2.9	8.5
OY16	56.1	5.9	0.2			14.2	5	15.2	0.6	2.5	5.3
OY17	47	7	2			17.1	3.2	20.2	0.5	2.8	8.2
OY18	48.1	8.5	0.7		0.5	15.7	3.5	15.3	1.4	4.5	3.9
OY19	46.8	7	1		0.6	20.3	1	19.6	1.3	2.4	4.6
OY20	53.2	5	0.5		0.5	16.5	2.3	18.9	1.3	1.8	3.2
OY21	50.1	8.2	0.7		0.7	15.1	1.7	18.8	1	3.8	5.4
OY22	47.9	7.2	1.9	0.1	0.8	18.5	2.2	18.2	1.7	2.4	4.2
OY23	36.4	7.7	2.6	0.2	0.9	22.1	2.9	21.6	1.7	3.9	11.2
OY24	55.7	5.5	0.4		0.2	16.8	1.4	15.6	1	2.7	5.9
OY25	41.6	7.9	1.5	0.3	0.6	19.9	3.5	19.6	1.2	3	13.1
OY26	42.5	7.2	1.6		0.1	21.1	2.4	19.8	1.3	3.5	6.5
OY27	44.9	8.2	1.5		0.8	20.1	1.6	16.9	1.5	3.6	4.9
OY28	44.3	8.2	0.3		0.1	19.6	2.6	18.4	1.2	3.1	6.2
OY29	44.4	8.2	0.7		0.5	19.8	0.8	20.4	1.3	2.9	4.9
OY30	38.4	7.6	1.9		0.5	15.4	1.5	20.9	1.3	3.3	9.2
OY31	59.7	6.8	0.9		0.4	11.1	3.2	13.2	0.9	4	3.7
OY32	65.7	6.4	0.2			11.7	0.6	11.1	0.8	3	2.7
OY33	41.4	7.4	1.8		1.4	19.8	4.2	18.5	1.7	3.3	4.9
OY34	80	3.3	0.4			8.4		7.4	0.5		2
OY35	69.3	7.1	0.2		0.2	7.9	2.1	9	0.4	3.7	4.2
OY36	79.5	3.5				7	1.2	4	0.1	2.2	2.4
OY37	87.1	5				3.5	1	0.4		2.9	1.2
OY38	89.7	4.4			0.1	2.4	0.8	1.2	0.3	2.6	1
OY39	83	3.1	0.1			4.9		8.1	0.2	1.6	1
OY40	83.9	1			0.3	4.2		6	0.2	3.3	1.2
OY41	55.1	7.9	0.6	0.1	0.3	15.4	2.5	14.8	0.7	2.6	3.1
OY42	34.3	8.1	1.7	0.1	0.4	22	2.6	19.4	1.3	3.3	13.6
OY43	48	8.3	1.8		0.6	19.1	1.2	16.3	1.4	3	5.3
OY44	41.2	7.6	2.6		1.1	20.8	3.1	19.5	1.2	2.8	6.2
OY45	60.5	6.2	0.3		0.3	10.8	1.9	14.9	1.1	4	3
OY46	49.1	8.3	1.3		0.4	17.1	2.6	14.9	1.4	4.3	5.7
OY47	41.4	7.9	0.4		0.3	22.3	2.8	19.2	1.8	3.9	4.9
OY48	68.3	5.5	0.3		0.3	10.4		13.5	0.8	1.5	3.4
OY49	81.1	4.2	0.1			7.2		7		0.4	1.4
OY50	85.8	1.5	0.1	0.1	0.2	6.2		6.6	0.4	0.2	1
OY51	41.4	7.4	1.3	0.1	0.7	19	1	21.7	2.8	3.9	6.8
OY52	50.1	7.8	0.7		0.2	16.6	0.6	14.7	1.2	1.4	6.5
OY53	79.5	3.5			0.3	6.7		5.4	0.2	4.4	1.9
OY54	49.3	6.2	1.6		1.3	14	3.6	18	0.8	3.5	2.6
OY55	82.8	4.5			0.4	4.9		3.6		3.2	1.4
Min	34.3	1	0.1	0.1	0.1	2.4	0.4	0.4	0.1	0.2	1
Max	89.7	8.5	2.6	0.4	1.4	22.3	5	21.7	3.2	4.5	23.5

Woronora River

Sample No	Quartz	Feldspar minerals	Calcite	Ankerite	Siderite	Kaolinite	Chlorite	Illite	Pyrite	Gypsum	Sodium Chloride
WOR1	91.9	1.6		0.6	0.2	2.8		0.9		1.2	0.9
WOR2	93.4	0.2		0.1		1.3		1.4		2.8	0.9
WOR3	54.7	3.2	0.1		0.2	10.3	5.4	22.6	0.2	3.5	0.8
WOR4	84.4	2.2				4.2	0.7	4.4		4.1	1
WOR5	89.3	2.4			0.2	3.8		1.2		2.6	0.6
WOR6	89.4	3.9			1.8	1.1		0.1		3.8	0.8
WOR7	91.6	4				2.1		1	0.1	0.4	0.8
WOR8	87.8	4		0.2		1.5	1.3	1.9	0.1	2.4	0.8
WOR9	87	0.9	0.3		0.2	5.2		5.2	0.5		1.7
WOR10	53.6	5.4	0.9	0.5	0.3	13.9	4.6	14.9	0.8	5.1	3.3
WOR11	86.1	1.4		0.8	0.1	3.5		4.9		3.3	0.8
WOR12	92.8	4.6			0.2	1		0.2		1.2	1
WOR13	98.4					0.1		0.7			0.8
WOR14	47.8	5.7	0.9	0.4	0.7	17.4	2.9	19.1	1.5	4.1	3.1
WOR15	91.8	3.2				0.9	0.6	0.2		3.5	1
WOR16	86.4	5.5			0.3	2.3		0.2		5.4	0.9
WOR17	89.7	3.6	0.8	1.3	0.1	1.7		1.2		0.4	1.2
WOR18	94.7				0.1	1.9		2.4		1.1	0.9
WOR19	87.7	5.7			0.3	1.7		0.2		3.6	1.9
WOR20	82.3	1.9	0.2			4.5	1	5.6	0.2	4.6	1.6
WOR21	71.5	5.1			0.2	12.1		7.5	0.6	2.7	3.3
WOR22	72.6	4.6	0.1	0.2	0.6	6.2	2.2	7.7	0.7	5.2	2.8
WOR23	93.1					1.5		1.2		4	1.2
WOR24	85.9	3.2				0.9	2.9	3		3.9	1.2
WOR25	89.4	4.5				1.5		0.2	0.1	3.4	0.9
WOR26	94.1	1.8			0.6	1.4		0.9	0.3	0.8	1.1
WOR27	42	5.2	1.6			21.7	4	20.2	1.6	3.7	4.6
WOR28	64.4	4.3	0.3		0.1	11.8	0.9	12.7	1.2	4.4	5
WOR29	62.9	2.2	0.8	0.3	0.2	9.6	1.5	16.9	1.3	4.3	6.5
WOR30	47.8	5.7	2.5		0.5	18.8	2.2	16.7	1.6	3.5	9.8
WOR31	33.8	5.1	2.8		0.3	23.5	4.3	24.2	1.9	3.4	16.6
WOR32	93.4	4.3				0.6		0.9	0.1	1.4	1.2
WOR33	93.5	3.1				2.3		0.7	0.1	0.8	1.2
WOR34	91.2	3.2			0.2	1.2	1.4	1	0.1	1.8	1
WOR35	95.7		0.1			1.1	0.2	1.7		1.3	0.9
WOR36	71.8	5.6	0.3		0.3	8.6		9.8	0.7	2.3	3
WOR37	72.3	5.2			0.3	9.7	5.7	6.7			2.4
WOR38	29.3	5.8	6.8	2.3	0.6	14.6		37.8	2.5		1.3
WOR39	95.4	1.9			0.5	0.1		1.3			0.6
WOR40	93.3				0.1	2.5		3.2	0.4		1.5
WOR41	93.1		0.1		0.2	1.5	2.1	2.6	0.2	0.2	1.1
WOR42	69.1	1.9	0.2			9.6	2.1	12	0.7	4.4	3
WOR43	38.9	5.1	1.7	0.3	0.5	21.1	2.4	23.2	2.6	4.2	7.4
WOR44	69.4	3.1	0.2		0.3	7.2	6.3	9.1	0.3	4.3	2.7
WOR45	35.5	5.1	2.1	0.3	0.8	22.4	2.4	25.2	2.6	3.4	11.2
WOR46	86.1	5.2		1.2	0.5	1	1.4	0.2		3.8	0.7
WOR47	58.2	5.9	1		0.3	9.8	7.3	13		4.3	4.2
Min	29.3	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.6
Max	98.4	5.9	6.8	2.3	1.8	23.5	7.3	37.8	2.6	5.4	16.6

Georges River and Salt Pan Creek

Sample No	Quartz	Feldspar minerals	Calcite	Ankerite	Siderite	Kaolinite	Chlorite	Illite	Pyrite	Gypsum	Sodium Chloride
GE1	33.6	0.9	0.7	0.7	0.4	27.1	8.1	26.5	1.5	0.6	17.1
GE2	42.3	1.6	0.6	0.6	0.8	19.5	9.1	22.9	1.6	1.1	5.5
GE3	30.6	4.5	0.1		0.6	26.4	10.1	25.1	0.3	2	25.4
GE4	87.6	1.6				3.2		4.2	0.1	3.1	1.2
GE5	93	0.1	0.1		0.4	2.5		2.6	0.3	1	0.8
GE6	93.4	0.6			0.1	1.8		0.9	0.3	2.9	0.5
GE7	69.2	5.4	5.4		0.3	5	2.9	7.9	0.5	3.4	1.1
GE8	77.4	6.3	0.1			6.8		6.8	0.1	2.4	1.2
GE9	60.3	7.4	0.1	0.6	1	9.9	6.1	10.6	1.1	2.9	1.5
GE10	60.7	7	0.4		0.7	11.7	1.3	12.3	2	3.7	2.3
GE11	94.2	0.6				1		0.6		3.8	0.8
GE12	46.1	0.1	0.5		0.1	20	8.4	22.3	1.7	0.1	7.7
GE13	48.7	1.1	0.5		0.6	16.4	11.6	19.2	1.2	0.8	5.1
GE14	66.2	4.4	0.4		0.1	11.8	3.9	9.4	1.1	2.3	1.4
GE15	86.9	6.6			0.2	1.1	1.3	0.2	0.1	3.5	0.7
GE16	26.2	8.1	0.8	0.3	0.4	23.1	12.6	25.9	0.8	1.9	31.4
GE17	53.4	2.1	1	1.9	0.2	16.9	4.5	16.8	1.2	2.1	3
GE18	86.7	2.6				4.7		2	0.3	3.8	0.9
GE19	93.4	4.5			0.5	0.6		0.1		1	0.9
GE20	91.6	4.1				1.2		0.1		3.2	0.6
GE21	89.9	6.7			0.5	1.4		0.2	0.2	0.8	0.7
GE22	89.6	7.2				0.7		0.2		2.3	0.8
GE23	56.2	4.9	0.7		0.5	13	4.5	15.9	0.9	3.4	7.8
GE24	80.7	1.2	0.3	0.4		4.3	1.9	7.2	0.4	3.4	1.2
GE25	39	2.1	0.5	0.2	0.4	25.9	5.7	21.3	1.6	3.1	2.7
GE26	46	1.3	1.1	0.3	0.3	16.7	3.9	26.7	2.1	1.6	7.9
GE27	66.5	6.2				10.2	6.6	9.1	0.5	0.9	1.2
GE28	74.5	1.3	0.2		0.3	11.9		9.2	0.7	1.9	2.3
GE29	61.6	7.3	0.4		0.4	15.5	0.9	10.4	2	1.5	0.1
GE30	54.8	1.9	0.4		0.3	13.9	8.9	14.8	1.9	3.1	2.7
GE31	65.8	4.7		1.3		9.7	5.1	10.2		3.3	2.8
GE32	96.4					0.2		0.1		3.3	0.8
GE33	37.3	1.7	0.7		0.7	23.2	9.9	21.4	1.7	3.5	7.9
GE34	36.2	7.7	0.7		0.4	17.3	12.5	22.3	2	1.1	10.4
GE35	49.8	2.2	0.5		0.3	18.2	6.7	19.2	1.2	1.9	8.4
GE36	52.1	1.8	0.5		0.1	20.6	4.7	15.9	1	3.3	2.8
GE37	48.9	1	0.3	0.2	0.1	22.9	7.7	16.4	1.6	0.9	4.7
GE38	51.1	2.1	0.4		0.8	18.4	6.3	17.1	2	1.8	2.8
GE39	48.4	1.4	0.4		0.2	20.9	9.6	15.8	2.4	1.2	4.7
GE40	88.3	5.1				0.9	2.7	0.2		2.8	0.6
GE41	80.5	8.3				3.7	0.3	4.7		1.5	1.3
GE42	87.9	4.2		0.4	0.2	0.2	3.2	0.9		2.5	1.6
GE43	87.8	6.8			0.4	1.5	0.6	0.2		2.7	1.8
GE44	76.4	5.1	0.2	1.7		5.3	2.3	6.1	0.3	2.6	1.8
GE45	88.4	2.8				2.6	2.7	0.2		3.2	1.2
GE46	92.9	1.6				0.7		0.2	2.4	2.1	0.8
GE47	95.9	0.2		0.9		0.1		1.3		1.6	0.9
GE48	93.7	2.9				0.9	1	0.2	0.1	1.2	1
GE49	49.1	8.1	1.5		0.8	15.6	1.5	17.2	3.2	3	4
GE50	49.1	2.7	0.7		0.3	15.1	9.5	18.9	3.1	0.6	3.3
GE51	47.1	0.2	0.2	0.1	0.4	19.4	8.7	20.6	3.2	0.8	3.7
GE52	44.7	1.3	0.4		0.4	16.6	10.1	22.4	2.8	1.3	5.8
GE53	55.2	8.1	0.6		0.5	13.2	2.6	14.9	2.3	2.7	2
GE54	47	0.9	0.5	1	0.9	13.9	10.4	21.6	3	1.2	4.5
Min	26.2	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.1
Max	96.4	8.3	5.4	1.9	1	27.1	12.6	26.7	3.2	3.8	31.4

B- Port Hacking Gunnamatta Bay

Sample No	Quartz	Feldspar minerals	Calcite	Ankerite	Siderite	Kaolinite	Chlorite	Illite	Pyrite	Gypsum	Sodium Chloride
GU1	78.5	5.5	8.9		0.2	1.4	0.9	3.9	0.3	0.4	1
GU2	70.3	8.3	10.4		0.6	1.7	0.4	6.1	1.4	0.8	2.3
GU3	76.9	7.4	10.5		0.4	1.7		0.3	0.5	2.1	1.2
GU4	69.3	10.8	8.5		0.8	2.6	1.9	4.1	1.6	1.2	1.3
GU5	83.3	7	3.8		0.2	1.8	1	3.1		0.2	0.7
GU6	79.6	9.5	5.1		0.2	1.6		3.3		0.7	0.6
GU7	87.5	3.4	1.5			1.8	1	4.3		0.5	0.8
GU8	70.5	7.6	13.9		0.7	1.5	0.2	2.5	0.8	1.8	1.4
GU9	78.1	9.5	7.8		0.2	1.2		2.7	0.3	0.3	1
GU10	70.8	7.3	1.6		0.5	2.4	0.7	4.4	0.8	1.9	1.5
GU11	49.4	11.1	19.4		0.5	8.9	2.2	6.5	1	1.1	2.9
GU12	87.2	5.4	0.6			1.4	0.3	4.4		0.7	0.7
GU13	82.9	8.6	2			2.2	0.5	2.8		0.8	0.7
GU14	59.5	9.1	18		1	4.7	1.4	3.4	1.1	1.6	1.2
GU15	26.1	12.5	25.1		1.7	12.8	1.9	12.6	2	1.8	2.9
GU16	37.2	12.1	21.2		0.9	13	3.5	9.5	2.2	0.4	2.9
GU17	36.2	11.7	21		1.4	10.3	2.1	13.8	2.4	0.7	3.9
GU18	27.8	13.1	20.6	0.3	2.3	12.9	3.7	13.9	4.2	0.9	4.5
GU19	65.1	6.9	10.9		0.6	4.8	0.9	6.8	1.4	2.2	2.6
GU20	49.2	9.6	16.5	1.1	1.2	4.6	2.6	11.4	3.3	1.1	2.7
GU21	27.8	11.1	23.5	0.1	0.7	12.8	1.5	17.7	4.2	0.7	7
GU22	59.4	9.1	24.1		0.5	0.4	0.5	3.8	1	0.9	2.1
GU23	84.7	5.7	4.6		0.3	0.9	0.3	1.4	0.4	1.5	1.1
GU24	75.8	9.6	9.4		0.2	0.6	0.6	1.3	0.5	1.5	1.6
GU25	22.7	11.6	22.4	0.1	0.6	15	3.9	20.9	3.1	0.2	5.3
GU26	82.1	1.7	8	1.9	0.6	0.6	1.1	2	1.1	0.5	1.1
GU27	31.3	13	24.5	0.2	1.3	11.3	2.2	11.3	2.8	2.1	6.5
GU28	72.4	6.7	14.6		0.1	0.9	0.7	2.4	0.8	1.4	1.4
GU29	84.8	5.7	3.4		0.3	0.9		2	0.7	1.5	0.7
GU30	40.4	4.7	22.7		0.7	14.7	0.3	12.1	2.1	2.3	6.3
GU31	73.4	7.4	14		0.5	2.2	1.7	0.2	0.6	0.2	1.7
GU32	86.1	3.9	4.7		0.2	1.9		1.5	0.7	1	3.4
GU33	75.1	3.5	10.2		0.5	1.3		4	2.2	2.3	1.9
GU34	91.8	3	1.8		0.2	0.4		2.1	0.4	0.3	1
GU35	92.7	2	1.4		0.1	0.5		2.3	0.6		1.5
GU36	74.3	8.4	5.9		0.8	2.4		4.1	2.1	1.7	2.4
GU37	90.5	4.3	2.1		0.2	0.3		1.7	0.3	0.5	1
GU38	84.1	8.9	3.8		0.1	0.8		0.4	0.3	1.7	0.9
GU39	39.4	6	19.9	0.5	1.4	11.6	3.8	12	3.8	1.6	5
GU40	47.3	6.4	20.9		0.4	9	1.7	10.2	2	2.1	3.2
GU41	86	4.8	4.4		0.4	0.7		1.5	0.7	0.8	1.8
GU42	76.4	9.1	6.1		0.5	1.3	0.7	3.8	1.4	0.5	1.1
GU43	87.4	6	1.2		0.4	0.7		2.1	0.8	1.2	1.1
GU44	72.6	6.4	11.8		0.3	2.3	0.3	4	0.9	1.2	2.3
GU45	47.1	9.2	15		0.8	9.9	2.2	13.5	1.6	0.9	7.7
GU46	88.8	5.9	1			0.9		0.6	0.2	1.9	0.9
GU47	69.4	8.2	8.5	0.1	0.7	3.3		6.6	2.4	0.8	2.8
GU48	89.2	6.2	0.7		0.2	1	0.3	0.3	0.4	1.6	1.1
GU49	94.6	2.4	0.6			1		0.9	0.2	0.6	0.8
GU50	87.2	4.4	2.6		0.3	1		2.5	0.7	1.3	1.2
GU51	85.9	7.5	2.1			0.8	0.2	0.8	0.4	2.1	1.2
GU52	87.4	4.9	1.5		0.3	1.7	0.3	1.8	0.6	1.1	1.4
GU53	86.6	6	0.2			1.4	1	1.5	0.2	2	0.9
GU54	90.3	4.4	0.1		0.2	1.9	1.8	0.3		0.9	1.3
GU55	76.9	7.7	1.2			5.2		7.2	1.4	0.4	2.8
GU56	88.9	6.3	7			1.7	0.3	0.8	0.1	1.9	1.1
GU57	87.2	6.6	0.6		0.1	1.7		1.6	0.3	1.7	1.1
GU58	65.5	11.7	11.4		0.8	2.8	0.5	4.2	1.7	1.4	2.2
GU59	81.1	5.1	8.1		0.5	1		2.5	0.7	1	1
Min	22.7	1.7	0.1	0.1	0.1	0.3	0.2	0.2	0.1	0.2	0.6
Max	94.6	13.1	25.1	1.9	2.3	15	3.9	20.9	4.2	2.3	7.7

South West Arm

Sample No	Quartz	Feldspar minerals	Calcite	Ankerite	Siderite	Kaolinite	Chlorite	Illite	Pyrite	Gypsum	Sodium Chloride
SWA1	75.9	5.5	8.1		0.5	1.8	0.4	4.6	1.8	1.4	2.3
SWA2	90.3	6.1	0.3		0.1	0.8	0.3	0.2	0.1	1.9	0.9
SWA3	84.9	6.4	4.1		0.2	0.7	0.4	1	0.8	1.5	1.2
SWA4	90.5	5.6			0.2	0.8	0.4	0.2	0.2	2.1	1
SWA5	93.9	3.7				0.6		1		1	0.7
SWA6	75.6	6.1	10		0.5	1.1		1.8	1.6	3.2	2
SWA7	90.6	6			0.1	0.7		0.2	0.1	2.2	1.1
SWA8	92.4	6.1			0.1	0.8		0.5		0.9	1.2
SWA9	93.5	4.6			0.2	0.8		0.2		2.7	1.3
SWA10	90.2	6				0.8	0.6	0.2	0.1	2.4	0.8
SWA11	92.2	4.4			0.1	0.7		0.4		2.2	1.1
SWA12	91.4	5.4				0.5	0.2	0.2		2.3	1.4
SWA13	93.6	4.1			0.1	0.5		0.6		1.3	0.9
SWA14	89.3	5.9			0.1	0.8	0.9	0.2		2.8	1
SWA15	91.5	5.8				0.6	0.2	0.3	0.2	1.2	1.3
SWA16	89.3	6.8			0.1	0.6	0.4	0.2		1.8	0.9
SWA17	30.7	6.3	17.3		0.6	20.6	3.8	15.9	4.8	0.1	8.9
SWA18	84.9	2.1	2.3		0.3	0.3	3	5.4		1.9	0.7
SWA19	64.9	5.8	12.8		0.6	2.9		8.7	1.9	2.5	2.9
SWA20	55.3	6.5	16.2		0.5	7.9	0.8	7.6	1.8	3.3	3.1
Min	30.7	2.1	0.3		0.1	0.3	0.2	0.2	0.1	0.1	0.7
Max	93.9	6.8	17.3		0.6	20.6	3.8	15.9	4.8	3.3	8.9

Gynea Bay

Sample No	Quartz	Feldspar minerals	Calcite	Ankerite	Siderite	Kaolinite	Chlorite	Illite	Pyrite	Gypsum	Sodium Chloride
GY1	30.8	7.7	18.1	0.2	0.3	19.4	2	16.9	2.1	2.1	16.3
GY2	30	6.7	7.3	2	1.2	23.3	2.2	21.3	4.8	1.4	10.8
GY3	87.2	5.2	0.2		0.2	1.1	1.2	0.6	0.2	2.8	1.2
GY4	71.9	6.1	9.8		0.7	2.6	0.2	4.3	2.2	1.4	1.9
GY5	31.3	6.6	5.7	0.7	0.3	24.8	2.8	21.3	4.8	1.3	8.8
GY6	83.2	4.5	5		0.3	1.6	1.5	0.7	1	1.9	1.3
GY7	87.6	4.4	3.5		0.4	1.2		0.6	0.5	1.7	1.1
GY8	29.4	6.8	7.1	1.6	0.7	25	3.4	20.7	4.1	1.2	25.8
GY9	32.8	7.8	7.1		1.3	22.3	3.3	21.4	3.7	0.5	11.7
GY10	82.2	1.3	7.8		0.2	1.9		4.5	1	1.1	1
GY11	89.2	0.7	2.8		0.2	2.8		3.4	0.7		1.3
GY12	27.4	7.2	9.9	0.6	0.5	21.6	3.5	23.6	5.6	0.1	13.3
GY13	28.8	6.3	13.4	2.4	0.5	22.4	0.6	21.4	2.6	1.5	20.2
GY14	79.3	3.2	4.2		0.9	2.6	2.1	5.5	1.2	1.7	1.9
GY15	93.7	1.8				0.6	2	0.2		1.1	0.7
GY16	92.9	2.6			0.2	1.5	0.5	0.7	0.1	1.3	0.8
GY17	95.2	1.1			0.1	0.8		1.8	0.1		1
GY18	88.4	7.6				0.9	1.8	0.2		0.6	0.6
GY19	68.2	3.1	3		0.8	11.6	0.2	9.4	1.1	2.6	11.5
GY20	89.3	5.4	1		0.2	1.4	1.3	0.2		1.4	0.8
GY21	83.6	2	3.1		0.2	1.6	0.5	6.2	0.4	2	1.4
GY22	80.3	4.8	5.1		0.2	1.6		4.8	0.5	2.7	1.3
GY23	69.3	3.2	7.6		0.5	5.6		10	2.7	1	1.1
GY24	89.1	7.8	0.6		0.3	1.2	0.6	0.2		0.4	1
GY25	90.5	0.5	5.2		0.2	1.2		1.4	0.3		0.7
GY26	88.4	6.1	2.1	1.2	0.1	0.8	0.6	0.2	0.1	0.3	1
GY27	92.2	4				1.2	0.2	0.2	0.1	1.2	1
GY28	88.1	3.4	0.7		0.3	3.4		1.9	0.2	1.9	1.5
GY29	86.1	2.3	7.2			1.6	0.9	0.6		1.2	1
GY30	90	0.7	5.4			0.2		1.4	0.3	0.8	1.1
GY31	92.1		2.7		0.1	1.4		2.7	0.2		0.9
GY32	74.6	2.2	12.4		0.6	1.8		5.3	0.5	2.5	1.2
Min	27.4	0.5	0.2	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.6
Max	95.2	7.8	18.1	2.4	1.3	25	3.5	23.6	5.6	2.8	25.8

Mansion Bay and Hacking River

Sample No	Quartz	Feldspar minerals	Calcite	Ankerite	Siderite	Kaolinite	Chlorite	Illite	Pyrite	Gypsum	Sodium Chloride
MA1	95.8				0.3	0.6		0.6	0.1	2.5	1.1
MA2	90.2	3.1			0.4	1.5	0.6	0.2		4.2	1.1
MA3	99.1					0.1		1			0.7
MA4	94.7	0.7			0.1	1		2.3	0.2	1.3	0.9
MA5	95.5	1.3				0.6		1.2	0.2	1.2	1.1
MA6	92.1	3.2			0.3	1.7	0.2	0.5	0.1	1.8	1.2
MA7	93	2.8			0.3	0.9	0.7	0.9	0.1	1.1	1.2
MA8	91.6	1.7			0.2	1	1.1	0.2		4	1.3
MA9	92.7	1.3			0.1	1.3		0.6		4	1
MA10	94.4	2.1				1.2		0.4	0.1	1.8	1
MA11	81.8	4.1			0.3	5.1	1.9	1.8	0.6	4.3	2.1
MA12	88.9	3.3		0.4		1.3	1.7	0.2		4	0.8
MA13	92.6	0.2				0.2	0.7	0.2		6.1	1.1
MA14	91.2	4.5			0.4	2.2	0.4	0.2		1.3	0.9
MA15	92.1	1.4				1.2	0.8	0.2	0.1	4.1	1.1
MA16	88.8	3	0.1	0.2	0.2	2.6	0.6	2.2	0.4	1.8	1.3
MA17	91.2	4			0.3	1.9	0.7	0.5	0.1	1.9	1.3
MA18	92	2.8				0.9	1.8	0.7	0.1	1.7	1.1
MA19	90.1	5			0.2	2.2		0.5	0.2	1.3	1.4
MA20	88.6	5.1	0.1		0.1	1.6	1.3	1.4	0.4	1.1	1.3
MA21	82.2		0.9		0.3	9.6		6	0.9		3
MA22	50.2	3.6	1.5	0.4	0.2	18.7	0.9	19.7	1.9	2.6	4.4
MA23	90.3	4.1	0.4		0.2	1.3	0.5	0.4	0.1	1.7	1.2
MA24	91	5.1				1		0.2	0.1	1.8	0.9
MA25	52.4	5.2	0.6	0.2	0.2	17.8	1.4	17.2	1.7	3.1	6.2
MA26	88.6	3.8				2		2.3		3.2	1.1
MA27	97.9					0.2		2	0.1		0.5
MA28	85	5.2		0.3		1.3	2.2	0.2	0.1	5.8	0.9
Min	50.2	0.2	0.1	0.2	0.1	0.1	0.2	0.2	0.1	1.1	0.5
Max	99.1	5.2	1.5	0.4	0.4	18.7	2.2	19.7	1.9	6.1	6.2

North West Arm

Sample No	Quartz	Feldspar minerals	Calcite	Ankerite	Siderite	Kaolinite	Chlorite	Illite	Pyrite	Gypsum	Sodium Chloride
NWA1	44.4	5.2	1.9		0.2	20.2	3.8	18.3	1.9	3.9	6.2
NWA2	87	2.1	1.4			2		3.8	0.3	3.4	1.1
NWA3	41	5.9	1.8		0.4	21.3	4.7	19.4	1.9	3.3	6.6
NWA4	40	5.1	1.9	0.1	0.5	22.9	4.3	20.3	2.5	2.6	7.8
NWA5	65.9	5.4	0.2			10.4	2	12.2	1	3.5	2.3
NWA6	90	5.2	0.1			1.4	0.5	0.8		2	1.1
NWA7	95.1	2	0.2			0.6		1.8		0.5	0.8
NWA8	89.4	2.8			0.2	1.1	1.5	1.7	0.1	3.1	1.2
Min	40	2	0.1	0.1	0.2	0.6	0.5	0.8	0.1	0.5	0.8
Max	95.1	5.9	1.9	0.1	0.5	22.9	4.7	20.3	2.5	3.9	7.8

Yowie Bay

Sample No	Quartz	Feldspar minerals	Calcite	Ankerite	Siderite	Kaolinite	Chlorite	Illite	Pyrite	Gypsum	Sodium Chloride
YO1	86	3.9	4.4		0.2	1.1		3.2	0.4		0.8
YO2	78.8	7.4	4.1					6	0.2	3.3	1.1
YO3	84.5	3.8	0.5			2.6	1.2	4.1	0.2	2.7	1.4
YO4	74.9	5.5	1.7		0.1	8	1.5	4.9	0.5	2.8	2.3
YO5	72.4	7.6	0.2		0.1	9.4	0.7	7.2	0.5	2.8	0
YO6	89.5	4.2	0.1	0.4		2.1		2.3	0.1	1.3	1
YO7	93.4	0.6	1.1		0.3	0.9		2.9	0.3	1.3	1.1
YO8	51	8.1	1.9		0.1	18.4	1.3	14.7	1.2	2.8	5.4
YO9	84.8	2.5	3.8	0.1		3.7		3.3	0.8	0.5	1.5
YO10	86.2	2.5	3.1		0.3	2.2		3.3	0.7	1.5	1.4
YO11	41	5.7	8.4		0.6	19.3	2.8	17.6	1.3	3.2	6.2
YO12	77.7	7.1	0.4		0.2	2.9	0.8	7.2		3.7	0.9
YO13	85.7	2.5	1.5			1.7		4.9	0.3	3.5	0.9
YO14	84.4		7.5		0.4	2.1		4	1	0.8	1.1
YO15	86.1	0.9	4.4		0.3	1.2		3.8	1	2.3	1
YO16	88.5	3.5	0.6	0.2		1.2	0.8	2.3		3	0.8
YO17	27.8	6.6	13.4		0.7	19.9	3.7	21.6	2.9	3.7	8.8
YO18	28.1	7.3	17.7		0.7	15.5	3.1	19.7	5.1	3	9.1
YO19	38.1	6.4	13.6		1	17.2	1.8	15.3	2.2	3.8	6.7
YO20	39.7	5.9	7.2		0.3	21		19.6	2	3.8	14.4
YO21	28.7	6.7	7.8	0.5	0.4	25.2	3.4	22.2	1.1	3.4	26.3
Min	27.8	0.6	0.1	0.1	0.1	0.9	0.7	2.3	0.1	0.5	0
Max	93.4	8.1	17.7	0.5	1	25.2	3.7	22.2	5.1	3.8	26.3

Appendix 3: Geochemical results

3.1 Total of trace element concentrations in the study areas, all results in mg/kg (ppm).

A- Botany Bay/Kogarah Bay

Samples No	S	Cl	V	Cr	Co	Ni	Cu	Zn	As	Br	Rb	Sr	Cd	Sn	Ba	Ce	Hg	Pb	Th	U
KO1	1880	141000	57.9	48.2	6.6	17.2	24.3	195.6	17.2	185.5	46.2	129.7	0.5	10.3	113.1	64.2	1	61.7	7.1	1
KO2	2	302600	25.6	12.1	3.4	13.6	27.1	194.3	20.4	146.4	77	160.2	2	8.7	175.1	76.2	0.4	103.6	11.8	2.5
KO3	734	273100	44.6	23.9	6.2	16.6	35.3	213.9	16.4	201.5	81.6	167.8	0.2	14.9	180.3	70.8	1	109.8	12.3	2.4
KO4	1913	118700	42.5	34.2	9	10	26.4	116.5	7.4	122.8	34.3	87.1	2	11.7	83.2	0.4	1	39.9	4.1	1
KO5	1882	201000	91	65.7	13.4	22.9	57.8	273.2	16.6	375.7	81.7	161.8	2	13.2	172.9	79.4	0.6	95.1	13.2	2.5
KO6	3501	76000	49	44.9	11.6	10.4	79.7	148.1	7.9	184.4	34.7	87.5	0.4	12.6	96.3	35.5	1	43.4	4.5	1
KO7	2	306000	29.6	14.2	7.8	14.9	38.1	200.6	19.8	163.3	82.6	151.6	0.8	12.5	192.6	62.2	0.4	114.6	12.4	2
KO8	1035	259100	32.4	27.9	7.9	13.2	39.3	157.9	14.7	158.5	58.4	109.2	2	12.2	138	39	1	90.5	8.5	0.7
KO9	2478	90230	20.6	19.8	4.2	5.2	10.6	49.5	5.9	115.7	18.3	45.5	2	8.3	66	0.3	0.6	18.4	1.4	1
KO10	2895	83840	13.2	15.2	6.4	4.8	9.2	27.5	4.9	97.5	9.9	28.7	0.3	6.1	48.4	0.2	1	10.3	0.5	1
KO11	875.2	2926	2.6	9.9	5	1.8	5.6	11.7	2	13.8	12.6	14.8	0.4	6.6	55.5	22.6	0.4	5.4	0.2	1
KO12	3664	122200	119.5	81.5	15.3	26.4	53.2	281.3	19.1	329.8	85.5	135.1	2	12.4	177	80	0.4	96.5	13.4	2.2
KO13	111	291600	25.8	14.3	8.2	15.4	34.5	180.7	21.9	122.3	81	133.1	0.5	14.1	191	79.4	1	131.5	11.8	2.9
KO14	2926	105500	65.1	55.4	4.9	15.7	47.5	177.6	12.3	166.4	51.4	85.2	0.3	10.9	118.1	61.5	1	72.9	7.7	0.4
KO15	1829	155000	61.2	43.3	5.5	13.1	42.4	159.6	11.5	146	48.1	76.4	2	10.4	128.3	48	1	66.1	7.4	1
KO16	1191	274900	53.4	25.4	8.7	18.2	85.5	244.7	20.2	191.3	83.4	132.6	2	13.6	195.5	82.8	1	156.5	12.3	2.8
KO17	623	287900	22.1	11.8	8.6	12.5	29.7	163.6	21.2	138.8	74.8	123.7	2	12.5	168.8	99.9	0.4	123.7	10.7	1.9
KO18	1477	10610	7.4	10.5	3	1.8	6.4	15.2	2.2	54.35	9.3	19.8	0.9	9.1	41.6	30.9	0.3	8.7	0.7	1
KO19	1326	263500	33.2	17.4	9	13.5	40.3	214.1	19.7	127.6	68.2	120.7	2	13.5	183.3	103.9	0.4	180.2	9.2	1.5
KO20	9115	91780	61	49.3	12.6	12.1	45.4	211.5	7.8	354.1	35.5	101.7	2	10.9	128.8	31.3	1	73.3	5.6	1
KO21	1945	17470	9.6	11.4	3.5	2.6	5.7	23	1.9	40.7	10.8	29.2	2	8.2	41.8	0.2	1	14.8	1	1
KO22	1495	244300	54.7	29.9	7.4	16.8	34.7	192.2	18.7	166.8	77.6	118.3	2	12.4	179.6	58.4	1	123	11.7	2.3
KO23	3365	39440	16.7	37.9	3.5	5.6	22	65.1	5	72.6	16.4	32.5	0.8	8.8	56.7	0.3	1	32	1.9	1
KO24	4404	124400	69.8	58.1	6.6	15.6	44.7	190.7	11.6	226	53.8	90.3	0.2	10.3	140.4	59.2	1	90.3	8.6	1
KO25	359	290600	37.4	25.2	6.5	15.8	40.2	199.1	26.2	157.4	78.3	131.6	0.9	12.1	186.4	73	1	181.6	11.2	1.8
KO26	179	296200	24.3	11.7	8	15.1	44.8	224.4	27.5	112.6	87.3	141.8	0.5	12.1	215	66.3	1	235.2	11.1	2.3
KO27	1091	6489	9.6	15.3	20.8	3.8	10.9	10.6	1.5	26.4	11	39.9	2	18.4	93.9	0.4	1	17.9	0.3	1
KO28	1357	8024	9.3	12.1	3	3.9	9.4	39.1	1.8	29.2	13.2	42.6	0.7	24.3	78	0.3	1	20.9	0.4	1
KO29	7088	60600	63.3	57.9	3.5	15.5	74.5	371	7.9	130.8	37.4	130.4	1.1	15	165.4	60.4	1	120	4.7	1.1
KO30	1542	5506	51.1	26.5	3.4	9.5	48.1	118.1	2.8	22.5	29.8	129.5	2	14.9	180.5	24.1	0.3	27.4	1.9	1
KO31	1743	8525	45.8	26.6	5.9	7.3	33.9	97	2.4	22.9	22.8	101.1	1.1	15	162	0.7	1	54.4	1.9	1
KO32	783	277800	24.1	15.8	5	10.8	32.3	158.2	17.9	175.3	55.6	102.5	0.6	12.8	158.2	55.7	1	170.2	7.6	1.2
KO33	1662	205700	37.4	38.8	3.5	10.9	32.5	130.8	10.9	106.2	41	72.7	0.4	11.7	118.6	61.7	0.3	76.5	5.6	1
KO34	3627	83750	31.9	31.9	4.4	7.8	24.6	91.1	6.1	126	24.7	51.8	2	10	74.5	25.4	0.3	42.3	3.5	1
KO35	3019	14280	1.9	7.9	3	1.3	7.6	13.2	1.6	32	3.1	15.6	2	10.1	29.4	24.2	1	7.7	1.4	1
KO36	4909	75940	92	88.3	6.4	19.7	47.2	225.7	14.2	146.3	63.3	135.2	2	12.6	141.7	49.9	0.4	114.1	10.4	2.7
KO37	2005	2568	4.5	11.5	3	3.75	6.25	20.2	1.5	14	14	25.6	2	6.4	52.1	6.7	1	10.7	2.8	1
KO38	3231	4720	12.1	17.8	3	4.7	11.8	44.6	2.8	24.4	14.2	32.6	0.5	10.6	51	0.2	1	27.4	2.6	1
KO39	10970	90270	107.2	84.1	14.3	23.3	73.9	337.5	18.2	533.5	74.8	138.6	0.1	9.9	168.7	69.7	0.5	140	11.7	2.1
KO40	3718	143600	25.2	27.7	3.6	6.8	22.3	95.5	7.2	190.2	22.6	51.6	1.5	9.5	84.6	37.1	1	46.3	3.7	1
KO41	6874	75430	111.7	88.3	9.5	24.6	90.4	397.9	18.4	257.2	77.3	140.7	2	15.4	192	89.2	1	168.8	12.3	1
KO42	2987	118700	5	11.2	4	2.9	11.2	37.2	2.5	108.3	7.6	53.3	2	8.7	67.2	0.3	1	24.6	1	1
KO43	3325	77790	161.3	39.9	18	18.5	99.65	143	4.5	57.45	55.1	323.95	1.05	2.35	417.8	21.2	1	69.55	4.35	1
KO44	7906	96410	53.3	60.1	3	15	55	253.2	8.7	186.7	35	101.8	0.2	13.9	139.3	26.9	0.3	118.5	6.6	0.4
KO45	5371	138800	125.3	91.4	10.8	27.9	94.3	433.1	17.6	246.4	85.4	145.6	2	13.1	196	39.3	0.4	193.7	12.3	1.8
KO46	5180	51650	91.9	69.4	6.3	19.4	60	253.9	15.6	111.2	59.6	122.6	0.5	13	140.4	65.3	0.3	115.6	8.9	1.7
KO47	1294	7146	8.6	14.5	3	3.2	11	30.4	3.3	19.1	11.4	21.7	2	6.7	61.2	0.3	0.6	15.4	0.7	1

KO48	1909	260800	27.9	15.6	4	13.1	39	200.7	18.8	109.8	69.6	127.2	2	10.2	189.9	67.7	1	174.4	9.7	2.2
KO49	1831	250300	38.5	15.2	5.4	15.1	39	191.8	21.3	97.7	73.8	133.3	0.4	11.7	190.6	67	1	155	10.6	2.3
KO50	1790	20250	10	11.3	3	1.5	4.8	19.4	3.8	39.6	8.6	66	1	9.2	42.5	0.2	1	11.6	1.2	1
KO51	2383	265400	47.5	18.7	10.5	17.5	41.8	209.5	24.6	119.6	86	155	2	13	193.7	66.9	1	141.6	12.2	3.1
KO52	1212	292800	16.7	7.8	6.6	11.9	27.5	154.8	23.8	114.3	74.7	134.3	0.4	13.2	188.2	61.2	1	159.1	10.3	2.4
KO53	3114	101500	96.3	66.5	13.5	20.6	77.8	243.7	19.4	190.1	61.7	206.9	2	11.6	154.8	50.8	1	91.6	10.4	1.3
KO54	169	306100	11.7	6.6	7.1	11.5	26.9	148.7	25.1	112.5	71.5	125.7	2	11.5	178	65.3	1	162.8	9.8	1.2
KO55	1789	261500	35.2	18.4	3.8	15.3	40	194.5	22.2	135.4	82.7	139.9	2	12	202.3	91.9	1	152.8	12.1	2.3
KO56	2066	27240	44.8	47.3	7.9	10	19	98.2	8.7	72.1	32.1	51.9	0.1	9.3	85.2	0.4	1	32.3	2.6	1
KO57	1384	25880	23.1	26.2	5.3	5.7	11.1	55.6	6.8	48.7	23.8	44.6	0.1	8	80.1	51.2	1	18.7	1.4	1
KO58	2679	249100	51.4	32	7.7	15.8	29.7	205	15.4	190.6	75.5	168.8	2	11.3	194.2	91.2	1	112.3	12	2.4
KO59	2375	98030	63.8	48.6	7.9	13.4	27.3	172.9	12.9	184.3	44.3	267.2	0.6	9.4	114.1	61.6	1	51.2	7.1	1
Min	2	2568	1.9	6.6	3	1.3	4.8	10.6	1.5	13.8	3.1	14.8	0.1	2.35	29.4	0.2	0.3	5.4	0.2	0.4
Max	10970.0	306100.0	161.3	91.4	20.8	27.9	99.7	433.1	27.5	533.5	87.3	324.0	2.0	24.3	417.8	103.9	1.0	235.2	13.4	3.1
Mean	2603.2	138686.3	44.23	33.06	7.0	12.25	36.80	158.1	12.38	138.18	48.51	105.36	1.27	11.41	136.61	45.09	0.82	86.85	6.85	1.46
StdD	2214.98	106928.19	34.74	23.67	3.95	6.66	24.18	99.67	7.86	96.32	27.81	60.13	0.76	3.21	66.26	31.31	0.28	59.85	4.47	0.69

Woolooware Bay

Samples No	S	Cl	V	Cr	Co	Ni	Cu	Zn	As	Br	Rb	Sr	Zr	Cd	Sn	Ba	Ce	Hg	Pb	Th	U
WO1	2954	49120	12	20.6	3.5	3.6	7.8	38.8	3.9	68.8	13.5	70.1	120.6	2	7.9	53.2	0.2	1	14.1	1	1
WO2	2830	34770	45.4	44.5	4.1	10.2	17.1	111.2	10.1	89.7	34.5	161.7	121	0.1	9	108.6	0.5	1	33.5	3.7	1
WO3	3748	137200	118.9	98.6	11.6	26	45.3	314.4	20.1	283.4	87.5	208.5	185.6	0.5	9.5	170.3	48	1	89	13.3	1.5
WO4	885	288000	20.9	14.5	7	15	28.3	189.5	17.1	216.5	77.6	151.2	163.8	2	12.4	174.3	82	1	104.1	11.8	1.8
WO5	2846	34890	29.9	32.6	4.9	7.4	12.6	69.3	6.5	68.9	29	46.7	74.8	1.2	7.3	85.6	0.4	1	21.8	1.6	1
WO6	1403	12730	2.3	8.7	6.3	6.3	6.6	9	2	38.5	14.4	17.8	48.5	1	7.8	79.4	32.7	0.6	4.3	1	1
WO7	2005	3088	1.7	6.1	3.1	2.3	5	7.7	1.3	18.1	15.6	17.8	37.3	0.1	6.7	79.5	18.2	1	4	0.2	1
WO8	7206	70910	114.9	98.6	15.1	26.1	44.2	281.8	21.4	396.4	79.2	184.1	156.8	2	8.4	154.7	87.7	0.4	77.3	12.2	2.9
WO9	2361	174400	68.8	58.6	5	15	29.9	171.1	13.2	248.9	48.9	264.1	140.4	2	9.4	115.9	41.6	0.4	53.6	8	2.1
WO10	2775	7485	20.3	32.8	3.4	5.9	15	66.2	5.8	25.2	19.3	41.2	186.8	0.3	8.6	62.7	23.6	1	20.1	1.6	1
WO11	3062	186100	69.9	65.7	6.3	17.4	58	224.8	14.1	201.8	54.5	113.3	163.7	2	14.4	130.7	64.5	1	62.5	7.9	0.4
WO12	2715	43750	14	24.5	3	4.6	19.5	52.9	5	63	13	34.1	172.3	2	10.5	47.5	0.2	0.3	14.7	2.4	1
WO13	3051	131800	64.5	54.9	6.8	13.8	27.3	161.8	12.7	210.9	43.8	204.1	125.1	2	7.7	110.5	31.9	1	45.8	7.2	0.9
WO14	2668	184800	83.7	64.5	7.1	19.7	35.5	214.3	19.6	277.8	67.8	257.6	169.1	2	8.9	140.7	52.6	1	65	11.6	2.4
WO15	1135	287100	18.1	14.7	4.5	8.8	18.5	119.1	12.7	203.9	49	329	114.5	2	9.5	133.4	72.7	1	58.1	9.3	3
WO16	2455	16850	1	6.8	3.9	1.1	3.1	9.3	1.4	39.4	14.2	18.9	49.9	2	6.4	71.9	0.3	1	4.2	1	1
WO17	2461.5	13980	0.65	7.2	4.9	4.65	5.1	9.4	1.25	38.95	10.45	17.05	45.2	0.6	6.25	61	0.3	1	3.35	1	1
WO18	4103	86840	66.6	60.2	10.9	14.1	22.9	134.2	12.8	173.9	48.5	85.4	125.6	0.7	8.8	126.9	49.8	1	39.1	5.1	1
WO19	3083	38400	39.9	43.3	10.9	10.1	18.5	88.4	9.2	93	32.4	81.9	86.4	1.3	10.4	102.2	0.5	1	26.5	2.5	1
WO20	7724	98620	103.2	83.7	12.5	21.8	36.9	210.2	14.6	565.7	64.4	190.8	152.4	2	4.9	136.1	47.6	0.4	61.2	11.5	5.2
WO21	4684	122800	101.6	78.5	15.7	22.1	36.6	220.9	21.9	274.7	70.7	128.1	129	2	11.9	125.9	50.9	1	63.3	10.2	1.7
WO22	1985	237900	25.4	22.6	15.2	8.3	18	75.1	9.5	144.3	33.1	614.2	85.4	0.7	3	84	52	1	28.2	6.8	1.9
WO23	2740	207300	87.5	59	8.7	22.5	34.9	216.9	22.4	322.6	80.3	136.7	178.2	2	9	163.3	74.1	0.4	72	12.5	2.5
WO24	1314	217300	26.7	26.7	3.8	7.8	14.2	86.1	7.8	186	38.4	97.2	111.9	2	10.4	114.7	0.5	1	31.9	3.9	1
WO25	3991	47770	1	5.7	3.3	1.3	2.8	10.7	1.3	60.3	9.9	18.3	31.4	0.8	7.8	64.8	0.3	1	3.4	1	1
WO26	3881	68890	0.9	9.1	3.5	1.8	4	16.4	2	85.7	12.9	24.5	48.2	0.2	4.9	72.1	0.3	1	5.2	0.1	1
WO27	3008	110300	44	37.8	3.7	9.1	15.5	92.2	6.9	161.9	38.1	142.3	98	0.2	8.3	107.7	34.1	1	28.8	4.8	0.7
WO28	5327	34470	63.3	60.7	20.1	12.8	22.3	97.8	10.2	110.7	43.7	316.9	133.2	2	9.2	112	43.1	0.5	31.5	6.3	1
WO29	2708	190500	92.9	59.4	16.7	20.6	32.7	195.3	22	324	69.5	235.5	161.1	2	10.3	142.3	63.5	0.9	61	11.9	2.9
WO30	7217	141400	80.8	56	15	17.3	25	154.8	18.7	201.5	60.1	158.8	213.4	0.7	8.1	149.7	72.3	1	44.3	9.9	2.3
WO31	9429	36290	55.6	50.8	9.6	11.4	20.5	126.9	12.8	106.3	39.6	91.2	173.1	0.5	9.4	113.7	37.5	1	32.8	5.6	0.6
WO32	7873	49570	65.1	55	15.5	14.4	22.3	97.5	12.8	134.9	44.2	150.1	122.6	2	7.4	109.1	53	0.5	30.1	6.2	0.4
WO33	8200	41840	90.8	76.1	20	18.9	25.1	138.6	14.5	157.8	64.9	192.7	153.1	2	7.3	132.9	59.3	0.5	42.4	9.6	2.2
WO34	3938	193600	70.5	51	3.8	17.9	27.7	172.4	16.8	351.4	69	121.3	179.8	2	8.1	152.4	86.4	0.5	57.5	11.4	3.5
WO35	7314	81710	66.5	56.3	8.9	14.7	23.3	130.4	12.5	154.1	52.1	90	147.1	0.7	11.1	133.1	65.6	1	36.4	6.7	0.7
WO36	3678	82660	66.9	55.4	12.2	14.6	22.6	131.3	11.9	140.5	51.8	157.1	113.4	2	10.7	116.5	75.9	1	38	6.6	0.8
WO37	4663	56990	58.6	56.1	8	13.5	21.5	124.6	9.7	118.9	48.3	76.9	131.6	0.6	10.8	119.2	42.7	1	36.7	5	1
WO38	4007	85300	27.2	37.6	6.6	7	11.6	63.1	5.8	155	27.6	59.8	69.4	2	9.7	92.2	32.8	1	19.6	2.7	1
WO39	3478	102300	30.4	28.1	6.3	7.9	12.8	73.5	6.5	119.1	31.5	76.4	85.9	2	10.4	97.6	0.4	1	22.7	2.5	1
WO40	4321	60240	51.1	42.7	10	11.8	18.7	96.7	8.5	126.9	40	85.3	113.4	0.7	10.8	101.4	41.4	1	28.5	3.5	1
WO41	3666.5	58445	36.05	34.7	7.8	11.1	14.85	67.2	6.9	108.8	32.9	70.65	98.7	0.45	7.8	101.8	26.45	2.2	21.25	2.6	1
WO42	1462	210400	18.3	22.3	8.9	9.4	13.9	58	6.2	91.1	29.2	170.8	78.4	2	8.4	95.7	24.4	1	20.7	2.7	1
WO43	4742	50210	77.2	63.6	19.6	15.6	25.4	133.7	13.4	188.2	51.6	385.9	139.7	0.5	6.7	129.5	64.8	0.5	43.5	9.2	2
WO44	2088	57100	16.3	20.6	3.5	3.1	6.1	56.9	10.1	80.8	12.8	386.2	52.9	2	4.4	55.6	15.9	1	20.8	1.9	1
WO45	3388	42060	50.9	46.1	8.1	11.1	20.5	118.8	9.8	109.2	35	191.1	121.9	0.5	6.2	99.3	55.7	1	34.5	4.1	0.4
Min	885	3088	0.65	5.7	3	1.1	2.8	7.7	1.25	18.1	9.9	17.05	31.4	0.1	3	47.5	0.2	0.3	3.35	0.1	0.4
Max	9429	288000	118.9	98.6	20.1	26.1	58	314.4	22.4	565.7	87.5	614.2	213.4	2	14.4	174.3	87.7	2.2	104.1	13.3	5.2
Mean	3790.5	99737.3	48.9	43.4	8.7	12.0	21.1	116.4	10.8	163.1	42.3	148.3	120.2	1.3	8.6	109.6	38.4	0.9	36.8	5.8	1.4
StdD	2039.0	76761.0	33.6	24.5	5.0	6.6	12.0	74.2	6.1	110.1	21.5	119.5	46.3	0.7	2.2	32.2	27.7	0.3	23.6	4.0	0.9

Oyster Bay

Samples No	S	Cl	V	Cr	Co	Ni	Cu	Zn	As	Br	Rb	Sr	Zr	Cd	Sn	Ba	Ce	Hg	Pb	Th	U
OY1	233	280400	31.7	33.4	20.6	13.9	31.1	157.9	18.3	148.2	67.5	115.5	177.3	2	11.4	157.3	56.2	1.5	94.7	9.8	0.4
OY2	2	297800	22	11.6	23.3	12	29.4	147.3	23.8	127.5	67.3	119.8	260.3	0.1	12.3	163.7	93.2	2.5	122.2	10.9	0.6
OY3	3076	126100	78.2	57.6	3	16.5	33.7	200.8	15.6	207.6	59.5	106.6	422.6	2	14	146.3	71	1	90.1	13.5	1.8
OY4	2050.5	99750	25.85	19.3	3	8.1	12	56.7	5.15	105.95	19	43.4	142.9	1.4	10.35	50.6	39.95	2.75	21.4	2.75	1
OY5	433	274600	22.8	21.4	4	13.1	29.7	162.8	19	178.8	65.6	126.2	228.5	2	9.1	177.9	86.1	1	100.8	11.1	1.4
OY6	309	312100	10.7	9.9	6.3	12.3	27.6	147.8	24.3	126.9	69.7	124.8	248.7	0.1	15.2	162.8	87.8	1	155	11	2
OY7	3422	88920	57	46.9	3	12.9	22.4	134.4	10.4	173.9	39.1	64.7	273.8	2	10.3	98.7	29.1	1	45.5	7.6	1
OY8	3128	63550	95.1	80	13.5	20.6	37.6	198.3	13.2	125.4	58.4	81.1	186.5	0.2	12.1	123.4	63.6	1	62.1	8.2	1
OY9	2957	154700	50.7	47.9	10.7	13.5	27.7	142.4	10.5	237	40.6	70.6	224.5	0.1	11	106.4	44.1	1	50.1	7	1
OY10	3774	71180	114.5	88.8	11	26.5	49.1	286.6	18.3	175.6	83.9	114.9	268.1	0.1	12.8	175.3	57.8	0.7	96.3	13.2	2.5
OY11	2076	243300	69.7	44.5	8.3	17.6	39.4	217.6	17.4	225.7	71	118.9	253.6	2	11.1	164.3	58.1	1	98.2	12.4	1.9
OY12	138	309500	23.9	9.6	18.9	12.2	27.9	146.8	25.6	108.4	74.5	127.6	243.5	2	12.8	185.6	68.7	1.4	171.1	10.7	0.8
OY13	971	265600	42.7	24.5	11.4	17.3	35.2	200.3	19.7	154.4	75.9	123.6	235.3	2	11.9	197.1	71.6	0.4	127.3	12	2.1
OY14	3370	71380	25.9	33.8	3	7.3	14.2	71.5	5.7	124.5	19.9	41	236.9	2	7.8	56.4	58.1	1	23.6	4.2	1
OY15	2	273000	26.5	19.5	25.4	14.5	29.9	144.6	22.6	88.9	69.7	110.1	229.9	0.3	12.1	178.3	95.5	0.7	141.7	9.5	1.4
OY16	2352	210500	79.6	52.3	7.4	22.3	38.4	250.9	17.1	167.3	76.8	110.2	258.9	0.2	14.5	180.1	68.8	1	115.2	12.8	2.2
OY17	2979	107800	112.7	83.3	11.6	27	48.5	297.2	15.8	244.7	86.8	120.1	226.4	2	14.7	188.7	68.1	1	105.4	13.5	2.9
OY18	3335	117400	101.7	72.2	5.7	24.3	45.1	276.3	15.4	181.1	80.1	116.4	251.6	2	13.5	176.3	78	1	105.9	13.1	2.7
OY19	3610	98140	126.8	94.5	14.4	28.7	50.9	333.5	17.8	240.1	92	125.1	219.3	2	13.9	194	56.9	0.4	105.2	14.3	2
OY20	818	284700	22.3	13.6	8.2	15.3	32	192.6	25.7	106.3	81.2	129.8	212.3	2	12.5	194.2	71	1	198.2	10.7	2.5
OY21	749	299200	20.6	10.6	3	10.9	24.3	157	19.3	126.4	61.8	120.6	247.6	2	10.2	199.9	62.3	1	144.3	10.1	1.5
OY22	1759	264800	39.2	30	9.2	17.5	37.9	240.6	20.7	171.4	74.5	118.5	218.4	0.8	14	202.4	75.3	1	163.5	11.3	1.6
OY23	2	296900	15.5	8.9	28.3	11.9	27.6	160.2	23.1	141.2	69.3	124	176.7	0.2	11.6	215.6	94.3	1.9	184.5	9.9	0.6
OY24	125	299400	22.7	14.3	19.5	14.1	33.8	197	25.3	134.8	72.5	122	206.9	2	14.3	198.7	77.7	0.8	183.2	10.2	1.2
OY25	366	293000	24.3	17.9	7.6	13.9	32.6	199.1	25.4	144.7	71.8	123.3	209	0.6	11.9	190.2	49.7	1	172	11	1.4
OY26	936	268700	44.2	21.6	5.2	18.3	37.5	234	22.7	141.5	80.8	127.9	220	2	12.7	195.8	80.5	1	157.9	12.5	2.3
OY27	480	282100	26.9	15	6.5	14.2	29.8	188.5	19	90.6	70.1	128.7	205.5	0.8	12.4	184	107.5	1	120.6	10.3	2.4
OY28	1761	273300	32.6	19.7	9.9	14.8	32.4	200.3	17	130.8	72.9	125.1	212.8	0.1	9.7	192.3	68	1	123.4	11.9	2.4
OY29	3338	80290	115.7	90.7	11.9	28.1	51.6	324.2	18.9	154.2	85.4	122.2	216.4	0.6	10.8	187	65.4	0.6	106.9	13	1.4
OY30	1935	235000	62.7	37	4	20.4	41	261.7	18.7	162.4	81.3	122.2	198.9	0.1	11.5	193.1	0.9	1	137	12.3	1.6
OY31	5626	33360	87.9	75.7	9.2	19.7	35.4	239.8	14.6	105.7	51.7	88.2	210.5	0.6	10	125.7	42.9	0.7	74.5	8.4	0.4
OY32	4326.5	45615	65.8	68.1	7.8	17.15	28.7	178.5	11.05	99	41.7	70	174.8	1.35	10.45	107.3	25.2	0.65	58.65	6	1
OY33	1705	263300	43.2	24.9	7.4	17.6	37.5	239.9	21.1	136.7	77.5	125.9	194.5	2	11.5	192	74.9	0.4	149.9	11.4	2.5
OY34	3090.5	35835	54.9	57.8	5.2	17.8	24.95	141.8	8.2	68.5	35.15	71.5	189.85	1.3	9.85	119.85	39.6		45.9	4.8	1
OY35	5023	46570	56.7	53.5	7.3	13.2	28.2	161.7	7.6	136.4	39.9	69.4	136	2	10.5	88	69.5	1	51.9	5	1.1
OY36	2682	25450	36.3	35.1	6.6	11.15	17.6	92.2	5.8	62.95	24.2	43.4	147.05	1.2	10.15	68.05	17.55	1	31.75	2.6	1
OY37	2294	21165	21.35	26.3	3	7.4	12.15	56.3	4.6	45.25	15.25	34.9	239.9	0.35	7.9	55.55	30.1	1	19.9	3.35	1
OY38	2570.5	20730	16	17.6	4.9	7	9.75	43.4	1.9	44.1	10.25	28.95	140.7	2	8.75	44.7	22.1	1	14.15	1.55	1
OY39	2903	21710	29.4	39.5	3.4	10.8	16.8	86.5	4.7	51.65	21.35	40.4	208.45	1.25	9.15	66.3	18.7	1	32.15	3.55	1
OY40	2471	23000	24.25	30.8	3	9.5	15.75	73.5	3.45	45.85	18.05	39.4	256.15	0.55	8.65	59.75	34.35	0.85	28.15	4.7	1
OY41	3512	45560	80.7	73.4	10.5	18.9	34.1	188.7	10.1	120.6	49.45	91.65	160.3	1.3	11.5	147.15	40.65	0.35	63.75	6.7	1
OY42	5323	85170	109.7	90.6	7.9	27.3	56.1	364.6	17.1	289	76.5	129.6	216.6	2	11.4	184.8	72.3	1	111.7	12.8	2.1
OY43	5525	50390	109.8	95.6	11	27.8	53	333.3	18.2	151.1	74	130.6	247.2	2	12.7	177.7	56.9	1	109.6	11.9	1.7
OY44	6248	39170	121.8	111.1	16.2	32.4	58.3	344	19.2	154.3	84.8	138.4	205.4	0.8	9.1	189.3	64.9	0.7	118.2	12.8	2
OY45	4601	62265	66.75	72.6	8.9	19.95	31.4	198.6	11.15	123.9	46.2	82.7	157.95	1.35	10.55	122.75	52.75	0.9	65.3	6.05	1
OY46	5668	41680	85.6	84.9	9.2	22.5	49	264.9	14.7	137.7	55.6	106	177.1	0.7	12	149.4	44	0.3	86.7	8.4	0.4
OY47	6051	89490	97.5	86.4	11.5	24.1	54.3	340.6	14.7	190	66.8	118.3	179.4	0.4	11.7	147.6	88.3	1	107.2	9.9	1.1
OY48	3716.5	68895	84.1	85.1	10.6	23.1	40.8	241.7	12.8	157.5	58.6	93.65	175.45	0.5	11	127.65	49.15	0.75	83.7	8.3	1
OY49	4352.5	29415	58.65	74.2	7.1	26.15	31.95	191.4	9.85	74.5	36.45	88.15	191.2	0.9	9.65	132	0.6	0.65	62.85	4.8	1
OY50	5002	19150	54.8	88.2	9.5	24	36.6	217.5	14.9	53.7	36.7	75.1	168.7	2	8.1	127.1	0.6	0.4	66.3	4.2	1
OY51	1893	241100	49.5	36.5	8	21.3	40.4	267.9	18.3	178.3	72.7	127	183.7	0.1	11.6	204	80.1	1	146.3	11.6	1.5
OY52	5505	43660	109.2	111.5	16.3	32.5	59.6	342.6	14.2	158.5	69.9	127.4	207.4	0.4	12.9	184.6	76.7	1	112.5	10.2	1.2
OY53	4452	26845	46.9	72.7	9.4	25.05	32.15	192.3	6.7	63.35	28.05	67.2	173.7	2	9.65	101.2	30.5	0.8	50.2	3.1	1
OY54	5448	33550	127.6	126.9	15.9	38.8	62.7	385.9	19.3	175.9	75.4	135.2	179.3	0.3	11.8	169.5	84.6	1	109.3	11	1.2
OY55	2493.5	29915	38.75	57.9	8.8	21.8	23.4	117.7	5.1	57.7	24.8	69.75	118.55	1.2	10.2	104.15	14.7	1.05	42.25	2.45	1
Min	2	19150	10.7	8.9	3	7	9.75	43.4	1.9	44.1	10.25	28.95	118.55	0.1	7.8	44.7	0.6	0.3	14.15	1.55	0.4
Max	6248	312100	127.6	126.9	28.3	38.8	62.7	385.9	25.7	289	92	138.4	422.6	2	15.2	215.6	107.5	2.75	198.2	14.3	2.9
Mean	2781.2	141565.5	58.6	51.4	9.8	18.5	34.6	204.3	15.3	136.9	58.7	100.3	210.1	1.2	11.3	149.7	57.0	1.0	97.6	9.0	1.4
StdD	1830.7	110212.6	34.8	32.0	5.8	7.1	12.6	83.9	6.5	54.7	22.3	31.5	46.7	0.8	1.8	48.0	25.7	0.4	47.8	3.6	0.6

Woronora River

Samples No	S	Cl	V	Cr	Co	Ni	Cu	Zn	As	Br	Rb	Sr	Zr	Cd	Sn	Ba	Ce	Hg	Pb	Th
WOR1	1616.5	14945	23.4	25.5	3.8	7.3	13.25	49.7	4	38.4	15.4	29.15	131.35	0.6	9.7	49.55	0.2	1	16.45	1.8
WOR2	2452	31350	13	13.2	3.4	3.4	7.9	32.1	3.1	57.2	14.1	25.6	88.6	2	9.4	45.4	0.2	1	11.8	0.7
WOR3	1970.5	23605	27.6	33.8	3.4	8.75	14.55	58.8	6.6	56.6	20.1	37.45	201.15	2	11.5	62.5	31.85	1	21.35	3.15
WOR4	1085	6464	21	18.9	1.5	4.3	9.1	47.9	4.6	25	14.7	26.3	123	0.1	7.3	48.1	31.4	1	14.8	1
WOR5	1529	15095	23.3	26.7	6.1	8.35	14.1	54.2	4.25	47.1	17.25	31.65	126.5	1.3	8.8	47.05	22.7	1	17.65	1.9
WOR6	1265	16860	7	8.4	3	2.2	4.5	19.8	2.2	41.1	10.8	42.6	52.6	2	8	41	20.1	1	7.4	0.6
WOR7	2244.5	32950	22.75	24.1	4	7.4	11.2	46.5	4.2	62.35	15.7	32.15	116.45	0.35	9.55	51.6	8.5	1	16.45	1.65
WOR8	1679.5	11196.5	9.85	10.9	3.8	17.15	7.55	27.7	2.9	43.2	8.8	21.2	127.2	1.2	6.95	37.45	9.6	1	8.1	1.45
WOR9	3277	26090	48.3	48.4	2.9	11.7	22.6	113.7	8.8	80.5	34.1	57.1	182.3	0.4	9	80.6	45.7	1	36.7	4.2
WOR10	4343	42220	81.7	65.2	24.6	15.8	33	146.3	11.3	119	50.4	87.6	197.4	0.5	15.3	117.7	43.2	0.5	54.2	7.9
WOR11	1602.5	13485	23.95	29.8	3.3	8.65	14.65	57.8	5.75	38.1	19.7	36.75	212.85	1.4	8.75	56.1	58.05	0.65	20.9	3.65
WOR12	909.1	10790	6.3	5.3	7.4	2.1	6.1	14.9	2	36.9	10.7	22.9	67	0.7	7.3	38	0.2	0.6	6.9	1.3
WOR13	547.9	2534	4.7	7.5	4	2	5.9	13.2	1.7	46.67	9.8	15.8	72.1	0.5	6.7	32.8	0.1	0.3	6.7	0.3
WOR14	3740	50450	99.5	73.7	19.7	21.1	41.2	207.4	15.2	132.3	68.2	103.7	194.2	0.1	11.1	134.5	64.9	0.5	70.2	10.6
WOR15	777.2	4082	1	5.5	4.7	1.1	5.3	9.3	1.9	33.5	10.1	15.8	65	0.1	5.8	53.4	13.6	1	3.8	0.6
WOR16	1997	15610	4.2	10.2	3	2.5	7.4	20.7	2.2	32.8	12.5	20.7	139.8	0.7	8.5	58.4	21.9	1	8	1
WOR17	2602.5	32250	6.7	9.8	3	2.1	4.6	22.4	2.2	59	10.1	22.5	151.4	2	7.5	41.1	13.2	1	8.9	0.5
WOR18	1960	14150	16.9	18.5	6.6	5	11.5	45.5	3.7	42.7	19.6	29.8	112.4	0.8	7.9	67.8	31.5	1	15.9	1.3
WOR19	1542.3	20506.5	2.9	3.8	2	1.65	3.75	11.7	1.1	41.3	6.15	21.6	59.75	0.35	6.85	38.45	14.6	1.05	4.6	0.45
WOR20	3607	27495	31.25	34	3.4	10.8	18.4	84.4	8.65	59.75	23.7	45.35	274.1	1.25	9.65	62	50.75	0.65	27.9	4.5
WOR21	3062	55850	62.6	54.8	6.9	18.5	24.4	129	10.1	109.7	37.8	64	172.1	0.3	11.2	89	0.4	1	40.7	5.2
WOR22	4154	47210	43.4	39	4.6	8.8	19.6	110.3	8.3	92.7	28.7	50.1	189.4	2	9.7	74.1	42	1	36.7	5
WOR23	1641	14450	9.9	9.5	3	1.6	3.8	13	1.4	40.1	11.2	20.2	196.2	2	6.1	34.3	0.2	1	5.3	2.9
WOR24	1487	14730	3.6	5.8	3	1.8	3.1	13.9	1.5	41.9	9.7	18.3	103.7	2	8.8	45.1	22.8	1	6.3	0.3
WOR25	2880	19200	8.8	13.1	3	5.6	7.1	26.2	2.4	34.4	7.1	20.55	242.45	1.25	10.25	38.85	22.5	0.75	7.2	2.95
WOR26	2768	60400	3.1	9.4	3.1	1.7	4.6	24.3	1.8	75.2	11.3	22.9	62.6	2	6.6	45.2	29	1	9	0.5
WOR27	5168	40150	114.3	84.4	13.3	23.3	51.8	255.7	16.9	171.6	79.8	125.7	228.2	2	9.4	150.3	63.8	1	87.3	12.6
WOR28	6885	38060	83.5	66	6.5	18	38.3	190.2	16.5	151.8	56.2	96	280.2	2	9.3	122.1	59.3	1	62.9	9.9
WOR29	7097	48230	83.4	68	5.4	19.3	38.2	183.6	18.7	198.8	59.9	115.8	194.2	2	10.5	131	69.2	1	61.7	9.4
WOR30	8966	50480	98.2	73.3	7.9	20.4	46	212.3	13.6	245.7	68.8	132.7	208	2	10.2	152.1	63.5	0.3	72	11.2
WOR31	11510	66350	94.2	71.2	8.4	18.9	37.8	197	16.5	381.4	57.4	132.5	188.6	2	7.5	118.7	66.1	0.4	58.6	10.9
WOR32	1255	7713	1	4.6	3.4	1.5	5.4	12.4	1.1	36.55	10.9	17.6	61.2	2	7.4	54.4	18.3	0.3	5.3	0.5
WOR33	2493.5	25750	20.4	32.1	3	7.45	11.05	47.5	4.7	57.45	15.25	36.1	388.55	1.2	7.45	46.85	52.85	1	17.35	5.9
WOR34	1994	22420	4.7	14.7	3	7	7.3	22.1	2.3	42.7	6.9	19.8	111.2	2	8.2	27.4	11.3	1	7.1	1
WOR35	1710	22570	9.1	9.5	3.4	6.8	8.6	15.5	2.3	42	5.1	17.3	121.9	1.15	8.1	40	18.7	1.3	5.2	0.6
WOR36	4863	9388	26.9	50.7	3	11.8	15.3	86.6	6	68.35	20	40.9	237	2	9	56.7	19.9	1	40.4	4
WOR37	3623	82240	38.7	39.3	5.9	9.6	21.6	110.2	5.6	121.2	30.4	55.5	133.5	2	7.7	79	36.5	0.3	33.6	3.8
WOR38	4332	181100	116.1	70.2	16.1	23.5	54.3	328.8	17.7	410.3	87.8	146.9	168.6	2	9.8	186.4	60.4	0.6	104.9	14.3
WOR39	1292	5888	2.1	6.8	2.3	1.5	4.4	11	0.8	26.4	10.3	17.5	91.1	2	6.2	48.8	0.2	0.6	4.5	0.6
WOR40	4963.5	38600	33.8	34.2	6.4	10.55	19.1	87.9	5.1	88.3	25.2	58.5	166.65	1.05	9.85	68.9	49.7	1	29.5	3.8
WOR41	2413	18280	18.6	33.2	3.4	9.5	11.3	42.6	3.3	47	12.9	28.7	145.3	0.1	6.7	42.2	6.8	1	19.2	1.6
WOR42	4637	25300	60.5	59.3	8.1	14.5	26.1	132.1	6.5	80	39.1	65.5	142.4	2	8.1	92.9	34.5	1	43.6	5.3
WOR43	9274	46290	115.5	83.6	13.7	23.7	55.3	297	14.3	178.9	76.1	148.5	186.3	0.5	12.5	161.7	66.1	1	100.1	12.1
WOR44	4856	25220	46.9	44.3	7.1	12.3	22.9	110.1	5.5	71.3	28.9	55.3	140	1.3	10	72.4	39.5	1	33.3	3.6
WOR45	5391	154100	106.2	72.2	11.1	23.2	54.6	308.5	14.5	366	80.9	158.5	161.2	2	12	164.9	54.4	1	97.2	13.5
WOR46	1701	11910	1.6	5.5	0.1	0.7	2.9	10.1	1.5	27.3	5.9	14.8	80.3	2	6.7	32.8	0.1	0.5	4.6	1
WOR47	3885	32080	40.1	40.7	2.3	8.7	18.2	87.6	7.1	76.4	26	46.3	153.7	0.9	9.3	67.5	51.1	0.4	27.8	2.7
Min	547.9	2534	1	3.8	0.1	0.7	2.9	9.3	0.8	25	5.1	14.8	52.6	0.1	5.8	27.4	0.1	0.3	3.8	0.3
Max	11510	181100	116.1	84.4	24.6	23.7	55.3	328.8	18.7	410.3	87.8	158.5	388.55	2	15.3	186.4	69.2	1.3	104.9	14.3
Mean	3298.9	33533.8	36.6	33.4	5.8	9.7	18.5	88.3	6.4	93.1	27.7	52.2	154.2	1.3	8.8	72.5	30.7	0.8	29.8	4.1
StdD	2364.6	33742.4	36.8	25.4	4.8	7.3	15.7	87.4	5.3	91.6	23.6	41.8	67.7	0.7	1.9	41.5	22.7	0.3	28.3	4.1

Georges River and Salt Pan Creek

Samples No	S	Cl	V	Cr	Co	Ni	Cu	Zn	As	Br	Rb	Sr	Zr	Cd	Sn	Ba	Ce	Hf	Hg	Pb	Th	U
GE1	302	298900	25.3	9	10.5	15.7	39	235.4	19.7	116.4	87.7	133.5	212.8	2	10.9	207.4	74	3.3	1	129.5	12	2.5
GE2	4610	104200	108.3	68	12.4	24.7	56.8	392.2	12.5	236.7	85.1	120.3	242.8	2	8.3	191.4	86.3	5.8	1	99.3	13.4	2.7
GE3	3691	152800	109.7	64.2	16.7	26.6	59.9	382	11.8	329	92.1	129.9	184.7	2	11	204.7	67.7	6	0.4	87.5	12.8	1.9
GE4	1878	11230	13	14.5	3	3.4	8.45	36.4	2.7	37.8	15.3	31.9	93.9	0.1	7.9	51.6	0.2	1.1	1	10.7	1.2	1
GE5	3730	26450	14.1	20.8	0.7	4.5	11.9	52.9	2.8	39.7	16.6	31.2	166.6	2	8	52.8	18.3	1.3	0.9	14.1	1.9	1
GE6	2420	14740	1	8.8	3	1.3	3.2	15.2	1.8	27.8	10.7	25	366.5	0.1	7.7	50.5	26.9	5.2	1	4.9	3.5	1
GE7	2054	25840	30.8	24.7	3	8.7	12.8	67.9	4	47.9	16.9	288.9	296.2	2	5	65.1	59.6	4.2	1	19.8	4	0.9
GE8	2862	45635	34.45	37.1	3	10.55	19.05	105	3.85	88.6	25.95	43.2	313.8	2	7.6	88.2	53.3	5.7	0.5	27.7	6.4	1
GE9	3136	23315	38.5	40	3	8.5	18.4	82.3	7.3	47.77	26.9	40.2	232.4	2	9.2	86.8	20.1	3.5	0.3	32.75	2.5	1
GE10	9493	27060	51.6	47.3	8.1	14.6	30.8	177.6	9.8	85.9	39.3	67.3	231.6	0.5	10.5	114.7	56	4.9	1	44.6	7.3	0.3
GE11	1366	6441	7.4	18.2	3	1.6	3.3	14.8	1.9	19.3	10.9	22.1	941.4	1.2	9.9	58.1	65.3	13.7	1	5.6	11.2	1.9
GE12	909	269200	39.6	29.3	12.4	16	42.2	251.4	18.8	99.2	74	116.3	249.5	2	12.9	198.5	58.7	4.5	1	131.6	9.9	2.9
GE13	1080	245200	40.9	29	8.7	13.9	32.7	225.4	10.4	202.3	56	96.7	222.9	0.8	10.7	148.6	70.5	4.1	1	71	8.5	1
GE14	4779	31575	61.6	55.8	9.4	18.1	32.9	184.2	8.4	48.85	43.7	56.9	216.7	0.4	10.9	115.1	55.9	4.9	0.3	57.2	5.5	0.4
GE15	1804	9708	10.1	16.3	3	3.1	5.8	29.5	1.5	27.2	14.5	27.9	275	2	5.2	72.5	27.8	4.2	1	10.1	3	1
GE16	411	297000	17.3	8.7	4	11.6	32	183.4	14.5	126.4	68.1	122.5	226.3	2	12.7	182.9	74	2.8	1	120.1	9.9	2.2
GE17	4826	55830	71	52.6	6.1	17.9	39.7	246.6	8.5	132.3	52.2	82.8	334.1	2	8.2	166.3	52.5	6.7	0.3	53.4	9.2	0.9
GE18	2654	10270	40.2	32	6.1	15.7	20.3	88.4	8	36.3	21.8	46.9	187.1	0.3	9.6	71.4	33.9	3.2	0.3	23	3	1
GE19	759.6	2929	6.2	5.5	3	1.7	3.1	17.8	1.8	10.4	9.6	15.2	81	2	6.4	47.4	0.2	0.7	1	6.6	1	1
GE20	2432	27670	9.1	11	3	2.2	4.4	27.9	2.9	50.5	10.3	25.3	155.3	0.1	7	39	18.9	1.6	1	6.9	1.1	1
GE21	1486	15720	11.9	9.1	3	2.8	5.5	29.4	2.1	29.8	12	19.6	105	2	7.8	42.5	29.6	1	1	8.4	1.7	1
GE22	1354	8403	3.8	6.1	3	2.2	5	18.7	2	21.1	11.1	18.3	142.9	0.1	5.9	50.4	0.2	1.2	0.9	5.8	0.3	1
GE23	2118	211600	48.6	39	3	13.6	32.9	211.8	9.6	122	51.6	90.1	693.5	0.9	13	160.7	64.8	10.9	1	75.9	14.2	3.2
GE24	3232	42280	25.8	37.3	3	8.7	16.5	98.3	3.4	55.9	25.5	44.6	404.5	0.7	10.6	108.9	34	7.9	1	25.4	5.1	0.4
GE25	1924	272500	39.1	25.6	4	16.1	39.6	233.6	13.3	126.9	72.2	127.5	351.8	0.4	12.8	192.5	103	5.2	1	98.2	11.4	3.1
GE26	2241	245400	77	43.6	14	23.5	59.4	431.1	12.9	253.2	81.9	127.4	199.4	0.6	10.5	206.9	56.7	5.5	1	113.1	11.2	2.1
GE27	4856	18030	57.9	53.3	3.8	14.3	28.4	155.6	11.4	65.2	38.8	63	308.5	0.4	10.5	121.5	0.6	6.6	1	46	7.2	0.7
GE28	5123	32720	65.9	56.6	8.4	14.1	32.2	167.5	8.4	103.7	45.4	76.7	235.7	2	9.5	136.2	0.6	5.6	1	48.4	7.3	0.6
GE29	2445	216500	45.4	26.1	5.5	14.1	31.9	167.9	15.1	92	58.5	96.7	292	2	13	158.2	59.8	4.6	1	73.1	9.9	2.2
GE30	7573	76700	95.6	68.1	11.1	23	41.1	231.5	16.5	158.4	73.3	100.5	254.4	2	9	169.1	52	5.5	1	73	11.6	2.9
GE31	3379	31460	49.4	43.3	7.9	10.2	19.9	107.3	4.9	72.7	29.2	49.4	197.9	1.4	9.1	80.7	32	2.2	0.3	29.3	3.6	1
GE32	1364.65	8383.5	1.55	3.8	3.4	1.4	2.6	11.4	1.9	26.8	9.7	15.4	76.7	2	11.1	52.4	21.4	0.9	1	3.7	0.5	1
GE33	1035	268600	44.5	21.6	14.1	17.2	40.9	273.7	10.8	185.5	79.1	125	179.6	0.5	10.8	228.9	1	2.9	1	105.6	11.1	1.8
GE34	2234	233500	64.8	31.6	10.8	19.9	40.7	244.4	15.3	217.3	78	139.5	169.7	2	11	187.4	72.8	3.4	1	96.1	11.9	3.7
GE35	840	285300	19.8	12.2	4.2	10.7	34.4	182.4	16.9	168.5	63.1	121	242.7	2	13.7	190.1	65.3	2.5	0.4	141	9.6	2.2
GE36	1325	268100	28.6	12.4	6.2	14.1	44.9	226.2	19.1	125.9	72.3	130.2	248	0.9	14.7	204.4	62.8	4	1	153.6	9.8	2.5
GE37	5275	121600	90.9	70.6	8.7	25.6	97.3	513	15	213.7	78.4	115.5	239	2	15.4	215.3	64.1	6.1	0.4	172.1	10.8	2.3
GE38	2810	241900	42	23.8	6.5	18	83.2	433.8	26.4	120.3	71.4	119.1	236.1	2	15.1	233.1	62.5	3.5	1	267.6	8.1	1.5
GE39	1057	265100	48.5	29.8	6.8	17.6	73.7	349.3	18.7	183.4	74.9	127.3	220.5	2	14.7	201.5	48.2	3.3	1	198.7	9.9	2.8
GE40	1586	10862.5	6.7	5.2	6.1	2	4.2	12.9	3.6	30.4	10.5	16.3	65.5	0.8	7	48.2	0.2	1	1	3.9	1.1	1
GE41	1737	42300	18.8	21	3	5.4	10.3	57.7	4.7	70.9	22	40.2	216.1	0.1	9	72	43.9	3.3	0.9	19.3	3.5	1
GE42	1445	18600	17.17	5	3.1	4.25	8.45	23.2	3.7	43.7	14.25	28.85	151	1.05	8.2	59.3	0.3	0.5	1	18.9	1.45	1
GE43	2151	34645	7.05	7.2	3	2.8	4.35	26.7	4.2	58.8	7.15	22.55	210.1	2	7.25	52.75	12.3	2.55	1	8.75	1.9	1
GE44	4117	22200	38	50.2	3	9.8	17.1	96	9.7	56.6	27.7	48.1	440.2	0.6	8.7	100.8	0.5	8.8	1	29.2	9.1	0.8
GE45	2292.5	17410	18.15	24.7	3	15.1	11.15	54.4	7.9	62.4	13.3	30	410.6	2	7.75	67.55	18.6	6.35	1	14.6	5.95	1
GE46	1542	11260	5.4	10.5	3.9	2.8	3.6	20.3	3.5	37.5	7.5	15.9	52.6	2	10.4	51.5	21.9	0.4	1	4.7	0.1	1
GE47	1849.5	13251	3.6	6.2	3.4	2.2	3.7	19.3	3.7	40.7	11.1	20.6	67.3	0.5	5.9	62.5	19.7	0.9	1	6.9	0.8	1
GE48	1939	16925	4.05	6.5	3	2.2	5.8	17.1	3.1	38.2	10.6	19	82.1	1.25	6.75	55.9	6.6	1	1	6.5	0.6	1
GE49	8153	159500	80.1	65.3	10.3	25.8	122.5	718.8	13.1	182.9	62	125.3	221.8	1.2	16.7	228.6	1	0.8	1	173	8	2.3
GE50	11400	72180	96.6	86.1	12.3	29.9	138.3	656.5	16.7	138.3	74.9	120.3	233.2	1.1	17.5	213.8	72.4	5.2	0.4	194.4	8.6	2.6
GE51	8362	127600	78.1	62.9	15.7	26.3	109.1	788.7	13.1	185.4	67.9	126.5	237.6	2	17.4	206.3	52.4	1.6	0.6	183.7	8.7	2.3
GE52	7129	133500	75.2	62.9	13.2	24.7	107.4	587.9	10.9	265.1	63.1	128.5	226.1	1.4	15.7	204.1	88.4	0.6	0.7	151	8.6	1.1
GE53	10400	16230	96.3	82	11.7	26.5	107.5	509	14.8	75	66.9	104.8	260.3	0.1	12.5	179.1	65.1	6.9	0.3	138.3	8.2	1.2
GE54	3623	237500	49.3	34.5	8.5	16.6	77.8	443.7	16.5	153	66.7	130	231.7	2	15.7	229.7	48.9	2.6	1	211.4	8.6	2.8
Min	302	2929	1	3.8	0.7	1.3	2.6	11.4	1.5	10.4	7.15	15.2	52.6	0.1	5	39	0.2	0.4	0.3	3.7	0.1	0.3
Max	11400	298900	109.7	86.1	16.7	29.9	138.3	788.7	26.4	329	92.1	288.9	941.4	2	17.5	233.1	103	13.7	1	267.6	14.2	3.7
Mean	3233.2	101551.0	40.5	32.2	6.5	12.7	35.9	202.5	9.4	103.5	43.1	77.9	243.2	1.3	10.4	129.4	40.8	3.9	0.9	71.4	6.6	1.6
StdID	2588.2	104972.4	30.8	22.7	4.1	8.4	34.6	197.9	6.1	74.9	28.1	53.5	144.9	0.7	3.2	67.6	28.3	2.7	0.3	68.2	4.2	0.9

B- Port Hacking / Gunnamatta Bay

Samples No	S	Cl	Cr	Co	Ni	Cu	Zn	As	Br	Rb	Sr	Cd	Sn	Ba	Ce	Hg	Pb	Zr	Hf	Th	U
GU1	2491	53185	8.5	3.9	3.05	5	11.7	1.95	60.35	11.65	603.85	2	4.1	80.85	0.4	1	4.85	67.85	0.85	1.2	1.1
GU2	2550	113640	5.6	3	1.5	5.65	14.5	3.9	98.3	10.15	1264.5	1	2.3	70.85	0.35	1	6.55	28.15	1	2.95	2.9
GU3	2987.5	30800	10.2	4.2	2.25	4.2	9.4	2.05	59.05	10.7	716.7	2	4.95	73.25	7.6	1	4.15	28.4	1	1.7	1.35
GU4	2727	45695	18.4	9.5	5.95	8	14	3.15	72.7	14.85	877.85	0.7	1.7	93.6	4.85	1	5.4	45.3	0.8	1.45	1.25
GU5	1830.5	9654.5	6.3	8.6	2.9	4.8	7.7	1.5	33.1	11.5	363.15	2	5.3	81.85	22.2	0.4	2.05	39.75	1	1.15	0.9
GU6	1577	8949.5	7	5.1	2.3	2.9	7.7	1.6	26.75	12.2	386.8	0.9	5.55	72.2	5.2	1	2.35	38.55	0.6	0.85	0.7
GU7	1588.25	11959	7.8	3	2.05	2.9	5.5	1.1	24.6	8.6	218.65	0.4	5.75	60	0.3	1	1.5	39.55	0.75	0.7	1
GU8	2652.5	42450	10.4	4.4	1.7	5.5	12.7	1.45	66.5	8.6	846.45	2	3.8	68.05	9.1	1	7.2	40.1	1	1.15	1.8
GU9	2032	25555	7.6	3.9	2.4	3.85	8.8	1.4	37.8	10.5	571.85	0.6	3.5	80.3	13.35	1	3.35	36.95	1	1.1	1.15
GU10	2635.5	91075	11.3	4.7	1.8	9.65	16.8	4.3	81.3	14.3	1108	2	1.7	89.6	11	0.4	11.85	34.75	1	2.1	2.25
GU11	4730	84900	23.6	4.4	6.45	39.45	76	4.1	180.3	18.1	976.9	2	2.85	86	0.4	0.4	24.5	46.9	0.8	4.25	2.7
GU12	1991	7238.5	5.7	5.2	3.35	3.9	6.6	2	24.55	10.3	160	2	5.45	69.25	4.8	1	1.7	38.2	0.75	0.85	0.7
GU13	2074	8548	9.7	3.5	2.4	3.5	10.2	1.35	28.1	12.9	321.3	2	5.85	70.75	9.3	1	5.2	40.7	1.05	1.25	0.7
GU14	2863	65665	10.7	3	0.4	7.75	17.3	2.15	85.35	6.05	1267	2	1.95	55.8	9	1	9.3	24	1	2.7	2.35
GU15	5978	54330	62.3	4.6	11.1	74.8	138.1	7.7	183.5	1.7	977.2	2	4.7	115.4	24.4	0.4	57.7	99.1	2.7	7.6	3
GU16	4696.5	101485	34.5	4.4	11.8	66.95	137.4	8.25	176.6	31.85	852.75	2	6.55	124	13.4	0.4	64.5	94.4	1.4	7.35	3.45
GU17	3464	130270	34.2	5.1	10.05	62.65	123.8	8	173.05	30.75	976.6	0.2	9.15	116.35	27.7	1.2	57.5	90.25	1.15	7.65	3.3
GU18	6053.5	90975	59.7	5.1	15.6	96.05	189.2	11.55	209.95	39.25	964.3	2	8.15	135.85	48.55	1.7	84	127.55	2.35	10	4.4
GU19	3150	81360	51.2	5.1	7.2	41.6	81	6.7	175.7	18	733.1	2	7.5	82.1	24.1	1	37	77.5	1	4.9	1.6
GU20	4350	56230	27.6	3	3.5	61	69.2	4.5	117.8	11	1038	2	0.9	55.4	22	0.4	29.9	78.8	1	4.1	1.7
GU21	4451.5	148070	37.9	6.8	16.1	117.35	231.3	11.55	249.9	44.75	773.25	2	10.65	162.05	49.05	1.1	107.35	119.25	2.5	10.9	3.8
GU22	1969.5	113935	9.8	4.9	1	6.65	13.4	1.35	77.55	8.75	1103	0.1	2.2	47.5	4.4	1	10	24.5	1	2.05	1.6
GU23	2028	26565	6	3.8	2.65	5.2	11.1	1.25	50.95	10.55	355.1	2	5.05	75.25	7.5	1	5.25	34.65	0.75	1.05	1
GU24	1690.5	39594	8.6	4.7	2.05	5	15.7	2.6	40.1	9.45	526.1	2	4	70.75	0.35	1	6.55	32	0.8	1.2	1.15
GU25	6922	42110	98.2	14.4	19.8	148.9	247.1	11.1	222.5	48.1	776.8	2	11.2	162	42.5	1.1	111.9	127.1	4.4	11.9	4.5
GU26	1622.8	36170	8.3	3.9	2.65	9.05	12.5	3.1	48.95	5.1	365.75	0.1	4.25	36.1	13.65	1	8.85	84.85	1.6	1.35	0.65
GU27	7248	53355	75.7	4.7	14.4	89.7	168	10.8	235.55	35.15	1024	2	4.35	137.75	41.5	1.35	69.05	103.45	1.7	9.05	2.8
GU28	1970.5	74903	16.9	4.2	3	11.95	25.1	2.85	83.25	6.8	428.95	1.3	5.95	38.85	15.65	1.35	11.7	121.3	1	3.15	1.3
GU29	1655.5	13718	10.5	3	3.2	12.5	17.1	2.1	41.35	6.25	329.7	1.1	7.05	41.1	28.6	1	9.9	170.6	2	2.65	1
GU30	6239	70610	97.5	4.2	11.2	77.3	134.7	8.2	251.2	28.5	774.9	0.4	5.7	111.1	34.1	0.4	55.4	78.4	1.8	7.2	2.2
GU31	3947.25	42164	20.4	3.6	7.2	44.9	40.2	5.15	146.275	17.375	552.3	1.65	6.375	76.1	0.2	1.3	32.65	124.5	1	4.925	1
GU32	3173	70985	14.3	4	2.5	31.65	66.1	2.45	77.15	7.3	537.7	1.55	5.4	43.2	6.4	1.55	16.05	72.9	1.6	2	1
GU33	3173	70985	13	4.3	2.5	31.65	26.3	2.45	77.15	7.3	537.7	2	5.4	43.2	16.3	1	16.05	72.9	1	2	0.9
GU34	3473	48540	8.2	3	2.2	9.55	10.4	1.1	67.95	4.15	223.15	1.05	6.45	35.7	21.45	1.7	7.95	128.85	1.65	1.65	1
GU35	3506	91735	8.2	4.7	2.3	21.3	45.2	1	122.05	5.45	268	0.3	7.4	48.25	15.8	1.45	13.85	77.35	0.5	1	1
GU36	3557.5	131150	31	4.7	4.45	60.3	81.8	3.85	182.5	13.05	566.35	2	6.35	65.5	29.75	0.65	44.4	114.6	1.55	5.15	1
GU37	2420	18876.5	9.1	3.3	3.9	14.6	12.1	2.95	47.75	2.3	138.5	0.5	10.95	28.15	0.1	3.25	6.75	110.25	1.2	1.6	1
GU38	1478	31100	14.5	4.1	3.3	21.6	20.4	2.4	62.5	13.7	334.1	0.1	8.1	75	0.4	3.3	23.3	65.8	0.9	2	1
GU39	5386	110400	91.8	3	13.4	101.5	183.4	10.3	238.3	34.7	678.9	2	11.5	146.6	25.5	0.8	93.1	138.7	3.6	9.4	2.4
GU40	4415	77110	76.2	9.6	10.7	78.3	151.1	9	178.3	27.8	674.4	2	6.9	113.3	27.5	1	69.4	114.9	1.7	7.3	2.2
GU41	1804.5	90355	3.7	4.7	1.85	6.25	11.4	2.1	78.05	2.2	251.75	2	4.65	30.85	16.4	3.45	6.35	73.45	0.95	0.95	1
GU42	2464.5	33115	14.7	3	2.35	17.5	25.2	2.75	56.35	6.7	593.55	2	5.3	35.15	13.3	0.85	18.45	154.35	1.6	3.5	1
GU43	2322	41265	7.8	3	2.85	13.5	15.3	1.1	57.7	4.65	266.1	0.2	8.1	44.6	11.8	1	7.8	116.8	1.35	1.35	1
GU44	2702	115900	71.3	4	7	45.4	84.4	6.2	136.2	16.7	446.5	0.5	8	81.8	0.4	0.5	48	106.7	1	4.5	0.5
GU45	2893	163550	62.1	14.9	16.1	132.15	182.2	10.45	308.8	35.75	552.85	2	11.3	144.45	46.45	2.65	101.85	153.55	2.7	9.75	0.9
GU46	3062.5	28325	9.3	3.6	3.2	14.2	22.2	2.45	51.7	10.65	120.1	1.05	8.95	71.6	25.6	1.85	17.15	70.15	0.95	1.1	1
GU47	3246.5	100380	12.6	3	2.6	25.5	34	1.45	119.6	6.5	560.2	2	4.5	48.65	12.75	0.85	21.45	67.4	0.8	2.15	1
GU48	2683.5	16560	4.2	3.5	2.1	6.3	6.6	1.7	45.7	2.35	130.4	1.15	5.85	33.5	7.4	1	3.75	76.8	0.4	1.35	1
GU49	2760	17015	13.1	3.5	2.6	10.15	13.2	1.9	36.6	3.75	98.4	2	7.35	35.25	6.75	1	6.05	78.45	0.6	0.9	1
GU50	4174.5	79190	13.6	3	3.75	30.75	38.5	2.3	91.3	9.2	263.5	2	7.7	60.25	19.15	1	24.7	145.5	2.05	2.5	1
GU51	4266	33890	18.2	3	4.3	14.6	22.5	5	54.4	5.1	217.7	0.6	7.2	41.9	0.2	1	18.6	168.4	1.1	1.3	1
GU52	4423	61910	21.9	3.6	4.5	34.9	57.7	4.4	79.8	10.8	165.4	1.4	20.3	81.8	0.4	1	42.6	119.7	2	1.5	1
GU53	2216.5	26983	28.9	3	7.85	32.8	76.3	6	44.2	12.8	89.65	0.35	10.55	93.65	33.45	3.35	43.85	189.45	4.35	2.9	1
GU54	2036	4495	58.7	5.8	7.1	40	81.1	4.1	18.3	14	70.5	2	8	112.6	21	1	45.5	115.2	2.1	0.7	1
GU55	7891	133800	106.7	4	14.2	398.3	412.8	7.8	182.5	26.8	174.8	0.2	19.4	184.5	32.9	0.4	203	212.7	6.8	4.9	0.9
GU56	4046	41850	25.7	4.7	8.05	71.3	102.1	3.4	60.1	12.55	79.1	2.5	11.1	93.55	4	1	48.75	139.2	3.45	1.5	1
GU57	3507	67830	24.5	6	7.75	35.8	68.4	3.15	77.35	12.3	80.75	1.3	8.7	100.85	13.55	2.4	47.2	151.05	2.15	1.5	1
GU58	2016	139015	16.7	3	4	47.95	73	5.25	105.1	13.4	570.9	1.05	6.5	72.2	17.85	2.1	48.55	131.4	1.8	4.35	0.9
GU59	2039	48480	15.6	3.8	2.6	15.95	26.1	5.7	61.05	5.9	397.65	2	5	26.7	17.9	0.55	18.4	96.9	0.75	2.4	0.95

Min	1478	4495	3.7	3	0.4	2.9	5.5	1	18.3	1.7	70.5	0.1	0.9	26.7	0.1	0.4	1.5	24	0.4	0.7	0.5
Max	7891	163550	106.7	14.9	19.8	398.3	412.8	11.55	308.8	48.1	1267	2.5	20.3	184.5	49.05	3.45	203	212.7	6.8	11.9	4.5
Mean	3276.3	62202.5	27.1	4.7	5.6	40.7	64.8	4.3	103.1	14.3	530.9	1.4	6.7	78.5	15.9	1.2	32.4	91.5	1.5	3.4	1.5
StdD	1516.8	40510.7	27.3	2.4	4.7	59.0	77.4	3.1	71.0	11.0	331.8	0.7	3.6	37.3	13.4	0.7	36.8	45.9	1.1	3.0	1.0

Gymea Bay

Samples No	S	Cl	Cr	Co	Ni	Cu	Zn	As	Br	Rb	Sr	Cd	Sn	Ba	Ce	Hg	Pb	Th	U
GY1	3714	172200	62.8	8.4	20.3	53.1	185.4	10.5	373.9	58.7	333.9	0.2	10.6	213.9	71.6	0.3	95.3	13.7	4
GY2	6420	111700	89.85	12.9	23.1	60.4	209.6	13.6	358.8	62.2	313.9	2	10.8	217.2	62	0.4	101.3	13.7	3.7
GY3	2754.5	40345	11.3	4.5	4.75	5.75	14.4	3.5	62.9	7.85	91.25	0.55	6.1	42.1	13.2	1.8	9.65	1.25	1
GY4	2310.5	54287	18.1	3.4	2.85	5.3	29.2	7.05	65.05	4.3	493.7	1.3	4.15	29.2	0.25	1.1	12.85	2.7	0.7
GY5	6920	71700	93.8	14.6	25	60.8	224.15	13.35	307.2	67.9	313.9	2	9.8	214.3	56.6	1	111.8	14.2	4.4
GY6	1704	34323	11.5	3.9	4.25	7.6	18.9	7.2	55.75	5.25	395.85	1.45	6.05	26.75	25.1	0.65	10	3.05	0.7
GY7	2194	27465	7.6	3	2.9	6.45	17.8	3.6	65.45	3.6	207.2	2	6.9	27.8	18.5	95	11.4	0.6	1
GY8	8441	107200	83.2	23.8	21.9	52	183.8	11.5	482.7	57.2	313.2	2	6.9	170.3	0.8	1.1	93.9	13.1	3.3
GY9	999	251000	31.5	33.4	18.1	48.4	167.8	12.8	278.2	62.1	305.2	2	12.6	214.9	64.5	0.8	113	13.8	3.4
GY10	2670	56950	13.5	7.2	3.4	8.05	16.2	4.65	73.75	6.2	491.8	0.6	7.4	35.6	26.9	1	15.05	3	1
GY11	2574.5	80775	23.2	3	5.6	10.35	39.5	7.95	93.4	16	269.15	2	5.25	65.45	36.6	2.2	24.1	6.25	1
GY12	4562	133300	84.1	11.4	24	54.7	205.7	12.3	409	64.2	326.2	2	12.7	204.4	45.4	0.4	105.45	14.4	4
GY13	4771	172700	63.1	17.5	18.8	46.6	179.75	10.6	702.9	55.2	275.1	2	8.1	183.8	60.1	0.8	95.9	13.9	5.2
GY14	1797.5	69760	5.7	5.4	4.95	4.8	12	3.4	106.35	4	232.9	0.35	3.9	30.3	23.35	2	4.9	1.15	1
GY15	2691.5	16217.5	10.2	4.5	3.65	4.2	10.7	1	36.75	3.7	24.3	1.4	6.3	35.45	14.5	1	5	0.6	1
GY16	1416.45	6364.5	21.1	3	4.75	5.65	16.3	1.25	24.5	5.25	28.9	2	8.5	46.3	22.6	0.65	8.45	1.75	1
GY17	2059.5	14140.5	10.9	3.4	4.05	9.9	22.7	1.3	34.6	4.05	31.5	1.2	7.3	43.1	7.8	1.15	10.4	0.8	1
GY18	1936	7676	10.4	3	3.1	4.45	14	1.2	25.4	5.9	24.5	2	8.3	37.9	7.5	1	5.7	0.1	1
GY19	3776	81180	58.8	3	13.75	26.3	73.8	8.6	228.85	21.9	200.8	2	9.55	96.25	48.3	0.85	55.6	6.6	1
GY20	1702.4	16775.75	11.2	3	3.25	3.9	13.4	2.5	38.75	8.05	42.5	2	11.7	45.6	20.3	1.5	8.7	2.2	1
GY21	2105	77790	18.8	3	3.4	8.5	19.9	5.3	120.1	7.8	159	2	6.3	46.5	34.8	0.5	16.8	5.7	1
GY22	2704.75	53832.5	11.1	3.35	3	6.37	35.6	6.35	70.05	7.45	250.8	2	8.8	40.95	16.55	0.9	22.75	2.35	1
GY23	3165	67640	21.5	3	1.65	10.35	28.4	8.3	84.25	7.7	812.1	1.35	0.6	37.95	20.8	1	18.1	2.9	1.5
GY24	3140.75	20502.5	17.9	3	5.65	8.4	40.5	1.3	46.6	6.85	44.55	2	11.6	38.2	92.4	1	9.025	22	1.05
GY25	2238.25	10102.25	11.6	2	3.15	5.9	40.9	1.725	27.2	8.85	65.9	1.25	10.25	59.05	9.1	1.15	9.85	2.85	1
GY26	1023	4763	18.3	4	2	7.9	21.5	2.5	16.7	13.9	55.4	0.4	7.8	68.9	0.3	0.3	9.7	0.5	1
GY27	3090	35555	10.9	3.2	4.3	6.95	20.4	1.05	61	4.7	32.35	1.6	9.3	59.7	20.35	2.05	10.975	1.4	1
GY28	2709	16810	33.1	3	5.8	16.7	74.7	5.8	46.6	15.4	116.5	1	10.9	79.4	29.5	1	36.7	4.3	1
GY29	2544	32185	13.6	3	3.35	10.3	82.9	2	55.6	7.35	112	2	20.85	50.95	11.6	1.05	24.85	3.3	1
GY30	2033.1	26758	17.6	3	5.35	21.35	28.65	2	40.325	5.65	74.875	1.45	21.275	46.45	10.45	0.85	11.175	1.55	1
GY31	1791.5	32974	17.6	3	5.2	8.35	18.6	1.9	46.9	16.85	98.35	1.2	5.05	79.8	27.2	1	5.85	4	0.7
GY32	2625	62885	10.1	3	2.55	5.4	20.6	2.85	75.2	11.75	206.85	1.2	9.45	62.7	26.3	0.9	6.9	3.7	0.65
Min	999	4763	5.7	2	1.65	3.9	10.7	1	16.7	3.6	24.3	0.2	0.6	26.75	0.25	0.3	4.9	0.1	0.65
Max	8441	251000	93.8	33.4	25	60.8	224.15	13.6	702.9	67.9	812.1	2	21.275	217.2	92.4	95	113	22	5.2
Mean	2955.7	61495.5	28.9	6.5	8.1	18.6	65.2	5.6	141.1	19.9	210.8	1.5	8.9	82.8	28.9	4.0	33.8	5.7	1.6
StdD	1670.1	56605.2	27.1	7.0	7.6	19.6	71.8	4.2	165.1	22.6	176.7	0.6	4.2	66.8	22.8	16.6	38.4	5.8	1.3

South West Arm

Samples No	S	Cl	V	Cr	Co	Ni	Cu	Zn	As	Br	Rb	Sr	Zr	Cd	Sn	Ba	Ce	W	Hg	Pb	Th	U
SWA1	4064.5	73200	25.1	21.8	3	5.35	13.1	33.5	3.7	135.95	12.1	588.5	145.35	2	6.65	41	26.4	1	0.7	21.1	4.8	1.5
SWA2	1662.5	11917.5	9.75	8.7	3	4.25	5.3	6.4	1.8	38.75	5.75	35.35	242.5	2	6.3	34.45	35.25	2.6	1	2.6	5.2	1
SWA3	1558.5	24740	5.3	6.3	4.6	3.1	4.9	7	2.9	46.55	3.25	207.6	150.95	1.05	4.65	29.5	18.7	2.7	0.8	3.5	1.55	0.7
SWA4	1618	10310	4.5	5.4	3	3.2	6.7	7.2	1.6	44.4	4.4	26.8	153.3	0.8	7.6	29.5	0.1	1.9	1	2.4	2.6	1
SWA5	1281.05	5258.5	1.4	2.8	3	4.75	4.25	4.5	1	24.6	2.3	16	121.9	1.25	3.85	1.15	17.7	2.4	1	0.5	1.45	1
SWA6	4171	45740	1.7	10.7	3	0.8	2.7	10.9	1.4	63.5	5.2	210	96.1	0.2	5.6	32	0.2	0.7	1	3.9	0.9	1
SWA7	2567.5	13310	1.2	4.3	3	5.45	6.45	4.8	1.3	41.4	3.05	20.65	80.1	2	7.55	22.1	1.05	2.8	1	1.15	1.45	1
SWA8	3050.5	24130	1.7	4.3	3	2.3	3.7	3.6	1.3	54.15	1.95	19.55	151.35	1.7	5.75	13.1	12	1.8	2.5	0.85	1.65	1
SWA9	1749.5	28465	4.55	6.8	3	2.85	5.4	5.7	2.6	52.95	3.1	21.65	121.5	2	6.3	35.7	43.1	2.6	1.25	1.9	1.05	1
SWA10	2821	30875	1	6.2	3.5	4.15	3.55	2.9	1.2	58	2.2	17.65	96.95	2	7.3	1.15	2	2.7	1	0.6	1.55	1
SWA11	1644.5	13046	1	2.1	3	3.65	4.3	3	1.4	43.15	1.65	16.6	85.5	1.15	6.9	25	7.9	2.2	1	0.8	1.5	1
SWA12	2393	24644	1.45	3.6	3	4.25	3.85	2.9	1.4	58.25	1.9	17.8	125.35	1.05	5	27.3	0.15	3.2	1	0.3	1.55	1
SWA13	1721	12043	2.8	5.1	3	2.8	5.25	4.8	1.9	39	2.1	16.65	162.15	1.3	5.95	27.6	24	2.2	1	0.7	2.1	1
SWA14	2041	14857	2.4	3	3	2.95	4	3.2	1.3	42.4	1.55	16.35	101.3	1.45	6.75	25.6	1.05	2.2	1	0.7	1.15	1
SWA15	2278.5	20115.5	1.2	3.2	3.4	3.55	3.95	3.1	0.75	55.95	1.8	18.8	104.7	1.3	5.8	22.25	18	2	1	0.6	1.25	1
SWA16	2816.5	19825	1	3.3	3	3.3	3.85	2.9	1.4	51.35	1.7	16.2	88.85	0.2	3.95	30.7	9.3	2	2.1	0.75	1.35	1
SWA17	14210	32480	88.6	70.3	3.6	16.3	50.2	163.7	12.7	306.7	43.3	703.6	124	6.3	3	117.1	50.2	1	1	72.5	11.3	3.3
SWA18	1194	12970	2.1	6.4	3	0.9	2.1	8.3	1.1	27.8	11.4	27.7	78.7	4.6	3	39.9	17.7	1.5	1	3.7	0.7	1
SWA19	4388	25530	17.2	69.7	4.3	7.7	11.2	33.5	5.9	80	11.3	831.1	93.5	3.6	3	57.9	4.1	1.9	1	14.5	3	2
SWA20	4508	27120	32.4	57.9	4.3	8	14.7	50.7	5.2	102.4	19.1	764.1	127.8	6.6	3	83.3	45.7	1	0.4	24.8	4.8	2.1
Min	1194	5258.5	1	2.1	3	0.8	2.1	2.9	0.75	24.6	1.55	16	78.7	0.2	3	1.15	0.1	0.7	0.4	0.3	0.7	0.7
Max	14210	73200	88.6	70.3	4.6	16.3	50.2	163.7	12.7	306.7	43.3	831.1	242.5	6.6	7.6	117.1	50.2	3.2	2.5	72.5	11.3	3.3
Mean	3086.9	23528.8	10.3	15.1	3.3	4.5	8.0	18.1	2.6	68.4	7.0	179.6	122.6	2.1	5.4	34.8	17.5	2.0	1.1	7.9	2.5	1.2
StdD	2822.0	15114.7	20.4	22.4	0.5	3.3	10.5	36.7	2.8	61.6	9.8	286.9	38.6	1.8	1.6	26.3	16.2	0.7	0.5	16.8	2.5	0.6

Mansion Bay and Hacking River

Samples No	S	Cl	V	Co	Ni	Cu	Zn	As	Br	Rb	Sr	Zr	Cd	Sn	Ba	Ce	W	Hg	Pb	Th	U
MA1	1843	5499	1.5	3	1.7	2	6.2	1.5	17.9	3.1	18	102.9	1.2	9.7	39.2	14.1	1.4	1	1.5	0.3	1
MA2	1000.35	5310.5	4.5	3	2.5	5.25	10.7	3.2	20.6	7.05	23.25	115.95	1.1	8.25	50.85	11.4	1.8	1	4.1	1.05	1
MA3	2118.875	12078.25	4.075	3	3.425	3.925	6.1	1.55	37.6	2.6	22.75	221.05	2	6.3	25.98	11.57	2.45	0.9	1.65	0.9	1
MA4	1669	11200	7.2	3	2.4	2.9	11.6	2.6	42.5	5.5	28.7	91.6	0.1	6.8	46.8	0.2	0.8	1	5	0.3	1
MA5	2410.5	33770	2.35	61.8	2.15	4.15	7.2	1.05	62.9	1.95	60.55	86.7	1.35	9.4	24.5	15.8	1.5	0.9	2.8	0.8	1
MA6	3029	32410	5.9	4.8	2.4	4.8	15.9	2.8	49.7	5.5	28.3	69.6	2	7.8	36.6	0.2	1.1	1	6	0.6	1
MA7	2300.5	30653.5	4.6	3.4	3.7	3.55	8.2	1.9	49.95	2.5	21.95	99.5	1.25	6.45	31.95	0.15	2.5	1	2.45	0.25	1
MA8	1118	3592	6.3	1.8	1.7	3.8	11.1	2.8	18.9	9.4	26	64.3	0.3	7.2	42.4	20	1.5	1	4.2	0.5	1
MA9	771.8	4023	4.3	3.7	2.2	3.1	9.9	2.4	17.8	3.5	20.7	80	2	6.5	29.6	40.3	1.2	1	3.2	1	1
MA10	1523	7146	3.5	3	3.4	6.8	15.6	3.9	28	7.7	27.5	160.2	0.9	7	30.7	0.2	1.5	1	6.4	1.5	1
MA11	7549	20270	45.3	3	11.8	17.2	55.9	7.7	55.7	19.9	76.1	413.4	0.4	11.8	103.3	37.4	0.9	1	23.9	9.5	0.5
MA12	1438	7705	1.6	3.4	1.4	2	7.1	2.6	25.1	2.5	21.4	59.2	2	7	42.1	0.2	1	1	1.7	1	1
MA13	1225	9785	3.3	0.8	1.8	5.8	8.7	1.4	28.3	9.5	21.1	85.4	2	7.2	37.9	0.2	1.7	0.3	4.5	0.4	1
MA14	1996	14912	2.15	3	4.75	4.9	8	2.2	41.15	2.8	21.65	72.75	0.2	6.55	30.75	0.1	2.2	0.75	1.95	0.65	0.1
MA15	942.6	4161	6.6	4.4	3.05	3.3	9.2	1.8	31.85	9.1	20.4	72.8	2	7.5	43.5	0.2	1.3	1	4.3	0.6	1
MA16	2997	25780	23.9	3.7	4.9	8.1	28.4	4.2	46.1	10.7	42.4	106.5	0.1	9.3	44.3	32.8	0.5	1	11	0.9	1
MA17	3027	28240	9.1	3.4	3.1	4.6	14.2	2.3	43.5	5.8	29.8	80.7	2	7	47.7	0.2	0.8	0.8	5.3	0.3	1
MA18	2144.5	19620.5	7.1	0.9	2.9	3.65	5.9	1.2	41.7	3.05	22.55	78.9	1.4	7.6	35.05	0.2	2.4	1	1.6	0.55	1
MA19	2359	23630	11.9	3.4	3.4	5.1	15	2.5	42.1	5.1	37.2	85.9	2	7.2	39.2	32.2	1.1	1	4.8	0.7	1
MA20	2978	53320	15.6	3.4	3.4	5.1	19.9	5.9	69.7	7	54.2	92.6	2	8.8	49.7	35.5	1.3	1	9	0.4	1
MA21	4621	45430	89.1	3.4	19.2	48	148.7	15.2	163.4	46.7	180.2	246.5	2	11.3	169.4	53.8	1	0.3	66.5	11.4	2
MA22	5988	66370	111.9	7.7	23.7	52.5	177.3	18	188.8	57.8	177.7	252.6	0.5	11.7	212.9	56.5	1	1	85	13.7	3.3
MA23	2957	58060	8	94.7	3.8	8.5	15	1.4	86	5.4	36.4	93.2	0.5	10.1	29.6	0.1	1.8	1	9.7	0.7	1
MA24	2517	39720	1.5	3	1.6	3.6	10	2.8	50.9	6.1	26	89	0.1	9.7	38.7	17	1.2	1	4.7	0.1	1
MA25	6164	90940	99.4	7.5	21.6	49.1	161.8	15.7	200.1	52.3	167.1	253.1	1	12.9	196.5	47.1	1	1	75.6	12.8	2.2
MA26	1877	9541	23.1	5.8	10.2	10.4	20.9	4.2	34.5	7.6	33.6	113.5	7.3	3	47.1	25.8	2.9	0.6	8.4	1.5	1
MA27	982.8	7652	13.3	3.2	1.9	5	10.6	3	21.4	10.8	23.1	125.7	5.1	3	41.3	23.5	1.4	1	5.6	0.7	1
MA28	985.1	8675	12.7	4.8	17.6	7.1	13.7	3.5	31.5	4.5	27.5	80.8	7.3	3	31	33.8	2.4	1	4.9	1	1
Min	771.8	3592	1.5	0.8	1.4	2	5.9	1.05	17.8	1.95	18	59.2	0.1	3	24.5	0.1	0.5	0.3	1.5	0.1	0.1
Max	7549	90940	111.9	94.7	23.7	52.5	177.3	18	200.1	57.8	180.2	413.4	7.3	12.9	212.9	56.5	2.9	1	85	13.7	3.3
Mean	2519	24267.6	18.9	8.9	5.9	10.2	29.7	4.3	55.3	11.3	46.3	124.8	1.8	7.9	57.1	18.9	1.5	0.9	13.1	2.3	1.1
StdD	1686.5	21957.2	30.2	20.1	6.6	14.3	48.0	4.5	48.5	15.0	47.3	80.8	1.9	2.5	50.3	18.4	0.6	0.2	22.7	4.0	0.6

North West Arm

Samples No	S	Cl	V	Co	Ni	Cu	Zn	As	Br	Rb	Sr	Zr	Cd	Sn	Cs	Ba	Ce	Hf	W	Hg	Pb	Th	U
NWA1	6515	26560	122	5.4	22.7	58.7	255.3	13.9	203.8	58.1	235.5	237.8	10.9	3	88.3	4	28.9	6.3	1.0	2.1	112.9	13.9	2.5
NWA2	1076	15090	15.7	3	6.7	5.9	34.9	5.8	43.1	5.2	112.2	130.2	14.2	3	13.6	4	2	1.7	1.5	0.5	16.9	1.3	1
NWA3	6639	52270	124.6	8.3	23.2	65.4	328.5	13.9	215.3	62.7	195.3	231.9	14.4	3	70.5	4	30.3	6	1.0	2.3	141.2	13.9	2.2
NWA4	7403	79220	108.3	8.6	22	76.6	417.3	13.2	246.5	55.1	187.7	241.4	14.4	3	58.2	4	20.4	6.1	1.0	2.3	158.8	13.5	2
NWA5	6571	16990	76.2	3.4	17.7	59	349	10.5	101	40.3	137.1	272.1	13.2	3	41.3	4	27.5	6.2	1.0	1.7	129.5	8.9	1.8
NWA6	1329	10180	13.9	3.4	10.5	10.3	41.6	2.8	31.3	6.1	30.4	137.4	3.7	3	10.5	35.4	0.2	1.5	1.4	0.5	11.7	0.8	1
NWA7	1553	16020	7.2	3.2	2.6	6.6	34.2	2.7	37.3	10.9	30.6	101.5	4.6	3	4	50.9	18	0.8	0.5	1	12.8	1.2	1
NWA8	1630	15510	10.2	3	1.6	4.2	26.8	2.2	35.4	10.4	27.3	107.2	4.3	3	4	45.5	13.6	0.6	0.5	1	11.1	0.6	1
Min	1076	10180	7.2	3	1.6	4.2	26.8	2.2	31.3	5.2	27.3	101.5	3.7	3	4	4	0.2	0.6	0.5	0.5	11.1	0.6	1
Max	7403	79220	124.6	8.6	23.2	76.6	417.3	13.9	246.5	62.7	235.5	272.1	14.4	3	88.3	50.9	30.3	6.3	1.5	2.3	158.8	13.9	2.5
Mean	4089	2898	59.8	4.8	13.4	35.8	186	8.1	114.2	31.1	119	182	10	3	36	19	18	4	1	1.4	74.4	7	2
StdD	2896	24237	53	2	9	32	168	5	93	25	83	70	5	0	33	21	12	3	1	1	67	6	1

Yowie Bay

Samples No	S	Cl	V	Co	Ni	Cu	Zn	As	Br	Rb	Sr	Zr	Cd	Ce	Hf	Hg	Pb	Th	U
YO1	1270	23960	16.5	3	2.9	16.3	55.5	6.1	41.3	10.8	308.4	187.7	8.6	18.3	3.1	0.8	40.3	2	1
YO2	6279	11940	28.1	3	11.3	45.6	138.4	5.1	42.6	15.3	59.9	248.7	10.4	39.4	3.9	0.6	69.2	2.9	1
YO3	4038	18530	20.6	3	4.8	19.7	79.9	5.2	39.1	14.9	58.2	135.6	9.2	2	2.6	0.7	41.6	1	1
YO4	3726	23300	47.1	3	11	54.6	181.3	9.5	81	24	109.9	363.8	11.6	26.7	6.6	1.3	114.4	6	0.3
YO5	3533	22090	59.6	3	14.7	60.2	198	10.2	89.2	29.5	119.2	383.6	12	19.6	7.4	1.7	144.6	7.4	0.4
YO6	1901	20270	13.8	4.8	3.3	12.5	42	3.5	40.5	12.5	39.5	123.1	7.3	22.9	1.8	0.7	28.4	0.6	1
YO7	1091	11330	14.8	3	6.8	13.6	22.9	4.1	33.2	5.1	72.6	243.2	11.4	22.4	2.6	0.6	14.6	3	1
YO8	5580	25730	98.9	3	19.9	107.4	304.2	14.6	177.1	49.1	206.1	312.5	12.3	27.2	8.5	2	176.5	11.1	1.8
YO9	1505	21810	24.8	3	7	17.7	49.6	7.3	56.3	10.4	289.9	180.3	7.5	2	2.5	0.9	37.7	2.8	1
YO10	1669	38220	23.6	3	7.1	16.8	38.7	7.9	69.5	7.4	239.4	269.7	7.4	26.1	2.8	0.8	31.5	3.9	1
YO11	3217	81510	119.3	11.3	19.1	79	229.2	17	267.7	53.5	452.4	193.2	9.5	30.4	5.1	2.5	128.2	12.8	1.8
YO12	1395	26480	8.5	3.5	1.8	5.9	15.2	2	48.3	17.2	54	150.2	7.4	2	1.5	0.7	9.2	2.3	1
YO13	1165	9541	8.7	3.4	1.7	4.6	16.4	1.6	20.9	15.4	52.8	114.2	8.9	2	1.1	0.5	6.8	0.6	1
YO14	1719	32550	19.6	3.5	2.3	8.8	43.9	4.3	66.1	19.6	510.8	115.7	7.7	21	1	0.9	23.8	3.3	1.1
YO15	1606	30790	7	3	2.4	4.5	16.1	2.6	61.2	10.9	383.4	87.2	5.5	17.3	1	0.9	9.8	2.3	0.5
YO16	1028	12350	21.5	3	9.2	7.4	17	2.6	37.3	6.5	68.9	161.1	6.6	17.4	1.4	0.6	6.3	2	0.3
YO17	4386	135400	100.6	6.5	19.8	59.3	192.2	10.3	422.5	55.3	507.8	127.4	9.9	25.6	3.2	2.5	102.5	12.1	3.1
YO18	6514	132900	77.8	4.4	17.5	37.1	133	12	400.2	43.6	644.8	133.9	6	16.5	2.4	2.4	63.3	12.2	4.4
YO19	2568	189700	75.8	6.5	13.5	48.4	145	11	324.8	40.7	530.7	138.9	8.6	18	2	2.2	86.5	11.3	2.7
YO20	2189	258500	71.7	9.1	15.7	60.6	190.5	12.3	291.3	58	404.2	146.1	10.7	29.4	3.5	2.9	143.3	13.2	2.7
YO21	7698	80670	91.2	5.3	16.3	60	195.7	11.6	576.3	41.9	386.7	125.6	6	5.5	3.9	2.8	93.9	11.2	2.5
Min	1028	9541	7	3	1.7	4.5	15.2	1.6	20.9	5.1	39.5	87.2	5.5	2	1	0.5	6.3	0.6	0.3
Max	7698	258500	119.3	11.3	19.9	107.4	304.2	17	576.3	58	644.8	383.6	12.3	39.4	8.5	2.9	176.5	13.2	4.4
Mean	3051.3	57503.4	45.2	4.3	10.0	35.2	110	7.7	151.7	25.8	261.9	187.7	8.8	18.7	3.2	1.4	65.4	6.0	1.5
StdD	2021.6	67341.2	36.3	2.3	6.5	28.9	87.3	4.4	161.8	18.0	196.2	84.5	2.1	10.6	2.1	0.8	52.8	4.7	1.1

Previous data/ Burraneer Bay

Sample No	East	Northing	Ni	Cu	Zn	As	Br	Rb	Sr	Cd	Sn	Ba	Pb
gh 1	327350	6228174	0.5	2.5	9.1	5	73.3	15.2	1057	2	3.7	107	5.8
gh 2	327206	6228207	0.5	4.1	9.2	3.9	88.8	16.8	1112	1.5	2.9	113	6.5
gh 3	326915	6228119	0.5	4.2	8.1	5.5	82.9	16.8	973.8	0.1	3.2	99.9	5
gh 4	326800	6227939	0.9	3.3	8.6	3.5	47.1	14	671.6	1.2	6.4	93.3	5.1
gh 5	326300	6227907	0.5	3.6	9.8	3.2	61.6	15.9	716.8	1.4	3.6	99.7	6
gh 6	326145	6228313	1.6	2.9	10.8	2.5	63.7	7.7	198.9	34.3	8.5	60.5	7
gh 7	326461	6228420	0.8	3.3	5.7	3.2	37	6.1	318	24.4	8.8	57	3.3
gh 8	326520	6228578	7.1	23.3	105.9	10.7	191.5	28.9	493.1	0.1	6.8	113.3	46.5
gh 9	326496	6228613	4.5	7.3	15.4	2.8	99.1	7	48.5	2.8	7.5	45.3	9.6
gh 10	326627	6228499	7.6	24.4	94	9	399.3	30.4	612.1	2	8.6	113.4	43.4
gh 11	326492	6228511	3	8.8	20.9	2.4	140.9	11.8	356.7	0.4	9.4	67.7	13.1
gh 12	326571	6228432	0.5	4	16.5	2.3	105.9	9	447.4	41.1	5.4	46.3	8.2
gh 13	326680	6228263	1.1	10	32	3.3	327.1	12.9	1012	14.7	5.6	69.8	15.4
gh 14	327071	6228353	23.7	7.3	17.6	1.6	121.8	13.2	951.7	2	8.2	68.4	10.5
gh 15	327429	6228709	1.5	15.2	37.6	2.1	121.7	9.2	179.8	12.4	5.8	76.9	17.1
gh 16	327455	6228872	2.4	14.6	36.1	3.6	155.5	8	360.4	0.3	9.5	51	21.6
gh 17	327113	6229171	11.4	37.8	38.4	1.8	86.6	7.5	63.4	18	7.6	60.8	18.8
gh 18	327184	6229281	6.9	101.6	138.6	8.8	273.9	22.5	173.4	0.2	14.6	102.7	101.1
gh 19	327140	6229246	27.2	19.1	29.4	3.3	73.5	6.8	65.4	4.5	12	51.1	22.4
gh 20	327231	6229439	7.2	21	98.9	2.4	74.1	13.2	82.4	4.4	26.1	109.8	22.7
gh 21	327235	6229336	5.8	43.8	102.9	7.5	167.9	17.2	134.6	13	10.5	90.7	60.2
gh 22	327373	6229143	3.5	24.7	43	2.4	118.4	13.5	241.2	1.6	8.6	76.1	23.6
gh 23	327508	6229135	17.2	20.2	49.1	3.2	209.5	15.4	496.7	3.2	11.8	81	27.5
gh 24	327572	6229132	7.1	96.8	150.7	8.8	365.8	27.5	899	2	8	135	55.9
gh 25	327724	6229666	3	231.8	59.1	5.6	136.8	9.5	82.4	4.5	7.4	60.1	57.5
gh 26	327712	6229775	4.1	12.7	23.7	1.7	71.7	6.5	50.1	1.2	7.6	59.2	13.3
gh 27	327874	6229904	3.5	17.1	26.2	3.5	134.4	8.5	62.3	2	9.1	73.8	32.4
gh 28	327823	6230015	4.5	14.8	45.6	4.2	103.9	6.8	50.7	0.3	6.1	57	24.9
gh 29	327784	6230054	3.7	9	23.2	2.3	96.7	5.1	33	1.6	8.1	46	12.7
gh 30	327915	6230036	2.6	10.2	17	2.7	102	4.4	75.2	0.7	7.8	37.8	14.2
gh 31	328005	6230035	17.7	27.9	37.9	3	95.9	8.6	67.2	5.3	8.4	76	22.3
gh 32	328064	6230007	1.6	10.9	33.5	2.2	137.6	6.2	41	0.5	8.3	51.9	25.1
gh 33	328158	6230039	4.6	10.4	45.1	1.8	41.4	9.3	55.3	0.5	8.7	75.1	59.5
gh 34	328053	6229624	3	27.8	45	2.1	96.3	6.7	41.9	21.9	16.1	46.1	30.1
gh 35	327951	6229380	2.1	153.2	178.6	4.9	148.7	19.4	454.9	24.7	19.6	145.1	96.8
gh 36	327940	6229183	4.8	25.1	55.7	4	205.2	7.8	362.5	1.6	8.3	68.8	38
gh 37	327794	6228602	1.4	5.5	11.4	2.4	93.4	6.5	121.3	25.2	7.6	46.2	9.2
gh 38	327745	6228362	6.3	13.9	41.7	4	144.8	14	621.3	6.5	12.6	97.7	26.4
gh 39	327926	6228179	0.5	1.9	7.9	3.4	51.6	3.3	667.8	1.2	4.4	35.8	2.5
gh 40	326568	6228376	2	3.6	5.2	3.1	37.2	4.5	180.4	1	4.5	42.2	1.4
gh 41	327016	6228264	2.2	4	6.2	4.8	50.6	9.5	433.3	35.4	6.7	63.2	3.3
gh 42	327469	6228320	1.5	2	5.2	4.3	42.3	8.1	359.5	4.6	5.8	51.3	3.5
gh 43	327635	6228438	15.1	4.6	14.4	3.9	56.5	14.1	730.5	26.5	2.6	81.4	5.4
gh 44	327524	6228546	0.5	4	9	3.5	43.8	10.4	568.2	8.8	4.3	64.7	4.4
gh 45	327561	6228738	0.4	4.2	7.2	2	104.3	10.6	220.2	6.2	6.7	71.7	3.5
gh 46	327710	6228715	0.4	4.2	10.1	3.7	56.9	10.6	501	0.3	8.4	65.1	7.2
gh 47	327746	6228954	13	42.3	121.8	12.1	295.5	39.5	929.9	1.7	6.5	131	60.7
gh 48	327869	6229208	13.3	45.8	125.9	11.2	443.7	38.9	882.4	1.4	6.5	114.1	59.4
gh 49	327903	6229405	8.1	33.3	91.2	9.8	245	28.5	752.2	23.4	8.1	94.6	50.4
gh 50	328048	6229849	3.6	16.7	45.6	7.8	148.4	14.2	513.7	15.3	7	49.4	30.2
gh 51	328024	6229952	0.6	7.6	14.3	3.5	110.5	5.4	165.8	2	6.7	38.7	9.7
gh 52	327902	6229979	7.9	51.1	108	10.4	252	24.5	325.1	0.6	10.5	87.4	74.4
gh 53	327914	6229790	0.5	4.5	10.8	2	203.4	3.8	349.7	18.8	6.2	34.2	8.5
gh 54	327784	6229746	0.5	11.5	23.1	5.7	210.9	7.4	748.7	52.7	4.5	34.8	18.6
gh 55	327695	6229459	24.6	50.3	103.6	8.5	214	22.3	713.8	1.9	11.3	80.8	47.6
gh 56	327667	6229337	1.4	23	38.3	5.4	117.7	11.6	823.5	20.9	3.2	59	23.6
gh 57	327555	6228987	2.8	18.4	52.2	9.3	169	21.4	1087	7.5	5.4	89.5	30.8
gh 58	327621	6229138	3.4	23.1	60.1	8.4	175.8	19.4	902.7	1	8.9	75.9	36
gh 59	327448	6229131	0.5	10.3	27.2	6	169.1	9.4	548.9	1.1	6.6	46.5	23.1
gh 60	327306	6229206	1.8	14.3	29.9	4.3	161.2	12.2	320.4	2	6.5	52.2	19.4
gh 61	327263	6229325	0.7	6.3	16	3.5	100.4	5.6	309.6	17.8	6.8	32.5	15.2
gh 62	327169	6229093	3.7	24.7	46.9	6.8	162.2	14.8	345	6.1	8.3	56.3	29
gh 63	327211	6229167	12.7	62.6	162.2	13.4	369.7	45.4	856	14.1	10.5	135.4	82
gh 64	327271	6229036	5.1	27.2	67.6	9.3	266	22.1	830.5	2	5.5	89.2	38.4
gh 65	327499	6228903	0.5	8	23	6.8	193.5	13.9	1335	2	9.3	77	20.4

Oatley Bay

Sample No	Easting	Northing	Cr	Co	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Pb
OBu1	323969	6237902	25.3	20.3	7.8	6.6	37.7	16	0.5	63.7	24.6	46.9	14.1
OBu2	323935	6237921	30.1	< 4.4	9	24.6	116.6	14.7	0.5	88.1	25.6	63.4	46.5
OBu3	323909	6237940	39.5	< 4.6	9.6	27.4	118.6	11.3	0.5	91.8	28	130.9	52.4
OBu4	323871	6237931	61.4	15	24.9	92.7	379.3	22	0.8	242	81.4	120.4	146.2
OBu5	323873	6237897	27.2	16.3	14.2	26.9	128	24.3	0.7	108.1	34.6	89.2	52.7
OBu6	323904	6237862	50.4	12.1	13.3	40.2	188.2	24.7	0.9	124.4	30.4	91.8	75.5
OBu7	323833	6237806	33.6	< 5.1	18.3	75.3	280.3	28.6	0.8	132.4	76	116.6	168.2
OBu8	323805	6237857	21.8	7.8	17.9	53.3	245.8	36.1	0.9	120.4	75.5	110.5	186.8
OBu9	323782	6237912	28.4	7.2	19.6	53.3	273.3	29.6	1.1	142.3	80	117.1	184.1
OBu10	323165	6237184	84.7	4.7	13.2	28	141.7	24.6	0.9	81.8	61	94.8	100.9
OBu11	323223	6237488	43.2	8.2	17.8	33.5	184.1	22.6	0.7	170.7	63	100.8	73.2
OBu12	323553	6237886	7.9	< 5.1	14.9	35.2	191.3	39.6	1.1	88	77.6	107.8	234.9
OBu13	323448	6238054	25.5	7.6	19.4	61.1	321.6	33.1	1.1	156.6	75.8	119.9	215.9
OBu14	323386	6238049	44	15.1	18.9	70.4	376.6	26.3	1	180.8	62.4	120.3	157.7
OBu15	323352	6238080	66.3	12.5	7.8	21.4	95.2	6.1	0.3	33	19	89.5	48.6
OBu16	323395	6238100	105.4	< 4.9	14.6	20.5	115.7	23.3	0.8	99.6	47.6	141	60.7
OBu17	323544	6238106	23.2	9.2	20.5	56.2	273.7	29.2	0.8	110.7	67.5	113.1	181
OBu18	323570	6238124	34.4	17.5	10.5	33.4	164.6	12.7	0.6	47.4	19.3	65.7	98.7
OBu19	323572	6238075	48.4	11.9	20.1	83.4	323.2	28.2	0.9	152.6	70.5	119	187.9
OBu20	323526	6238068	26.3	13.2	19	62.1	285.2	28.6	1	164	78.1	129.3	150.6
OBu21	323476	6238028	34	10.6	22.1	64.3	323.3	28.9	0.8	181.8	85.1	121.8	167.5
OBu22	323418	6238012	50.4	12.7	24.6	80	381.8	25.7	0.9	193.5	74.8	118.9	169.9
OBu23	323443	6238092	64.6	20.5	21.7	84.4	454	28.2	0.9	182.8	65.2	128.5	218
OBu24	323480	6238086	129.8	13.6	19.3	56.8	338.5	17.6	0.5	177	65.6	141.4	138.8
OBu25	323470	6237934	34.6	< 4.4	9.4	26.4	115	12.6	0.4	93.4	30.3	63.3	44.7
OBu26	323551	6237965	24.7	8.3	17.9	48.7	236.7	32.7	1	126.9	81.9	117.9	173.5
OBu27	323600	6237978	33.1	6.5	13.6	26.6	118.2	13.7	< 0.2	92.5	31.4	59.9	48.2
OBu28	323615	6237880	37.3	9.6	22.8	50.5	253.1	22.3	0.8	173	78.8	112.8	128.1
OBu29	323632	6237821	11	4.9	17.1	50.3	213	30.7	0.8	111.8	79.7	118.7	151.1
OBu30	323792	6237809	39.3	14.9	11.5	34	171.1	21.9	0.8	120.1	34.3	76.4	77
OBu31	323718	6237858	16.1	6.5	19.6	56.5	228.6	33.8	0.9	108.9	84.5	120.9	174.5
OBu32	323717	6237911	45	15.3	7.4	17.4	62.8	6.1	0.2	47.8	17.1	58.6	36.1
OBu33	323530	6237752	34.5	13	7.7	11.3	39	14.1	0.4	66.5	24.7	54.5	14.8
OBu34	323472	6237772	30.2	< 4.8	10.1	20.3	92.6	21.5	0.7	75.7	48.4	86.8	62.7
OBu35	323426	6237799	15.4	< 5.0	15.1	36.8	188.4	29.2	1	97.8	68.7	102	152.8
OBu36	323334	6237723	50.4	6.1	7.5	18.4	90.5	11.6	0.6	89	24.8	44.2	41.7
OBu37	323376	6237685	21	< 4.9	14.7	30.2	166.7	27.7	0.7	107.4	65.9	96.3	116.5
OBu38	323427	6237651	35	9.2	9.1	18	98	14.5	0.5	93.7	29.2	61.8	40.4
OBu39	323386	6237553	20.1	4.8	11.4	29.1	139.7	26.8	0.8	74.3	54.9	87.8	121
OBu40	323319	6237576	33.1	< 4.8	10.6	14.8	72.1	21.9	0.6	96.3	48.5	82.8	41.3
OBu41	323243	6237622	13.1	< 5.1	14.8	35.1	170.6	28.8	0.7	103	68.6	100	136.5
OBu42	323168	6237041	25.9	9.5	8.5	23.5	90.1	11.3	0.6	122.2	26.4	253.2	35.7
OBu43	323260	6237090	44	5	15.9	31	174.4	29.7	0.7	82.5	66.1	95.5	135.4
OBu44	323341	6237129	30.4	12.4	10.4	21.1	90.1	11.4	0.6	98.3	27.1	49	34.3
OBu45	323105	6237205	26.5	< 4.8	12.4	33.1	153.3	19.9	0.7	92.1	51	80.8	93.7
OBu46	323171	6237234	19.2	6.7	14.7	33.3	173.4	24.9	0.9	95.2	64	94.3	106.7
OBu47	323221	6237276	41.6	< 4.7	12.7	25.9	154.5	19	0.7	80.3	44.7	78.4	97.6
OBu48	323202	6237367	82.2	4.4	10.4	27.7	122.2	24.5	0.9	79.7	45.3	79.4	95.1
OBu49	323131	6237369	19.1	< 5.0	14.9	30.9	176	24.9	0.7	112.5	66.2	100.2	114.6
OBu50	323032	6237377	29.6	< 3.0	14.7	28.1	170.8	22.8	0.7	132.6	61.8	93.7	100.5
OBu51	322894	6237324	45.9	10.1	6.6	21.8	77.3	5.9	0.3	49.5	17.3	58.9	26.7
OBu52	322929	6237422	69	< 4.7	9.6	18.9	98	20.5	0.9	73	41.1	70.4	75.6
OBu53	323024	6237414	71.1	< 5.0	14.4	27.3	150	29.7	0.8	87.5	63.1	94.2	131.5
OBu54	322990	6237498	21.6	7.4	11.4	27.6	132.5	23.4	0.7	88.2	53.3	84.7	91.3
OBu55	323063	6237474	45.1	6.4	12.7	30.8	144.1	18.8	0.9	103.5	48.7	77.8	84.7
OBu56	323150	6237449	62.5	< 4.9	13.6	29.6	132.7	26.1	0.7	80.7	57.9	90.4	93.3
OBu57	323253	6237431	35.9	< 3.0	13.2	28.6	160.9	20.8	0.7	116.5	53.1	83.7	101.5
OBu58	323206	6237489	28.2	< 5.1	14.1	37.7	174.3	32.6	0.6	104.5	68.2	102	152.5
OBu59	323128	6237538	29.4	< 4.9	14.2	27.7	156.5	25.6	0.8	87.5	63.7	94.1	119.3
OBu60	323030	6237575	31.1	< 5.0	11.7	35.9	155.3	31.3	0.7	88.2	56.6	91.7	164.3
OBu61	323185	6237582	29.2	6.5	15.6	38.2	191.8	27.6	0.8	102.3	70.3	102.7	144.5
OBu62	323250	6237533	18.2	< 5.1	15.8	32.8	199.1	27.9	0.7	110.1	69.3	99	146
OBu63	323298	6237474	42.9	5	13.3	30.9	149.4	31.4	0.9	97.8	61.4	91.2	129.9
OBu64	323336	6237483	34.3	19.7	9.7	22.1	107.8	10.5	0.5	77.3	28.2	63.4	41.8
OBu65	323294	6237549	26.3	< 4.9	10.8	16.8	65.6	21	0.5	80.2	53.3	91.9	37.7
OB66U	323946	6237924	54.1	17.6	23.1	98.9	591.7	42.1	1.3	121	67.1	136	234.9
OB67U	323933	6237940	83.3	18.7	30.3	156.6	915.4	36.5	1.7	165.4	63	153.7	582.2

3.2 Concentrations of trace elements in subsurface sediments (cores)

A- Botany Bay

Kogarah Bay core 1

Sample No	Depth	V	Cr	Co	Ni	Cu	Zn	As	Br	Rb	Sr	Sn	Ba	Pb
	Cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	0	127.3	87.6	17	23.7	57	244.5	16	164.6	81.7	201.4	13.8	152.6	108.1
2	5	134.6	58.6	14.1	22.3	40.9	178.8	9.7	172.7	74.3	200.4	9.1	125.9	88.7
3	10	112.7	51.6	12.9	24.1	35.3	153.2	10	147.1	78.9	146.3	9.8	125.3	82.8
4	20	57.5	79.4	6	12.2	16.4	74.3	18.1	53.9	33.7	158.1	2.6	95.3	32.1
5	30	65.7	73.9	5.9	13.6	14.9	72.8	15.1	93.8	39.9	124.2	2.6	134	30.9
6	40	91.1	81.2	3.6	18.1	12.8	60.8	15.8	62.2	54.8	116.7	2.5	100.5	20.9

Kogarah Bay core 2

Sample No	Depth	V	Co	Ni	Cu	Zn	As	Br	Rb	Sr	Sn	Ba	Ce	Pb
	Cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	0	51.1	7.7	18.8	36.1	173.8	4.4	39.5	23.2	112.6	11.2	150.5	27.3	115.2
2	5	60.2	9.4	20.1	36	128.5	4.4	21.6	21	144	9.6	148.2	19.7	104
3	10	41.6	3.4	14.1	26.4	96.4	3.7	31.6	17.5	92.9	6.7	165	24.8	60.2
4	20	21.4	3.4	11.4	25.9	50	1.8	27.3	10.5	59	9.7	96.1	31	30.1
5	30	20	5.3	12.4	18.8	57.1	2	22	11.6	57.8	12.7	93.1	20.4	37.7
6	34	19.7	3.5	10.8	17.7	64.3	3	27.5	12.1	61	8.5	97.7	0.4	52

Woolooware Bay 3

Sample No	Depth	V	Cr	Ni	Cu	Zn	As	Br	Rb	Sr	Ba	Ce	Pb	U
	Cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	0	128.9	108	27.8	49.4	321.3	23.5	194.9	87.3	965.6	168.5	89.5	85.3	6.8
2	5	121.5	111.1	28.6	46.1	330.4	18.8	155.5	90.3	727.1	165.2	84.8	89.9	4
3	10	130.4	106.1	29.1	44.3	302.8	20.5	149.1	92.2	220.6	177.6	73.2	87.5	4.3
4	20	66	112.5	13.6	12.3	72.5	17.4	86.8	43.2	205.9	92.2	56.2	22	2.8
5	30	55.5	51.6	10.9	6.1	33	14.3	103.3	35.6	206	59.8	41	10.2	1.5

Oyster Bay 4

Sample No	Depth	V	Cr	Ni	Cu	Zn	Br	Rb	Sr	Zr	Ba	Pb
	Cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	0	129.4	103.8	31.6	57.6	351.5	196.2	89.9	139.9	310.4	194.3	114.4
2	5	136.2	116.5	32.8	60.4	356.7	135.4	96.3	134.6	314.1	189.1	117.9
3	10	137.2	112.8	32.9	61.4	358.7	123.5	92.6	133.3	252.4	194.2	118.9
4	20	134	113.5	33.1	59.9	363.2	101.8	89.4	132.8	234.8	198.4	124.7
5	30	131	106.6	36.1	35	232.3	76	86.2	150.8	219.7	163.3	76
6	40	96	68.1	19.5	13.1	66.8	83	66.1	99.2	206.6	150	23.9
7	45	89	62	18.1	10.8	53.5	73	69.9	101	210.1	152.3	20.3

Woronora River 5

Sample No	Depth	V	Ni	Cu	Zn	Br	Rb	Sr	Zr	Ba	Ce	Pb
	Cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	0	16	10.2	30.6	41.1	28.5	13.5	29.1	275.5	51.8	53.1	13.1
2	5	27.4	9.1	9.6	25.6	25.6	13.7	157.8	199.6	41	38.4	8.3
3	10	15.7	6.6	11	36.3	25.1	13.1	29	262.9	50.6	36.1	12.3
4	20	13.9	7.7	12.7	32.1	22.9	11.5	25.5	271.1	38.4	31.2	11.4
5	30	19.9	8.8	11.7	36.3	26.2	12.9	27	295.1	41.7	42.9	11.9
6	40	11.5	6.8	6.9	24.7	26.8	9.6	22.2	237.5	46.8	29.7	8.8
7	47	9.7	7.4	10	35.9	24.9	14.5	30	222.4	46.3	25.3	8.6

George River and Salt Pan Creek 6

Sample No	Depth	V	Cr	Co	Ni	Cu	Zn	As	Br	Rb	Sr	Sn	Ba	Pb
	Cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	0	114.3	95.8	20	30.6	76.7	579.9	15.7	78.8	78.9	116.2	18.1	208.9	91.8
2	5	130.3	127.2	21.4	43.3	140.8	695.1	29.3	45.7	91.8	118.4	18.4	215.5	178.9
3	10	131.3	123.9	17.1	52.8	167.1	449.6	26.4	43	95.3	109.5	18.9	232.2	169.3
4	20	129	84.8	16.5	32.7	300.7	282.2	20.7	45	95.2	101	16	233.4	330.7
5	30	108.9	60.6	11.8	22.4	30.4	126	14.5	46.9	82.2	83.5	8.2	164.7	44
6	40	86.9	60.9	13	17.2	17.8	80.5	14.5	47.6	61.4	72.4	6.3	131.2	22.6
7	50	86	52.3	9.2	15.5	18.9	68.7	11.8	42.5	55.9	65.1	9.1	137	26.9

B-Port Hacking Bay

Gunnamatta Bay 7

Sample No	Depth	Cr	Ni	Cu	Zn	Br	Rb	Sr	Zr	Sn	Ba	Ce	Pb
	Cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	0	65.7	12.6	1058	624.9	105.4	22.3	271.7	202.5	27.6	172.5	0.8	180
2	5	70.9	12.9	838.4	537.6	84.2	24.2	181.5	277.1	19.8	183.8	24.6	172
3	10	76.8	14.1	622.1	451.1	67.6	26	205	268.6	24.9	173.6	34.9	193.4
4	20	65.2	13.7	533.2	408.6	59.9	23.9	146.9	184.6	22.3	184.3	22.8	273.7
5	30	53.4	9.7	388.3	380.8	41	17.9	180.1	182.3	39.2	145.6	51.5	188.5

Mansion Bay and Hacking River 8

Sample No	Depth	Co	Ni	Cu	Zn	Br	Rb	Sr	Zr	Sn	Ce	Pb
	Cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	0	6.9	6.7	6.8	13.4	22.9	4.3	26.3	114.9	5.2	31.5	5.4
2	5	3	5.5	4.4	12.4	27.9	2.7	26	98	5.8	11	5.6
3	10	5.7	14.3	6.4	11.5	20.9	2.9	20.3	105	6.8	17.9	4.5
4	20	< 3.4	8	5.9	8.5	23.6	3.6	20.3	75.5	7	< 0.1	4
5	30	< 3.3	7.4	8.6	11.3	19	3.6	17.2	70.8	9	< 2.0	2.7
6	40	< 3.0	5.9	6	8.3	16	3.5	18.6	66.4	4.2	< 0.1	2.8

Oatley Bay 9

Depth	Depth	V	Cr	Ni	Cu	Zn	As	Br	Rb	Sr	Ba	Pb
	cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	0	43.8	11.3	13.4	44.6	196.5	29.5	89	60	103.8	195.9	157.4
2	10	36.9	204.1	11.9	31.4	134.3	25.8	50.7	41.5	82.4	126.8	116.2
3	20	51.9	72.6	12	24.2	104.1	25.5	49.3	41.7	79.8	120	91.2
4	30	38.8	27.6	15.2	27	145.8	47.7	65.1	69.1	107.6	189	220.1
5	40	26.3	18.6	14	27.8	185.9	54	70.8	61.8	117	196	344.8
6	50	47.3	8.3	18.7	16.9	104.6	31.6	91.7	81	141.8	185.9	79.6
7	60	56.1	8.3	16	21.8	164.5	44	2.3	69.6	124.9	214.8	243.3
8	70	36.5	13.4	14.7	24.9	166.4	34	77.6	69.5	118	204.4	206.3
9	80	61.9	5.5	17	13.6	80.5	28.7	75.3	76.5	128.3	199.9	56.7
10	90	71.6	17.5	16.3	13.8	80.3	27.5	66.2	69.2	121.7	175.7	41.4
11	100	57.2	17.1	17	21.6	140.4	33.4	73.5	73.7	116.3	190.9	137.4
12	120	97.4	18.1	20.5	13.5	96	30.6	91.1	82.4	143.4	171.3	50.7
13	140	83.6	16.7	18.2	11.3	79.6	29.1	82.6	78.3	128.1	193.7	48.5
14	160	92.6	61	17.9	12.6	63.8	28	66.4	61.4	111.8	162.7	35.6
15	180	89.1	37.6	16.2	10.4	53.2	27.4	57.5	57.6	203.1	117.1	33.3
16	200	78.4	67.1	14.8	10.4	40.6	36.1	60.2	52.4	116.9	120.8	22.1
17	250	83.9	16.3	19.5	10.1	52.7	21.7	67.2	74.1	278.8	179.8	27.4

3.3 Lead Isotopes

Locations	Samples No	Depth(cm)	$^{204}\text{Pb}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{206}\text{Pb}$
Kogarah Bay	KO26	5	0.0584	0.912	2.168
Kogarah Bay	KO45	5	0.0592	0.916	2.17
Woolooware Bay	WO4	5	0.0586	0.905	2.159
Oyster Bay	OY20	5	0.0586	0.909	2.163
Oyster Bay	OY33	5	0.0586	0.91	2.164
Woronora River	WOR38	5	0.0587	0.907	2.156
Georges River	Core6-0	2	0.06	0.931	2.188
Georges River	GE12	5	0.0581	0.906	2.158
Georges River	GE38	5	0.0592	0.918	2.174
Oatley Bay	OBU67	5	0.0595	0.921	2.173
Oatley Bay	OBU66	5	0.0586	0.913	2.168
Gunnamatta Bay	GU55	5	0.0596	0.925	2.175
Gymea Bay	GY9	5	0.0578	0.91	2.163
Mansion Bay	MA25	5	0.0584	0.901	2.157
North West Arm	NWA4	5	0.059	0.914	2.168
Yowie Bay	YO8	5	0.0591	0.914	2.168
Kogarah Bay	Core1	40	0.0543	0.848	2.096
Georges River	Core 6	40	0.0556	0.866	2.113
Woolooware Bay	Core 3	30	0.0546	0.85	2.102
Mansion Bay	Core 8	40	0.0568	0.899	2.151

3.4 Data of potential ecological risk assessment (RI)

Kogarah Bay

Sample No	ErNi	ErCu	ErZn	ErAs	ErPb	RI
KO1	6.83	13.35	4.66	8.87	13.18	46.88
KO2	5.40	14.89	4.63	10.52	22.14	57.57
KO3	6.59	19.40	5.09	8.45	23.46	62.99
KO4	3.97	14.51	2.77	3.81	8.53	33.59
KO5	9.09	31.76	6.50	8.56	20.32	76.23
KO6	4.13	43.79	3.53	4.07	9.27	64.79
KO7	5.91	20.93	4.78	10.21	24.49	66.32
KO8	5.24	21.59	3.76	7.58	19.34	57.51
KO9	2.06	5.82	1.18	3.04	3.93	16.04
KO10	1.90	5.05	0.65	2.53	2.20	12.34
KO11	0.71	3.08	0.28	1.03	1.15	6.25
KO12	10.48	29.23	6.70	9.85	20.62	76.87
KO13	6.11	18.96	4.30	11.29	28.10	68.76
KO14	6.23	26.10	4.23	6.34	15.58	58.47
KO15	5.20	23.30	3.80	5.93	14.12	52.35
KO16	7.22	46.98	5.83	10.41	33.44	103.88
KO17	4.96	16.32	3.90	10.93	26.43	62.53
KO18	0.71	3.52	0.36	1.13	1.86	7.59
KO19	5.36	22.14	5.10	10.15	38.50	81.26
KO20	4.80	24.95	5.04	4.02	15.66	54.47
KO21	1.03	3.13	0.55	0.98	3.16	8.85
KO22	6.67	19.07	4.58	9.64	26.28	66.23
KO23	2.22	12.09	1.55	2.58	6.84	25.28
KO24	6.19	24.56	4.54	5.98	19.29	60.57
KO25	6.27	22.09	4.74	13.51	38.80	85.41
KO26	5.99	24.62	5.34	14.18	50.26	100.38
KO27	1.51	5.99	0.25	0.77	3.82	12.35
KO28	1.55	5.16	0.93	0.93	4.47	13.04
KO29	6.15	40.93	8.83	4.07	25.64	85.63
KO30	3.77	26.43	2.81	1.44	5.85	40.31
KO31	2.90	18.63	2.31	1.24	11.62	36.69
KO32	4.29	17.75	3.77	9.23	36.37	71.39
KO33	4.33	17.86	3.11	5.62	16.35	47.26
KO34	3.10	13.52	2.17	3.14	9.04	30.96
KO35	0.52	4.18	0.31	0.82	1.65	7.48
KO36	7.82	25.93	5.37	7.32	24.38	70.83
KO37	1.49	3.43	0.48	0.77	2.29	8.46
KO38	1.87	6.48	1.06	1.44	5.85	16.71
KO39	9.25	40.60	8.04	9.38	29.91	97.18
KO40	2.70	12.25	2.27	3.71	9.89	30.83
KO41	9.76	49.67	9.47	9.48	36.07	114.46
KO42	1.15	6.15	0.89	1.29	5.26	14.74
KO43	7.34	54.75	3.40	2.32	14.86	82.68
KO44	5.95	30.22	6.03	4.48	25.32	72.01
KO45	11.07	51.81	10.31	9.07	41.39	123.66
KO46	7.70	32.97	6.05	8.04	24.70	79.45
KO47	1.27	6.04	0.72	1.70	3.29	13.03
KO48	5.20	21.43	4.78	9.69	37.26	78.36
KO49	5.99	21.43	4.57	10.98	33.12	76.09
KO50	0.60	2.64	0.46	1.96	2.48	8.13
KO51	6.94	22.97	4.99	12.68	30.26	77.84
KO52	4.72	15.11	3.69	12.27	34.00	69.78
KO53	8.17	42.75	5.80	10.00	19.57	86.30
KO54	4.56	14.78	3.54	12.94	34.79	70.61
KO55	6.07	21.98	4.63	11.44	32.65	76.77
KO56	3.97	10.44	2.34	4.48	6.90	28.13
KO57	2.26	6.10	1.32	3.51	4.00	17.19
KO58	6.27	16.32	4.88	7.94	24.00	59.40
KO59	5.32	15.00	4.12	6.65	10.94	42.02
Mean	4.86	20.22	3.76	6.38	18.56	53.78
Min	0.52	2.64	0.25	0.77	1.15	6.25
Max	11.07	54.75	10.31	14.18	50.26	123.66

Woolooware Bay

Samples No	ErCr	ErNi	ErCu	ErZn	ErAs	ErPb	RI
WO1	1.23	1.43	4.29	0.92	2.00	3.01	12.88
WO2	2.66	4.05	9.40	2.65	5.18	7.16	31.09
WO3	5.89	10.32	24.89	7.49	10.31	19.02	77.90
WO4	0.87	5.95	15.55	4.51	8.77	22.24	57.89
WO5	1.95	2.94	6.92	1.65	3.33	4.66	21.45
WO6	0.52	2.50	3.63	0.21	1.03	0.92	8.80
WO 7	0.36	0.91	2.75	0.18	0.67	0.85	5.73
WO8	5.89	10.36	24.29	6.71	10.97	16.52	74.73
WO9	3.50	5.95	16.43	4.07	6.77	11.45	48.18
WO10	1.96	2.34	8.24	1.58	2.97	4.29	21.39
WO11	3.92	6.90	31.87	5.35	7.23	13.35	68.63
WO12	1.46	1.83	10.71	1.26	2.56	3.14	20.97
WO13	3.28	5.48	15.00	3.85	6.51	9.79	43.91
WO14	3.85	7.82	19.51	5.10	10.05	13.89	60.22
WO15	0.88	3.49	10.16	2.84	6.51	12.41	36.30
WO16	0.41	0.44	1.70	0.22	0.72	0.90	4.38
WO17	0.43	1.85	2.80	0.22	0.64	0.72	6.66
WO18	3.59	5.60	12.58	3.20	6.56	8.35	39.89
WO19	2.59	4.01	10.16	2.10	4.72	5.66	29.24
WO20	5.00	8.65	20.27	5.00	7.49	13.08	59.49
WO21	4.69	8.77	20.11	5.26	11.23	13.53	63.58
WO22	1.35	3.29	9.89	1.79	4.87	6.03	27.22
WO23	3.52	8.93	19.18	5.16	11.49	15.38	63.66
WO24	1.59	3.10	7.80	2.05	4.00	6.82	25.36
WO25	0.34	0.52	1.54	0.25	0.67	0.73	4.04
WO26	0.54	0.71	2.20	0.39	1.03	1.11	5.98
WO27	2.26	3.61	8.52	2.20	3.54	6.15	26.27
WO28	3.62	5.08	12.25	2.33	5.23	6.73	35.25
WO29	3.55	8.17	17.97	4.65	11.28	13.03	58.65
WO30	3.34	6.87	13.74	3.69	9.59	9.47	46.69
WO31	3.03	4.52	11.26	3.02	6.56	7.01	35.41
WO32	3.28	5.71	12.25	2.32	6.56	6.43	36.57
WO33	4.54	7.50	13.79	3.30	7.44	9.06	45.63
WO34	3.04	7.10	15.22	4.10	8.62	12.29	50.37
WO35	3.36	5.83	12.80	3.10	6.41	7.78	39.29
WO36	3.31	5.79	12.42	3.13	6.10	8.12	38.87
WO37	3.35	5.36	11.81	2.97	4.97	7.84	36.30
WO38	2.24	2.78	6.37	1.50	2.97	4.19	20.06
WO39	1.68	3.13	7.03	1.75	3.33	4.85	21.78
WO40	2.55	4.68	10.27	2.30	4.36	6.09	30.26
WO41	2.07	4.40	8.16	1.60	3.54	4.54	24.31
WO42	1.33	3.73	7.64	1.38	3.18	4.42	21.68
WO43	3.80	6.19	13.96	3.18	6.87	9.29	43.29
WO44	1.23	1.23	3.35	1.35	5.18	4.44	16.79
WO45	2.75	4.40	11.26	2.83	5.03	7.37	33.65
Mean	2.59	4.76	11.60	2.77	5.53	7.87	35.13
Min	0.34	0.44	1.54	0.18	0.64	0.72	4.04
Max	5.89	10.36	31.87	7.49	11.49	22.24	77.90

Oyster Bay

Sample No	ErCr	ErNi	ErCu	ErZn	ErAs	ErPb	RI
OY1	1.99	5.52	17.09	3.76	9.38	20.24	57.98
OY2	0.69	4.76	16.15	3.51	12.21	26.11	63.43
OY3	3.44	6.55	18.52	4.78	8.00	19.25	60.54
OY4	1.15	3.21	6.59	1.35	2.64	4.57	19.52
OY5	1.28	5.20	16.32	3.88	9.74	21.54	57.95
OY6	0.59	4.88	15.16	3.52	12.46	33.12	69.74
OY7	2.80	5.12	12.31	3.20	5.33	9.72	38.48
OY8	4.78	8.17	20.66	4.72	6.77	13.27	58.37
OY9	2.86	5.36	15.22	3.39	5.38	10.71	42.92
OY10	5.30	10.52	26.98	6.82	9.38	20.58	79.58
OY11	2.66	6.98	21.65	5.18	8.92	20.98	66.38
OY12	0.57	4.84	15.33	3.50	13.13	36.56	73.93
OY13	1.46	6.87	19.34	4.77	10.10	27.20	69.74
OY14	2.02	2.90	7.80	1.70	2.92	5.04	22.39
OY15	1.16	5.75	16.43	3.44	11.59	30.28	68.66
OY16	3.12	8.85	21.10	5.97	8.77	24.62	72.43
OY17	4.97	10.71	26.65	7.08	8.10	22.52	80.04
OY18	4.31	9.64	24.78	6.58	7.90	22.63	75.84
OY19	5.64	11.39	27.97	7.94	9.13	22.48	84.55
OY20	0.81	6.07	17.58	4.59	13.18	42.35	84.58
OY21	0.63	4.33	13.35	3.74	9.90	30.83	62.78
OY22	1.79	6.94	20.82	5.73	10.62	34.94	80.84
OY23	0.53	4.72	15.16	3.81	11.85	39.42	75.50
OY24	0.85	5.60	18.57	4.69	12.97	39.15	81.83
OY25	1.07	5.52	17.91	4.74	13.03	36.75	79.01
OY26	1.29	7.26	20.60	5.57	11.64	33.74	80.11
OY27	0.90	5.63	16.37	4.49	9.74	25.77	62.90
OY28	1.18	5.87	17.80	4.77	8.72	26.37	64.71
OY29	5.41	11.15	28.35	7.72	9.69	22.84	85.17
OY30	2.21	8.10	22.53	6.23	9.59	29.27	77.93
OY31	4.52	7.82	19.45	5.71	7.49	15.92	60.90
OY32	4.07	6.81	15.77	4.25	5.67	12.53	49.09
OY33	1.49	6.98	20.60	5.71	10.82	32.03	77.64
OY34	3.45	7.06	13.71	3.38	4.21	9.81	41.61
OY35	3.19	5.24	15.49	3.85	3.90	11.09	42.76
OY36	2.10	4.42	9.67	2.20	2.97	6.78	28.14
OY37	1.57	2.94	6.68	1.34	2.36	4.25	19.13
OY38	1.05	2.78	5.36	1.03	0.97	3.02	14.22
OY39	2.36	4.29	9.23	2.06	2.41	6.87	27.21
OY40	1.84	3.77	8.65	1.75	1.77	6.01	23.80
OY41	4.38	7.50	18.74	4.49	5.18	13.62	53.91
OY42	5.41	10.83	30.82	8.68	8.77	23.87	88.38
OY43	5.71	11.03	29.12	7.94	9.33	23.42	86.55
OY44	6.63	12.86	32.03	8.19	9.85	25.26	94.82
OY45	4.33	7.92	17.25	4.73	5.72	13.95	53.90
OY46	5.07	8.93	26.92	6.31	7.54	18.53	73.29
OY47	5.16	9.56	29.84	8.11	7.54	22.91	83.11
OY48	5.08	9.17	22.42	5.75	6.56	17.88	66.87
OY49	4.43	10.38	17.55	4.56	5.05	13.43	55.40
OY50	5.27	9.52	20.11	5.18	7.64	14.17	61.89
OY51	2.18	8.45	22.20	6.38	9.38	31.26	79.85
OY52	6.66	12.90	32.75	8.16	7.28	24.04	91.78
OY53	4.34	9.94	17.66	4.58	3.44	10.73	50.69
OY54	7.58	15.40	34.45	9.19	9.90	23.35	99.86
OY55	3.46	8.65	12.86	2.80	2.62	9.03	39.41
Mean	3.07	7.34	18.99	4.86	7.84	20.85	62.95
Min	0.53	2.78	5.36	1.03	0.97	3.02	14.22
Max	7.58	15.40	34.45	9.19	13.18	42.35	99.86

Woronora River

Samples No	ErNi	ErCu	ErZn	ErAs	ErPb	RI
WOR1	2.90	7.28	1.18	2.05	3.51	16.93
WOR2	1.35	4.34	0.76	1.59	2.52	10.57
WOR3	3.47	7.99	1.40	3.38	4.56	20.81
WOR4	1.71	5.00	1.14	2.36	3.16	13.37
WOR5	3.31	7.75	1.29	2.18	3.77	18.30
WOR6	0.87	2.47	0.47	1.13	1.58	6.53
WOR7	2.94	6.15	1.11	2.15	3.51	15.87
WOR8	6.81	4.15	0.66	1.49	1.73	14.83
WOR9	4.64	12.42	2.71	4.51	7.84	32.12
WOR10	6.27	18.13	3.48	5.79	11.58	45.26
WOR11	3.43	8.05	1.38	2.95	4.47	20.27
WOR12	0.83	3.35	0.35	1.03	1.47	7.04
WOR13	0.79	3.24	0.31	0.87	1.43	6.65
WOR14	8.37	22.64	4.94	7.79	15.00	58.74
WOR15	0.44	2.91	0.22	0.97	0.81	5.36
WOR16	0.99	4.07	0.49	1.13	1.71	8.39
WOR17	0.83	2.53	0.53	1.13	1.90	6.92
WOR18	1.98	6.32	1.08	1.90	3.40	14.68
WOR19	0.65	2.06	0.28	0.56	0.98	4.54
WOR20	4.29	10.11	2.01	4.44	5.96	26.80
WOR21	7.34	13.41	3.07	5.18	8.70	37.70
WOR22	3.49	10.77	2.63	4.26	7.84	28.99
WOR23	0.63	2.09	0.31	0.72	1.13	4.88
WOR24	0.71	1.70	0.33	0.77	1.35	4.86
WOR25	2.22	3.90	0.62	1.23	1.54	9.52
WOR26	0.67	2.53	0.58	0.92	1.92	6.63
WOR27	9.25	28.46	6.09	8.67	18.65	71.12
WOR28	7.14	21.04	4.53	8.46	13.44	54.62
WOR29	7.66	20.99	4.37	9.59	13.18	55.79
WOR30	8.10	25.27	5.05	6.97	15.38	60.78
WOR31	7.50	20.77	4.69	8.46	12.52	53.94
WOR32	0.60	2.97	0.30	0.56	1.13	5.55
WOR33	2.96	6.07	1.13	2.41	3.71	16.28
WOR34	2.78	4.01	0.53	1.18	1.52	10.01
WOR35	2.70	4.73	0.37	1.18	1.11	10.08
WOR36	4.68	8.41	2.06	3.08	8.63	26.86
WOR37	3.81	11.87	2.62	2.87	7.18	28.35
WOR38	9.33	29.84	7.83	9.08	22.41	78.48
WOR39	0.60	2.42	0.26	0.41	0.96	4.65
WOR40	4.19	10.49	2.09	2.62	6.30	25.69
WOR41	3.77	6.21	1.01	1.69	4.10	16.79
WOR42	5.75	14.34	3.15	3.33	9.32	35.89
WOR43	9.40	30.38	7.07	7.33	21.39	75.58
WOR44	4.88	12.58	2.62	2.82	7.12	30.02
WOR45	9.21	30.00	7.35	7.44	20.77	74.76
WOR46	0.28	1.59	0.24	0.77	0.98	3.86
WOR47	3.45	10.00	2.09	3.64	5.94	25.12
Mean	3.83	10.17	2.10	3.30	6.37	25.76
Min	0.28	1.59	0.22	0.41	0.81	3.86
Max	9.40	30.38	7.83	9.59	22.41	78.48

Georges River and Salt Pan Creek

Samples No	ErNi	ErCu	ErZn	ErAs	ErPb	RI
GE1	6.23	21.43	5.60	10.10	27.67	71.04
GE2	9.80	31.21	9.34	6.41	21.22	77.98
GE3	10.56	32.91	9.10	6.05	18.70	77.31
GE4	1.35	4.64	0.87	1.38	2.29	10.53
GE5	1.79	6.54	1.26	1.44	3.01	14.03
GE6	0.52	1.76	0.36	0.92	1.05	4.61
GE7	3.45	7.03	1.62	2.05	4.23	18.38
GE8	4.19	10.47	2.50	1.97	5.92	25.05
GE9	3.37	10.11	1.96	3.74	7.00	26.18
GE10	5.79	16.92	4.23	5.03	9.53	41.50
GE11	0.63	1.81	0.35	0.97	1.20	4.97
GE12	6.35	23.19	5.99	9.64	28.12	73.28
GE13	5.52	17.97	5.37	5.33	15.17	49.35
GE14	7.18	18.08	4.39	4.31	12.22	46.18
GE15	1.23	3.19	0.70	0.77	2.16	8.05
GE16	4.60	17.58	4.37	7.44	25.66	59.65
GE17	7.10	21.81	5.87	4.36	11.41	50.56
GE18	6.23	11.15	2.10	4.10	4.91	28.51
GE19	0.67	1.70	0.42	0.92	1.41	5.14
GE20	0.87	2.42	0.66	1.49	1.47	6.92
GE21	1.11	3.02	0.70	1.08	1.79	7.70
GE22	0.87	2.75	0.45	1.03	1.24	6.33
GE23	5.40	18.08	5.04	4.92	16.22	49.66
GE24	3.45	9.07	2.34	1.74	5.43	22.03
GE25	6.39	21.76	5.56	6.82	20.98	61.51
GE26	9.33	32.64	10.26	6.62	24.17	83.01
GE27	5.67	15.60	3.70	5.85	9.83	40.66
GE28	5.60	17.69	3.99	4.31	10.34	41.93
GE29	5.60	17.53	4.00	7.74	15.62	50.48
GE30	9.13	22.58	5.51	8.46	15.60	61.28
GE31	4.05	10.93	2.55	2.51	6.26	26.31
GE32	0.56	1.43	0.27	0.97	0.79	4.02
GE33	6.83	22.47	6.52	5.54	22.56	63.92
GE34	7.90	22.36	5.82	7.85	20.53	64.46
GE35	4.25	18.90	4.34	8.67	30.13	66.28
GE36	5.60	24.67	5.39	9.79	32.82	78.27
GE37	10.16	53.46	12.21	7.69	36.77	120.30
GE38	7.14	45.71	10.33	13.54	57.18	133.90
GE39	6.98	40.49	8.32	9.59	42.46	107.84
GE40	0.79	2.31	0.31	1.85	0.83	6.09
GE41	2.14	5.66	1.37	2.41	4.12	15.71
GE42	1.69	4.64	0.55	1.90	4.04	12.82
GE43	1.11	2.39	0.64	2.15	1.87	8.16
GE44	3.89	9.40	2.29	4.97	6.24	26.78
GE45	5.99	6.13	1.30	4.05	3.12	20.58
GE46	1.11	1.98	0.48	1.79	1.00	6.37
GE47	0.87	2.03	0.46	1.90	1.47	6.74
GE48	0.87	3.19	0.41	1.59	1.39	7.45
GE49	10.24	67.31	17.11	6.72	36.97	138.34
GE50	11.87	75.99	15.63	8.56	41.54	153.59
GE51	10.44	59.95	18.78	6.72	39.25	135.13
GE52	9.80	59.01	14.00	5.59	32.26	120.66
GE53	10.52	59.07	12.12	7.59	29.55	118.84
GE54	6.59	42.75	10.56	8.46	45.17	113.53
Mean	5.02	19.72	4.82	4.80	15.26	49.63
Min	0.52	1.43	0.27	0.77	0.79	4.02
Max	11.87	75.99	18.78	13.54	57.18	153.59

Gunnamatta Bay

Samples No	ErCr	ErNi	ErCu	ErZn	ErPb	RI
GU1	0.51	1.21	2.75	0.28	1.04	5.78
GU2	0.33	0.60	3.10	0.35	1.40	5.78
GU3	0.61	0.89	2.31	0.22	0.89	4.92
GU4	1.10	2.36	4.40	0.33	1.15	9.34
GU5	0.38	1.15	2.64	0.18	0.44	4.79
GU6	0.42	0.91	1.59	0.18	0.50	3.61
GU7	0.47	0.81	1.59	0.13	0.32	3.32
GU8	0.62	0.67	3.02	0.30	1.54	6.16
GU9	0.45	0.95	2.12	0.21	0.72	4.45
GU10	0.67	0.71	5.30	0.40	2.53	9.62
GU11	1.41	2.56	21.68	1.81	5.24	32.69
GU12	0.34	1.33	2.14	0.16	0.36	4.33
GU13	0.58	0.95	1.92	0.24	1.11	4.81
GU14	0.64	0.16	4.26	0.41	1.99	7.45
GU15	3.72	4.40	41.10	3.29	12.33	64.84
GU16	2.06	4.68	36.79	3.27	13.78	60.58
GU17	2.04	3.99	34.42	2.95	12.29	55.69
GU18	3.56	6.19	52.77	4.50	17.95	84.98
GU19	3.06	2.86	22.86	1.93	7.91	38.61
GU20	1.65	1.39	33.52	1.65	6.39	44.59
GU21	2.26	6.39	64.48	5.51	22.94	101.57
GU22	0.59	0.40	3.65	0.32	2.14	7.09
GU23	0.36	1.05	2.86	0.26	1.12	5.65
GU24	0.51	0.81	2.75	0.37	1.40	5.85
GU25	5.86	7.86	81.81	5.88	23.91	125.33
GU26	0.50	1.05	4.97	0.30	1.89	8.71
GU27	4.52	5.71	49.29	4.00	14.75	78.27
GU28	1.01	1.19	6.57	0.60	2.50	11.86
GU29	0.63	1.27	6.87	0.41	2.12	11.29
GU30	5.82	4.44	42.47	3.21	11.84	67.78
GU31	1.22	2.86	24.67	0.96	6.98	36.68
GU32	0.85	0.99	17.39	1.57	3.43	24.24
GU33	0.78	0.99	17.39	0.63	3.43	23.21
GU34	0.49	0.87	5.25	0.25	1.70	8.56
GU35	0.49	0.91	11.70	1.08	2.96	17.14
GU36	1.85	1.77	33.13	1.95	9.49	48.18
GU37	0.54	1.55	8.02	0.29	1.44	11.84
GU38	0.87	1.31	11.87	0.49	4.98	19.51
GU39	5.48	5.32	55.77	4.37	19.89	90.83
GU40	4.55	4.25	43.02	3.60	14.83	70.24
GU41	0.22	0.73	3.43	0.27	1.36	6.02
GU42	0.88	0.93	9.62	0.60	3.94	15.97
GU43	0.47	1.13	7.42	0.36	1.67	11.05
GU44	4.26	2.78	24.95	2.01	10.26	44.25
GU45	3.71	6.39	72.61	4.34	21.76	108.81
GU46	0.56	1.27	7.80	0.53	3.66	13.82
GU47	0.75	1.03	14.01	0.81	4.58	21.19
GU48	0.25	0.83	3.46	0.16	0.80	5.50
GU49	0.78	1.03	5.58	0.31	1.29	9.00
GU50	0.81	1.49	16.90	0.92	5.28	25.39
GU51	1.09	1.71	8.02	0.54	3.97	15.32
GU52	1.31	1.79	19.18	1.37	9.10	32.75
GU53	1.73	3.12	18.02	1.82	9.37	34.05
GU54	3.50	2.82	21.98	1.93	9.72	39.95
GU55	6.37	5.63	218.85	9.83	43.38	284.06
GU56	1.53	3.19	39.18	2.43	10.42	56.75
GU57	1.46	3.08	19.67	1.63	10.09	35.92
GU58	1.00	1.59	26.35	1.74	10.37	41.04
GU59	0.93	1.03	8.76	0.62	3.93	15.28
Mean	1.62	2.23	22.37	1.54	6.92	34.68
Min	0.22	0.16	1.59	0.13	0.32	3.32
Max	6.37	7.86	218.85	9.83	43.38	284.06

Gymea Bay

Samples No	ErCr	ErNi	ErCu	ErZn	ErAs	ErPb	RI
GY1	3.75	8.06	29.18	4.41	5.38	20.36	71.14
GY2	5.36	9.17	33.19	4.99	6.97	21.65	81.33
GY3	0.67	1.88	3.16	0.34	1.79	2.06	9.92
GY4	1.08	1.13	2.91	0.70	3.62	2.75	12.18
GY5	5.60	9.92	33.41	5.34	6.85	23.89	85.00
GY6	0.69	1.69	4.18	0.45	3.69	2.14	12.83
GY7	0.45	1.15	3.54	0.42	1.85	2.44	9.85
GY8	4.97	8.69	28.57	4.38	5.90	20.06	72.57
GY9	1.88	7.18	26.59	4.00	6.56	24.15	70.36
GY10	0.81	1.35	4.42	0.39	2.38	3.22	12.56
GY11	1.39	2.22	5.69	0.94	4.08	5.15	19.46
GY12	5.02	9.52	30.05	4.90	6.31	22.53	78.34
GY13	3.77	7.46	25.60	4.28	5.44	20.49	67.04
GY14	0.34	1.96	2.64	0.29	1.74	1.05	8.02
GY15	0.61	1.45	2.31	0.25	0.51	1.07	6.20
GY16	1.26	1.88	3.10	0.39	0.64	1.81	9.08
GY17	0.65	1.61	5.44	0.54	0.67	2.22	11.13
GY18	0.62	1.23	2.45	0.33	0.62	1.22	6.46
GY19	3.51	5.46	14.45	1.76	4.41	11.88	41.47
GY20	0.67	1.29	2.14	0.32	1.28	1.86	7.56
GY21	1.12	1.35	4.67	0.47	2.72	3.59	13.92
GY22	0.66	1.19	3.50	0.85	3.26	4.86	14.32
GY23	1.28	0.65	5.69	0.68	4.26	3.87	16.43
GY24	1.07	2.24	4.62	0.96	0.67	1.93	11.49
GY25	0.69	1.25	3.24	0.97	0.88	2.10	9.15
GY26	1.09	0.79	4.34	0.51	1.28	2.07	10.09
GY27	0.65	1.71	3.82	0.49	0.54	2.35	9.55
GY28	1.98	2.30	9.18	1.78	2.97	7.84	26.05
GY29	0.81	1.33	5.66	1.97	1.03	5.31	16.11
GY30	1.05	2.12	11.73	0.68	1.03	2.39	19.00
GY31	1.05	2.06	4.59	0.44	0.97	1.25	10.37
GY32	0.60	1.01	2.97	0.49	1.46	1.47	8.01
Mean	1.72	3.20	10.22	1.55	2.87	7.22	26.78
Min	0.34	0.65	2.14	0.25	0.51	1.05	6.20
Max	5.60	9.92	33.41	5.34	6.97	24.15	85.00

Mansion Bay and Hacking River

Samples No	ErCu	ErZn	ErPb	RI
MA1	1.10	0.15	0.32	1.57
MA2	2.88	0.25	0.88	4.02
MA3	2.16	0.15	0.35	2.65
MA4	1.59	0.28	1.07	2.94
MA5	2.28	0.17	0.60	3.05
MA6	2.64	0.38	1.28	4.30
MA7	1.95	0.20	0.52	2.67
MA8	2.09	0.26	0.90	3.25
MA9	1.70	0.24	0.68	2.62
MA10	3.74	0.37	1.37	5.48
MA11	9.45	1.33	5.11	15.89
MA12	1.10	0.17	0.36	1.63
MA13	3.19	0.21	0.96	4.36
MA14	2.69	0.19	0.42	3.30
MA15	1.81	0.22	0.92	2.95
MA16	4.45	0.68	2.35	7.48
MA17	2.53	0.34	1.13	4.00
MA18	2.01	0.14	0.34	2.49
MA19	2.80	0.36	1.03	4.18
MA20	2.80	0.47	1.92	5.20
MA21	26.37	3.54	14.21	44.12
MA22	28.85	4.22	18.16	51.23
MA23	4.67	0.36	2.07	7.10
MA24	1.98	0.24	1.00	3.22
MA25	26.98	3.85	16.15	46.98
MA26	5.71	0.50	1.79	8.01
MA27	2.75	0.25	1.20	4.20
MA28	3.90	0.33	1.05	5.27
Mean	5.58	0.71	2.79	9.08
Min	1.10	0.14	0.32	1.57
Max	28.85	4.22	18.16	51.23

Yowie Bay

Samples No	ErNi	ErCu	ErZn	ErAs	ErPb	RI
YO1	1.15	8.96	1.32	3.13	8.61	23.17
YO2	4.48	25.05	3.30	2.62	14.79	50.24
YO3	1.90	10.82	1.90	2.67	8.89	26.19
YO4	4.37	30.00	4.32	4.87	24.44	68.00
YO5	5.83	33.08	4.71	5.23	30.90	79.75
YO6	1.31	6.87	1.00	1.79	6.07	17.04
YO7	2.70	7.47	0.55	2.10	3.12	15.94
YO8	7.90	59.01	7.24	7.49	37.71	119.35
YO9	2.78	9.73	1.18	3.74	8.06	25.48
YO10	2.82	9.23	0.92	4.05	6.73	23.75
YO11	7.58	43.41	5.46	8.72	27.39	92.55
YO12	0.71	3.24	0.36	1.03	1.97	7.31
YO13	0.67	2.53	0.39	0.82	1.45	5.87
YO14	0.91	4.84	1.05	2.21	5.09	14.08
YO15	0.95	2.47	0.38	1.33	2.09	7.24
YO16	3.65	4.07	0.40	1.33	1.35	10.80
YO17	7.86	32.58	4.58	5.28	21.90	72.20
YO18	6.94	20.38	3.17	6.15	13.53	50.18
YO19	5.36	26.59	3.45	5.64	18.48	59.53
YO20	6.23	33.30	4.54	6.31	30.62	80.99
YO21	6.47	32.97	4.66	5.95	20.06	70.11
Mean	3.93	19.36	2.61	3.93	13.96	43.80
Min	0.67	2.47	0.36	0.82	1.35	5.87
Max	7.90	59.01	7.24	8.72	37.71	119.35

South West Arm

Samples No	ErCu	ErZn	ErPb	RI
SWA1	7.20	0.80	4.51	12.50
SWA2	2.91	0.15	0.56	3.62
SWA3	2.69	0.17	0.75	3.61
SWA4	3.68	0.17	0.51	4.37
SWA5	2.34	0.11	0.11	2.55
SWA6	1.48	0.26	0.83	2.58
SWA7	3.54	0.11	0.25	3.90
SWA8	2.03	0.09	0.18	2.30
SWA9	2.97	0.14	0.41	3.51
SWA10	1.95	0.07	0.13	2.15
SWA11	2.36	0.07	0.17	2.61
SWA12	2.12	0.07	0.06	2.25
SWA13	2.88	0.11	0.15	3.15
SWA14	2.20	0.08	0.15	2.42
SWA15	2.17	0.07	0.13	2.37
SWA16	2.12	0.07	0.16	2.34
SWA17	27.58	3.90	15.49	46.97
SWA18	1.15	0.20	0.79	2.14
SWA19	6.15	0.80	3.10	10.05
SWA20	8.08	1.21	5.30	14.58

North West Arm

Sample No	ErCu	ErZn	ErPb	RI
NWA1	32.25	6.08	24.12	62.46
NWA2	3.24	0.83	3.61	7.68
NWA3	35.93	7.82	30.17	73.93
NWA4	42.09	9.94	33.93	85.96
NWA5	32.42	8.31	27.67	68.40
NWA6	5.66	0.99	2.50	9.15
NWA7	3.63	0.81	2.74	7.18
NWA8	2.31	0.64	2.37	5.32

Burraneer Bay

Sample No	ErNi	ErCu	ErZn	ErAs	ErPb	RI
gh 1	0.20	1.37	0.22	2.56	1.24	5.59
gh 2	0.20	2.25	0.22	2.00	1.39	6.06
gh 3	0.20	2.31	0.19	2.82	1.07	6.59
gh 4	0.36	1.81	0.20	1.79	1.09	5.26
gh 5	0.20	1.98	0.23	1.64	1.28	5.33
gh 6	0.63	1.59	0.26	1.28	1.50	5.26
gh 7	0.32	1.81	0.14	1.64	0.71	4.61
gh 8	2.82	12.80	2.52	5.49	9.94	33.56
gh 9	1.79	4.01	0.37	1.44	2.05	9.65
gh 10	3.02	13.41	2.24	4.62	9.27	32.55
gh 11	1.19	4.84	0.50	1.23	2.80	10.55
gh 12	0.20	2.20	0.39	1.18	1.75	5.72
gh 13	0.44	5.49	0.76	1.69	3.29	11.68
gh 14	9.40	4.01	0.42	0.82	2.24	16.90
gh 15	0.60	8.35	0.90	1.08	3.65	14.57
gh 16	0.95	8.02	0.86	1.85	4.62	16.30
gh 17	4.52	20.77	0.91	0.92	4.02	31.15
gh 18	2.74	55.82	3.30	4.51	21.60	87.98
gh 19	10.79	10.49	0.70	1.69	4.79	28.47
gh 20	2.86	11.54	2.35	1.23	4.85	22.83
gh 21	2.30	24.07	2.45	3.85	12.86	45.53
gh 22	1.39	13.57	1.02	1.23	5.04	22.26
gh 23	6.83	11.10	1.17	1.64	5.88	26.61
gh 24	2.82	53.19	3.59	4.51	11.94	76.05
gh 25	1.19	127.36	1.41	2.87	12.29	145.12
gh 26	1.63	6.98	0.56	0.87	2.84	12.88
gh 27	1.39	9.40	0.62	1.79	6.92	20.13
gh 28	1.79	8.13	1.09	2.15	5.32	18.48
gh 29	1.47	4.95	0.55	1.18	2.71	10.86
gh 30	1.03	5.60	0.40	1.38	3.03	11.46
gh 31	7.02	15.33	0.90	1.54	4.76	29.56
gh 32	0.63	5.99	0.80	1.13	5.36	13.91
gh 33	1.83	5.71	1.07	0.92	12.71	22.25
gh 34	1.19	15.27	1.07	1.08	6.43	25.05
gh 35	0.83	84.18	4.25	2.51	20.68	112.46
gh 36	1.90	13.79	1.33	2.05	8.12	27.19
gh 37	0.56	3.02	0.27	1.23	1.97	7.05
gh 38	2.50	7.64	0.99	2.05	5.64	18.82
gh 39	0.20	1.04	0.19	1.74	0.53	3.71
gh 40	0.79	1.98	0.12	1.59	0.30	4.78
gh 41	0.87	2.20	0.15	2.46	0.71	6.39
gh 42	0.60	1.10	0.12	2.21	0.75	4.77
gh 43	5.99	2.53	0.34	2.00	1.15	12.02
gh 44	0.20	2.20	0.21	1.79	0.94	5.35
gh 45	0.16	2.31	0.17	1.03	0.75	4.41
gh 46	0.16	2.31	0.24	1.90	1.54	6.14
gh 47	5.16	23.24	2.90	6.21	12.97	50.48
gh 48	5.28	25.16	3.00	5.74	12.69	51.88
gh 49	3.21	18.30	2.17	5.03	10.77	39.48
gh 50	1.43	9.18	1.09	4.00	6.45	22.14
gh 51	0.24	4.18	0.34	1.79	2.07	8.62
gh 52	3.13	28.08	2.57	5.33	15.90	55.01
gh 53	0.20	2.47	0.26	1.03	1.82	5.77
gh 54	0.20	6.32	0.55	2.92	3.97	13.96
gh 55	9.76	27.64	2.47	4.36	10.17	54.40
gh 56	0.56	12.64	0.91	2.77	5.04	21.92
gh 57	1.11	10.11	1.24	4.77	6.58	23.81
gh 58	1.35	12.69	1.43	4.31	7.69	27.47
gh 59	0.20	5.66	0.65	3.08	4.94	14.52
gh 60	0.71	7.86	0.71	2.21	4.15	15.63
gh 61	0.28	3.46	0.38	1.79	3.25	9.16
gh 62	1.47	13.57	1.12	3.49	6.20	25.84
gh 63	5.04	34.40	3.86	6.87	17.52	67.69
gh 64	2.02	14.95	1.61	4.77	8.21	31.55
gh 65	0.20	4.40	0.55	3.49	4.36	12.99
Mean	2.03	13.39	1.09	2.53	5.68	24.71
Min	0.16	1.04	0.12	0.82	0.30	3.71
Max	10.79	127.36	4.25	6.87	21.60	145.12

Oatley Bay

Sample No	ErCr	ErCu	ErZn	ErAs	ErPb	RI
OBu1	1.51	3.63	0.90	8.21	3.01	17.25
OBu2	1.80	13.52	2.78	7.54	9.94	35.56
OBu3	2.36	15.05	2.82	5.79	11.20	37.23
OBu4	3.67	50.93	9.03	11.28	31.24	106.15
OBu5	1.62	14.78	3.05	12.46	11.26	43.17
OBu6	3.01	22.09	4.48	12.67	16.13	58.38
OBu7	2.01	41.37	6.67	14.67	35.94	100.66
OBu8	1.30	29.29	5.85	18.51	39.91	94.87
OBu9	1.70	29.29	6.51	15.18	39.34	92.01
OBu10	5.06	15.38	3.37	12.62	21.56	57.99
OBu11	2.58	18.41	4.38	11.59	15.64	52.60
OBu12	0.47	19.34	4.55	20.31	50.19	94.87
OBu13	1.52	33.57	7.66	16.97	46.13	105.86
OBu14	2.63	38.68	8.97	13.49	33.70	97.46
OBu15	3.96	11.76	2.27	3.13	10.38	31.50
OBu16	6.29	11.26	2.75	11.95	12.97	45.23
OBu17	1.39	30.88	6.52	14.97	38.68	92.43
OBu18	2.05	18.35	3.92	6.51	21.09	51.93
OBu19	2.89	45.82	7.70	14.46	40.15	111.02
OBu20	1.57	34.12	6.79	14.67	32.18	89.33
OBu21	2.03	35.33	7.70	14.82	35.79	95.67
OBu22	3.01	43.96	9.09	13.18	36.30	105.54
OBu23	3.86	46.37	10.81	14.46	46.58	122.08
OBu24	7.75	31.21	8.06	9.03	29.66	85.70
OBu25	2.07	14.51	2.74	6.46	9.55	35.32
OBu26	1.47	26.76	5.64	16.77	37.07	87.71
OBu27	1.98	14.62	2.81	7.03	10.30	36.73
OBu28	2.23	27.75	6.03	11.44	27.37	74.81
OBu29	0.66	27.64	5.07	15.74	32.29	81.40
OBu30	2.35	18.68	4.07	11.23	16.45	52.79
OBu31	0.96	31.04	5.44	17.33	37.29	92.07
OBu32	2.69	9.56	1.50	3.13	7.71	24.58
OBu33	2.06	6.21	0.93	7.23	3.16	19.59
OBu34	1.80	11.15	2.20	11.03	13.40	39.58
OBu35	0.92	20.22	4.49	14.97	32.65	73.25
OBu36	3.01	10.11	2.15	5.95	8.91	30.13
OBu37	1.25	16.59	3.97	14.21	24.89	60.91
OBu38	2.09	9.89	2.33	7.44	8.63	30.38
OBu39	1.20	15.99	3.33	13.74	25.85	60.11
OBu40	1.98	8.13	1.72	11.23	8.82	31.88
OBu41	0.78	19.29	4.06	14.77	29.17	68.07
OBu42	1.55	12.91	2.15	5.79	7.63	30.03
OBu43	2.63	17.03	4.15	15.23	28.93	67.97
OBu44	1.81	11.59	2.15	5.85	7.33	28.73
OBu45	1.58	18.19	3.65	10.21	20.02	53.65
OBu46	1.15	18.30	4.13	12.77	22.80	59.14
OBu47	2.48	14.23	3.68	9.74	20.85	50.99
OBu48	4.91	15.22	2.91	12.56	20.32	55.92
OBu49	1.14	16.98	4.19	12.77	24.49	59.57
OBu50	1.77	15.44	4.07	11.69	21.47	54.44
OBu51	2.74	11.98	1.84	3.03	5.71	25.29
OBu52	4.12	10.38	2.33	10.51	16.15	43.50
OBu53	4.24	15.00	3.57	15.23	28.10	66.15
OBu54	1.29	15.16	3.15	12.00	19.51	51.12
OBu55	2.69	16.92	3.43	9.64	18.10	50.79
OBu56	3.73	16.26	3.16	13.38	19.94	56.48
OBu57	2.14	15.71	3.83	10.67	21.69	54.04
OBu58	1.68	20.71	4.15	16.72	32.59	75.85
OBu59	1.76	15.22	3.73	13.13	25.49	59.32
OBu60	1.86	19.73	3.70	16.05	35.11	76.44
OBu61	1.74	20.99	4.57	14.15	30.88	72.33
OBu62	1.09	18.02	4.74	14.31	31.20	69.35
OBu63	2.56	16.98	3.56	16.10	27.76	66.96
OBu64	2.05	12.14	2.57	5.38	8.93	31.07
OBu65	1.57	9.23	1.56	10.77	8.06	31.19
Mean	2.30	20.26	4.25	11.78	23.16	61.76
Min	0.47	3.63	0.90	3.03	3.01	17.25
Max	7.75	50.93	10.81	20.31	50.19	122.08

3.5 : Concentration for trace elements for International standard and Detection limits (D.L)

A- International Standard G-2

	V	Cr	Co	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Y	Zr	Mo	Cd	Sn	Sb	Cs	Ba	Ce	W	Hg	Pb	Bi	Th	U
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
G-2	36		5		11	86				170	478	11	309					1	1880	160	1		30		25	2.1
G-2	47	5	3.0	3	11	91	1	0	0	170	482	9	316	1.0	2.0	7	3.0	4.0	1876	166	1.0	0.3	32	1.0	26	4
G-2	51	3	3.0	3	10	90	0.5	0	0	170	478	9	322	1.0	6	2	3.0	4.0	1911	138	1.0	0.3	32	1.0	25.4	3.9
G-2	48	4	3.0	3	10	90	0	0	0	170	480	10	319	1.0	2.0	6	3.0	4.0	1880	182	1.0	0.3	31	1.0	25.4	3.1
G-2	49	5	3.0	3	10	90	0.5	0	0	169	479	9	318	1.0	2.0	5	3.0	4.0	1884	161	1.0	0.3	32	1.0	25.6	2.7
G-2	44	5	3.0	3	10	90	0.5	0	0.1	169	476	9	315	1.0	2.0	6	3.0	4.0	1921	189	1.0	0	32	1.0	25.8	2.6
G-2	45	6	3.0	3	12	91	0	0	0	170	479	9	316	1.0	2.0	4	3.0	4.0	1888	145	1.0	1.0	31	1.0	25.8	3.6
G-2	51	4	3.0	3	10	90	0.1	0	0	169	479	9	323	1.0	1	2	1	4.0	1883	132	1.0	0.3	32	0.1	26	3.1
G-2	47.1	7.6	3.0	3.1	9.9	90.3	0.2	0.4	0.2	169	479	9.4	325	1.0	0.8	6	3.0	4.0	1898	164	1.0	0.3	31.7	1.0	26.1	3.7
G-2	53.6	3.9	3.0	3	10.1	91.1	0.6	0.3	0.2	171	486	9.2	326	1.0	2.0	5	3.0	4.0	1892	140	1.0	1.0	31.4	1.0	26.4	2.9
G-2	52	4	3.0	3.7	13.3	90.2	0.5	0.5	0.2	170	481	9.2	325	1.0	2.0	2.4	0.8	4.0	1910	235	1.0	0.3	31.9	1.0	26.5	3.2
G-2	51	4	3.0	3	11	90	0.5	0	0	169	479	9	319	1.0	2.0	6	0.1	1.7	1846	121	1.0	1	32	1.0	25.5	3.4
G-2	47	6	3.0	3	10	91	0.5	0	0	170	481	9	326	1.0	1	4	3.0	4.0	1921	191	1.0	1.0	32	1.0	25.7	3.4
G-2	49	5	3.0	3	10	90	0	0	0	169	479	9	325	1.0	1	5	3.0	4.0	1896	201	1.0	1	32	1.0	25.9	2.6
G-2	50	5	3.0	3	10	90	0.5	0	0	170	478	9	321	1.0	2.0	7	3.0	4.0	1872	120	1.0	1.0	32	1.0	25.8	2.9
G-2	51	6	3.0	3	10	90	0.5	0	0	169	478	9	322	1.0	2.0	7	1	4.0	1874	147	1.0	0.3	32	1.0	25.8	3.8
G-2	54	5	3.0	3	12	90	0.2	0	0	169	481	9	319	1.0	1	5	2	1.0	1911	166	1.0	1	32	1.0	26	3.4
G-2	52	4	3.0	3	10	90	1	0	0	170	479	9	322	1.0	2.0	4	1	4.0	1882	190	1.0	1.0	31	1.0	26.1	2.2
G-2	46	4	3.0	3	10	90	0	0	0	169	479	10	319	1.0	2.0	4	1	4.0	1872	201	1.0	0.3	31	1.0	25.5	3.6
G-2	50	4	3.0	3	12	90	0	0	0.1	169	479	9	321	1.0	2.0	6	3.0	4.0	1884	201	1.0	0	31	0.3	25.4	2.4
G-2	52	3	3.0	4	10	91	0.2	0	0	169	481	9	321	1.0		4	3.0	4.0	1888	175	1.0	0.3	32	1.0	26.1	3
G-2	46	6	3.0	4	12	90	0.5	0	0.5	169	480	9	321	1.0	2.0	2	1	4.0	1904	173	1.0	1	32	1.0	25.9	3.5
G-2	51	6	3.0	5	11	90	0.5	0	0.1	168	478	10	321	1.0	2.0	6	1	4.0	1873	131	1.0	0	32	1.0	25.8	3.1
G-2	49	4	3.0	3	10	89	0	0	0	169	479	9	319	1.0	2.0	3	1	4.0	1958	198	1.0	0	32	1.0	26.1	2.3
G-2	48	4	3.0	3	13	90	0.5	0	0	170	479	9	322	1.0	2.0	6	3.0	0.1	1874	149	1.0	0.3	32	1.0	25.8	3.9
G-2	46	6	3.0	2	10	89	0.5	0	0	169	479	9	321	1.0	2.0	5	3.0	4.0	1893	199	1.0	1.0	32	1.0	26.1	3
G-2	47	5	3.0	3	10	91	0	0	0	169	480	9	321	1.0	0.1	4	1	4.0	1888	184	1.0	0.3	32	1.0	26.4	3
G-2	47	5	3.0	3	10	91	0	0	0	170	480	10	322	1.0	0	2	3.0	4.0	1877	173	1.0	0.3	32	1.0	26.0	2.6
G-2	50	4	3.0	2	10	91	0.2	0	0	171	483	9	323	1.0	0.1	3	3.0	2.0	1924	216	1.0	0.3	32	1.0	26	3.5
G-2	48	4	3.8	3	13	90	0	0	0	170	480	9	323	1.0	2.0	5	3.0	0.4	1910	189	1.0	0.3	32	1.0	26.1	3.8
G-2	45	6	3.0	3	10	90	0	0	0	169	479	9	321	1.0	2.0	5	3.0	4.0	1902	181	1.0	1.0	31	1.0	25.6	3.5
G-2	45.4	6.3	3.0	2.4	9.5	89.6	0.3	0.3	0.3	170	478	9.3	321	1.0	2.0	4.1	2.3	4.0	1913	215	1.0	1.0	31.4	1.0	26.1	3.1
G-2	71	20	3.0	3	13	91	0.5	0	0	170	479	9	319	1.0	1	4	15	48	755	34	1.0	0.3	32	1.0	25.5	2.9
G-2	47	6	3.0	3	10	90	0.5	0	0	170	478	9	324	1.0	0	5	1	4.0	1880	121	1.0	1.0	32	1.0	26	3
G-2	52	16	3.0	3	10	90	0.5	0	0	170	480	9	318	1.0	1	6	16	49	752	34	1.0	1.0	32	1.0	26.5	2.6
G-2	52.4	4.9	3.0	2.4	10.1	89.7	0.5	0.3	0.3	170	481	9.2	328	1.0	2.0	5.1	3.0	4.0	1965	36	1.0	1.0	31.2		26.7	2.8
Mean	49.2	5.6	3.1	3.0	10.7	90.1	0.3	0.1	0.1	169	480	9.2	321	1.0	1.7	4.6	3.0	6.0	1832	160	1.0	0.6	31.7	1.0	25.9	3.1
SD.	5.0	3.3	0.4	0.5	1.1	0.9	0.3	0.1	0.1	0.7	1.7	0.4	3.6	0.0	1.0	1.5	3.3	10.5	266.2	47.9	0.0	0.4	0.5	0.2	0.4	0.5
D.L.	1	1	1	1	0.5	0.5	0.5	0.5	0.5	0.5	1	0.5	1	1	1	3	3	4	1	0.2	1	1	1	1	1	1

B- BIR-1

	V	Cr	Co	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Y	Zr	Mo	Cd	Sn	Sb	Cs	Ba	Ce	W	Hg	Pb	Bi	Th	U
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
BIR-1	313	382	51	166	126	71				1	108	16							7	2						
BIR-1	326	414	51	164	132	68	0.5	0.5	0	1	110	16	13	1.0	3.0	3.0	3.0	4.0	27	0.1	2	1.0	2	1.0	1.0	1.0
BIR-1	316	403	52	165	130	68	0.5	0.5	0.5	1	109	17	13	1.0	1	3.0	3.0	4.0	1.7	2.0	1	0	2	1.0	1.0	1.0
BIR-1	329	414	55	162	130	69	0.5	0.5	0.5	1	110	17	14	1.0	0	3.0	3.0	4.0	1.7	2.0	1	1.0	2	1.0	1.0	1.0
BIR-1	324	403	54	161	127	68	0.5	0.5	0.5	1	110	17	13	1.0	2.0	3.0	3.0	4.0	1.7	6	1	1.0	2	1.0	1.0	1.0
BIR-1	327.1	419	61	164	129	69	0.5	0.5	0.5	1	110	17	13	1.0	1	3.0	3.0	4.0	30	0.2	1	1.0	2	1.0	1.0	1.0
BIR-1	320.6	396	57	163	129	67	0.5	0.5	0.5	1	108	16	13	1.0	2.0	3.0	3.0	4.0	1.6	2.0	1	1.0	2	1.0	1.0	1.0
BIR-1	373.7	423	61.7	166	131	69	0.5	0.5	0.5	0.9	110	16.5	14.1	1.0	2.0	3.0	3.0	4.0	1.7	2.0	0.9	0.3	2.1	1.0	1.0	1.0
BIR-1	328.5	403	59.7	166	131	68.7	0.5	0.5	0.5	1.1	111	16.6	13.8	1.0	2.0	3.0	3.0	4.0	1.7	2.0	1.8	1.0	2.1	1.0	0.6	1.0
BIR-1	330.5	417	56.9	166	130	69.3	0.5	0.5	0.1	0.9	110	16.6	13.4	1.0	2.0	3.0	3.0	4.0	24.4	0.1	2	1.0	1.9	1.0	1.0	1.0
BIR-1	322	400	51	162	128	68	0.5	0.5	0.1	1	110	17	13	1.0	2.0	3.0	3.0	4.0	1.7	2.0	2	1.0	2	1.0	1.0	1.0
BIR-1	329	413	60	165	133	69	0.5	0.5	0.5	1	111	17	13	1.0	2.0	3.0	3.0	4.0	1.7	2.0	1	1.0	2	1.0	1.0	1.0
BIR-1	317	409	47	163	128	68	0.5	0.5	0.5	1	110	17	13	1.0	1	3.0	3	4.0	1.7	2.0	1	0.6	2	1.0	1.0	1.0
BIR-1	325	414	61	164	131	69	0.5	0.5	0.5	1	110	17	13	1.0	2.0	3.0	3.0	4.0	1.7	2.0	2	1.0	2	1.0	1.0	1.0
BIR-1	327	409	61	162	130	69	0.5	0.5	0.5	1	109	16	13	1.0	2.0	3.0	3.0	4.0	1.7	2.0	2	1.0	2	1.0	1.0	1.0
BIR-1	342	418	56	165	132	69	0.5	0.5	0.5	1	110	17	13	1.0	2.0	3.0	3.0	4.0	23	29	1	1.0	2	1.0	1.0	1.0
BIR-1	329	408	53	163	130	68	0.5	0.5	0.5	1	110	17	13	1.0	1	3.0	3.0	4.0	1.7	1	1	0.5	2	1.0	1.0	1.0
BIR-1	339.7	412	55	166	132	68	0.5	0.5	0.5	1	110	17	13	1.0	0	3.0	3.0	4.0	21	3	1	1.0	2	1.0	1.0	1.0
BIR-1	323.3	405	62	164	130	68.3	0.5	0.5	0.5	1	110	17	13	1.0		3.0	3.0	4.0	15	0.1	2	1.0	2	1.0	1.0	1.0
BIR-1	332.6	409	57	165	132	69	0.5	0.5	0.5	1	110	17	13	1.0	1	3.0	3.0	4.0	1.7	2.0	1	1.0	2	1.0	1.0	1.0
BIR-1	334	410	49	168	127	68	0.5	0.5	0.5	1	109	16	13	1.0	2.0	3.0	2	4.0	25	0.1	2	1.0	2	1.0	1.0	1.0
BIR-1	317	403	54	163	129	68	0.5	0.5	0.1	1	110	17	13	1.0	2.0	3.0	3.0	4.0	26	16	1	1.0	2	1.0	1.0	1.0
BIR-1	323.9	410	45	161	125	69	0.5	0.5	0.5	1	109	17	13	1.0	2.0	3.0	3.0	4.0	24	0.1	1	1.0	2	1.0	1.0	1.0
BIR-1	334	404	54	163	132	69	0.5	0.5	0.5	1	110	16	13	1.0	0.1	3.0	3.0	4.0	1.7	14	3	1.0	2	1.0	1.0	1.0
BIR-1	328	410	55	163	130	68	0.5	0.5	0.5	1	110	17	13	1.0	2.0	3.0	3.0	4.0	1.7	2.0	1	1.0	2	1.0	1.0	1.0
BIR-1	315	403	53	162	127	68	0.5	0.5	0.5	1	110	17	13	1.0	2.0	3.0	3.0	4.0	23	0.1	1	1.0	2	1.0	1.0	1.0
BIR-1	325.4	404	47	161	127	68	0.5	0.5	0.5	1	110	17	13	1.0	2.0	3.0	3.0	4.0	1.7	2.0	2	1	3	1.0	1.0	1.0
BIR-1	328.1	412	58	162	130	69	0.5	0.5	0.5	1	110	17	13	1.0	2.0	3.0	3.0	4.0	25	0.1	3	1.0	2	1.0	1.0	1.0
BIR-1	322.3	408	58	162	129	69	0.5	0.5	0.5	1	109	16	13	1.0	0.1	3.0	3.0	4.0	1.7	2.0	1	1.0	2	1.0	1.0	1.0
BIR-1		406	49.3	165	131	68	0.5	0.5	0.5	1	109	17	13	1.0	2.0	3.0	3.0	4.0	24	0.1	1	1.0	2	1.0	1.0	1.0
BIR-1	334.2	416	55.4	168	129	68.9	0.5	0.5	0.5	1	110	16.5	13.3	1.0	2.0	3.0	3.0	4.0	1.7	7.9	2.4	0.8	2.7	1.0	1.0	1.0
BIR-1	327	413	60	168	130	69	0.5	0.5	0.5	1	110	17	13	1.0	0	3.0	12	39	37	0.2	2	0.5	2	1.0	1.0	1.0
BIR-1	332	407	53	167	130	68	0.5	0.5	0.1	1	109	17	13	1.0	0.3	3.0	3	4.0	19	7	1	1.0	2	1.0	1.0	1.0
BIR-1	333	407	53	163	130	69	0.5	0.5	0.5	1	109	16	13	1.0	1	3.0	12	41	33	0	1	1.0	2	1.0	1.0	1.0
BIR-1	334.9	417	58.7	164	130	67.6	0.5	0.5	0.2	0.9	111	16.7	13.5	1.0	0.6	3.0	3.0	4.0	26.2		2.2	1.0	2		1.0	1.0
Mean	328.3	408.6	55.0	164.1	130	68.5	0.5	0.5	0.4	1.0	110	16.7	13.1	1.0	1.5	3.0	3.5	6.1	12.6	3.4	1.5	0.9	1.2	1.0	1.0	1.0
SD.	10.5	7.5	4.5	2.0	1.9	0.7	0.0	0.0	0.2	0.0	0.7	0.4	0.3	0.0	0.8	0.0	2.2	8.6	12.2	5.8	0.6	0.2	0.2	0.0	0.1	0.0

C- AC-E

	V	Cr	Co	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Y	Zr	Mo	Cd	Sn	Sb	Cs	Ba	Ce	W	Hg	Pb	Bi	Th	U
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
AC-E	3	3	1	2	4	224	2			152	3	184	780	3	1	13	1	3	55	154	2		39		18.5	4.6
AC-E	1	1	3	9	5	231	2	0.5	1	151	2	190	876	1.0	22	3.0	3.0	4.0	66	154	2	1.0	38	1.0	18.9	4
AC-E	1.0	1.0	3.0	9	5	231	1	0.5	0	151	2	191	871	1.0	1	19	3.0	4.0	60	174	3	1.0	39	1.0	18.6	4.4
AC-E	1.0	1.0	3.7	9	6	231	2	0.5	1	151	3	190	876	1.0	0.1	20	3.0	4.0	66	184	3	1.0	38	1.0	18.6	3.5
AC-E	1.0	1.0	5	9	5	231	2	0.5	1	150	2	190	870	1.0	1	19	3.0	4.0	66	184	2	1.0	38	1.0	17.8	4.5
AC-E	1.0	1.0	8	10	6	233	1	0.5	1	151	2	191	875	1.0	2.0	23	3.0	4.0	61	159	4	1.0	39	1.0	18.3	3.9
AC-E	1.0	1.0	3.7	9	6	228	2	0.5	1	150	2	189	873	1.0	0	20	3.0	4.0	63	156	3	1.0	38	1.0	19.1	4.2
AC-E	1.0	1.0	4	9	6	232	1	0.5	1	152	2	192	866	1.0	0	19	3.0	4.0	62	184	4	1.0	39	1.0	17.9	4.1
AC-E	1.0	1.0	5.7	8.9	5.5	231.3	1.7	0.5	0.4	151	2.3	191	885	1.0	0.5	18.3	3.0	4.0	62.1	177	3	1.0	38.5	1.0	18.1	4.9
AC-E	1.0	1.0	3.7	9.2	5.5	232.3	1.2	0.5	0.6	152	2.4	193	890	1.0	2.0	17.9	3.0	4.0	37.9	169	4	1.0	39.2	1.0	18.5	4.4
AC-E	1.0	1.0	3.7	9.6	5.2	230.4	0.8	0.5	0.4	151	2.4	191	886	1.0	0.1	18.8	3.0	4.0	67.2	194	3.5	0.4	39.2	1.0	18.7	4.6
AC-E	1.0	1.0	3.8	9	6	231	2	0.5	1	152	2	193	894	1.0	2.0	18	3.0	4.0	65	167	4	1.0	39	1.0	19.1	4.3
AC-E	1.0	1.0	3.0	9	6	232	1	0.5	0	151	2	192	884	1.0	1	19	3.0	4.0	59	197	3	1.0	39	1.0	18.2	4.4
AC-E	1.0	1.0	5	9	5	230	2	0.5	0	151	2	191	875	1.0	2.0	18	3.0	4.0	54	157	3	1.0	38	1.0	18.4	4
AC-E	1.0	1.0	4	9	5	231	2	0.5	1	150	2	190	875	1.0	2.0	20	3.0	4.0	57	154	2	1.0	38	1.0	18.9	5.1
AC-E	1.0	1.0	3.8	9	5	231	2	0.5	1	151	3	191	881	1.0	0	18	3.0	4.0	61	159	2	1.0	38	1.0	18.3	4.2
AC-E	1.0	1.0	5	9	5	231	1	0.5	1	151	3	191	876	1.0	0	19	3.0	4.0	59	158	3	1.0	39	1.0	17.9	4.5
AC-E	1.0	1.0	3.7	9	5	230	1	0.5	0	151	2	192	872	1.0	2.0	20	3.0	4.0	52	196	3	1.0	39	1.0	18	4.2
AC-E	1.0	1.0	3.0	10	5	231	2	0.5	1	151	2	191	874	1.0	2.0	18	3.0	4.0	59	177	2	1.0	39	1.0	18.3	4.1
AC-E	1.0	1.0	6	27	5	231	2	0.5	1	150	2	191	886	1.0	2.0	18	3.0	4.0	63	174	2	1.0	38	1.0	18.4	4.7
AC-E	1.0	1.0	5	9	6	231	2	0.5	1	151	2	191	876	1.0		24	3.0	4.0	66	165	3	1.0	38	1.0	18.5	3.6
AC-E	1.0	1.0	3.7	9	6	231	1	0.5	1	151	2	190	871	1.0	2.0	18	3.0	4.0	52	188	3	1.0	39	1.0	18.5	4.2
AC-E	1.0	1.0	3.0	9	5	230	2	0.5	1	150	2	191	875	1.0	2.0	21	3.0	4.0	56	147	3	1.0	38	1.0	18.4	4.9
AC-E	1.0	1.0	5	9	4	230	1	0.5	1	151	2	191	881	1.0	1	20	3.0	4.0	67	166	3	1.0	39	1.0	18.9	4.5
AC-E	1.0	1.0	3.7	9	5	230	2	0.5	1	151	2	190	873	1.0	1	25	3.0	4.0	61	158	6	1.0	39	1.0	18.6	5.1
AC-E	1.0	1.0	3.0	9	5	229	2	0.5	1	151	2	191	879	1.0	2.0	20	3.0	4.0	57	170	4	1.0	38	1.0	18.4	4.3
AC-E	1.0	1.0	5	9	6	231	2	0.5	1	151	2	190	875	1.0	2.0	21	3.0	4.0	60	171	3	1.0	38	1.0	18.3	3.7
AC-E	1.0	1.0	3.0	9	6	232	2	0.5	0	151	2	191	878	1.0	2.0	19	3.0	4.0	63	147	3	1.0	38	1.0	18.5	4.1
AC-E	1.0	1.0	3.0	9	5	230	2	0.5	0	151	2	191	876	1.0	1	20	3.0	4.0	63	171	3	1.0	38	1.0	18.8	4.1
AC-E	1.0	1.0	3.7	9	5	231	2	0.5	0	151	2	191	879	1.0	2.0	21	3.0	4.0	51	176	3	1.0	38	1.0	18.8	3.6
AC-E	1.0	1.0	3.7	9	5	230	1	0.5	1	151	2	191	881	1.0	0.1	20	3.0	4.0	64	172	4	1.0	39	1.0	18.9	3.8
AC-E	1.0	1.0	3.7	9	6	231	1	0.5	1	150	2	190	879	1.0	2.0	21	3.0	4.0	58	179	3	1.0	39	1.0	18.5	3.7
ACE	1.0	1.0	3.7	9	5	228	2	0.5	0	151	2	190	882	1.0	2.0	21	3.0	4.0	67	201	2	1.0	38	1.0	18.9	4
AC-E	1.0	1.0	3.7	14	6	229	2	0.5	1	150	3	189	878	1.0	1	15	14	43	61	57	2	1.0	38	1.0	18.6	4.6
AC-E	1.0	1.0	5	9	5	231	2	0.5	0	151	2	191	877	1.0	2.0	19	3.0	4.0	53	169	4	1.0	38	1.0	18.8	4.7
AC-E	4	7	3.7	8	5	227	2	0.5	0	150	2	190	871	1.0	1	15	11	42	54	29	3	1.0	38	1.0	18.7	4.3
AC-E	1.0	1.0	3.7	8.8	5.4	227	1.3	0.5	0.6	150	2.4	190	893	1.0	0.4	22.6	3.0	4.0	57.9		3.3	1.0	38.3		18.8	4.2
Mean	1.1	1.2	4.0	9.5	5.3	230	1.6	0.5	0.7	151	2.2	191	875	1.1	1.8	19.0	3.5	6.1	59.6	164	3.0	1.0	38.5	1.0	18.5	4.3
SD.	0.6	1.0	1.2	3.3	0.6	1.7	0.5	0.0	0.4	0.6	0.4	1.4	17.3	0.3	3.5	3.5	2.2	8.8	5.9	33.0	0.8	0.1	0.5	0.0	0.3	0.4

Appendix 4: Statistical analysis (Hierarchical cluster (HCA) and Principle Component analysis (PCA))

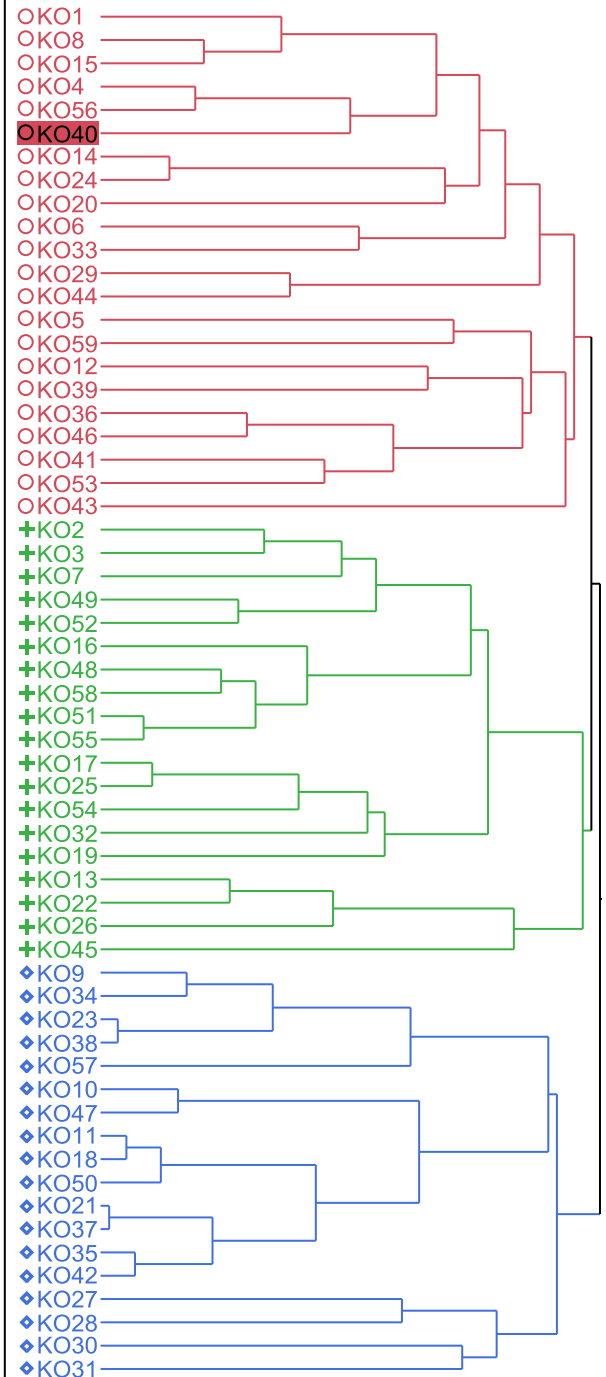
4.1 Kogarah Bay (HCA)

Variables	Cluster A	Cluster B	Cluster C
Depth	2.30	3.11	1.14
Sand	23.95	7.09	81.58
Silt	61.71	74.56	14.89
Clay	14.34	18.34	3.54
Mean Size	100.54	25.94	380.80
StdD	2.15	6.36	1.77
GsKew	-0.13	0.11	0.40
Kurt	1.06	1.03	1.64
S	4151.64	1201.20	2116.96
Cl	113583.6	270173.6	30575.2
V	72.62	38.37	15.72
Cr	55.70	21.44	17.64
Co	8.67	7.09	4.86
Ni	16.10	15.33	4.29
Cu	51.83	41.09	13.90
Zn	210.70	206.52	42.69
As	12.40	20.98	3.27
Br	200.69	148.93	50.43
Rb	51.54	77.19	14.53
Sr	127.62	137.56	44.16
Cd	1.13	1.38	1.32
Sn	11.30	12.38	10.52
Ba	146.30	187.30	71.24
Ce	49.67	72.58	10.47
Pb	85.19	142.20	20.48
Th	7.66	20.11	1.38
U	1.23	2.58	1.00
Quartz	64.15	47.14	88.82
Feldspar	6.42	7.87	5.47
Calcite	1.62	1.41	2.28
Ankerite	0.43	0.26	0.60
Siderite	0.28	0.48	0.27
Kaolinite	11.15	17.94	1.68
Chlorite	2.67	3.13	0.93
Illite	11.16	18.18	1.01
Pyrite	0.97	1.65	0.21
Gypsum	2.00	2.30	1.51

Hierarchical Clustering

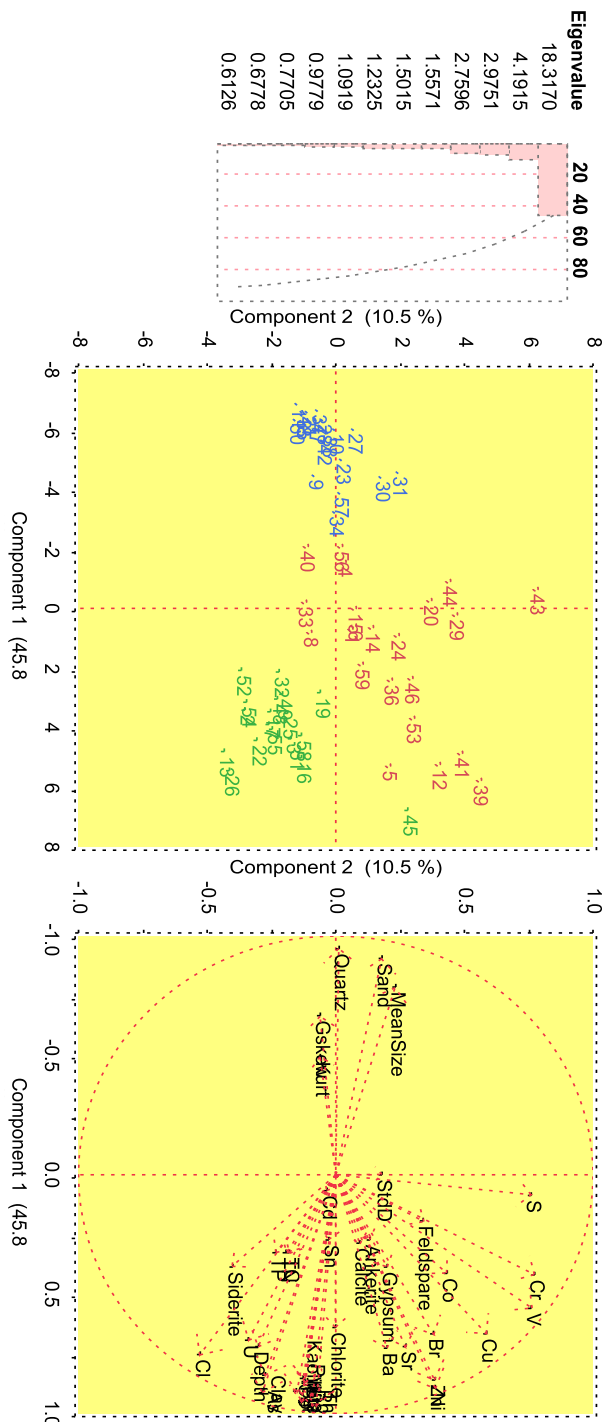
Method War

Dendrogram



Kogarah Bay (PCA)

	PCA1	PCA2
Eigenvalue	18.317	4.1915
Components	45.80%	10.50%
KO1	0.712	0.450
KO2	3.439	-2.817
KO3	4.394	-1.382
KO4	-1.568	0.187
KO5	5.293	1.626
KO6	0.596	0.515
KO7	3.882	-2.088
KO8	0.818	-0.849
KO9	-4.465	-0.688
KO10	-6.043	-0.036
KO11	-6.854	-1.223
KO12	5.219	3.146
KO13	4.787	-3.461
KO14	0.614	1.082
KO15	0.016	0.521
KO16	5.005	-1.092
KO17	3.461	-2.037
KO18	-6.634	-1.050
KO19	2.809	-0.470
KO20	-0.264	2.864
KO21	-6.603	-0.883
KO22	4.419	-2.440
KO23	-5.028	0.141
KO24	0.901	1.862
KO25	3.544	-1.483
KO26	5.439	-3.329
KO27	-6.040	0.520
KO28	-6.331	-0.443
KO29	0.220	3.668
KO30	-4.451	1.378
KO31	-4.575	1.932
KO32	2.141	-1.754
KO33	-0.205	-1.039
KO34	-3.255	-0.076
KO35	-6.503	-1.075
KO36	2.382	1.660
KO37	-6.683	-0.587
KO38	-5.916	-0.263
KO39	5.743	4.424
KO40	-2.060	-0.946
KO41	4.858	3.824
KO42	-5.676	-0.436
KO43	-0.627	6.212
KO44	-0.909	3.492
KO45	6.772	2.218
KO46	2.325	2.301
KO47	-6.354	-0.621
KO48	3.019	-1.813
KO49	2.896	-1.646
KO50	-6.344	-1.274
KO51	4.598	-1.261
KO52	2.077	-2.931
KO53	3.676	2.348
KO54	3.138	-2.776
KO55	4.054	-1.981
KO56	-2.080	0.113
KO57	-3.878	0.086
KO58	4.241	-1.070
KO59	1.857	0.755



Principal Components: on Correlations

Summary Plots

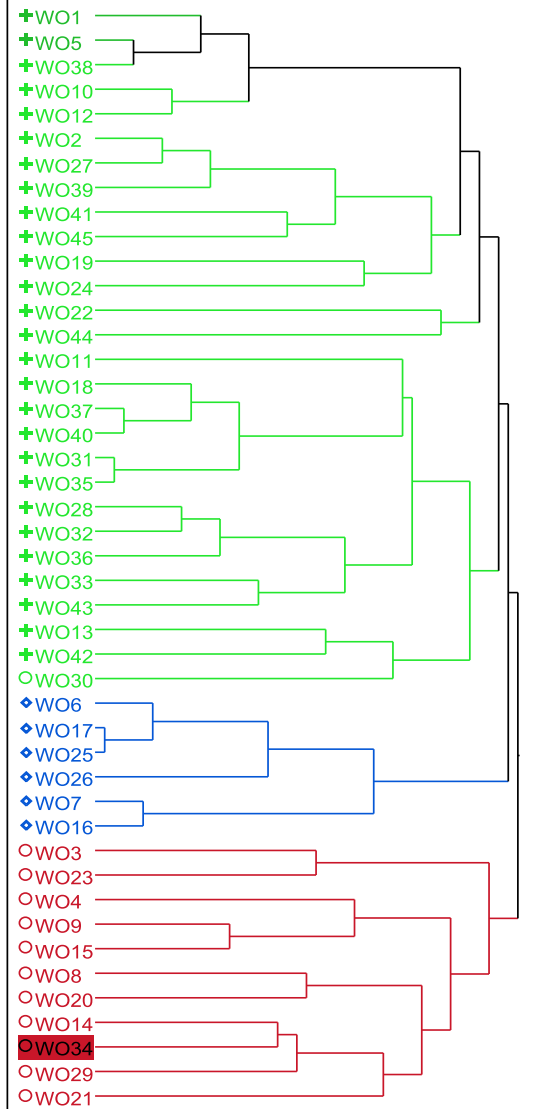
4.2 Woollooware Bay (HCA)

Variables	Cluster A	Cluster B	Cluster C
Depth	2.6	1.7	1.0
Sand	15.8	38.0	90.7
Silt	70.8	51.3	8.0
Clay	13.3	10.6	1.3
Mean Size	48.0	134.1	309.6
StdD	2.0	2.5	1.0
GsKew	-0.2	0.0	0.3
Kurt	1.1	0.8	2.2
S	3617.9	4092.1	2699.4
Cl	177748.2	84630.0	27218.0
V	80.1	46.9	1.3
Cr	61.9	43.9	7.3
Co	9.8	9.2	4.2
Ni	19.6	11.0	2.9
Cu	33.7	19.7	4.4
Zn	209.6	102.5	10.4
As	18.3	9.8	1.5
Br	315.0	128.3	46.8
Rb	69.4	38.0	12.9
Sr	200.6	155.4	19.1
Zr	157.3	122.1	43.4
Cd	1.9	1.3	0.8
Sn	9.3	8.7	6.6
Ba	146.3	103.3	71.5
Ce	64.3	34.6	8.7
Pb	69.3	31.1	4.1
Th	11.2	4.8	0.7
U	2.7	1.0	1.0
Quartz	40.9	73.0	93.0
Feldspar	6.9	5.8	4.3
Calcite	3.0	1.7	0.2
Ankerite	0.3	1.2	
Siderite	0.9	0.5	0.4
Kaolinite	19.7	7.1	0.5
Chlorite	3.7	1.6	1.5
Illite	18.9	7.4	0.7
Pyrite	2.4	1.3	0.1
Gypsum	2.2	2.2	1.1

Hierarchical Clustering

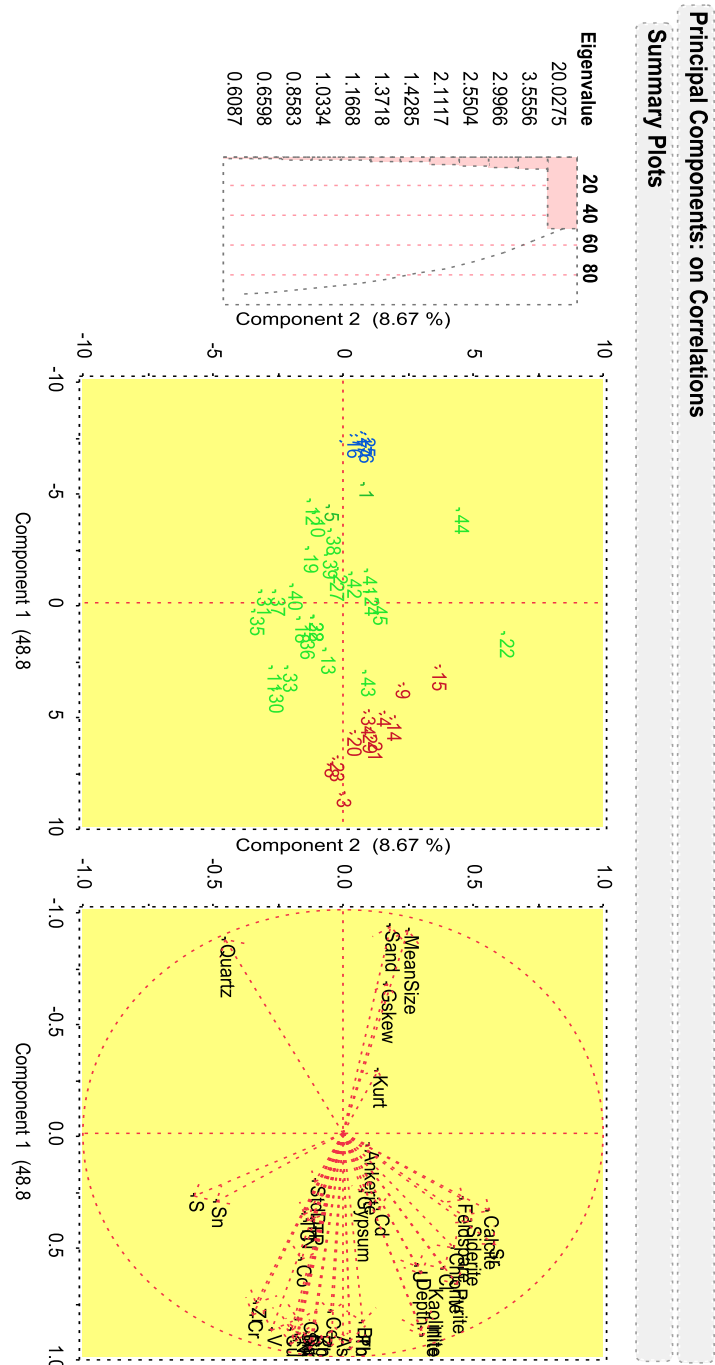
Method War

Dendrogram



Woollooware Bay (PCA)

	PCA1	PCA2
Eigenvalue	20.0275	3.5556
Components	48.80%	8.67%
WO1	-5.280	0.784
WO2	-1.458	-0.174
WO3	8.539	-0.087
WO4	4.909	1.437
WO5	-4.252	-0.513
WO6	-6.833	0.830
WO7	-7.558	0.513
WO8	7.211	-0.521
WO9	3.673	2.224
WO10	-3.990	-1.055
WO11	2.931	-2.720
WO12	-4.542	-1.275
WO13	2.119	-0.678
WO14	5.156	1.875
WO15	2.856	3.610
WO16	-7.531	0.300
WO17	-7.679	0.732
WO18	0.735	-1.656
WO19	-2.429	-1.328
WO20	5.819	0.312
WO21	5.981	1.115
WO22	1.372	6.175
WO23	6.918	-0.364
WO24	-0.485	0.970
WO25	-7.603	0.842
WO26	-7.276	-0.090
WO27	-1.104	-0.350
WO28	0.685	-1.142
WO29	5.640	0.953
WO30	3.882	-2.633
WO31	-0.448	-3.140
WO32	0.697	-1.164
WO33	2.919	-2.120
WO34	4.855	0.839
WO35	0.419	-3.369
WO36	1.467	-1.439
WO37	-0.490	-2.627
WO38	-3.231	-0.435
WO39	-2.103	-0.599
WO40	-0.736	-1.953
WO41	-1.416	0.938
WO42	-1.273	0.305
WO43	3.130	0.891
WO44	-4.147	4.456
WO45	-0.047	1.332



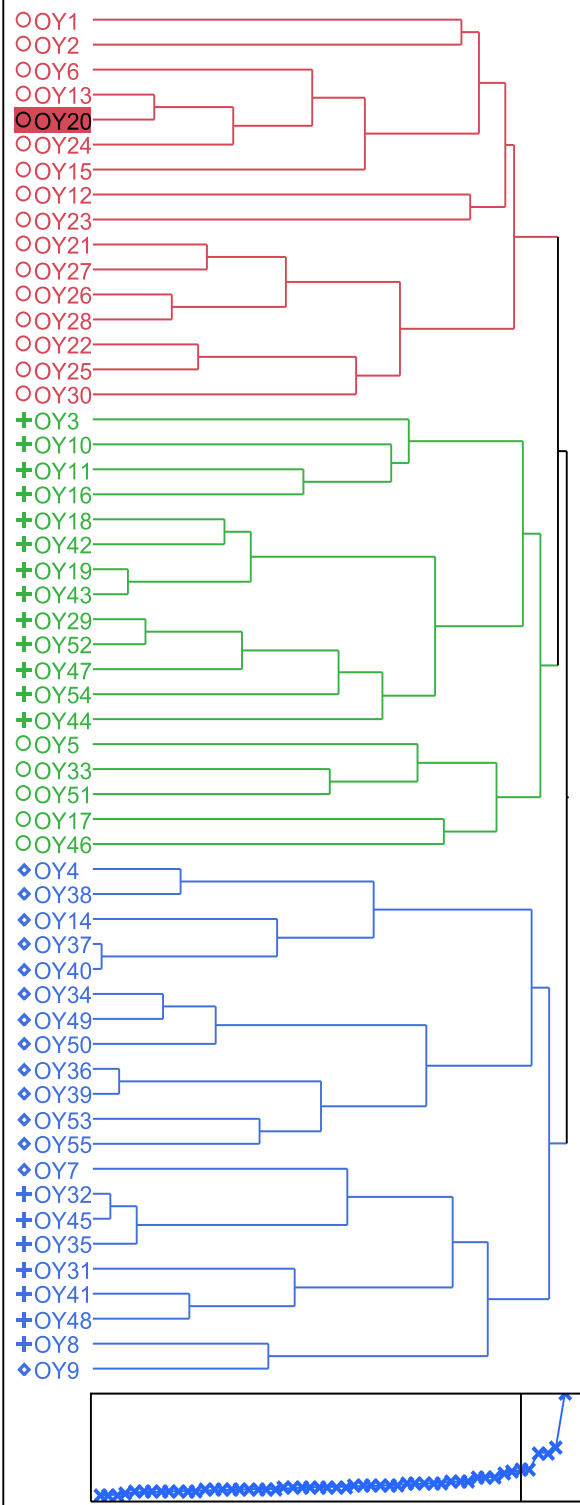
4.3 Oyster Bay (HCA)

Variables	Cluster A	Cluster B	Cluster C
Depth	1.09	1.00	0.71
Sand	7.08	9.31	36.94
Silt	75.29	74.14	50.30
Clay	17.63	16.56	12.75
Mean Size	27.68	32.41	170.34
StdD	1.64	1.70	2.67
GsKew	-0.07	-0.08	-0.08
Kurt	1.17	1.08	0.84
S	661.63	3796.61	3525.88
Cl	283468.7	123156.67	49227.62
V	29.28	93.09	51.32
Cr	18.57	76.32	55.07
Co	12.96	10.04	7.07
Ni	14.59	24.91	15.95
Cu	31.88	47.63	25.41
Zn	185.98	290.76	144.04
As	21.95	17.34	8.45
Se	0.69	0.46	0.44
Br	131.53	185.92	98.92
Rb	72.55	75.24	34.04
Sr	122.72	122.17	64.53
Zr	218.94	229.78	186.37
Cd	1.07	1.20	1.22
Sn	12.28	12.17	9.89
Ba	188.19	177.16	96.80
Ce	72.51	69.61	34.47
Pb	149.79	109.74	47.34
Th	10.88	12.05	5.01
U	1.55	1.81	0.98
Quartz	47.2	47.8	76.1
Feldspar	6.5	6.9	4.70
Calcite	0.68	0.74	0.31
Ankerite	0.25	0.10	0.10
Siderite	0.45	0.53	0.27
Kaolinite	18.70	17.99	7.45
Chlorite	2.35	2.24	1.51
Illite	18.64	17.79	7.73
Pyrite	1.39	1.32	0.49
Gypsum	2.88	3.00	2.58

Hierarchical Clustering

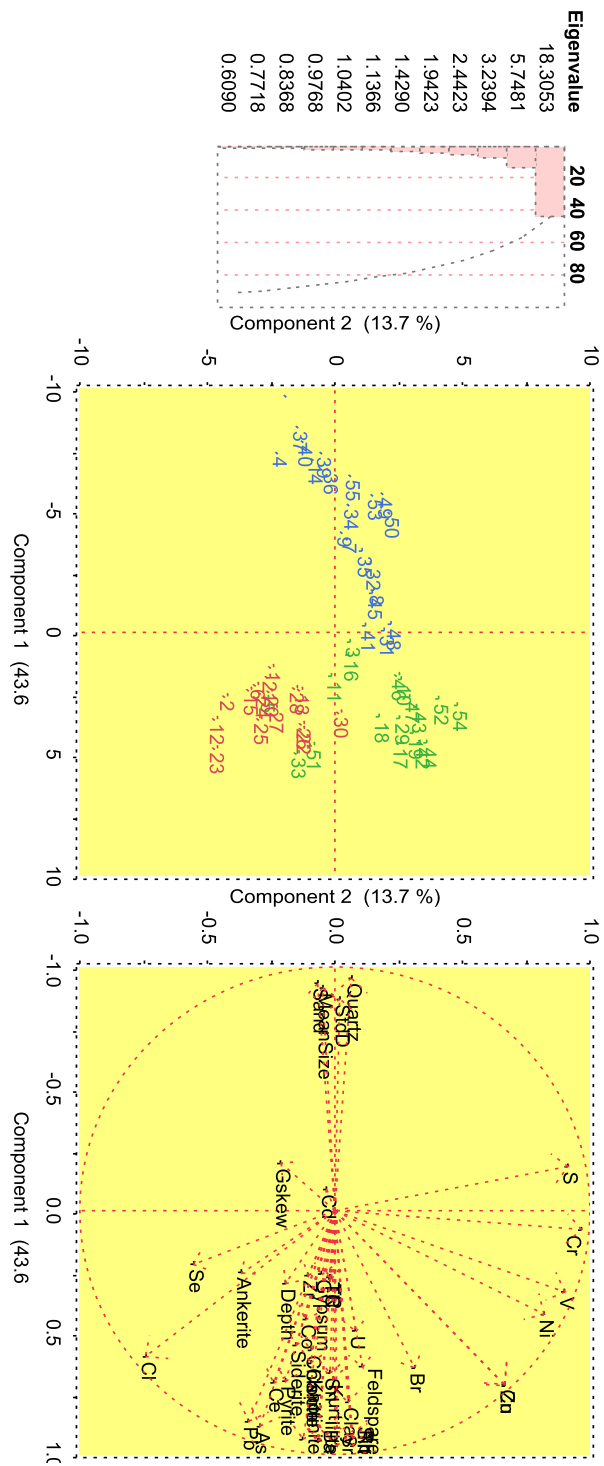
Method War

Dendrogram



Oyster Bay (PCA)

	PCA1	PCA2
Eigenvalue	18.3053	5.7481
Components	43.6 %	13.7 %
OY1	1.41352	-2.53836
OY2	2.586053	-4.33376
OY3	0.389794	0.590051
OY4	-7.38192	-2.24414
OY5	2.665967	-2.75731
OY6	2.149729	-3.13826
OY7	-3.86067	0.444736
OY8	-1.74645	1.53969
OY9	-4.16509	0.264866
OY10	1.935572	2.584049
OY11	1.810043	-0.15781
OY12	3.526075	-4.74867
OY13	2.346551	-1.37629
OY14	-7.10598	-0.84477
OY15	2.334665	-3.36985
OY16	0.917582	0.503991
OY17	4.505226	2.489973
OY18	3.434639	1.712028
OY19	4.119256	3.054733
OY20	2.432133	-2.60403
OY21	1.833243	-2.67788
OY22	3.916497	-1.33742
OY23	4.7272	-4.71668
OY24	2.438367	-2.92219
OY25	3.540857	-2.96918
OY26	3.719607	-1.36596
OY27	3.067165	-2.40188
OY28	2.258771	-1.57926
OY29	3.540791	2.560753
OY30	3.257499	0.10822
OY31	-0.03427	1.948034
OY32	-2.79844	1.389818
OY33	4.963182	-1.51871
OY34	-5.24668	0.525849
OY35	-3.30634	1.05047
OY36	-6.70917	-0.26715
OY37	-8.45652	-1.44465
OY38	-9.75	-1.96372
OY39	-7.38038	-0.54798
OY40	-7.84454	-1.27772
OY41	-0.26786	1.184172
OY42	4.5004	3.361774
OY43	3.044247	3.227456
OY44	4.51963	3.627442
OY45	-1.60026	1.455495
OY46	1.7627	2.408915
OY47	2.693886	2.911503
OY48	-0.32211	2.209414
OY49	-5.71794	1.839206
OY50	-4.93684	2.151771
OY51	4.627131	-0.94443
OY52	2.741042	4.065223
OY53	-5.63777	1.462047
OY54	3.022582	4.784167
OY55	-6.47236	0.592223



Principal Components: on Correlations

Summary Plots

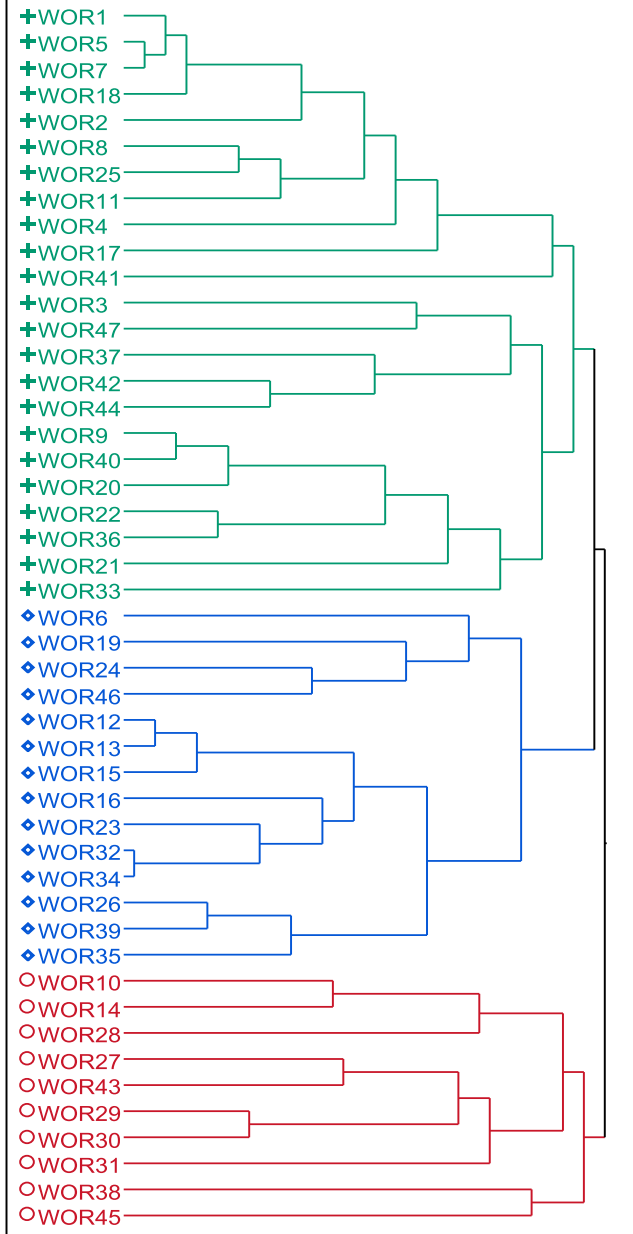
4.4 Woronora River (HCA)

Variables	Cluster A	Cluster B	Cluster C
Depth	1.35	1.21	1.63
Sand	15.07	55.33	92.09
Silt	70.50	35.37	6.49
Clay	14.43	9.30	1.42
Mean Size	47.37	258.24	538.52
StdD	1.95	2.79	1.10
GsKew	-0.12	0.33	0.32
Kurt	1.03	0.72	2.33
S	6670.60	2932.87	1491.89
Cl	71743.00	27312.7	16461.6
V	99.26	29.07	4.37
Cr	72.78	44.94	7.61
Co	12.67	4.30	3.24
Ni	20.72	9.23	2.44
Cu	45.05	15.05	5.22
Zn	232.68	70.03	15.14
As	15.52	5.36	1.70
Se	0.52	0.36	0.23
Br	235.58	63.33	40.32
Rb	68.55	21.07	9.38
Sr	124.79	39.85	20.56
Zr	200.69	172.10	91.75
Cd	1.51	1.20	1.39
Sn	10.76	8.92	7.23
Ba	143.94	59.90	42.15
Ce	61.09	28.67	12.22
Hf	5.00	2.83	1.09
Pb	76.91	23.75	6.05
Th	11.24	3.03	0.83
Quartz	45.6	82.0	91.5
Feldspar	4.9	3.2	3.8
Calcite	1.33	0.26	0.10
Ankerite	0.68	0.53	1.20
Siderite	0.44	0.23	0.55
Kaolinite	17.48	4.95	1.06
Chlorite	2.36	3.41	1.30
Illite	21.09	5.44	0.84
Pyrite	1.76	0.35	0.17
Gypsum	4.01	2.70	2.88

Hierarchical Clustering

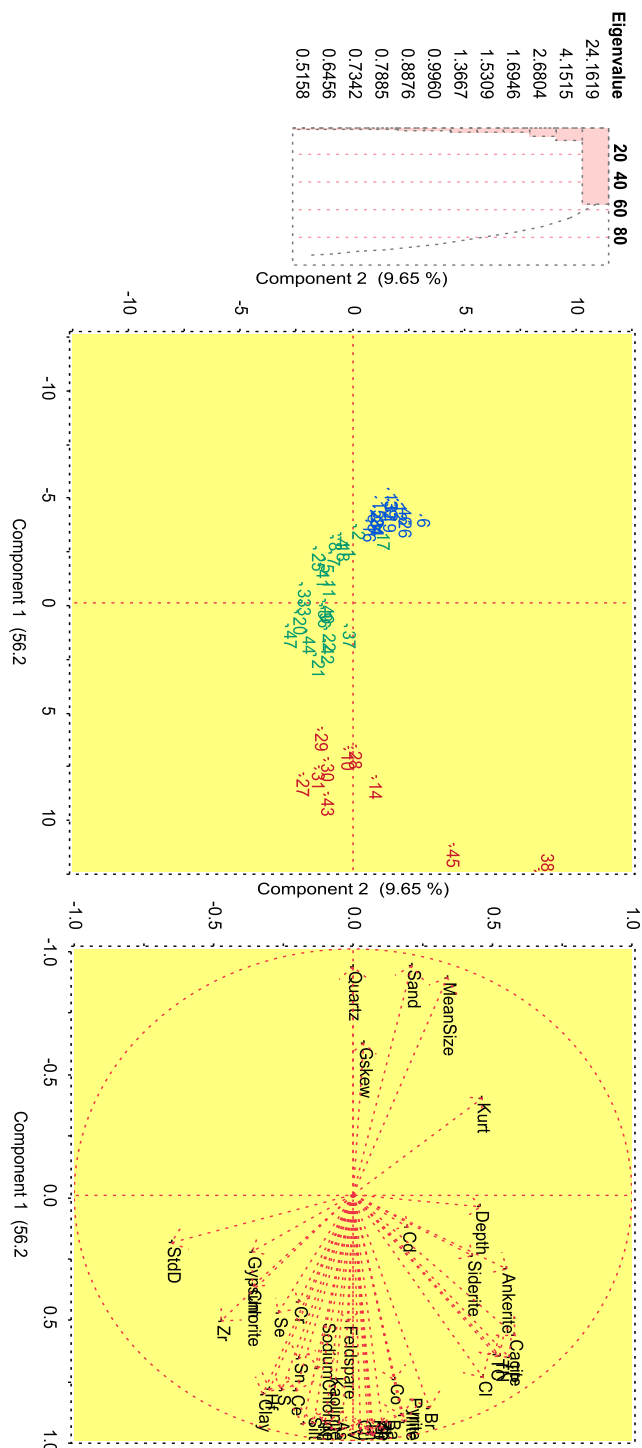
Method War

Dendrogram



Woronora River (PCA)

	PCA1	PCA2
Eigenvalue	24.1619	4.1515
Component	56.20%	9.65%
WOR1	-2.73135	-0.27606
WOR2	-3.55056	0.197967
WOR3	0.022401	-2.23816
WOR4	-3.16585	-0.51718
WOR5	-1.97604	-1.17963
WOR6	-4.15529	3.115385
WOR7	-2.32799	-0.93956
WOR8	-2.99847	-0.88623
WOR9	0.259052	-1.30412
WOR10	6.775808	-0.2828
WOR11	-1.27819	-1.17715
WOR12	-4.84994	2.054155
WOR13	-5.35794	1.63003
WOR14	8.142638	0.908261
WOR15	-4.97688	1.065097
WOR16	-3.8619	0.674458
WOR17	-3.45807	1.29237
WOR18	-2.98363	-0.48995
WOR19	-4.32538	1.56929
WOR20	0.433331	-2.46768
WOR21	2.450133	-1.6419
WOR22	1.20857	-1.16949
WOR23	-4.52637	0.970748
WOR24	-4.17408	1.01615
WOR25	-2.53671	-1.66009
WOR26	-4.07262	2.239105
WOR27	7.995241	-2.2988
WOR28	6.67619	0.055149
WOR29	5.88017	-1.50712
WOR30	7.28249	-1.19433
WOR31	7.636477	-1.63677
WOR32	-4.81329	1.659806
WOR33	-0.81716	-2.26799
WOR34	-4.14326	1.015213
WOR35	-4.34703	0.835407
WOR36	0.107127	-1.36154
WOR37	1.121297	-0.27056
WOR38	12.42688	8.185192
WOR39	-4.97445	1.61252
WOR40	-0.09122	-1.24074
WOR41	-1.72991	-1.40278
WOR42	1.811787	-1.18078
WOR43	8.894448	-1.22854
WOR44	1.330467	-2.06832
WOR45	11.27773	4.39976
WOR46	-4.62874	2.249336
WOR47	1.120089	-2.8571



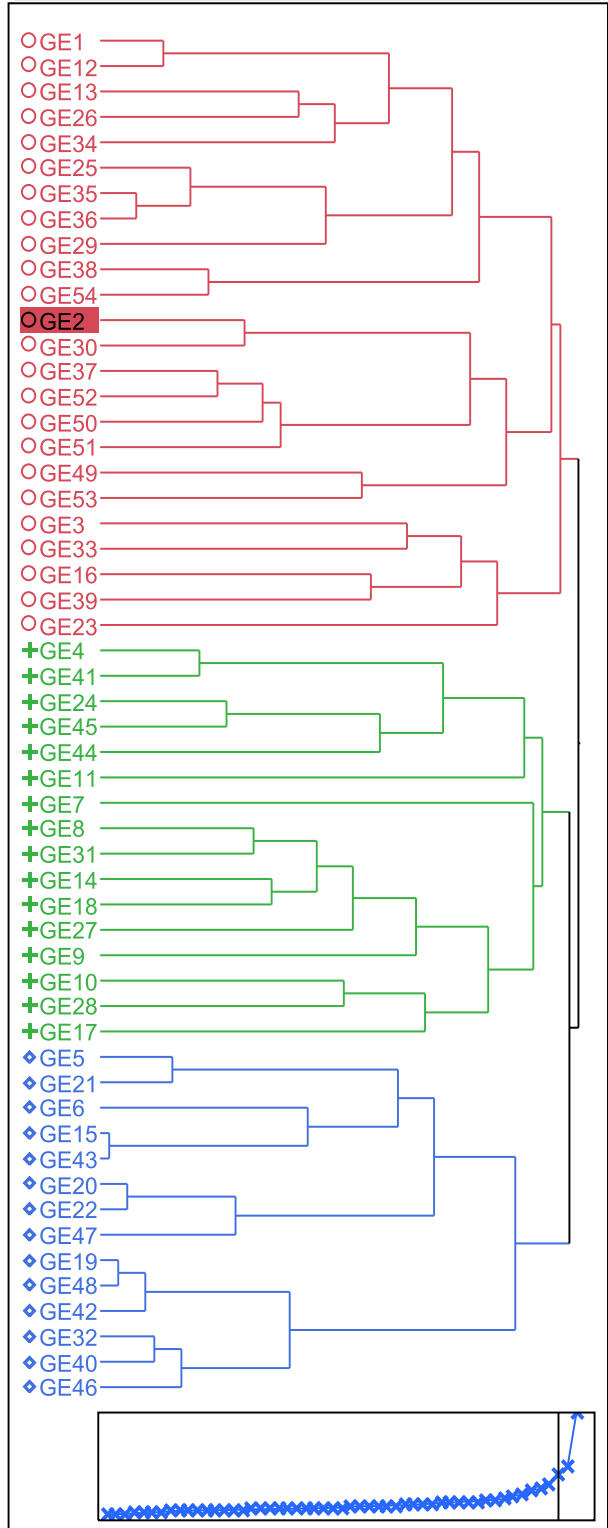
4.5 Georges River and Salt Pan Creek (HCA)

Variables	Cluster A	Cluster B	Cluster C
Depth	3.9	6.8	4.2
Sand	10.2	49.8	92.7
Silt	74.4	39.9	6.0
Clay	15.4	10.3	1.3
Mean Size	32.1	191.6	491.3
StdD	1.8	2.5	1.1
GsKew	0.0	0.1	0.3
Kurt	1.1	0.8	1.9
S	3789.5	3611.5	1847.3
Cl	200858.8	27724.8	15681.9
V	60.9	38.9	7.3
Cr	41.9	38.0	8.7
Co	9.6	4.8	3.2
Ni	19.7	11.0	2.5
Cu	64.4	20.1	5.1
Zn	369.7	108.8	23.0
As	15.1	6.6	2.8
Br	169.9	64.5	34.5
Rb	71.6	28.4	11.1
Sr	119.8	64.5	21.5
Zr	253.2	316.3	142.7
Cd	1.5	1.1	1.3
Sn	13.2	9.0	7.5
Ba	197.6	94.1	52.7
La	33.9	23.5	12.9
Ce	61.4	32.9	14.6
Hf	4.2	5.5	1.6
Pb	135.8	30.4	7.9
Th	10.3	5.8	1.4
U	2.3	0.9	1.0
Quartz	45.8	74.8	91.4
Feldspar	3.0	4.1	3.9
Calcite	0.5	0.9	0.1
Ankerite	0.4		0.7
Siderite	0.4	0.4	0.3
Kaolinite	18.9	7.4	1.0
Chlorite	7.6	3.4	1.8
Illite	19.8	7.3	0.5
Pyrite	1.9	0.7	0.6
Gypsum	1.8	2.8	2.2

Hierarchical Clustering

Method War

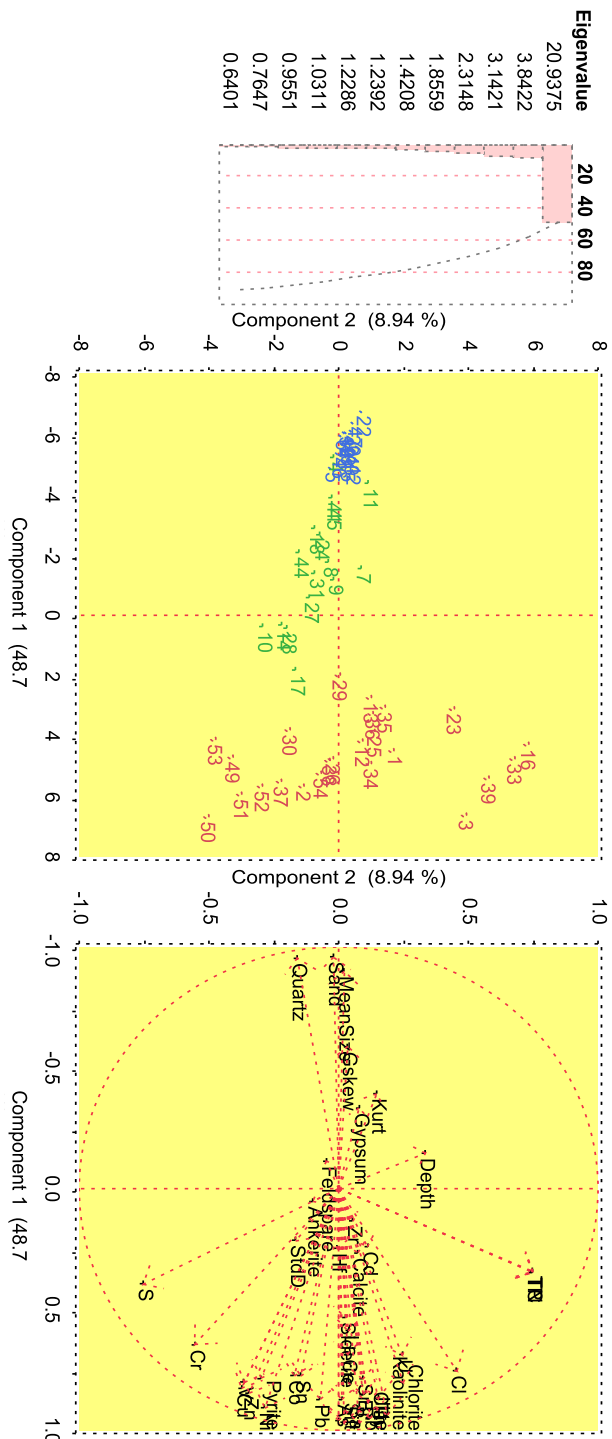
Dendrogram



Georges River and Salt Pan Creek (PCA)

	PCA1	PCA2
Eigenvalue	20.9375	3.8422
Components	48.70%	8.94%
GE1	4.5052	1.6267
GE2	5.6350	-1.1570
GE3	6.6155	3.8427
GE4	-5.2266	-0.1835
GE5	-4.8896	-0.2920
GE6	-5.9665	0.0794
GE7	-1.5688	0.6686
GE8	-1.7395	-0.3215
GE9	-1.1652	-0.1495
GE10	0.3926	-2.3223
GE11	-4.3929	0.8863
GE12	4.1488	0.6250
GE13	2.7156	0.9321
GE14	0.3215	-1.7465
GE15	-5.2999	0.2284
GE16	4.2736	5.7800
GE17	1.8092	-1.3089
GE18	-2.8545	-0.7354
GE19	-5.7875	0.2373
GE20	-6.1339	0.3518
GE21	-5.7967	0.3459
GE22	-6.7594	0.6676
GE23	3.0888	3.4741
GE24	-2.6930	-0.6062
GE25	3.8428	0.9980
GE26	4.7662	-0.2755
GE27	-0.5635	-0.9236
GE28	0.4373	-1.5761
GE29	1.9902	-0.0333
GE30	3.7645	-1.6121
GE31	-1.3694	-0.7465
GE32	-6.0659	0.1736
GE33	4.7251	5.3159
GE34	4.9069	0.9076
GE35	3.0296	1.3583
GE36	3.2403	0.9761
GE37	5.5129	-1.8576
GE38	4.7965	-0.3796
GE39	5.3844	4.5380
GE40	-6.0690	0.2378
GE41	-3.8962	-0.1958
GE42	-5.1698	0.3635
GE43	-5.5174	0.3218
GE44	-2.0857	-1.2393
GE45	-3.6874	-0.1990
GE46	-5.3888	-0.0765
GE47	-6.3855	0.4033
GE48	-5.7317	0.1262
GE49	4.6940	-3.3509
GE50	6.6711	-4.0933
GE51	5.9064	-3.0675
GE52	5.6764	-2.4683
GE53	4.1174	-3.8894
GE54	5.2367	-0.6588

Principal Components: on Correlations
Summary Plots



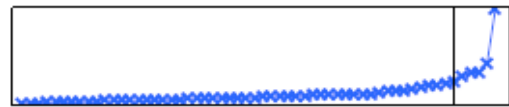
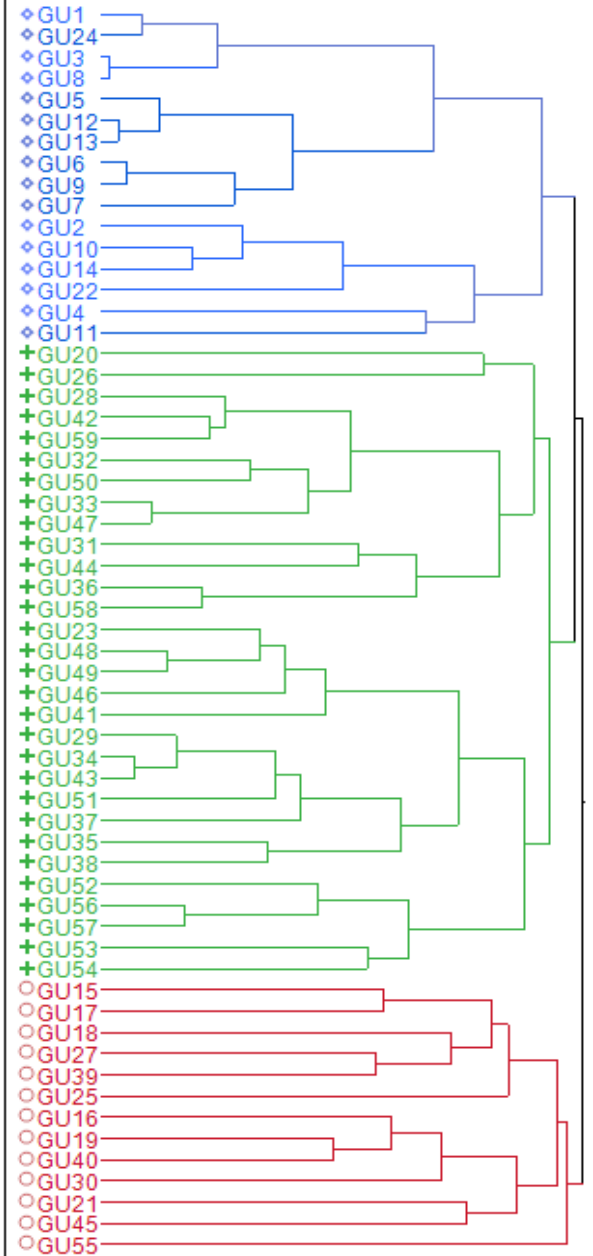
4.6 Gunnamatta Bay (HCA)

Variable s	Cluster r A	Cluster r B	Cluster r C
Depth	9.6	4.1	3.5
Sand	26.1	81.4	97.9
Silt	63.3	15.9	1.9
Clay	10.6	2.6	0.2
Mean Size	74.4	363.4	409.5
StdD	2.1	1.8	0.7
GsKew	0.0	0.4	0.0
Kurt	1.0	1.4	0.9
S	5291.3	2870.8	2399.3
Cl	96725. 0	55322. 7	47052. 7
Cr	68.3	18.3	10.1
Co	6.6	3.8	4.8
Ni	13.2	3.9	2.6
Cu	114.3	26.6	7.4
Zn	183.1	39.9	15.5
As	9.3	3.1	2.2
Br	214.3	76.6	62.3
Rb	31.0	8.7	11.2
Sr	764.1	335.9	707.0
Cd	1.6	1.3	1.5
Sn	9.0	7.2	3.8
Ba	133.5	57.6	73.2
Ce	33.7	13.3	6.4
Pb	85.5	23.1	6.7
Zr	118.2	108.6	37.9
Hf	2.6	1.4	0.9
Th	8.3	2.2	1.7
U	2.7	1.0	1.5
Quartz	40.4	82.2	75.8
Feldspar	9.6	5.9	9.6
Calcite	19.1	5.2	9.4
Ankerite	0.2	1.0	---
Siderite	1.1	0.4	0.5
Kaolinite	10.3	1.4	2.1
Chlorite	2.1	0.8	0.9
Illite	12.2	2.4	3.6
Pyrite	2.6	0.9	0.8
Gypsum	1.3	1.2	1.0

Hierarchical Clustering

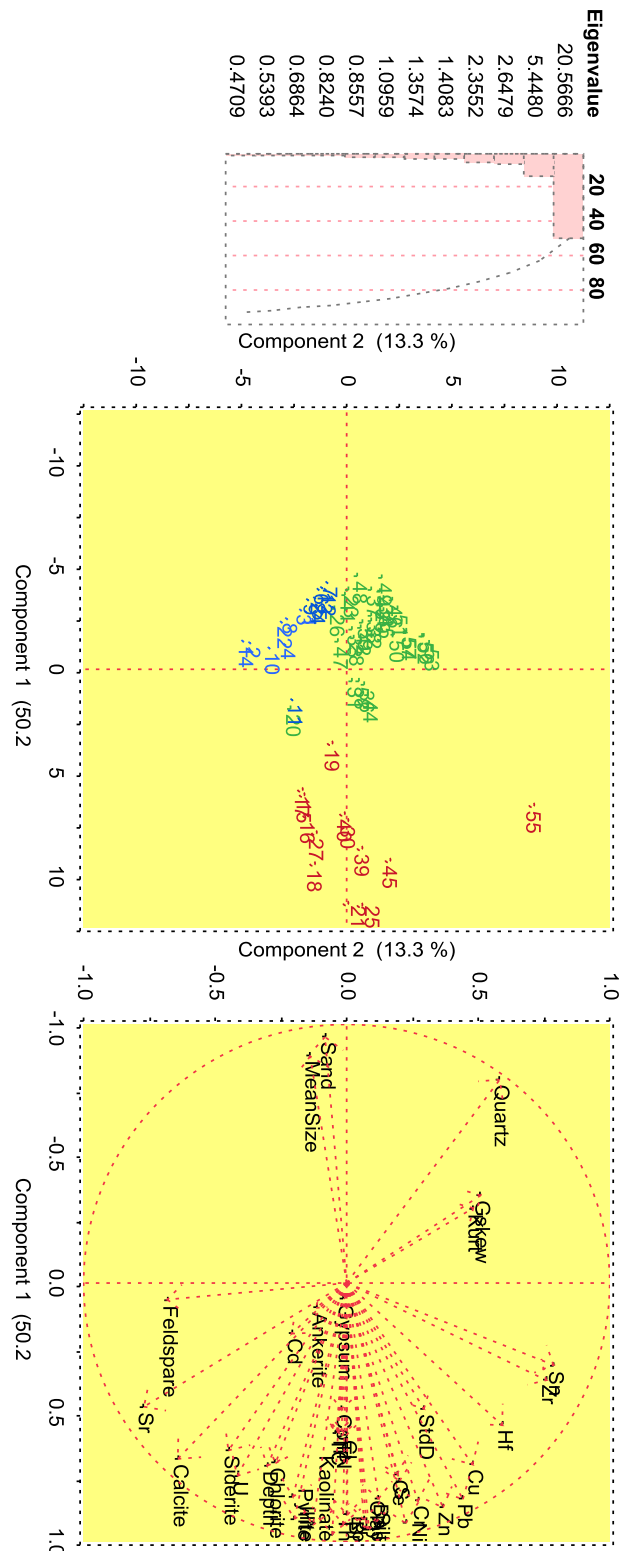
Method = Ward

Dendrogram



Gunamatta Bay (PCA)

	PCA1	PCA2
Eigenvalues	20.5666	5.448
Components	50.20%	13.30%
GU1	-2.79977	-1.9122
GU2	-1.30551	-4.57496
GU3	-2.89015	-2.17747
GU4	-1.26471	-2.88148
GU5	-3.13595	-1.44876
GU6	-3.90865	-1.37021
GU7	-4.25339	-0.95737
GU8	-2.5125	-2.82775
GU9	-3.39308	-1.83637
GU10	-1.10171	-3.70548
GU11	1.447862	-2.57665
GU12	-3.9497	-1.00138
GU13	-4.02115	-1.13745
GU14	-1.44487	-4.93691
GU15	6.070633	-2.13403
GU16	7.078874	-2.00405
GU17	5.804396	-2.26763
GU18	9.380324	-1.6627
GU19	3.577323	-0.81496
GU20	1.882923	-2.66235
GU21	11.36455	-0.11424
GU22	-2.3395	-3.08187
GU23	-3.86084	0.094489
GU24	-3.52939	-1.48751
GU25	11.44529	0.624238
GU26	-2.95446	-0.60418
GU27	7.90952	-1.5675
GU28	-1.50561	0.321621
GU29	-3.08538	1.596887
GU30	7.306728	-0.07035
GU31	0.573854	0.264338
GU32	-2.3406	1.137417
GU33	-1.88724	0.22734
GU34	-3.44174	1.748721
GU35	-2.86897	1.709576
GU36	0.757157	0.804386
GU37	-3.8534	1.188651
GU38	-2.60475	1.158031
GU39	8.679673	0.604494
GU40	7.038005	-0.21501
GU41	-3.60665	-0.09631
GU42	-1.99614	0.685124
GU43	-3.76055	1.609654
GU44	1.260866	1.014031
GU45	9.247446	1.885969
GU46	-3.30266	2.20566
GU47	-1.35214	-0.43845
GU48	-4.49672	0.460382
GU49	-4.44799	1.697945
GU50	-1.65527	2.224767
GU51	-2.91058	2.389669
GU52	-1.60747	3.569398
GU53	-1.22023	3.888137
GU54	-1.77657	2.815565
GU55	6.618023	8.772832
GU56	-1.55766	3.70522
GU57	-1.8202	2.866413
GU58	0.547026	0.563089
GU59	-2.2266	0.731521



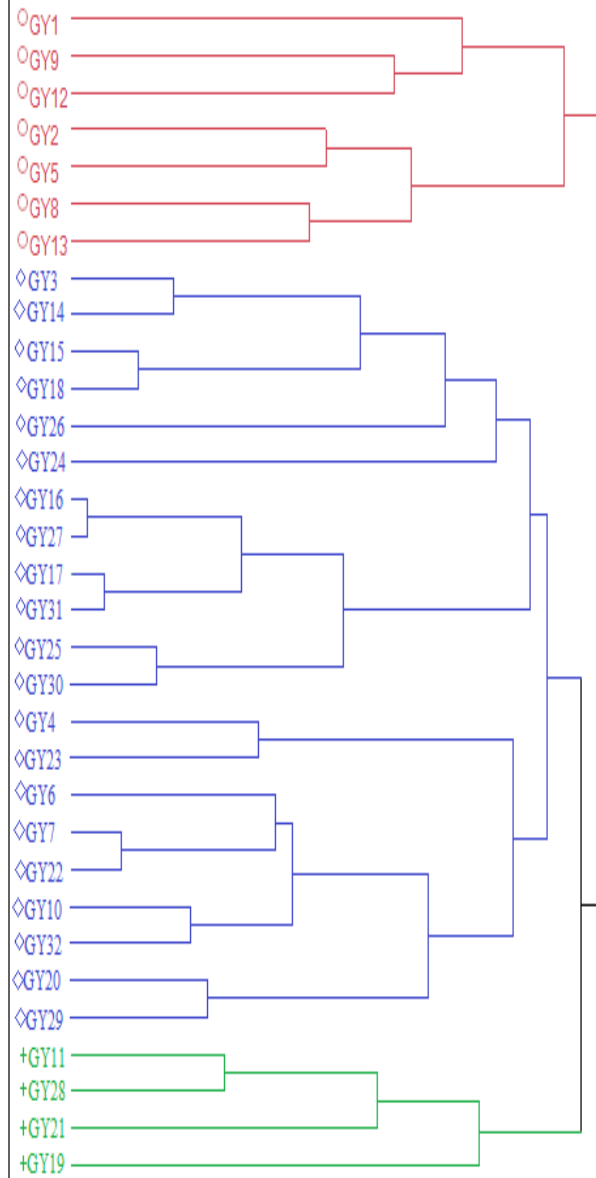
4.7 Gynea Bay (HCA)

Variables	Cluster A	Cluster B	Cluster C
Depth	17.7	8.3	3.3
Sand	5.3	39.4	93.5
Silt	82.8	52.2	5.9
Clay	12.0	8.5	0.6
Mean Size	22.1	130.1	470.6
StdD	1.5	2.2	1.1
GsKew	0.0	0.1	0.2
Kurt	1.1	0.9	1.6
S	5118.1	2791.1	2266.3
Cl	145685.7	64138.8	32928.6
Cr	72.6	33.5	13.4
Co	17.4	3.0	3.6
Ni	21.6	7.1	3.7
Cu	53.7	15.5	7.5
Zn	193.7	52.0	24.9
As	12.1	6.9	3.2
Br	416.1	122.2	53.0
Rb	61.1	15.3	7.1
Sr	311.6	186.4	181.8
Cd	1.7	1.8	1.4
Sn	10.2	8.0	8.6
Ba	202.7	71.9	45.0
Ce	51.6	37.3	19.8
Pb	102.4	33.3	11.0
Th	13.8	5.7	2.9
U	4.0	1.0	1.0
Quartz	29.6	82.3	85.5
Feldspar	8.9	2.3	3.9
Calcite	9.7	2.4	5.0
Ankerite	0.9	---	1.2
Siderite	0.5	0.4	0.3
Kaolinite	22.7	4.9	1.5
Chlorite	2.5	0.4	1.1
Illite	20.7	5.2	2.2
Pyrite	4.0	0.6	0.7
Gypsum	1.15	2.2	1.4

Hierarchical Clustering

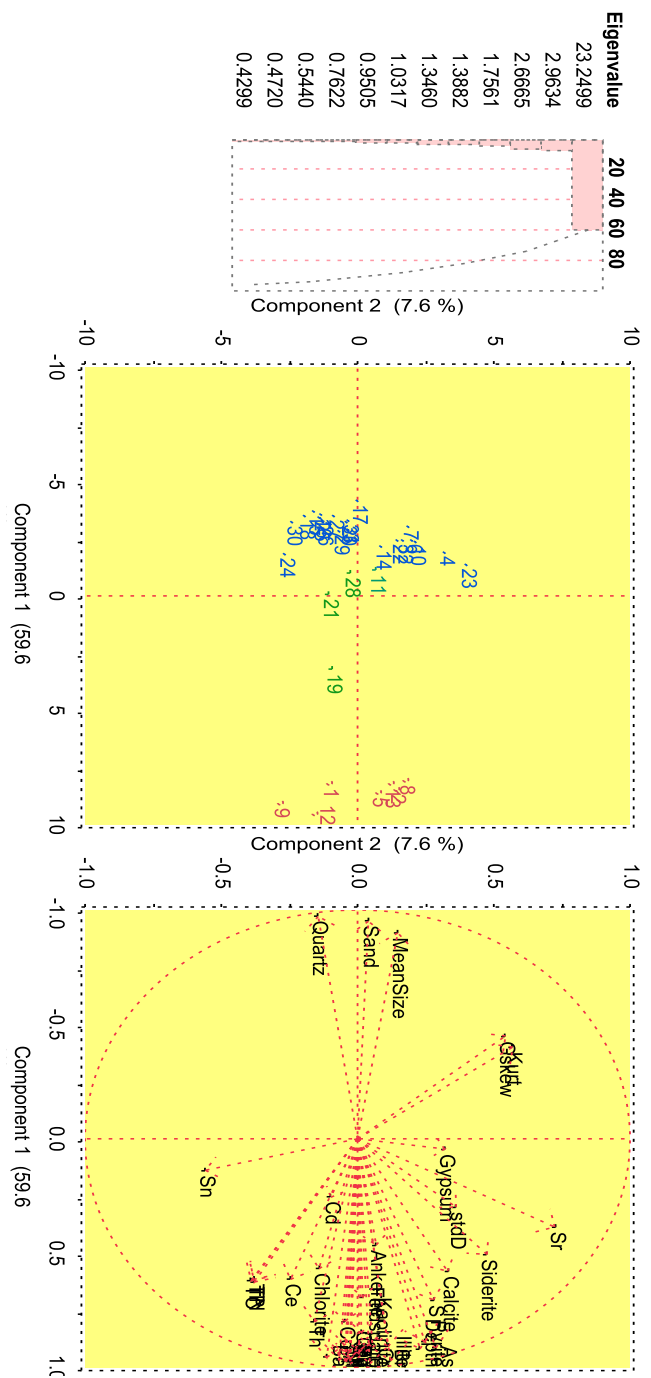
Method = Ward

Dendrogram



Principal Components: on Correlations

Summary Plots



Gymea Bay (PCA)

Eigenvalue	23.2499	2.9634
Components	59.60%	7.60%
GY1	8.2270	-1.0455
GY2	8.4914	1.4300
GY3	-2.9173	-0.3205
GY4	-1.9029	3.2202
GY5	8.6292	0.7157
GY6	-2.4523	2.0237
GY7	-3.0369	1.8761
GY8	8.0883	1.7612
GY9	9.0409	-2.8649
GY10	-2.4145	2.1056
GY11	-1.1279	0.6948
GY12	9.5422	-1.6114
GY13	8.1698	1.2143
GY14	-2.2158	0.8652
GY15	-3.7490	-1.5669
GY16	-3.5724	-1.3225
GY17	-4.2054	-0.0273
GY18	-3.5530	-1.9022
GY19	3.2171	-0.9526
GY20	-3.2564	-0.3773
GY21	-0.0597	-1.0909
GY22	-2.4352	1.4702
GY23	-1.3752	4.0276
GY24	-1.8803	-2.6660
GY25	-3.4828	-1.4321
GY26	-3.2545	-1.2554
GY27	-3.5499	-0.8957
GY28	-0.9675	-0.2738
GY29	-2.8843	-0.6992
GY30	-3.2667	-2.3947
GY31	-3.3591	-0.3433
GY32	-2.4871	1.6378

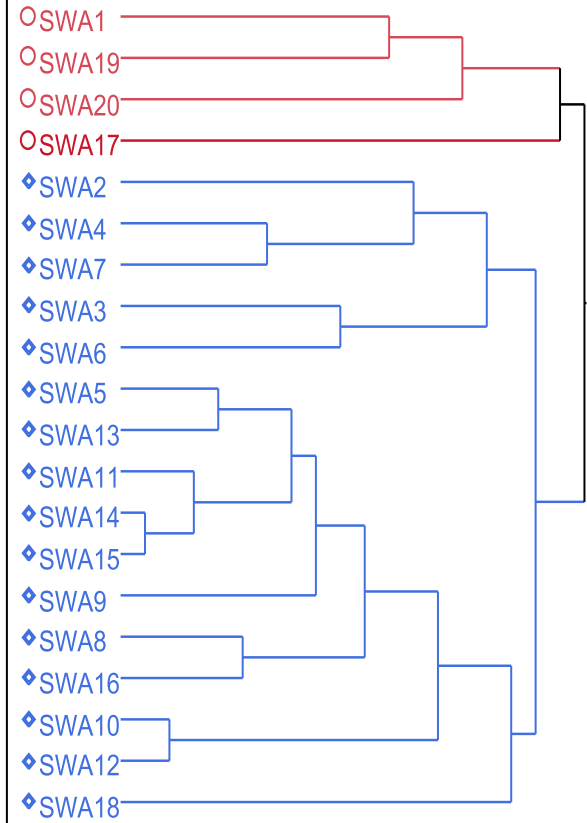
4.8 South West Arm (HCA)

Variables	Cluster A	Cluster C
Depth	11.6	1.2
Sand	51.3	96.4
Silt	43.2	3.3
Clay	5.5	0.2
Mean Size	173.8	463.5
StdD	2.3	0.8
GsKew	0.3	0.1
Kurt	0.8	1.2
S	6792.6	2160.5
Cl	39582.5	19515.4
V	40.8	2.7
Co	3.8	3.2
Ni	9.3	3.3
Cu	22.3	4.4
Zn	70.4	5.1
Ga	5.2	1.3
As	6.9	1.5
Se	0.7	1.5
Br	156.3	46.4
Rb	21.5	3.3
Sr	721.8	44.1
Y	9.5	4.0
Zr	122.7	122.6
Nb	5.1	2.7
Mo	1.0	1.4
Cd	4.6	1.5
Sn	3.9	5.8
Ba	74.8	24.8
La	16.5	13.7
Ce	31.6	13.0
Hf	1.6	1.6
Ta	2.4	2.0
Hg	0.8	1.2
Pb	33.2	1.6
Th	6.0	1.7
U	2.2	1.0
Quartz	56.7	89.6
Feldspar	6.0	5.3
Calcite	13.6	4.2
Ankerite		
Siderite	0.6	0.2
Kaolinite	7.8	0.7
Chlorite	1.7	0.7
Illite	9.2	0.8
Pyrite	2.6	0.4
Gypsum	1.81	2.0

Hierarchical Clustering

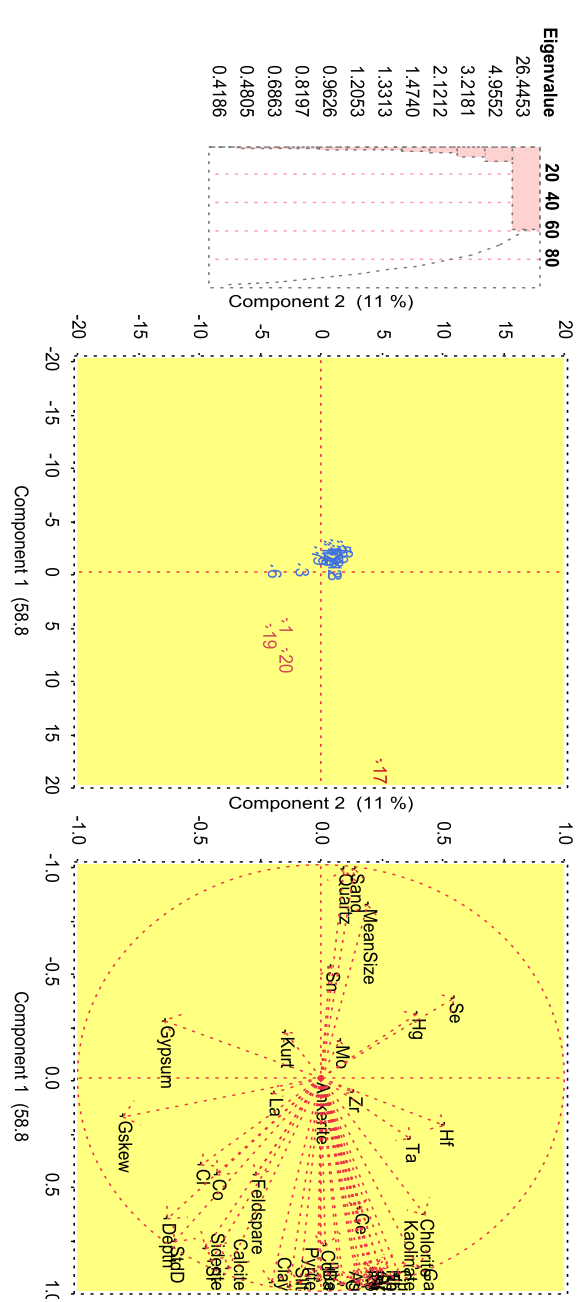
Method War

Dendrogram



South West Arm (PCA)

	PCA1	PCA2
Eigenvalue	26.4453	4.9552
Components	58.80%	11.00%
SWA1	4.585	-3.042
SWA2	-0.622	0.906
SWA3	-0.865	-1.797
SWA4	-1.914	1.176
SWA5	-2.874	1.739
SWA6	-0.715	-4.000
SWA7	-2.402	-0.372
SWA8	-2.565	1.899
SWA9	-1.828	-0.290
SWA10	-2.633	0.343
SWA11	-3.045	0.867
SWA12	-2.843	0.753
SWA13	-2.578	1.111
SWA14	-2.978	0.455
SWA15	-2.727	0.670
SWA16	-2.902	1.461
SWA17	17.744	4.657
SWA18	-1.276	0.909
SWA19	5.051	-4.398
SWA20	7.384	-3.048



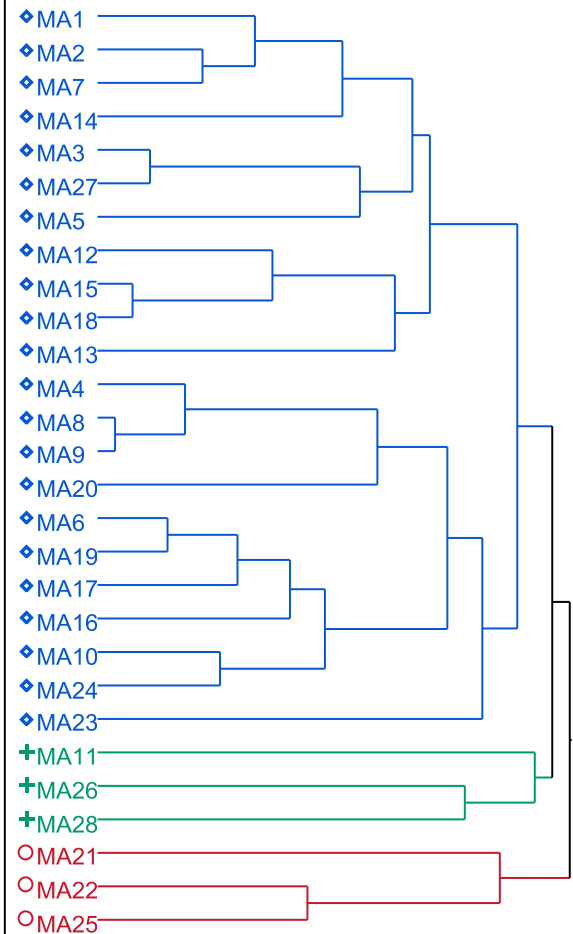
4.9 Mansion Bay and Hacking River (HCA)

Variables	Cluster A	Cluster B	Cluster C
Depth	4.8	1.7	1.8
Sand	20.6	72.1	90.8
Silt	68.9	24.3	8.2
Clay	10.5	3.6	1.0
Mean Size	52.7	333.0	480.9
StdD	1.9	2.1	1.2
GsKew	0.0	0.5	0.3
Kurt	1.0	1.6	1.7
S	5591.0	3470.4	1970.4
Cl	67580.0	12828.7	19921.3
V	100.1	27.0	6.7
Co	6.2	4.5	5.7
Ni	21.5	13.2	2.8
Cu	49.9	11.6	4.5
Zn	162.6	30.2	11.6
Ga	15.4	2.7	1.1
Ge	2.3	0.7	1.1
As	16.3	5.1	2.5
Se	0.7	0.2	0.4
Br	184.1	40.6	39.7
Rb	52.3	10.7	5.8
Sr	175.0	45.7	28.8
Y	23.6	9.5	4.7
Zr	250.7	202.6	97.0
Nb	13.7	5.1	2.4
Mo	1.0	4.7	1.2
Cd	1.2	5.0	1.4
Sn	12.0	5.9	7.6
Ba	192.9	60.5	38.1
La	27.0	12.5	13.9
Ce	52.5	32.3	11.6
Hf	5.9	3.3	0.9
Ta	4.8	3.7	2.8
Hg	0.8	0.9	0.9
Pb	75.7	12.4	4.6
Th	12.6	4.0	0.6
U	2.5	0.8	1.0
Quartz	61.6	85.1	92.4
Feldspar	4.9	4.4	3.0
Calcite	1.0	--	0.2
Ankerite	0.3	0.3	0.3
Siderite	0.2	0.3	0.2
Kaolinite	15.4	2.8	1.2
Chlorite	1.2	2.1	0.9
Illite	14	1.4	0.8
Pyrite	1.5	0.4	0.2
Gypsum	2.8	4.4	2.4

Hierarchical Clustering

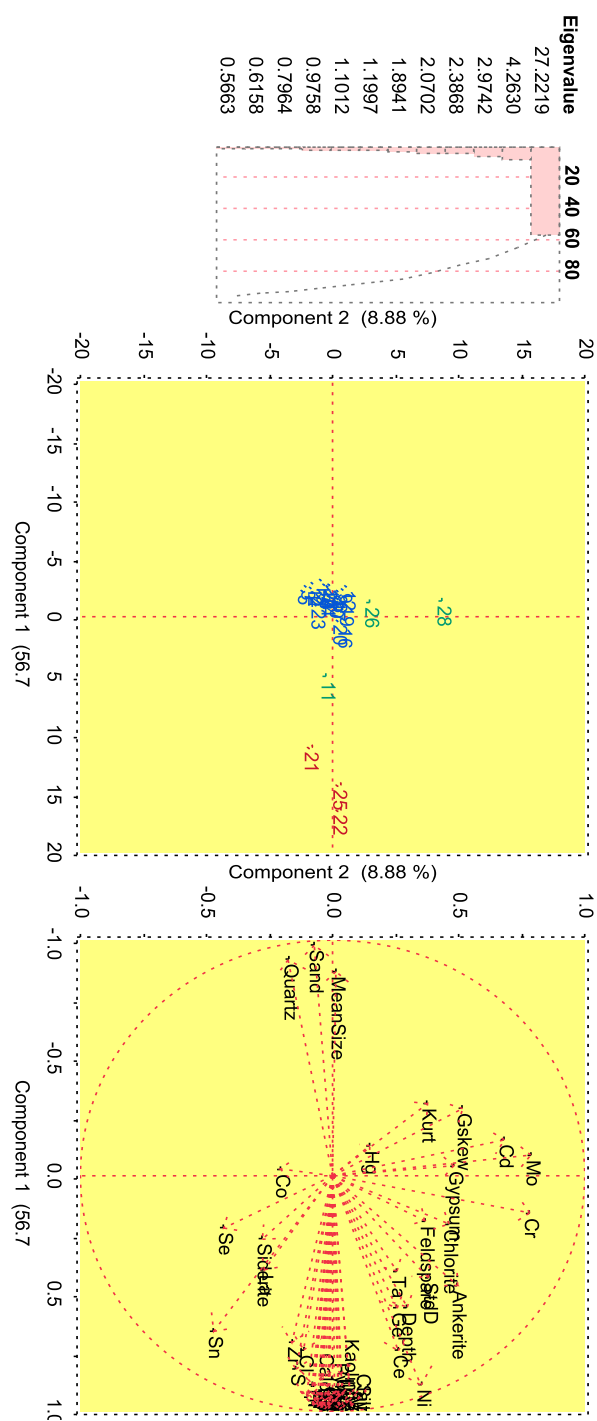
Method War

Dendrogram



Principal Components: on Correlations

Summary Plots



Mansion Bay and Hacking River (PCA)

	PCA1	PCA2
Eigenvalue	27.22%	4.26%
Components	56.70%	8.88%
MA1	-2.525	-1.729
MA2	-2.096	-1.623
MA3	-2.601	-2.116
MA4	-1.885	-0.681
MA5	-2.248	-2.434
MA6	-1.587	0.422
MA7	-2.298	-0.588
MA8	-2.300	0.357
MA9	-2.420	0.799
MA10	-2.050	0.079
MA11	5.090	-0.550
MA12	-2.669	1.066
MA13	-3.151	-0.918
MA14	-2.917	-1.538
MA15	-2.781	-0.329
MA16	0.522	0.760
MA17	-1.755	0.210
MA18	-2.741	-0.712
MA19	-1.332	0.882
MA20	0.206	0.440
MA21	11.118	-1.926
MA22	16.436	0.344
MA23	-1.038	-1.331
MA24	-2.151	-0.556
MA25	14.292	0.394
MA26	-1.156	2.917
MA27	-2.659	-0.343
MA28	-1.302	8.704

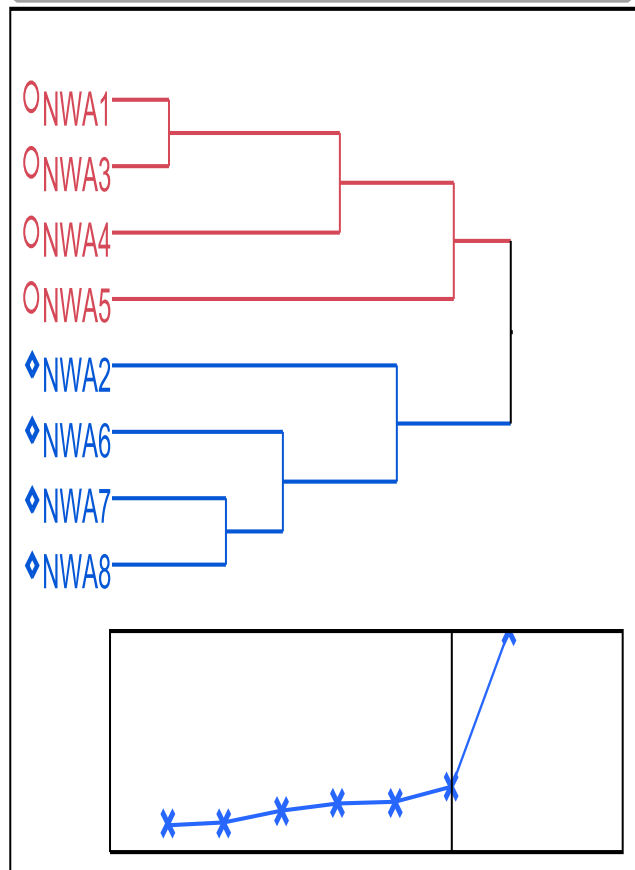
4.10 North West Arm (HCA)

Variables	Cluster A	Cluster C
Depth	11.1	2.1
Sand	14.5	89.7
Silt	72.3	9.4
Clay	13.1	1.0
Mean Size	39.8	391.4
StdD	1.8	1.3
GsKew	0.0	0.4
Kurt	1.0	1.9
S	6782.0	1397.0
Cl	43760.0	14200.0
V	107.8	11.8
Co	6.4	3.2
Ni	21.4	5.4
Cu	64.9	6.8
Zn	337.5	34.4
Ga	14.4	1.7
Ge	1.8	1.2
As	12.9	3.4
Se	0.7	0.2
Br	191.7	36.8
Rb	54.1	8.2
Sr	188.9	50.1
Y	22.3	4.9
Zr	245.8	119.1
Nb	13.9	3.3
Cd	13.2	6.7
Sn	3.0	3.0
Cs	64.6	8.0
Ba	4.0	34.0
La	193.9	17.4
Ce	26.8	8.5
Hf	6.2	1.2
Ta	6.7	2.5
Hg	2.1	0.8
Pb	135.6	13.1
Th	12.6	1.0
U	2.1	1.0
Quartz	45.8	90.4
Feldspar	5.4	3.0
Calcite	1.5	0.6
Ankerite	0.1	-----
Siderite	0.4	0.2
Kaolinite	18.7	1.3
Chlorite	3.5	1.0
Illite	17.3	2.0
Pyrite	1.8	0.2
Gypsum	3.3	2.3

Hierarchical Clustering

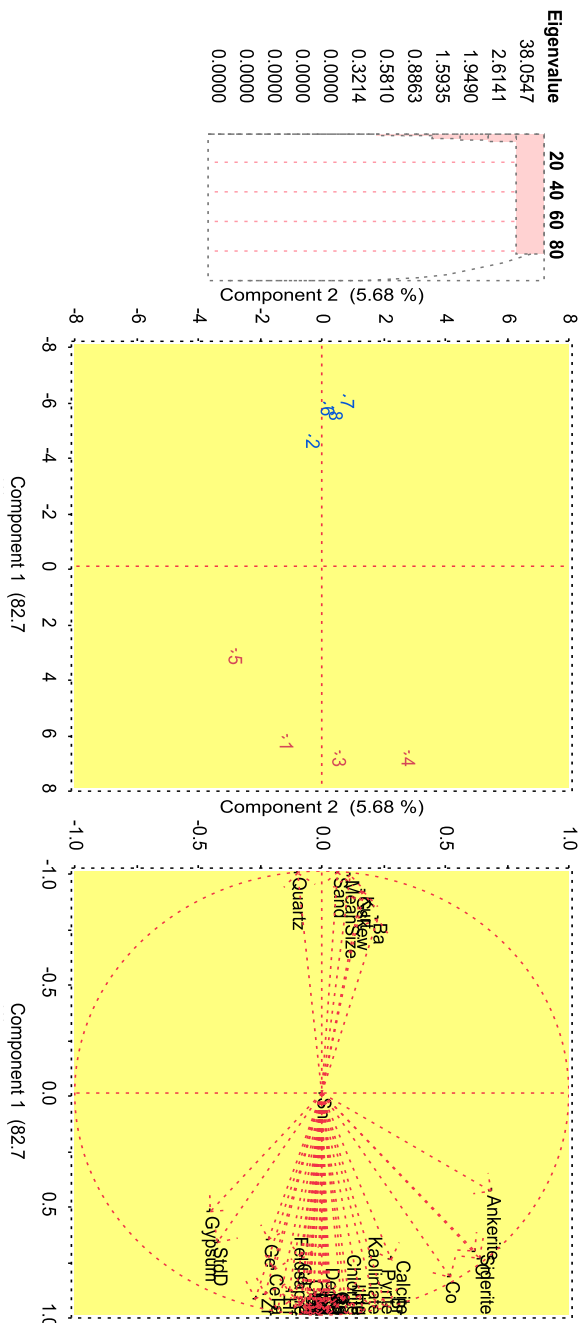
Method War

Dendrogram



Principal Components: on Correlations

Summary Plots



North West Arm (PCA)

	PCA1	PCA2
Eigenvalue	38.0547	2.6141
Components	82.70%	5.68%
NWA1	6.129	-1.235
NWA2	-4.766	-0.380
NWA3	6.713	0.498
NWA4	6.744	2.741
NWA5	3.034	-2.855
NWA6	-5.932	0.106
NWA7	-6.169	0.752
NWA8	-5.753	0.374

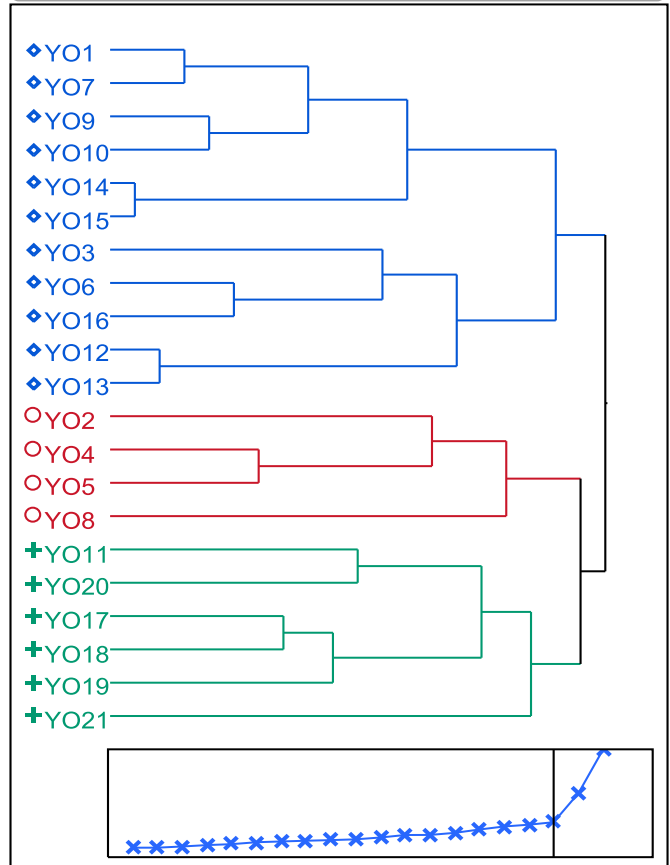
4.11 Yowie Bay (HCA)

Variables	Cluster A	Cluster B	Cluster C
Depth	4.7	17.8	4.8
Sand	39.3	10.0	85.8
Silt	51.8	76.1	11.9
Clay	8.9	13.9	2.2
Mean Size	91.6	34.5	402.4
StdD	2.1	1.8	1.7
GsKew	0.2	0.0	0.4
Kurt	0.9	1.2	1.5
S	4779.5	4428.7	1671.5
Cl	20765.0	146446.7	22348.3
V	58.4	89.4	16.3
Co	3.0	7.2	3.3
Ni	14.2	17.0	4.5
Cu	67.0	57.4	11.6
Zn	205.5	180.9	36.1
As	9.9	12.4	4.3
Se	0.5	0.8	0.2
Br	97.5	380.5	46.7
Rb	29.5	48.8	11.9
Sr	123.8	487.8	188.9
Y	16.5	18.2	6.1
Zr	327.2	144.2	160.7
Nb	10.2	10.5	4.3
Cd	11.6	8.5	8.0
Cs	38.3	111.4	10.6
Ce	28.2	20.9	13.9
Hf	6.6	3.4	1.9
Ta	6.1	4.0	2.3
Pb	126.2	103.0	22.7
Th	6.9	12.1	2.2
U	0.9	2.9	0.9
Quartz	69.2	33.9	86.0
Feldspar	7.1	6.4	3.1
Calcite	2.0	11.4	2.5
Ankerite	---	0.5	0.2
Siderite	0.1	0.6	0.3
Kaolinite	11.9	19.7	2.0
Chlorite	1.2	2.8	0.9
Illite	8.2	19.3	3.8
Pyrite	0.6	2.4	0.5
Gypsum	2.9	3.5	2.1

Hierarchical Clustering

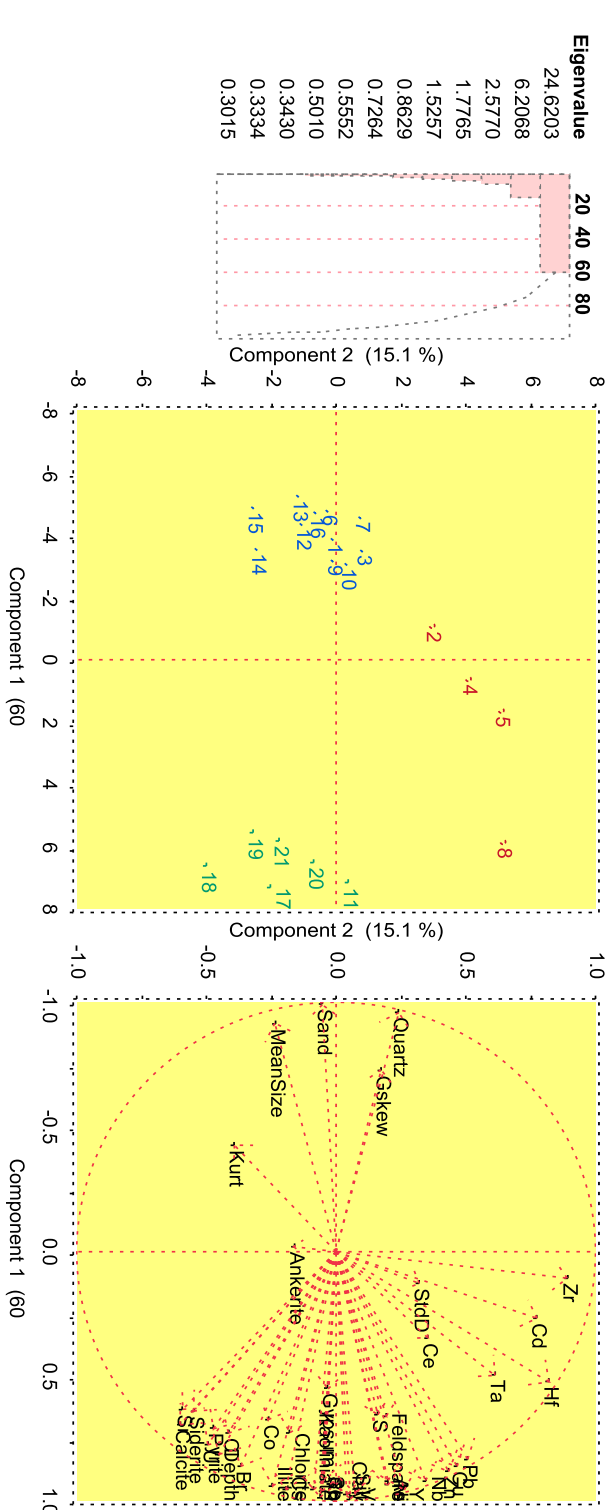
Method Ward

Dendrogram



Yowie Bay (PCA)

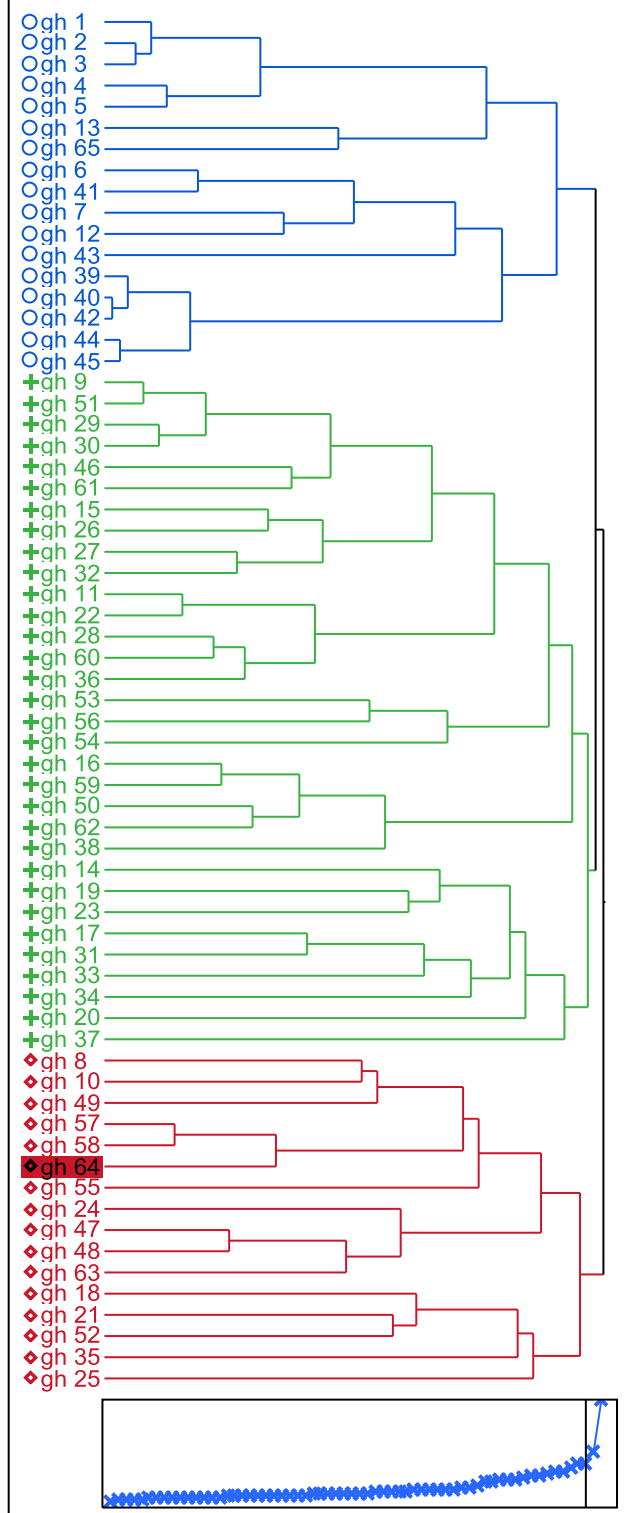
	PCA1	PCA2
Eigenvalue	60.00%	15.10%
Components	24.620	6.207
YO1	-3.880	-0.110
YO2	-1.082	2.926
YO3	-3.544	0.779
YO4	0.651	4.062
YO5	1.657	5.085
YO6	-4.798	-0.283
YO7	-4.593	0.767
YO8	5.857	5.098
YO9	-3.188	-0.083
YO10	-3.087	0.310
YO11	7.161	0.360
YO12	-4.367	-1.067
YO13	-5.303	-1.173
YO14	-3.573	-2.443
YO15	-4.931	-2.552
YO16	-4.770	-0.618
YO17	7.290	-2.004
YO18	6.610	-4.010
YO19	5.560	-2.559
YO20	6.515	-0.700
YO21	5.815	-1.786



4.12 Burraneer Bay (HCA)

Sample No	Cluster A	Cluster B	Cluster C
Depth	7.1	3.5	3.4
Sand	41.5	74.4	97.3
Silt	52.4	23.3	2.6
Clay	6.1	2.3	0.1
Mean Size	4.5	2.6	1.7
StdD	2.2	1.8	0.7
GsKew	0.1	0.3	0.1
Kurt	0.8	1.3	1.1
Ni	8.2	5.4	1.7
Cu	64.3	15.1	4.1
Zn	107.7	33.0	11.1
As	9.2	3.4	3.8
Br	257.2	123.9	86.3
Rb	26.1	9.1	11.1
Sr	633.1	282.9	647.2
Cd	6.3	7.9	12.1
Sn	9.3	8.7	5.4
Ba	103.6	59.1	72.6
Pb	58.8	21.2	6.3

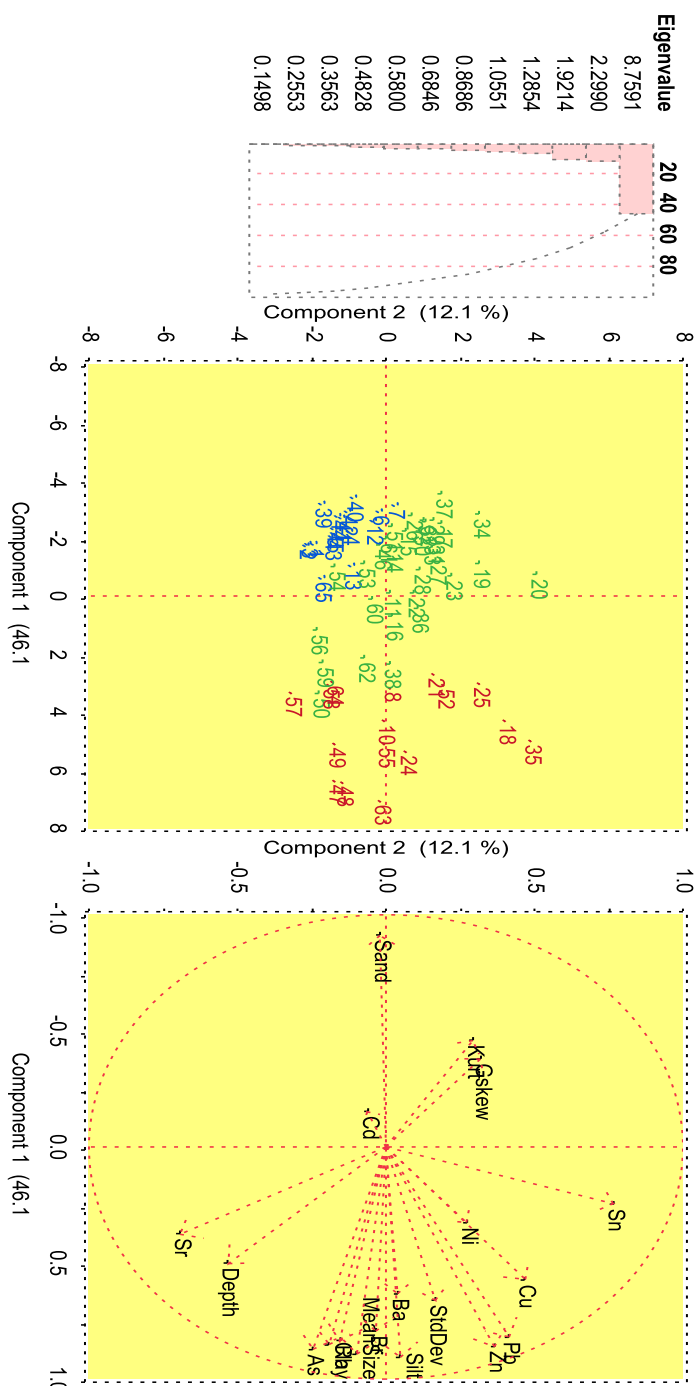
Dendrogram



Burraneer Bay (PCA)

	PCA1	PCA2
Eigenvalue	8.7591	2.299
Components	46.10%	12.10%
gh 1	-1.810	-1.947
gh 2	-1.766	-2.178
gh 3	-1.802	-2.160
gh 4	-2.261	-0.994
gh 5	-2.165	-1.465
gh 6	-2.932	-0.208
gh 7	-3.132	0.209
gh 8	3.125	0.104
gh 9	-2.628	0.989
gh 10	4.263	-0.053
gh 11	-0.087	0.111
gh 12	-2.620	-0.367
gh 13	-1.068	-0.948
gh 14	-1.636	0.166
gh 15	-2.230	0.530
gh 16	0.693	0.148
gh 17	-2.508	1.497
gh 18	4.279	3.192
gh 19	-1.133	2.497
gh 20	-0.723	4.043
gh 21	2.677	1.303
gh 22	-0.103	0.772
gh 23	-0.709	1.760
gh 24	5.332	0.548
gh 25	3.009	2.526
gh 26	-2.788	0.676
gh 27	-1.252	1.353
gh 28	-0.899	0.886
gh 29	-2.631	1.255
gh 30	-2.266	0.890
gh 31	-1.894	1.256
gh 32	-2.538	1.077
gh 33	-1.927	1.200
gh 34	-2.846	2.510
gh 35	4.968	3.897
gh 36	0.401	0.832
gh 37	-3.542	1.496
gh 38	2.328	0.125
gh 39	-3.198	-1.746
gh 40	-3.427	-0.931
gh 41	-2.726	-1.253
gh 42	-2.951	-1.080
gh 43	-2.100	-1.516
gh 44	-2.790	-1.328
gh 45	-2.342	-1.453
gh 46	-1.744	-0.142
gh 47	6.342	-1.393
gh 48	6.382	-1.152
gh 49	5.083	-1.371
gh 50	3.340	-1.806
gh 51	-2.398	0.166
gh 52	3.027	1.565
gh 53	-1.104	-0.583
gh 54	-1.011	-1.401
gh 55	5.049	-0.049
gh 56	1.171	-1.891
gh 57	3.327	-2.579
gh 58	3.056	-1.530
gh 59	2.301	-1.703
gh 60	0.084	-0.396
gh 61	-1.972	0.002
gh 62	2.120	-0.597
gh 63	7.027	-0.154
gh 64	2.935	-1.460
gh 65	-0.665	-1.746

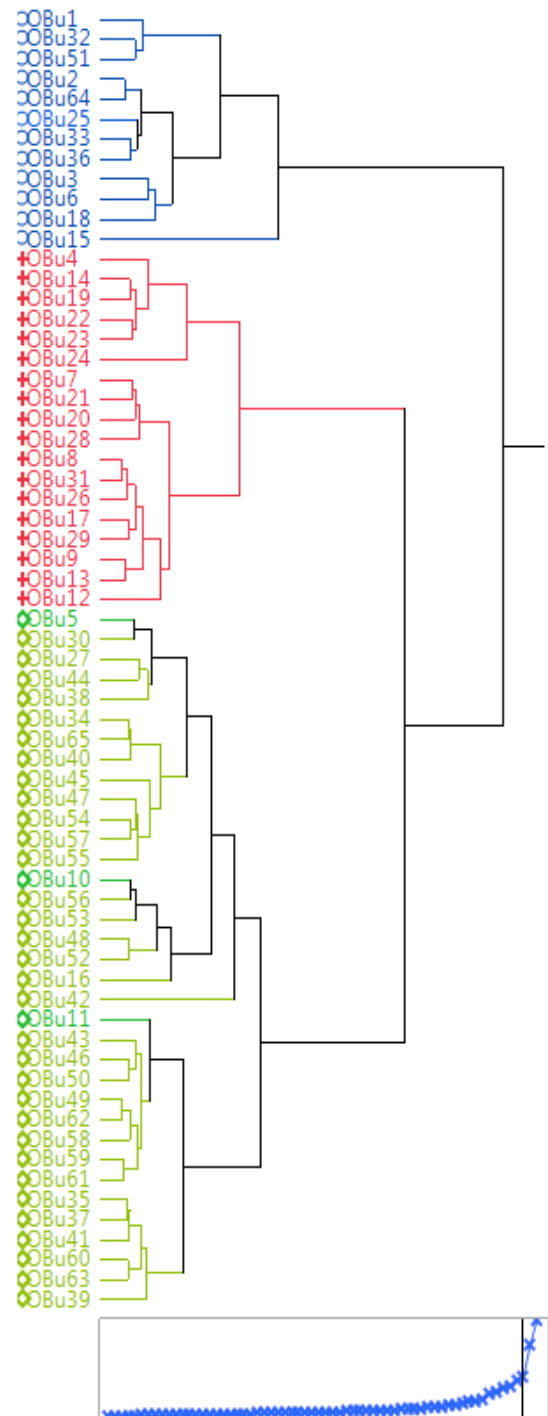
Summary Plots



4.13 Oatley Bay (HCA)

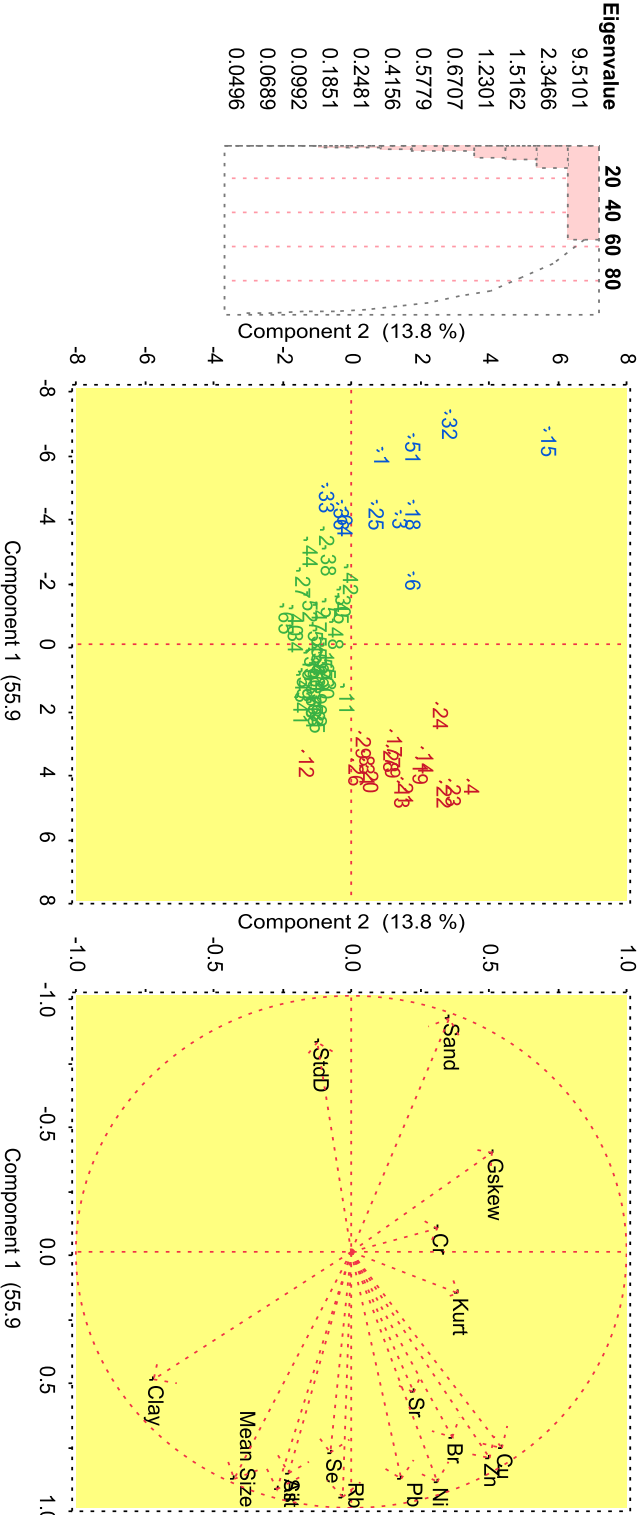
Sample	Cluster A	Cluster B	Cluster C
Depth	1.78	1.57	0.95
Sand	6.5	18.1	57.6
Silt	83.9	69.8	37.3
Clay	9.6	12.0	5.1
Mean size	6.2	5.7	3.4
StdD	1.4	2.0	2.6
GsKew	-0.1	-0.2	0.2
Kurt	1.0	0.9	0.8
Cr	38.2	37.8	41.9
Ni	19.9	12.9	8.8
Cu	63.0	28.2	22.4
Zn	298.9	142.2	99.7
As	29.0	23.4	12.0
Se	0.9	0.7	0.5
Br	152.5	97.9	71.3
Rb	75.6	52.6	24.0
Sr	119.7	92.8	69.8
Pb	174.2	94.9	45.0

Dendrogram



Oatley Bay (PCA)

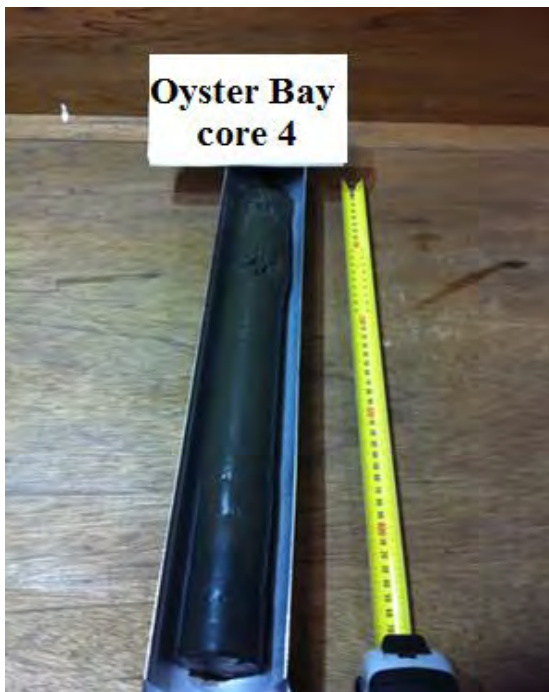
	PCA1	PCA2
Eigenvalue	9.5101	2.3466
Components	55.90%	13.80%
OBu1	-6.080	0.783
OBu2	-3.567	-0.801
OBu3	-4.124	1.330
OBu4	4.231	3.407
OBu5	-1.349	-0.729
OBu6	-2.184	1.696
OBu7	3.336	1.107
OBu8	3.318	0.367
OBu9	3.676	1.120
OBu10	0.278	-1.303
OBu11	1.312	-0.213
OBu12	3.300	-1.396
OBu13	4.254	1.360
OBu14	3.199	2.070
OBu15	-6.723	5.667
OBu16	0.058	-0.806
OBu17	2.671	1.187
OBu18	-4.419	1.703
OBu19	3.506	1.944
OBu20	3.761	0.489
OBu21	4.171	1.478
OBu22	4.268	2.620
OBu23	4.203	2.855
OBu24	1.836	2.501
OBu25	-4.445	0.632
OBu26	3.549	0.033
OBu27	-2.292	-1.514
OBu28	3.148	1.067
OBu29	2.734	0.253
OBu30	-1.714	-0.319
OBu31	3.562	0.393
OBu32	-7.246	2.749
OBu33	-4.955	-0.808
OBu34	-0.566	-1.714
OBu35	1.944	-1.089
OBu36	-4.428	-0.374
OBu37	1.050	-1.163
OBu38	-2.990	-0.762
OBu39	0.217	-1.236
OBu40	-1.107	-1.709
OBu41	1.669	-1.564
OBu42	-2.422	-0.097
OBu43	0.949	-1.511
OBu44	-3.234	-1.261
OBu45	-1.470	-0.359
OBu46	0.481	-1.063
OBu47	-1.206	-1.011
OBu48	-0.672	-0.554
OBu49	1.021	-1.025
OBu50	0.590	-1.103
OBu51	-6.503	1.707
OBu52	-1.554	-1.274
OBu53	0.590	-0.757
OBu54	-0.599	-1.142
OBu55	-0.410	-1.028
OBu56	0.082	-1.035
OBu57	0.273	-0.857
OBu58	1.691	-1.110
OBu59	0.831	-1.434
OBu60	0.851	-0.818
OBu61	1.826	-1.195
OBu62	1.720	-0.999
OBu63	1.465	-1.160
OBu64	-4.212	-0.248
OBu65	-1.150	-1.978



Summary Plots

Attached Appendices

1. Photos of subsurface sediments (cores) for both Botany Bay and Port Hacking.



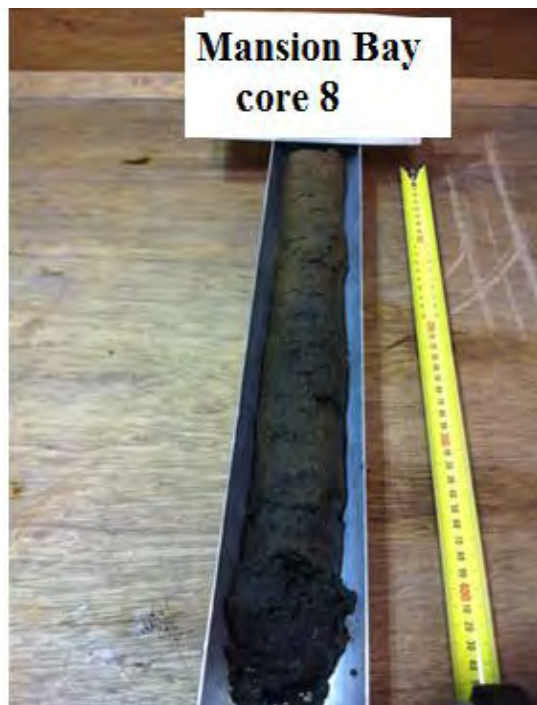
**Salt Pan Creek
core 6**



**Gunnamatta Bay
core 7**



**Mansion Bay
core 8**



2. Wind data (Speed and direction)

1- At 9AM

January

Direction	Speed
SSE	13
SE	20
S	13
N	19
NE	17
NE	15
S	24
NW	13
S	35
NE	19
N	11
NW	11
SE	15
SSW	41
SSE	13
W	9
SSE	15
N	15
S	28
SE	19
SW	9
N	17
SSW	31
S	26
N	17
NE	20
NE	7
NNE	17
NNW	17
S	19
N	20

February

Direction	Speed
S	50
SSW	39
W	19
SW	17
NNW	11
N	13
NW	13
NNE	15
N	17
N	6
S	37
S	28
SSW	20
WSW	7
S	15
SSW	19
S	11
NW	9
W	6
ESE	19
SE	20
SE	35
ESE	35
NE	31
NNE	17
NNE	24
NNE	19
NNE	11

March

Direction	Speed
SE	39
SSE	41
SE	31
E	24
E	24
N	13
NW	15
NNW	13
NNW	11
NNW	13
SSW	9
SW	7
NNW	11
W	9
SSW	26
N	13
SSW	31
SSW	24
NW	9
NW	11
N	13
N	28
SSE	7
W	7
NW	13
NW	11
NW	11
N	11
SW	24
NW	11
WNW	17

April

Direction	Speed
SSW	9
WNW	17
S	39
NE	17
NW	9
NNW	11
NW	9
NW	13
SSW	13
WNW	13
WNW	13
W	7
WNW	13
WNW	15
WNW	13
SW	20
WSW	9
NW	15
SW	37
SSW	22
WSW	11
NNW	17
W	15
W	24
W	20
WNW	17
NW	13
WNW	11
WSW	9
SSW	26

May

Direction	Speed
NW	17
SSW	28
NW	13
WNW	13
WSW	11
SSW	24
S	20
NW	11
NW	15
NW	15
NW	11
NNW	11
NW	17
WSW	33
WNW	9
NNW	22
W	28
WSW	31
WNW	22
W	30
WNW	28
NW	13
SE	22
SSW	30
NW	15
NW	15
NW	13
NNW	9
NW	13
NW	13
NW	15

June

Direction	Speed
N	20
WNW	22
W	24
WNW	19
NNW	9
NW	15
N	22
SSW	19
NW	11
NW	13
NW	17
NNW	7
NW	17
NNW	20
WSW	33
W	26
WNW	17
W	26
SSW	30
W	19
NNW	11
NNW	7
SSW	26
SE	13
NNW	11
SE	46
E	17
NW	7
E	9
SW	15

July

Direction	Speed
NNW	9
WNW	15
NW	19
WSW	9
NW	24
NW	19
NW	13
WNW	13
SW	13
W	9
NW	13
NW	17
NW	11
NNW	11
NW	11
WNW	11
NW	4
NW	11
NNE	19
N	19
NW	28
SSW	9
WNW	20
SSW	33
NW	13
NW	17
NW	17
NNW	9
NW	13
WNW	13
SSW	31

August

Direction	Speed
NW	17
WNW	15
WSW	15
NW	15
NW	17
NNW	30
WSW	31
W	19
W	17
W	11
W	17
NW	13
N	17
N	24
WSW	33
NW	17
NNE	24
NW	26
N	13
WSW	31
W	20
N	17
NW	24
WSW	31
NW	13
WSW	19
WNW	15
W	15
WNW	6
N	28
WNW	13

September

Direction	Speed
NW	15
NW	13
NW	11
N	9
NW	13
S	26
NNW	17
S	17
NNW	22
NNW	43
W	31
W	17
SSW	28
WNW	19
SSW	13
ENE	13
N	26
NW	28
WSW	9
NNW	19
WSW	24
NW	13
NW	9
NNE	11
NW	15
N	28
W	17
NW	13
SW	11
NW	15

October

Direction	Speed
N	35
NNW	24
WSW	30
SSW	28
NW	20
WNW	9
S	37
WSW	9
NW	19
NW	17
S	30
WNW	11
NW	17
SSW	37
WNW	17
NW	13
N	33
SW	20
WNW	11
N	13
NW	17
SW	26
NNW	28
W	28
W	22
WSW	31
NNW	19
E	19
WNW	15
SSW	26
W	11

November

Direction	Speed
ESE	9
NW	11
WNW	11
SSW	43
SSW	30
W	11
NW	13
NW	15
NNW	17
SSE	33
SSE	46
Calm	
WNW	17
WSW	20
SSW	13
SSE	22
SSW	33
SSW	44
SSW	30
WNW	11
NE	28
NE	33
W	11
SSE	17
SSW	13
S	30
WNW	13
N	17
S	20
S	30

December

Direction	Speed
SSE	11
NE	13
N	17
NNE	13
SW	13
WSW	33
WNW	15
NE	17
WNW	11
NW	28
WSW	17
ENE	20
W	9
S	37
NNE	9
NNW	17
NNE	15
NNE	17
NNE	24
N	13
SSW	31
NNE	17
SSE	15
SSE	31
NW	9
SSW	20
SW	11
NNE	19
S	59
E	13
WNW	11

2- At 3PM**January**

Direction	Speed
E	20
SSE	33
E	24
NE	35
NE	35
ENE	28
E	24
NW	35
SSE	31
ENE	33
ENE	28
S	39
SSE	20
S	41
ENE	20
ENE	31
ENE	33
W	17
S	30
SE	19
ENE	28
NE	35
S	39
S	24
NE	37
NE	43
NNW	6
NE	19
S	37
SE	24
NE	37

February

Direction	Speed
S	54
SSW	50
S	30
S	31
E	22
ENE	30
NE	35
NE	30
NNE	35
S	44
S	35
S	28
S	26
E	26
E	24
S	30
ESE	19
ENE	30
ENE	20
SE	24
SE	28
SE	41
ESE	48
NE	43
NE	39
NE	39
NE	39
S	44

March

Direction	Speed
S	44
SSE	37
SE	31
ESE	24
ENE	30
NE	28
NE	30
ENE	26
NE	31
NE	30
ENE	35
ENE	22
NE	33
SSW	24
S	31
ENE	28
SSW	48
S	24
SE	20
ENE	22
NNE	39
NNW	30
ESE	20
ENE	26
SSE	24
NE	30
NE	24
W	17
S	28
NE	24
S	31

April

Direction	Speed
SE	17
SSE	17
S	37
WNW	9
SE	11
NNE	9
E	17
SE	15
SE	9
ENE	26
NE	19
ENE	26
NE	30
ENE	17
SSE	11
SSW	35
S	20
S	35
SSW	50
S	44
SE	13
NW	9
SE	17
SE	22
SE	15
S	13
NE	22
WNW	17
SE	15
SSE	20

May

Direction	Speed
S	28
S	35
N	17
SSE	41
SSE	19
S	26
SSE	19
E	17
NNE	11
S	13
NE	28
NE	20
WSW	7
S	15
WNW	37
W	39
W	41
WSW	22
WSW	24
WSW	28
SSE	26
SSW	26
SE	35
SSE	31
S	17
SSE	7
S	30
NE	26
NNE	13
NE	22
N	17

June

Direction	Speed
N	24
SSW	50
S	19
S	17
NE	22
N	15
SSW	19
SSW	15
NE	26
WNW	19
W	9
WNW	17
NW	26
W	31
SW	30
SSW	20
SW	28
SSW	28
SSW	39
S	30
S	20
SW	13
SSW	20
NW	13
SSE	22
SSE	30
ESE	19
ENE	11
SSE	24
SW	13

July

Direction	Speed
SE	11
ESE	11
NE	13
NW	22
WNW	35
W	17
W	17
S	24
SSW	15
S	17
SE	13
NW	9
SSE	6
ENE	19
NNW	15
SE	13
SE	11
NE	20
N	26
NW	28
WNW	35
W	30
SSW	17
SSW	28
N	11
WNW	13
ENE	19
NNE	17
N	15
ESE	11
S	31

August

Direction	Speed
SE	15
W	24
SW	11
W	31
WNW	22
WNW	43
ESE	17
SSW	48
NNW	15
W	17
SE	13
WNW	48
WNW	11
NW	35
SSE	24
NNE	33
WNW	33
NW	26
W	37
W	37
WSW	24
WNW	31
WNW	39
SE	22
E	19
E	9
SSE	17
SSE	22
NE	28
ENE	20
SE	20

September

Direction	Speed
ENE	26
NNE	19
ENE	24
NE	37
NW	15
SE	17
S	26
SSE	19
NNE	24
WNW	57
W	7
W	28
ENE	20
S	39
ESE	17
NE	33
NNW	33
WNW	30
WNW	43
W	50
ESE	19
ENE	22
E	17
NE	11
NE	35
WNW	41
E	22
WNW	44
ENE	24
NE	28

October

Direction	Speed
WNW	59
NW	26
S	44
SE	17
E	17
NE	24
SSE	39
SSE	28
NE	28
W	35
ENE	22
ENE	31
WNW	54
S	24
ENE	33
NE	35
NW	48
E	28
NE	31
ENE	30
NE	28
WSW	11
WNW	41
SW	48
ENE	31
SE	28
ESE	20
ESE	20
S	59
SE	24
E	28

November

Direction	Speed
ENE	30
ENE	24
WSW	43
S	50
SSE	24
ENE	37
NE	31
NE	37
SSE	37
SE	33
SSE	43
ENE	9
ENE	28
ESE	28
SE	31
SE	37
S	39
SSE	37
SSE	24
ENE	28
NE	35
NNE	44
S	15
SE	28
SSW	46
S	30
E	28
NE	39
SSW	41
S	28

December

Direction	Speed
E	17
ENE	30
NE	37
NE	31
W	54
SE	24
ENE	20
NE	37
NNE	26
ESE	26
ENE	30
ENE	31
ENE	33
SSE	33
SE	24
ENE	26
ENE	33
ENE	31
NE	41
NNE	30
S	43
NE	28
ENE	15
S	24
NE	20
SE	22
ENE	26
NE	37
S	37
ENE	33
E	24

3. Current and tide velocities

Kogarah Bay velocity 1

Latitude	Longitude	Time AETS	Speed M/Sec
33.98484	151.1295	12:34:15	0.007294
33.98486	151.1295	12:35:15	0.04119
33.98487	151.1295	12:36:15	0.004144
33.98488	151.1295	12:37:15	0.009571
33.98488	151.1295	12:38:15	0.005016
33.98489	151.1294	12:39:15	0.003363
33.9849	151.1294	12:40:15	0.00026
33.9849	151.1294	12:41:15	0.003211
33.98491	151.1294	12:42:15	0.007372
33.98492	151.1294	12:43:15	0.002623
33.98492	151.1294	12:44:15	0.003063
33.98493	151.1294	12:45:15	0.00029
33.98494	151.1294	12:46:15	0.003535
33.98494	151.1294	12:47:15	0.005855
33.98495	151.1293	12:48:15	0.001999
33.98496	151.1293	12:49:15	0.009516
33.98498	151.1293	12:50:15	0.007428
33.98499	151.1293	12:51:15	0.003259
33.985	151.1292	12:52:15	0.007302
33.98501	151.1292	12:53:15	0.002966
33.98502	151.1292	12:54:15	0.008471
33.98503	151.1291	12:55:15	0.00576
33.98504	151.1291	12:56:15	0.002846
33.98505	151.1291	12:57:15	0.002577
33.98507	151.1291	12:58:15	0.006689
33.98508	151.129	12:59:15	0.003349
33.98509	151.129	13:00:15	0.005775
33.9851	151.129	13:01:15	0.004691
33.98511	151.129	13:02:15	0.007272
33.98512	151.129	13:03:15	0.009283
33.98512	151.1289	13:04:15	0.00607
33.98513	151.1289	13:05:15	0.009254
33.98515	151.1289	13:06:15	0.004754
33.98517	151.1288	13:07:15	0.003036
33.98517	151.1288	13:08:15	0.005538
33.98519	151.1288	13:09:15	0.004179
33.9852	151.1287	13:10:15	0.007051
33.98521	151.1287	13:11:15	0.009152
33.98522	151.1287	13:12:15	0.003846
33.98522	151.1287	13:13:15	0.014142
33.98523	151.1287	13:14:15	0.003689
33.98524	151.1286	13:15:15	0.007701
33.98525	151.1286	13:16:15	0.022026
33.98527	151.1286	13:17:15	0.089826
33.98531	151.1284	13:18:15	0.264093
33.98533	151.1283	13:19:15	0.198439
33.98535	151.1282	13:20:15	0.138872
33.9854	151.1282	13:21:15	0.072738
33.9854	151.1282	13:22:15	0.008637
33.98541	151.1281	13:23:15	0.074612
33.98548	151.128	13:24:15	0.082074
33.98551	151.128	13:25:15	0.175516
33.98552	151.128	13:26:15	0.238725
33.98552	151.1279	13:27:15	0.149858
33.98556	151.1279	13:28:15	0.127459
33.98558	151.1279	13:29:15	0.191751
33.98559	151.1279	13:30:15	0.004433
33.9856	151.1279	13:31:15	0.002604
33.98561	151.1279	13:32:15	0.267901
33.98562	151.1279	13:33:15	0.079436
33.98563	151.1278	13:34:15	0.005421

Kogarah Bay velocity 2

Latitude	Longitude	Time AEST	Speed M/Sec
33.98841	151.1227	12:29:20	0.048989
33.98842	151.1226	12:29:30	0.097844
33.98842	151.1226	12:29:35	0.211191
33.98842	151.1226	12:29:40	0.081361
33.98842	151.1226	12:29:45	0.062828
33.98842	151.1226	12:29:50	0.102914
33.98842	151.1226	12:29:55	0.235128
33.98842	151.1226	12:30:00	0.062424
33.98842	151.1226	12:30:05	0.138446
33.98843	151.1226	12:30:10	0.065479
33.98843	151.1226	12:30:15	0.00823
33.98843	151.1226	12:30:20	0.007571
33.98843	151.1226	12:30:25	0.000962
33.98843	151.1226	12:30:30	0.008801
33.98843	151.1226	12:30:35	0.007236
33.98843	151.1226	12:30:40	0.032371
33.98843	151.1226	12:30:45	0.007126
33.98843	151.1226	12:30:50	0.00586
33.98843	151.1226	12:30:55	0.001819
33.98843	151.1226	12:31:00	0.003682
33.98843	151.1226	12:31:05	0.003459
33.98843	151.1226	12:31:10	0.006515
33.98843	151.1226	12:31:15	0.13236
33.98843	151.1226	12:31:20	0.058044
33.98843	151.1226	12:31:25	0.05067
33.98843	151.1226	12:31:30	0.066053
33.98844	151.1226	12:31:35	0.081678
33.98844	151.1226	12:31:40	0.050921
33.98844	151.1226	12:31:45	0.004741
33.98844	151.1226	12:31:50	0.002176
33.98844	151.1226	12:31:55	0.005909
33.98844	151.1226	12:32:00	0.006227
33.98844	151.1226	12:32:05	0.009644
33.98844	151.1226	12:32:10	0.000744
33.98844	151.1226	12:32:15	0.005471
33.98844	151.1226	12:32:20	0.002877
33.98844	151.1226	12:32:25	0.001895
33.98844	151.1226	12:32:30	0.006211
33.98844	151.1226	12:32:35	0.002024
33.98844	151.1226	12:32:40	0.007315
33.98844	151.1226	12:32:45	0.103897
33.98844	151.1226	12:32:50	0.143829
33.98845	151.1226	12:32:55	0.12045
33.98845	151.1226	12:33:00	0.115504
33.98845	151.1226	12:33:05	0.062924
33.98845	151.1226	12:33:10	0.04248
33.98846	151.1226	12:33:15	0.009158
33.98846	151.1226	12:33:20	0.053188
33.98846	151.1226	12:33:25	0.163161
33.98846	151.1225	12:33:30	0.129643
33.98846	151.1225	12:33:35	0.11815
33.98846	151.1225	12:33:40	0.165573
33.98847	151.1225	12:33:45	0.280047
33.98848	151.1225	12:33:50	0.303006
33.98848	151.1225	12:33:55	0.12919
33.98848	151.1225	12:34:00	0.437964
33.98848	151.1225	12:34:05	0.180627
33.98848	151.1225	12:34:10	0.250945
33.98849	151.1225	12:34:15	0.168773
33.98849	151.1225	12:34:20	0.212489
33.9885	151.1225	12:34:25	0.196198
33.9885	151.1225	12:34:30	0.169839
33.98851	151.1225	12:34:35	0.169092
33.98851	151.1225	12:34:40	0.114465
33.98851	151.1225	12:34:45	0.105315
33.98851	151.1225	12:34:50	0.320433
33.98851	151.1225	12:34:55	0.103461
33.98852	151.1225	12:35:00	0.13451
33.98852	151.1225	12:35:05	0.089152
33.98852	151.1225	12:35:10	0.149683
33.98852	151.1225	12:35:15	0.160365
33.98852	151.1225	12:35:20	0.142616

33.98852	151.1225	12:35:25	0.074833
33.98852	151.1225	12:35:30	0.245779
33.98852	151.1225	12:35:35	0.045453
33.98852	151.1225	12:35:40	0.240627
33.98852	151.1225	12:35:45	0.065083
33.98853	151.1225	12:35:50	0.023707
33.98853	151.1225	12:35:55	0.070046
33.98853	151.1224	12:36:00	0.335599
33.98853	151.1224	12:36:05	0.276026
33.98854	151.1224	12:36:10	0.189923
33.98854	151.1224	12:36:15	0.260423
33.98855	151.1224	12:36:20	0.288912
33.98855	151.1224	12:36:25	0.198429
33.98855	151.1224	12:36:30	0.178802
33.98855	151.1224	12:36:35	0.268272
33.98855	151.1224	12:36:40	0.173666
33.98855	151.1224	12:36:45	0.151952
33.98855	151.1224	12:36:50	0.214657
33.98856	151.1224	12:36:55	0.079228
33.98856	151.1224	12:37:00	0.195695
33.98856	151.1224	12:37:05	0.147468
33.98856	151.1224	12:37:10	0.361186
33.98856	151.1224	12:37:15	0.099809
33.98857	151.1224	12:37:20	0.148185
33.98857	151.1224	12:37:25	0.267889
33.98857	151.1224	12:37:30	0.188168
33.98857	151.1224	12:37:35	0.186792
33.98857	151.1224	12:37:40	0.273378
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33.98955	151.1211	13:11:15	0.239047
33.98955	151.1211	13:11:20	0.192961
33.98956	151.1211	13:11:25	0.239783
33.98955	151.1211	13:11:30	0.164398
33.98956	151.1211	13:11:35	0.159844
33.98956	151.1211	13:11:40	0.182614
33.98956	151.1211	13:11:45	0.257643
33.98957	151.1211	13:11:50	0.248741
33.98958	151.1211	13:11:55	0.092345
33.98958	151.1211	13:12:00	0.023794
33.98958	151.1211	13:12:05	0.315356
33.98957	151.1211	13:12:10	0.098381
33.98958	151.1211	13:12:15	0.164985
33.98958	151.1211	13:12:20	0.324922
33.98958	151.1211	13:12:25	0.243717
33.98958	151.1211	13:12:30	0.164288
33.98958	151.1211	13:12:35	0.123606
33.98958	151.1211	13:12:40	0.321968
33.98959	151.1211	13:12:45	0.203763
33.98959	151.1211	13:12:50	0.474715
33.98959	151.1211	13:12:55	0.181438
33.9896	151.1211	13:13:00	0.201248
33.98959	151.1211	13:13:05	0.145539
33.9896	151.1211	13:13:10	0.400064
33.98961	151.1211	13:13:15	0.360122
33.98961	151.1211	13:13:20	0.030083
33.98961	151.1211	13:13:25	0.182066
33.98961	151.1211	13:13:30	0.245108
33.98962	151.1211	13:13:35	0.147262
33.98962	151.1211	13:13:40	0.304703
33.98962	151.1211	13:13:45	0.316918
33.98962	151.1211	13:13:50	0.0815
33.98962	151.1211	13:13:55	0.00316
33.98962	151.1211	13:14:00	0.268165
33.98963	151.1211	13:14:05	0.223447
33.98963	151.1211	13:14:10	0.34926
33.98963	151.1211	13:14:15	0.115318
33.98963	151.1211	13:14:20	0.193007
33.98964	151.1211	13:14:25	0.052385
33.98964	151.1211	13:14:30	0.227849
33.98965	151.1211	13:14:35	0.104892
33.98965	151.1211	13:14:40	0.137759
33.98965	151.1211	13:14:45	0.278745
33.98966	151.1211	13:14:50	0.264586
33.98965	151.1211	13:14:55	0.241974
33.98966	151.1211	13:15:00	0.378988
33.98966	151.1211	13:15:05	0.251524
33.98967	151.1211	13:15:10	0.280196
33.98968	151.121	13:15:15	0.052966
33.98968	151.121	13:15:20	0.074419
33.98968	151.121	13:15:25	0.049578
33.98968	151.121	13:15:30	0.271705
33.98969	151.121	13:15:35	0.065284
33.98969	151.121	13:15:40	0.121375
33.98969	151.121	13:15:45	0.179784
33.9897	151.121	13:15:50	0.16988
33.98969	151.121	13:15:55	0.124305
33.98969	151.121	13:16:00	0.144358
33.98969	151.121	13:16:05	0.059713
33.98969	151.121	13:16:10	0.151244
33.98968	151.121	13:16:15	0.156076
33.98968	151.121	13:16:20	0.201081
33.98968	151.121	13:16:25	0.027784
33.98969	151.121	13:16:30	0.115971
33.98969	151.121	13:16:35	0.110409
33.98969	151.121	13:16:40	0.037757
33.98969	151.121	13:16:45	0.090659
33.98969	151.121	13:16:50	0.081366
33.98969	151.121	13:16:55	0.217323
33.98969	151.121	13:17:00	0.262514
33.98969	151.121	13:17:05	0.135399
33.98969	151.1211	13:17:10	0.035151
33.98969	151.121	13:17:15	0.174551
33.98969	151.121	13:17:20	0.208245
33.98969	151.121	13:17:25	0.126493
33.98969	151.121	13:17:30	0.146873

33.98969	151.121	13:17:35	0.079387
33.98969	151.121	13:17:40	0.206837
33.98968	151.121	13:17:45	0.162688
33.98969	151.121	13:17:50	0.130305
33.98969	151.121	13:17:55	0.168867
33.9897	151.121	13:18:00	0.117999
33.9897	151.121	13:18:05	0.171263
33.98971	151.121	13:18:10	0.21066
33.98971	151.121	13:18:15	0.221391
33.98971	151.121	13:18:20	0.130475
33.98971	151.121	13:18:25	0.134592
33.9897	151.121	13:18:30	0.101779
33.9897	151.121	13:18:35	0.200439
33.9897	151.121	13:18:40	0.134303
33.9897	151.121	13:18:45	0.117019
33.9897	151.121	13:18:50	0.098008
33.9897	151.121	13:18:55	0.160403
33.98969	151.121	13:19:00	0.15173
33.98969	151.121	13:19:05	0.159919
33.9897	151.121	13:19:10	0.108037
33.98969	151.121	13:19:15	0.076518
33.98969	151.121	13:19:20	0.24932
33.98969	151.121	13:19:25	0.219528
33.98969	151.121	13:19:30	0.040388
33.98969	151.121	13:19:35	0.055933
33.98969	151.121	13:19:40	0.191911
33.98969	151.121	13:19:45	0.118479
33.98969	151.121	13:19:50	0.209522
33.98969	151.121	13:19:55	0.16911
33.98969	151.121	13:20:00	0.050061
33.98969	151.121	13:20:05	0.052343
33.98969	151.121	13:20:10	0.093141
33.98969	151.121	13:20:15	0.081327
33.98969	151.121	13:20:20	0.063042
33.98969	151.121	13:20:25	0.164786
33.98969	151.121	13:20:30	0.175187
33.98969	151.121	13:20:35	0.035766
33.98968	151.121	13:20:40	0.183098
33.98968	151.121	13:20:45	0.359061
33.98969	151.121	13:20:50	0.325255
33.98969	151.121	13:20:55	0.227962
33.98969	151.121	13:21:00	0.455858
33.9897	151.121	13:21:05	0.336871
33.9897	151.121	13:21:10	0.165087
33.98969	151.121	13:21:15	0.405834
33.9897	151.1211	13:21:20	0.249705
33.98969	151.121	13:21:25	0.074599
33.9897	151.121	13:21:30	0.359562
33.9897	151.121	13:21:35	0.256011
33.98971	151.121	13:21:40	0.168648
33.98971	151.121	13:21:45	0.333278
33.9897	151.121	13:21:50	0.214913
33.9897	151.121	13:21:55	0.155933
33.9897	151.121	13:22:00	0.137558
33.98971	151.121	13:22:05	0.291228
33.98971	151.121	13:22:10	0.230059
33.98971	151.121	13:22:15	0.326409
33.98971	151.121	13:22:20	0.397018
33.98971	151.121	13:22:25	0.218543
33.9897	151.121	13:22:30	0.282853
33.9897	151.121	13:22:35	0.138951
33.9897	151.121	13:22:40	0.207791
33.98971	151.121	13:22:45	0.194382
33.9897	151.121	13:22:50	0.207162
33.9897	151.121	13:22:55	0.385617
33.9897	151.121	13:23:00	0.216661
33.98971	151.121	13:23:05	0.070189
33.9897	151.121	13:23:10	0.288557
33.98971	151.121	13:23:15	0.240534
33.98971	151.121	13:23:20	0.441991
33.98971	151.121	13:23:25	0.077008
33.98971	151.121	13:23:30	0.171614
33.98971	151.121	13:23:35	0.312655
33.9897	151.121	13:23:40	0.196004
33.9897	151.121	13:23:45	0.266885
33.9897	151.121	13:23:50	0.131473
33.9897	151.121	13:23:55	0.167935
33.9897	151.121	13:24:00	0.277759
33.9897	151.121	13:24:05	0.102056
33.9897	151.121	13:24:10	0.260259
33.9897	151.121	13:24:15	0.255574
33.9897	151.121	13:24:20	0.169833
33.98971	151.121	13:24:25	0.134694
33.98971	151.121	13:24:30	0.167553
33.9897	151.121	13:24:35	0.170378
33.98971	151.121	13:24:40	0.078945

33.9897	151.121	13:24:45	0.234386
33.9897	151.121	13:24:50	0.204167
33.9897	151.121	13:24:55	0.434097
33.9897	151.121	13:25:00	0.112605
33.9897	151.121	13:25:05	0.147366
33.9897	151.121	13:25:10	0.370965
33.9897	151.121	13:25:15	0.147897
33.9897	151.121	13:25:20	0.197572
33.9897	151.121	13:25:25	0.351592
33.98969	151.121	13:25:30	0.144507
33.98969	151.121	13:25:35	0.213255
33.98969	151.121	13:25:40	0.226975
33.98969	151.121	13:25:45	0.113801
33.98969	151.121	13:25:50	0.236798
33.98969	151.121	13:25:55	0.260499
33.98969	151.121	13:26:00	0.300381
33.9897	151.121	13:26:05	0.258541
33.98969	151.121	13:26:10	0.075085
33.98969	151.121	13:26:15	0.218503
33.98969	151.121	13:26:20	0.315163
33.98969	151.121	13:26:25	0.042849
33.98969	151.121	13:26:30	0.233489
33.98969	151.121	13:26:35	0.119358
33.9897	151.121	13:26:40	0.261961
33.98969	151.121	13:26:45	0.190083
33.98969	151.121	13:26:50	0.344974
33.98969	151.121	13:26:55	0.09581
33.9897	151.121	13:27:00	0.113997
33.9897	151.121	13:27:05	0.353846
33.9897	151.121	13:27:10	0.131407
33.9897	151.121	13:27:15	0.294524
33.9897	151.121	13:27:20	0.428038
33.9897	151.121	13:27:25	0.258053
33.9897	151.121	13:27:30	0.234808
33.9897	151.121	13:27:35	0.237058
33.9897	151.121	13:27:40	0.085141
33.9897	151.121	13:27:45	0.285819
33.9897	151.121	13:27:50	0.231351
33.9897	151.121	13:27:55	0.343605
33.9897	151.121	13:28:00	0.095784
33.9897	151.121	13:28:05	0.077728
33.9897	151.121	13:28:10	0.101345
33.9897	151.121	13:28:15	0.448107
33.9897	151.121	13:28:20	0.179355
33.9897	151.121	13:28:25	0.339433
33.9897	151.121	13:28:30	0.162833
33.9897	151.121	13:28:35	0.099691
33.9897	151.121	13:28:40	0.087173
33.9897	151.121	13:28:45	0.166416
33.9897	151.121	13:28:50	0.303536
33.9897	151.121	13:28:55	0.02098
33.9897	151.121	13:29:00	0.239276
33.9897	151.121	13:29:05	0.253773
33.9897	151.121	13:29:10	0.273964
33.9897	151.121	13:29:15	0.269225
33.9897	151.121	13:29:20	0.112248
33.9897	151.121	13:29:25	0.086796
33.9897	151.121	13:29:30	0.299907
33.9897	151.121	13:29:35	0.341032
33.9897	151.121	13:29:40	0.260532
33.9897	151.121	13:29:45	0.205583
33.98969	151.121	13:29:50	0.071574
33.98969	151.121	13:29:55	0.214904
33.98969	151.121	13:30:00	0.281849
33.98969	151.121	13:30:05	0.210183
33.98969	151.121	13:30:10	0.614316
33.9897	151.121	13:30:15	0.356736
33.9897	151.121	13:30:20	0.122015
33.9897	151.121	13:30:25	0.409464
33.9897	151.121	13:30:30	0.320908
33.9897	151.121	13:30:35	0.245156
33.9897	151.121	13:30:40	0.127746
33.9897	151.121	13:30:45	0.147219

Kogarah Bay velocity 3

Latitude	Longitude	Time AEST	Speed M/Sec
33.99171	151.1195	12:25:30	0.145782
33.99171	151.1194	12:26:00	0.246546
33.99173	151.1194	12:26:30	0.162378
33.99174	151.1194	12:27:00	0.21973
33.99174	151.1194	12:27:30	0.138797
33.99174	151.1194	12:28:00	0.14883
33.99175	151.1193	12:28:30	0.108478
33.99176	151.1193	12:29:00	0.319098
33.99177	151.1193	12:29:30	0.121664
33.99177	151.1193	12:30:00	0.006712
33.99179	151.1193	12:30:30	0.275349
33.99181	151.1193	12:31:00	0.228826
33.99183	151.1193	12:31:30	0.064129
33.99183	151.1193	12:32:00	0.136385
33.99185	151.1192	12:32:30	0.233731
33.99187	151.1193	12:33:00	0.204273
33.99186	151.1192	12:33:30	0.109259
33.99185	151.1192	12:34:00	0.007189
33.99184	151.1192	12:34:30	0.057859
33.99186	151.1192	12:35:00	0.083891
33.99187	151.1192	12:35:30	0.152133
33.99187	151.1191	12:36:00	0.338079
33.99188	151.1191	12:36:30	0.181125
33.99189	151.1191	12:37:00	0.115636
33.99189	151.1191	12:37:30	0.022901
33.9919	151.119	12:38:00	0.231896
33.99192	151.119	12:38:30	0.124493
33.99193	151.119	12:39:00	0.071981
33.99193	151.119	12:39:30	0.18088
33.99195	151.119	12:40:00	0.122535
33.99196	151.119	12:40:30	0.147463
33.99198	151.119	12:41:00	0.151638
33.99199	151.119	12:41:30	0.146024
33.992	151.1189	12:42:00	0.126286
33.99202	151.1189	12:42:30	0.131957
33.99202	151.1189	12:43:00	0.446861
33.99203	151.1189	12:43:30	0.248534
33.99204	151.1188	12:44:00	0.122674
33.99205	151.1188	12:44:30	0.077345
33.99207	151.1188	12:45:00	0.160854
33.99209	151.1188	12:45:30	0.086129
33.99208	151.1188	12:46:00	0.092151
33.99207	151.1188	12:46:30	0.158734
33.99207	151.1188	12:47:00	0.287681
33.99208	151.1187	12:47:30	0.330282
33.99208	151.1188	12:48:00	0.077775
33.99209	151.1188	12:48:30	0.132523
33.99211	151.1187	12:49:00	0.082871
33.99212	151.1187	12:49:30	0.136089
33.99213	151.1187	12:50:00	0.110244
33.99213	151.1187	12:50:30	0.220591
33.99214	151.1187	12:51:00	0.042602
33.99214	151.1186	12:51:30	0.238027
33.99216	151.1186	12:52:00	0.077051
33.99217	151.1186	12:52:30	0.153326
33.99216	151.1186	12:53:00	0.230464
33.99216	151.1186	12:53:30	0.089487

33.99216	151.1186	12:54:00	0.225117
33.99217	151.1186	12:54:30	0.308323
33.99219	151.1186	12:55:00	0.276276
33.99218	151.1186	12:55:30	0.158566
33.99217	151.1185	12:56:00	0.204246
33.99219	151.1185	12:56:30	0.330193
33.99218	151.1185	12:57:00	0.04733
33.99218	151.1185	12:57:30	0.159894
33.99219	151.1185	12:58:00	0.256818
33.9922	151.1185	12:58:30	0.322708
33.9922	151.1185	12:59:00	0.124375
33.99219	151.1185	12:59:30	0.249376
33.99219	151.1185	13:00:00	0.39254
33.99219	151.1185	13:00:30	0.189778
33.99219	151.1185	13:01:00	0.168253
33.99219	151.1185	13:01:30	0.34218
33.9922	151.1185	13:02:00	0.11646
33.99218	151.1185	13:02:30	0.202738
33.99218	151.1185	13:03:00	0.267396
33.99218	151.1185	13:03:30	0.136433
33.99217	151.1184	13:04:00	0.157709
33.99216	151.1184	13:04:30	0.054909
33.99216	151.1184	13:05:00	0.136581
33.99215	151.1184	13:05:30	0.121199
33.99216	151.1184	13:06:00	0.201542
33.99216	151.1184	13:06:30	0.092015
33.99215	151.1184	13:07:00	0.057223
33.99215	151.1184	13:07:30	0.332002
33.99218	151.1184	13:08:00	0.10686
33.99218	151.1184	13:08:30	0.170908
33.99218	151.1184	13:09:00	0.267588
33.99217	151.1184	13:09:30	0.13846
33.99217	151.1184	13:10:00	0.191051
33.99217	151.1184	13:10:30	0.191861
33.99217	151.1184	13:11:00	0.067338
33.99218	151.1184	13:11:30	0.157821
33.99218	151.1183	13:12:00	0.404081
33.99217	151.1184	13:12:30	0.071877
33.99216	151.1183	13:13:00	0.173007
33.99216	151.1183	13:13:30	0.472804
33.99215	151.1183	13:14:00	0.359932
33.99214	151.1183	13:14:30	0.08322
33.99217	151.1183	13:15:00	0.255928
33.99217	151.1183	13:15:30	0.075127
33.99217	151.1183	13:16:00	0.177808
33.99216	151.1183	13:16:30	0.224775
33.99216	151.1182	13:17:00	0.144708
33.99215	151.1182	13:17:30	0.055201
33.99214	151.1182	13:18:00	0.114424
33.99213	151.1182	13:18:30	0.062422
33.99212	151.1182	13:19:00	0.226437
33.99212	151.1182	13:19:30	0.188796
33.99212	151.1182	13:20:00	0.358453
33.99216	151.1182	13:20:30	0.321589
33.99216	151.1182	13:21:00	0.246226
33.99214	151.1182	13:21:30	0.225846
33.99216	151.1181	13:22:00	0.098076
33.99216	151.1181	13:22:30	0.108125
33.99215	151.1181	13:23:00	0.131633
33.99214	151.1181	13:23:30	0.124406
33.99216	151.1181	13:24:00	0.066197

33.99215	151.1181	13:24:30	0.404252
33.99215	151.1181	13:25:00	0.107291
33.99216	151.1181	13:25:30	0.076846

Oyster Bay velocity 1

Latitude	Longitude	Time AEST	Speed M/Sec
34.00954	151.088	10:44:05	0.066688
34.00954	151.088	10:44:35	0.001031
34.00954	151.088	10:45:05	0.005108
34.00954	151.088	10:45:35	0.002434
34.00954	151.088	10:46:05	0.002209
34.00954	151.088	10:46:35	0.001006
34.00955	151.088	10:47:05	0.002069
34.00955	151.088	10:47:35	0.002137
34.00955	151.088	10:48:05	0.003577
34.00955	151.088	10:48:35	0.005717
34.00956	151.088	10:49:05	0.006778
34.00956	151.088	10:49:35	0.004451
34.00956	151.088	10:50:05	0.004524
34.00956	151.088	10:50:35	0.00197
34.00956	151.088	10:51:05	0.012616
34.00956	151.088	10:51:35	0.003017
34.00957	151.088	10:52:05	0.003048
34.00957	151.088	10:52:35	0.004126
34.00957	151.088	10:53:05	0.004868
34.00957	151.088	10:53:35	0.003208
34.00958	151.088	10:54:05	0.007176
34.00958	151.0881	10:54:35	0.006655
34.00958	151.0881	10:55:05	0.001691
34.00958	151.0881	10:55:35	0.005721
34.00959	151.0881	10:56:05	0.005829
34.00959	151.0881	10:56:35	0.00415
34.00962	151.0881	10:58:05	0.003611
34.00962	151.0881	10:58:35	0.002004
34.00962	151.0881	10:59:05	0.002472
34.00962	151.0881	10:59:35	0.003619
34.00962	151.0881	11:00:05	0.0055
34.00963	151.0881	11:00:35	0.006035
34.00963	151.0881	11:01:05	0.001525
34.00963	151.0881	11:01:35	0.006004
34.00963	151.0881	11:02:05	0.008039
34.00963	151.0881	11:02:35	0.001408
34.00964	151.0881	11:03:05	0.007163
34.00964	151.0881	11:03:35	0.001416
34.00964	151.0881	11:04:05	0.004531
34.00964	151.0881	11:04:35	0.004993
34.00964	151.0881	11:05:05	0.000994
34.00964	151.0882	11:05:35	0.009223
34.00965	151.0882	11:06:05	0.002232
34.00965	151.0882	11:06:35	0.000718
34.00965	151.0882	11:07:05	0.001917
34.00965	151.0882	11:07:35	0.004254
34.00965	151.0882	11:08:05	0.003923
34.00965	151.0882	11:08:35	0.004923
34.00965	151.0882	11:09:05	0.005286
34.00965	151.0882	11:09:35	0.007105
34.00965	151.0882	11:10:05	0.003279
34.00965	151.0882	11:10:35	0.003717

34.00965	151.0882	11:11:05	0.002921
34.00966	151.0882	11:11:35	0.004696
34.00966	151.0882	11:12:05	0.004969
34.00966	151.0882	11:12:35	0.0053
34.00966	151.0882	11:13:05	0.004071
34.00966	151.0882	11:13:35	0.006381
34.00967	151.0882	11:14:05	0.004806
34.00967	151.0882	11:14:35	0.005836
34.00967	151.0882	11:15:05	0.000663
34.00968	151.0882	11:15:35	0.000823
34.00968	151.0882	11:16:05	0.010417
34.00968	151.0882	11:16:35	0.007999
34.00969	151.0882	11:17:05	0.006362
34.00969	151.0882	11:17:35	0.002935
34.00969	151.0882	11:18:05	0.004422
34.00969	151.0883	11:18:35	0.003024
34.0097	151.0883	11:19:05	0.004655
34.0097	151.0883	11:19:35	0.00652
34.0097	151.0883	11:20:05	0.003782
34.0097	151.0883	11:20:35	0.008544
34.00971	151.0883	11:21:05	0.005789
34.00971	151.0883	11:21:35	0.004418
34.00971	151.0883	11:22:05	0.003744
34.00971	151.0883	11:22:35	0.002949
34.00972	151.0883	11:23:05	0.00435
34.00972	151.0883	11:23:35	0.002352
34.00972	151.0883	11:24:05	0.002174
34.00972	151.0883	11:24:35	0.003699
34.00972	151.0883	11:25:05	0.002628
34.00973	151.0883	11:25:35	0.004553
34.00973	151.0883	11:26:05	0.004666
34.00973	151.0883	11:26:35	0.004234
34.00974	151.0883	11:27:05	0.002181
34.00974	151.0883	11:27:35	0.003406
34.00974	151.0883	11:28:05	0.003211
34.00974	151.0883	11:28:35	0.004775
34.00975	151.0883	11:29:05	0.002641
34.00975	151.0883	11:29:35	0.002333
34.00975	151.0883	11:30:05	0.00237
34.00976	151.0883	11:30:35	0.002822
34.00976	151.0883	11:31:05	0.002851
34.00976	151.0883	11:31:35	0.001037
34.00977	151.0883	11:32:05	0.001728
34.00977	151.0883	11:32:35	0.000878
34.00977	151.0883	11:33:05	0.001424
34.00977	151.0884	11:33:35	0.00402
34.00977	151.0884	11:34:05	0.004049
34.00977	151.0884	11:34:35	0.005084
34.00978	151.0884	11:35:05	0.000132
34.00978	151.0884	11:35:35	0.000179
34.00978	151.0884	11:36:05	0.003126
34.00978	151.0884	11:36:35	0.007319
34.00978	151.0884	11:37:05	0.004496
34.00978	151.0884	11:37:35	0.000536
34.00978	151.0884	11:38:05	0.002126
34.00979	151.0884	11:38:35	0.001123
34.00979	151.0884	11:39:05	0.005992
34.00979	151.0884	11:39:35	0.006031
34.00979	151.0884	11:40:05	0.003147
34.00979	151.0884	11:40:35	0.003027
34.00979	151.0884	11:41:05	0.002915

34.0098	151.0884	11:41:35	0.002935
34.0098	151.0884	11:42:05	0.001806
34.0098	151.0884	11:42:35	0.00035
34.0098	151.0884	11:43:05	0.002017
34.0098	151.0884	11:43:35	0.000998
34.0098	151.0884	11:44:05	0.002064
34.0098	151.0884	11:44:35	0.003014
34.0098	151.0884	11:45:05	0.003192
34.00981	151.0884	11:45:35	0.001477
34.00981	151.0884	11:46:05	0.003982
34.00981	151.0884	11:46:35	0.002572
34.00981	151.0884	11:47:05	0.004894
34.00981	151.0884	11:47:35	0.002584
34.00981	151.0884	11:48:05	0.001557
34.00981	151.0884	11:48:35	0.000568
34.0098	151.0884	11:49:05	0.007211
34.00981	151.0884	11:49:35	0.003132
34.0098	151.0884	11:50:05	0.001938
34.0098	151.0884	11:50:35	0.004556
34.0098	151.0884	11:51:05	0.001108
34.0098	151.0884	11:51:35	0.003363
34.0098	151.0884	11:52:05	0.004413
34.0098	151.0884	11:52:35	0.001757
34.0098	151.0884	11:53:05	0.004176
34.0098	151.0884	11:53:35	0.003398
34.0098	151.0884	11:54:05	0.0027
34.00979	151.0884	11:54:35	0.003618
34.00979	151.0884	11:55:05	0.002126
34.00979	151.0883	11:55:35	0.002309
34.00979	151.0883	11:56:05	0.000788
34.00978	151.0883	11:56:35	0.002863
34.00978	151.0883	11:57:05	0.000992
34.00978	151.0883	11:57:35	0.002462
34.00978	151.0883	11:58:05	0.001329
34.00977	151.0883	11:58:35	0.001774
34.00977	151.0883	11:59:05	0.003088
34.00977	151.0883	11:59:35	0.000741
34.00977	151.0883	12:00:05	0.002659
34.00977	151.0883	12:00:35	0.000838
34.00977	151.0883	12:01:05	0.00171
34.00977	151.0883	12:01:35	0.007251
34.00977	151.0883	12:02:05	0.00219
34.00977	151.0883	12:02:35	0.002525

Oyster Bay Velocity 2

Latitude	Longitude	Time AEST	Speed M/Sec
34.006	151.0869	10:41:34	0.00101
34.00601	151.0869	10:41:39	0.003451
34.00602	151.0869	10:41:44	0.001969
34.00602	151.0869	10:41:49	0.003244
34.00603	151.0869	10:41:54	0.002261
34.00603	151.0869	10:41:59	0.002601
34.00603	151.0869	10:42:04	0.002393
34.00603	151.0869	10:42:09	0.001571
34.00603	151.0869	10:42:14	0.002346
34.00603	151.0869	10:42:19	0.001669
34.00603	151.0869	10:42:24	0.001713
34.00603	151.0869	10:42:29	0.002889

34.00603	151.0869	10:42:34	0.001023
34.00603	151.0869	10:42:39	0.002846
34.00603	151.0869	10:42:44	0.000374
34.00603	151.0869	10:42:49	0.002866
34.00603	151.0869	10:42:54	0.002137
34.00603	151.0869	10:42:59	0.0031
34.00603	151.0869	10:43:04	0.002297
34.00603	151.0869	10:43:09	0.002059
34.00603	151.0869	10:43:14	0.000425
34.00603	151.0869	10:43:19	0.002
34.00603	151.0869	10:43:24	0.003539
34.00603	151.0869	10:43:29	0.001369
34.00603	151.0869	10:43:34	0.000228
34.00603	151.0869	10:43:39	0.002156
34.00603	151.0869	10:43:44	0.001501
34.00603	151.0869	10:43:49	0.005057
34.00603	151.0869	10:43:54	0.004911
34.00603	151.0869	10:43:59	0.003481
34.00603	151.0869	10:44:04	0.001739
34.00603	151.0869	10:44:09	0.001784
34.00603	151.0869	10:44:14	0.003591
34.00603	151.0869	10:44:19	0.00071
34.00603	151.0869	10:44:24	0.002875
34.00603	151.0869	10:44:29	0.000709
34.00603	151.0869	10:44:34	0.002355
34.00604	151.0869	10:44:39	0.003138
34.00604	151.0869	10:44:44	0.001767
34.00604	151.0869	10:44:49	0.000776
34.00604	151.0869	10:44:54	0.00384
34.00604	151.0869	10:44:59	0.002122
34.00604	151.0869	10:45:04	0.005971
34.00604	151.0869	10:45:09	0.001129
34.00604	151.0869	10:45:14	0.002565
34.00604	151.0869	10:45:19	0.000751
34.00604	151.0869	10:45:24	0.00622
34.00604	151.0869	10:45:29	0.002846
34.00604	151.0869	10:45:34	0.00106
34.00604	151.0869	10:45:39	0.001903
34.00604	151.0869	10:45:44	0.002368
34.00604	151.0869	10:45:49	0.002948
34.00604	151.0869	10:45:54	0.001192
34.00604	151.0869	10:45:59	0.000608
34.00604	151.0869	10:46:04	0.003984
34.00604	151.0869	10:46:09	0.00133
34.00604	151.0869	10:46:14	0.001498
34.00604	151.0869	10:46:19	0.002504
34.00604	151.0869	10:46:24	0.002871
34.00604	151.0869	10:46:29	0.002135
34.00604	151.0869	10:46:34	0.004447
34.00604	151.0869	10:46:39	0.002304
34.00604	151.0869	10:46:44	0.002192
34.00605	151.0869	10:46:49	0.002872
34.00605	151.0869	10:46:54	0.001847
34.00605	151.0869	10:46:59	0.003036
34.00605	151.0869	10:47:04	0.002405
34.00605	151.0869	10:47:09	0.005783
34.00605	151.0869	10:47:14	0.001874
34.00605	151.0869	10:47:19	0.001135
34.00605	151.0869	10:47:24	0.001839
34.00605	151.0869	10:47:29	0.002645
34.00605	151.0869	10:47:34	0.004709

34.00605	151.0869	10:47:39	0.004291
34.00605	151.0869	10:47:44	0.003411
34.00605	151.0869	10:47:49	0.002694
34.00605	151.0869	10:47:54	0.008723
34.00605	151.0869	10:47:59	0.005118
34.00605	151.0869	10:48:04	0.004575
34.00605	151.0869	10:48:09	0.004796
34.00605	151.0869	10:48:14	0.003968
34.00605	151.0869	10:48:19	0.002615
34.00605	151.0869	10:48:24	0.001405
34.00606	151.0869	10:48:29	0.002196
34.00606	151.0869	10:48:34	0.003097
34.00606	151.0869	10:48:39	0.004692
34.00606	151.0869	10:48:44	0.003233
34.00606	151.0869	10:48:49	0.004218
34.00606	151.0869	10:48:54	0.00237
34.00606	151.0869	10:48:59	0.002878
34.00606	151.0869	10:49:04	0.003197
34.00606	151.0869	10:49:09	0.00269
34.00606	151.0869	10:49:14	0.002438
34.00606	151.0869	10:49:19	0.003077
34.00606	151.0869	10:49:24	0.003478
34.00606	151.0869	10:49:29	0.003692
34.00606	151.0869	10:49:34	0.003399
34.00606	151.0869	10:49:39	0.001343
34.00606	151.0869	10:49:44	0.002027
34.00607	151.0869	10:49:49	0.002033
34.00607	151.0869	10:49:54	0.003506
34.00607	151.0869	10:49:59	0.00497
34.00607	151.0869	10:50:04	0.00699
34.00607	151.0869	10:50:09	0.003122
34.00607	151.0869	10:50:14	0.003726
34.00607	151.0869	10:50:19	0.003036
34.00607	151.0869	10:50:24	0.003009
34.00607	151.0869	10:50:29	0.006225
34.00607	151.0869	10:50:34	0.002729
34.00607	151.0869	10:50:39	0.002826
34.00607	151.0869	10:50:44	0.004971
34.00607	151.0869	10:50:49	0.005644
34.00607	151.0869	10:50:54	0.004282
34.00608	151.0869	10:50:59	0.001894
34.00608	151.0869	10:51:04	0.003171
34.00608	151.0869	10:51:09	0.002674
34.00608	151.0869	10:51:14	0.003216
34.00608	151.0869	10:51:19	0.003016
34.00608	151.0869	10:51:24	0.003145
34.00608	151.0869	10:51:29	0.003619
34.00608	151.0869	10:51:34	0.001514
34.00608	151.0869	10:51:39	0.005103
34.00608	151.0869	10:51:44	0.003502
34.00608	151.0869	10:51:49	0.003932
34.00608	151.0869	10:51:54	0.003081
34.00608	151.0869	10:51:59	0.00127
34.00608	151.0869	10:52:04	0.003253
34.00608	151.0869	10:52:09	0.004205
34.00609	151.0869	10:52:14	0.005599
34.00609	151.0869	10:52:19	0.00423
34.00609	151.0869	10:52:24	0.00379
34.00609	151.0869	10:52:29	0.002471
34.00609	151.0869	10:52:34	0.003013
34.00609	151.0869	10:52:39	0.003076

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34.00609	151.0869	10:52:49	0.00514
34.00609	151.0869	10:52:54	0.006262
34.00609	151.0869	10:52:59	0.004908
34.00609	151.0869	10:53:04	0.007964
34.00609	151.0869	10:53:09	0.004319
34.00609	151.087	10:53:14	0.005053
34.00609	151.087	10:53:19	0.00728
34.0061	151.087	10:53:24	0.003181
34.0061	151.087	10:53:29	0.003272
34.0061	151.087	10:53:34	0.00577
34.0061	151.087	10:53:39	0.003834
34.0061	151.087	10:53:44	0.002858
34.0061	151.087	10:53:49	0.003964
34.0061	151.087	10:53:54	0.008565
34.0061	151.087	10:53:59	0.003594
34.0061	151.087	10:54:04	0.004212
34.0061	151.087	10:54:09	0.003931
34.0061	151.087	10:54:14	0.002651
34.0061	151.087	10:54:19	0.000868
34.0061	151.087	10:54:24	0.00285
34.0061	151.087	10:54:29	0.003439
34.0061	151.087	10:54:34	0.00354
34.0061	151.087	10:54:39	0.002954
34.00611	151.087	10:54:44	0.00174
34.00611	151.087	10:54:49	0.003227
34.00611	151.087	10:54:54	0.002722
34.00611	151.087	10:54:59	0.003379
34.00611	151.087	10:55:04	0.003328
34.00611	151.087	10:55:09	0.001222
34.00611	151.087	10:55:14	0.003556
34.00611	151.087	10:55:19	0.001331
34.00611	151.087	10:55:24	0.002599
34.00611	151.087	10:55:29	0.003258
34.00611	151.087	10:55:34	0.003599
34.00611	151.087	10:55:39	0.002604
34.00611	151.087	10:55:44	0.001676
34.00611	151.087	10:55:49	0.002208
34.00611	151.087	10:55:54	0.002957
34.00612	151.087	10:55:59	0.001913
34.00612	151.087	10:56:04	0.003691
34.00612	151.087	10:56:09	0.002953
34.00612	151.087	10:56:14	0.002327
34.00612	151.087	10:56:19	0.002834
34.00612	151.087	10:56:24	0.003149
34.00612	151.087	10:56:29	0.001602
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34.00612	151.087	10:56:39	0.001447
34.00612	151.087	10:56:44	0.002751
34.00612	151.087	10:56:49	0.002081
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34.00612	151.087	10:57:04	0.00202
34.00612	151.087	10:57:09	0.004219
34.00612	151.087	10:57:14	0.001752
34.00613	151.087	10:57:19	0.001587
34.00613	151.087	10:57:24	0.00333
34.00613	151.087	10:57:29	0.004032
34.00613	151.087	10:57:34	0.002245
34.00613	151.087	10:57:39	0.003614
34.00613	151.087	10:57:44	0.003859

34.00613	151.087	10:57:49	0.004886
34.00613	151.087	10:57:54	0.002474
34.00613	151.087	10:57:59	0.001517
34.00613	151.087	10:58:04	0.003234
34.00613	151.087	10:58:09	0.002901
34.00613	151.087	10:58:14	0.004056
34.00613	151.087	10:58:19	0.002953
34.00613	151.087	10:58:24	0.002863
34.00613	151.087	10:58:29	0.002343
34.00614	151.087	10:58:34	0.002882
34.00614	151.087	10:58:39	0.001959
34.00614	151.087	10:58:44	0.00187
34.00614	151.087	10:58:49	0.002882
34.00614	151.087	10:58:54	0.003082
34.00614	151.087	10:58:59	0.001417
34.00614	151.087	10:59:04	0.003414
34.00614	151.087	10:59:09	0.001564
34.00614	151.087	10:59:14	0.004525
34.00614	151.087	10:59:19	0.003356
34.00614	151.087	10:59:24	0.003266
34.00614	151.087	10:59:29	0.003201
34.00614	151.087	10:59:34	0.000931
34.00614	151.087	10:59:39	0.002931
34.00614	151.087	10:59:44	0.000437
34.00615	151.087	10:59:49	0.003737
34.00615	151.087	10:59:54	0.002333
34.00615	151.087	10:59:59	0.004247
34.00615	151.087	11:00:04	0.001891
34.00615	151.087	11:00:09	0.002232
34.00615	151.087	11:00:14	0.002122
34.00615	151.087	11:00:19	0.002105
34.00615	151.087	11:00:24	0.002238
34.00615	151.087	11:00:29	0.002668
34.00615	151.087	11:00:34	0.005142
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34.00657	151.0877	11:31:44	0.003952
34.00657	151.0877	11:31:49	0.002545
34.00657	151.0877	11:31:54	0.000895
34.00657	151.0877	11:31:59	0.001001
34.00657	151.0877	11:32:04	0.002478
34.00657	151.0877	11:32:09	0.000748
34.00657	151.0877	11:32:14	0.001583
34.00658	151.0877	11:32:19	0.002034
34.00658	151.0877	11:32:24	0.001049
34.00658	151.0877	11:32:29	0.00237
34.00658	151.0877	11:32:34	0.001405
34.00658	151.0877	11:32:39	0.000525
34.00658	151.0877	11:32:44	0.00195
34.00659	151.0877	11:32:49	0.001836
34.00659	151.0877	11:32:54	0.002363
34.00659	151.0877	11:32:59	0.002816
34.00659	151.0877	11:33:04	0.00236
34.00659	151.0877	11:33:09	0.001179
34.00659	151.0877	11:33:14	0.001793
34.00659	151.0877	11:33:19	0.001321

34.00659	151.0877	11:33:24	0.001711
34.00659	151.0877	11:33:29	0.007818
34.00659	151.0877	11:33:34	0.001592
34.00659	151.0877	11:33:39	0.002465
34.0066	151.0877	11:33:44	0.003095
34.0066	151.0877	11:33:49	0.001207
34.0066	151.0877	11:33:54	0.001526
34.0066	151.0877	11:33:59	0.003919
34.0066	151.0877	11:34:04	0.00075
34.0066	151.0877	11:34:09	0.001783
34.0066	151.0877	11:34:14	0.00068
34.0066	151.0877	11:34:19	0.002257
34.0066	151.0877	11:34:24	0.000333
34.0066	151.0877	11:34:29	0.002267
34.0066	151.0877	11:34:34	0.002082
34.0066	151.0878	11:34:39	0.000733
34.0066	151.0878	11:34:44	0.001469
34.00661	151.0878	11:34:49	0.003118
34.00661	151.0878	11:34:54	0.003939
34.00661	151.0878	11:34:59	0.000851
34.00661	151.0878	11:35:04	0.001915
34.00661	151.0878	11:35:09	0.002935
34.00661	151.0878	11:35:14	0.001314
34.00661	151.0878	11:35:19	0.001538
34.00661	151.0878	11:35:24	0.005549
34.00661	151.0878	11:35:29	0.001977
34.00661	151.0878	11:35:34	0.003439
34.00661	151.0878	11:35:39	0.001729
34.00662	151.0878	11:35:44	0.002752
34.00662	151.0878	11:35:49	0.002698
34.00662	151.0878	11:35:54	0.005036
34.00662	151.0878	11:35:59	0.002244
34.00662	151.0878	11:36:04	0.003737
34.00662	151.0878	11:36:09	0.006042
34.00662	151.0878	11:36:14	0.004405
34.00662	151.0878	11:36:19	0.002083
34.00662	151.0878	11:36:24	0.001418
34.00662	151.0878	11:36:29	0.002439
34.00662	151.0878	11:36:34	0.000529
34.00662	151.0878	11:36:39	0.000853
34.00662	151.0878	11:36:44	0.001019
34.00662	151.0878	11:36:49	0.001208
34.00663	151.0878	11:36:54	0.000983
34.00663	151.0878	11:36:59	0.004666
34.00663	151.0878	11:37:04	0.001845
34.00663	151.0878	11:37:09	0.006909
34.00663	151.0878	11:37:14	0.003105
34.00663	151.0878	11:37:19	0.002298
34.00663	151.0878	11:37:24	0.001798
34.00663	151.0878	11:37:29	0.004085
34.00663	151.0878	11:37:34	0.000764
34.00663	151.0878	11:37:39	0.002433
34.00663	151.0878	11:37:44	0.000132
34.00663	151.0878	11:37:49	0.003162
34.00663	151.0878	11:37:54	0.003021
34.00663	151.0878	11:37:59	0.002206
34.00664	151.0878	11:38:04	0.003678
34.00664	151.0878	11:38:09	0.001823
34.00664	151.0878	11:38:14	0.001138
34.00664	151.0878	11:38:19	0.001037
34.00664	151.0878	11:38:24	0.001595

34.00664	151.0878	11:38:29	0.002683
34.00664	151.0878	11:38:34	0.003286
34.00664	151.0878	11:38:39	0.002079
34.00664	151.0878	11:38:44	0.001525
34.00665	151.0878	11:38:49	0.003755
34.00665	151.0878	11:38:54	0.001973
34.00665	151.0878	11:38:59	0.003392
34.00665	151.0878	11:39:04	0.002488
34.00665	151.0878	11:39:09	0.002412
34.00665	151.0878	11:39:14	0.00791
34.00665	151.0878	11:39:19	0.007814
34.00665	151.0878	11:39:24	0.003828
34.00665	151.0878	11:39:29	0.004881
34.00665	151.0878	11:39:34	0.007257
34.00665	151.0878	11:39:39	0.001959
34.00665	151.0878	11:39:44	0.001166
34.00665	151.0878	11:39:49	0.00247
34.00665	151.0878	11:39:54	0.003592
34.00665	151.0878	11:39:59	0.004753
34.00665	151.0878	11:40:04	0.001599
34.00665	151.0878	11:40:09	0.0022
34.00665	151.0879	11:40:14	0.001631
34.00665	151.0879	11:40:19	0.002165
34.00665	151.0879	11:40:24	0.002174
34.00665	151.0879	11:40:29	0.003374
34.00665	151.0879	11:40:34	0.004316
34.00666	151.0879	11:40:39	0.002448
34.00666	151.0879	11:40:44	0.002728
34.00666	151.0879	11:40:49	0.000335
34.00666	151.0879	11:40:54	0.002516
34.00666	151.0879	11:40:59	0.004065
34.00666	151.0879	11:41:04	0.002792
34.00666	151.0879	11:41:09	0.005278
34.00666	151.0879	11:41:14	0.004573
34.00666	151.0879	11:41:19	0.00307
34.00666	151.0879	11:41:24	0.003963
34.00666	151.0879	11:41:29	0.006265
34.00666	151.0879	11:41:34	0.003108
34.00666	151.0879	11:41:39	0.000407
34.00666	151.0879	11:41:44	0.001831
34.00666	151.0879	11:41:49	0.002113
34.00666	151.0879	11:41:54	0.002563
34.00666	151.0879	11:41:59	0.003092
34.00666	151.0879	11:42:04	0.002437
34.00666	151.0879	11:42:09	0.002461
34.00666	151.0879	11:42:14	0.003439
34.00666	151.0879	11:42:19	0.001186
34.00667	151.0879	11:42:24	0.002878
34.00667	151.0879	11:42:29	0.001291
34.00667	151.0879	11:42:34	0.003897
34.00667	151.0879	11:42:39	0.002268
34.00667	151.0879	11:42:44	0.00276
34.00667	151.0879	11:42:49	0.001581
34.00667	151.0879	11:42:54	0.00214
34.00667	151.0879	11:42:59	0.002885
34.00667	151.0879	11:43:04	0.001441
34.00667	151.0879	11:43:09	0.000554
34.00667	151.0879	11:43:14	0.001192
34.00667	151.0879	11:43:19	0.006004
34.00667	151.0879	11:43:24	0.001456
34.00667	151.0879	11:43:29	0.00187

34.00668	151.0879	11:43:34	0.005734
34.00668	151.0879	11:43:39	0.001036
34.00668	151.0879	11:43:44	0.004004
34.00668	151.0879	11:43:49	0.001134
34.00668	151.0879	11:43:54	0.009731
34.00668	151.0879	11:43:59	0.00317
34.00668	151.0879	11:44:04	0.003231
34.00668	151.0879	11:44:09	0.005024
34.00668	151.0879	11:44:14	0.003366
34.00668	151.0879	11:44:19	0.004469
34.00668	151.0879	11:44:24	0.001587
34.00668	151.0879	11:44:29	0.004656
34.00668	151.0879	11:44:34	0.001889
34.00668	151.0879	11:44:39	0.001244
34.00668	151.0879	11:44:44	0.003387
34.00668	151.0879	11:44:49	0.000868
34.00668	151.0879	11:44:54	0.002114
34.00668	151.0879	11:44:59	0.004304
34.00668	151.0879	11:45:04	0.002505
34.00668	151.0879	11:45:09	0.003116
34.00668	151.0879	11:45:14	0.001281
34.00668	151.0879	11:45:19	0.005512
34.00668	151.0879	11:45:24	0.002316
34.00668	151.0879	11:45:29	0.00472
34.00668	151.0879	11:45:34	0.002014
34.00668	151.0879	11:45:39	0.000887
34.00668	151.0879	11:45:44	0.001322
34.00669	151.0879	11:45:49	0.003564
34.00669	151.0879	11:45:54	0.006346
34.00669	151.088	11:45:59	0.002182
34.00669	151.088	11:46:04	0.00205
34.00669	151.088	11:46:09	0.003668
34.00669	151.088	11:46:14	0.00175
34.00669	151.088	11:46:19	0.004448
34.00669	151.088	11:46:24	0.002494
34.00669	151.088	11:46:29	0.002459
34.00669	151.088	11:46:34	0.002562
34.00669	151.088	11:46:39	0.004639
34.00669	151.088	11:46:44	0.001034
34.00669	151.088	11:46:49	0.000998
34.00669	151.088	11:46:54	0.003008
34.00669	151.088	11:46:59	0.001329
34.00669	151.088	11:47:04	0.004467
34.00669	151.088	11:47:09	0.004283
34.00669	151.088	11:47:14	0.004214
34.00669	151.088	11:47:19	0.003158
34.00669	151.088	11:47:24	0.002986
34.00669	151.088	11:47:29	0.005506
34.00669	151.088	11:47:34	0.005499
34.00669	151.088	11:47:39	0.003842
34.00669	151.088	11:47:44	0.004821
34.00669	151.088	11:47:49	0.002536
34.00669	151.088	11:47:54	0.000561
34.00669	151.088	11:47:59	0.005937
34.00669	151.088	11:48:04	0.00198
34.00669	151.088	11:48:09	0.004126
34.00669	151.088	11:48:14	0.000758
34.00669	151.088	11:48:19	0.001328
34.00669	151.088	11:48:24	0.002494
34.00669	151.088	11:48:29	0.001831
34.00669	151.088	11:48:34	0.001521

34.00669	151.088	11:48:39	0.002011
34.00669	151.088	11:48:44	0.002089
34.00669	151.088	11:48:49	0.002731
34.00669	151.088	11:48:54	0.000291
34.00669	151.088	11:48:59	0.000404
34.00669	151.088	11:49:04	0.002097
34.00669	151.088	11:49:09	0.004265
34.00669	151.088	11:49:14	0.003655
34.00669	151.088	11:49:19	0.00133
34.00669	151.088	11:49:24	0.003907
34.00669	151.088	11:49:29	0.005869
34.00669	151.088	11:49:34	0.00283
34.0067	151.088	11:49:39	0.004743
34.0067	151.088	11:49:44	0.001404
34.0067	151.088	11:49:49	0.003943
34.0067	151.088	11:49:54	0.001688
34.0067	151.088	11:49:59	0.007972
34.0067	151.088	11:50:04	0.001677
34.0067	151.088	11:50:09	0.001741
34.0067	151.088	11:50:14	0.001669
34.0067	151.088	11:50:19	0.004496
34.0067	151.088	11:50:24	0.001441
34.0067	151.088	11:50:29	0.001088
34.0067	151.088	11:50:34	0.004869
34.0067	151.088	11:50:39	0.004297
34.0067	151.088	11:50:44	0.00182
34.0067	151.088	11:50:49	0.003632
34.0067	151.088	11:50:54	0.00207
34.0067	151.088	11:50:59	0.00348
34.0067	151.088	11:51:04	0.007347
34.0067	151.088	11:51:09	0.003181
34.0067	151.088	11:51:14	0.002435
34.0067	151.088	11:51:19	0.006234
34.0067	151.088	11:51:24	0.00232
34.0067	151.088	11:51:29	0.005178
34.0067	151.088	11:51:34	0.002235
34.0067	151.088	11:51:39	0.003823
34.0067	151.0881	11:51:44	0.002713
34.0067	151.0881	11:51:49	0.000415
34.0067	151.0881	11:51:54	0.001746
34.0067	151.0881	11:51:59	0.001224
34.0067	151.0881	11:52:04	0.003363
34.0067	151.0881	11:52:09	0.002105
34.0067	151.0881	11:52:14	0.000351
34.0067	151.0881	11:52:19	0.003438
34.0067	151.0881	11:52:24	0.001288
34.0067	151.0881	11:52:29	0.004602
34.0067	151.0881	11:52:34	0.001237
34.0067	151.0881	11:52:39	0.001733
34.0067	151.0881	11:52:44	0.00192
34.0067	151.0881	11:52:49	0.001135
34.0067	151.0881	11:52:54	0.006961
34.0067	151.0881	11:52:59	0.003614
34.0067	151.0881	11:53:04	0.002382
34.0067	151.0881	11:53:09	0.002833
34.0067	151.0881	11:53:14	0.004052
34.0067	151.0881	11:53:19	0.001159
34.0067	151.0881	11:53:24	0.00188
34.0067	151.0881	11:53:29	0.005551
34.0067	151.0881	11:53:34	0.001907
34.0067	151.0881	11:53:39	0.003211

34.0067	151.0881	11:53:44	0.002135
34.0067	151.0881	11:53:49	0.004572
34.0067	151.0881	11:53:54	0.004893
34.0067	151.0881	11:53:59	0.004881
34.0067	151.0881	11:54:04	0.001944
34.0067	151.0881	11:54:09	0.003135
34.0067	151.0881	11:54:14	0.002752
34.0067	151.0881	11:54:19	0.00581
34.0067	151.0881	11:54:24	0.003689
34.0067	151.0881	11:54:29	0.00216
34.0067	151.0881	11:54:34	0.006789
34.0067	151.0881	11:54:39	0.002285
34.0067	151.0881	11:54:44	0.001968
34.0067	151.0881	11:54:49	0.001745
34.0067	151.0881	11:54:54	0.000969
34.0067	151.0881	11:54:59	0.003592
34.0067	151.0881	11:55:04	0.001063
34.0067	151.0881	11:55:09	0.003843
34.0067	151.0881	11:55:14	0.001621
34.0067	151.0881	11:55:19	0.0022
34.0067	151.0881	11:55:24	0.001439
34.0067	151.0881	11:55:29	0.002658
34.0067	151.0881	11:55:34	0.003277
34.0067	151.0881	11:55:39	0.001997
34.0067	151.0881	11:55:44	0.000597
34.0067	151.0881	11:55:49	0.003935
34.0067	151.0881	11:55:54	0.002327
34.0067	151.0881	11:55:59	0.000329
34.0067	151.0881	11:56:04	0.004164
34.0067	151.0881	11:56:09	0.001881
34.0067	151.0881	11:56:14	0.001761
34.0067	151.0881	11:56:19	0.002864
34.0067	151.0881	11:56:24	0.004348
34.0067	151.0881	11:56:29	0.001073
34.0067	151.0881	11:56:34	0.003725
34.00669	151.0881	11:56:39	0.002057
34.00669	151.0882	11:56:44	0.004226
34.00669	151.0882	11:56:49	0.001436
34.00669	151.0882	11:56:54	0.00109
34.00669	151.0882	11:56:59	0.000969
34.00669	151.0882	11:57:04	0.00186
34.00669	151.0882	11:57:09	0.001135
34.00669	151.0882	11:57:14	0.002445
34.00669	151.0882	11:57:19	0.005397
34.00669	151.0882	11:57:24	0.001513
34.00669	151.0882	11:57:29	0.000549
34.00669	151.0882	11:57:34	0.002005
34.00669	151.0882	11:57:39	0.003353
34.00669	151.0882	11:57:44	0.004152
34.00669	151.0882	11:57:49	0.004219
34.00669	151.0882	11:57:54	0.000711
34.00669	151.0882	11:57:59	0.001447
34.00669	151.0882	11:58:04	0.001669
34.00669	151.0882	11:58:09	0.001176
34.00669	151.0882	11:58:14	0.00061
34.00669	151.0882	11:58:19	0.001473
34.00669	151.0882	11:58:24	0.002077
34.00669	151.0882	11:58:29	0.003838
34.00669	151.0882	11:58:34	0.003034
34.00669	151.0882	11:58:39	0.001257
34.00669	151.0882	11:58:44	0.003278

34.00669	151.0882	11:58:49	0.005826
34.00669	151.0882	11:58:54	0.001689
34.00669	151.0882	11:58:59	0.004694
34.00669	151.0882	11:59:04	0.001179
34.00669	151.0882	11:59:09	0.004126
34.00669	151.0882	11:59:14	0.002643
34.00669	151.0882	11:59:19	0.002382
34.00669	151.0882	11:59:24	0.001521
34.00669	151.0882	11:59:29	0.004661
34.00669	151.0882	11:59:34	0.001655
34.00668	151.0882	11:59:39	0.003827
34.00668	151.0882	11:59:44	0.004159

Oyster Bay Velocity 3

Latitude	Longitude	Time AEST	Speed M/Sec
34.00707	151.0914	10:35:23	0.101898
34.00704	151.0914	10:36:23	0.077855
34.00702	151.0915	10:37:23	0.003237
34.00702	151.0915	10:38:23	0.002848
34.00701	151.0915	10:39:23	0.005972
34.007	151.0915	10:40:23	0.001722
34.00699	151.0915	10:41:23	0.007129
34.00698	151.0915	10:42:23	0.007765
34.00696	151.0915	10:43:23	0.002877
34.00695	151.0915	10:44:23	0.003005
34.00694	151.0915	10:45:23	0.01225
34.00692	151.0915	10:46:23	0.004536
34.00688	151.0915	10:47:23	0.166572
34.0068	151.0916	10:48:23	0.215441
34.00675	151.0916	10:49:23	0.149764
34.00667	151.0916	10:50:23	0.103417
34.0066	151.0916	10:51:23	0.18871
34.00655	151.0917	10:52:23	0.071138
34.00647	151.0917	10:53:23	0.091505
34.00643	151.0917	10:54:23	0.093055
34.00642	151.0917	10:55:23	0.005624
34.00641	151.0917	10:56:23	0.001334
34.0064	151.0917	10:57:23	0.007264
34.00634	151.0918	10:58:23	0.148291
34.00623	151.0918	10:59:23	0.042179
34.00619	151.0919	11:00:23	0.145723
34.00615	151.0919	11:01:23	0.127209
34.00614	151.0919	11:02:23	0.072567
34.00614	151.0919	11:03:23	0.007468
34.00605	151.092	11:04:23	0.09311
34.00601	151.092	11:05:23	0.017477
34.00601	151.092	11:06:23	0.013177
34.00597	151.0921	11:07:23	0.142841
34.00588	151.0922	11:08:23	0.138535
34.00581	151.0922	11:09:23	0.09492
34.00577	151.0923	11:10:23	0.136864
34.00573	151.0923	11:11:23	0.223731
34.00569	151.0924	11:12:23	0.150439
34.00566	151.0924	11:13:23	0.129913
34.00564	151.0924	11:14:23	0.108764
34.00558	151.0925	11:15:23	0.224088
34.00557	151.0925	11:16:23	0.187669
34.00552	151.0926	11:17:23	0.166802

34.00546	151.0926	11:18:23	0.148588
34.00541	151.0927	11:19:23	0.129891
34.00537	151.0927	11:20:23	0.155513
34.00533	151.0927	11:21:23	0.088694
34.00528	151.0928	11:22:23	0.056512
34.00525	151.0928	11:23:23	0.102763
34.00523	151.0929	11:24:23	0.147087
34.0052	151.0929	11:25:23	0.209434
34.00517	151.093	11:26:23	0.074163
34.00509	151.093	11:27:23	0.165452
34.00504	151.093	11:28:23	0.059664
34.00504	151.093	11:29:23	0.006353
34.00504	151.093	11:30:23	0.00076
34.00503	151.0931	11:31:23	0.006609
34.00502	151.0931	11:32:23	0.004338
34.00502	151.0931	11:33:23	0.004299
34.00501	151.0931	11:34:23	0.001691
34.005	151.0931	11:35:23	0.006386
34.00498	151.0931	11:36:23	0.001236
34.00495	151.0932	11:37:23	0.002492
34.00492	151.0932	11:38:23	0.002694
34.00488	151.0932	11:39:23	0.00311
34.00485	151.0933	11:40:23	0.002643
34.00481	151.0933	11:41:23	0.00134
34.00477	151.0934	11:42:23	0.003005
34.00474	151.0934	11:43:23	0.004269
34.0047	151.0934	11:44:23	0.004332
34.00467	151.0935	11:45:23	0.005101
34.00462	151.0935	11:46:23	0.005495
34.00458	151.0936	11:47:23	0.004695
34.00454	151.0936	11:48:23	0.003801
34.00449	151.0936	11:49:23	0.003931
34.00444	151.0937	11:50:23	0.002634
34.0044	151.0937	11:51:23	0.002242
34.00436	151.0937	11:52:23	0.004463
34.00431	151.0938	11:53:23	0.004441
34.00426	151.0938	11:54:23	0.004708
34.00423	151.0938	11:55:23	0.004924
34.00418	151.0939	11:56:23	0.005838
34.00413	151.0939	11:57:23	0.003269
34.00409	151.0939	11:58:23	0.002068
34.00404	151.094	11:59:23	0.004143
34.00399	151.094	12:00:23	0.002159
34.00396	151.094	12:01:23	0.002725
34.00391	151.0941	12:02:23	0.002375
34.00386	151.0941	12:03:23	0.004195
34.00381	151.0941	12:04:23	0.004622
34.00377	151.0941	12:05:23	0.004989
34.00372	151.0942	12:06:23	0.004684
34.00367	151.0942	12:07:23	0.001898
34.00363	151.0942	12:08:23	0.003276
34.00359	151.0943	12:09:23	0.003955
34.00355	151.0943	12:10:23	0.003631

Salt Pan Creek Velocity 1

Latitude	Longitude	Time AEST	Speed M/Sec
33.95822	151.042	15:28:24	0.002324
33.95821	151.042	15:29:24	0.002321
33.95821	151.042	15:30:24	0.002493
33.9582	151.042	15:31:24	0.003517
33.95819	151.042	15:32:24	0.003251
33.95818	151.042	15:33:24	0.002826
33.95818	151.042	15:34:24	0.003106
33.95817	151.042	15:35:24	0.001995
33.95816	151.042	15:36:24	0.002391
33.95815	151.042	15:37:24	0.002729
33.95814	151.042	15:38:24	0.002404
33.95814	151.042	15:39:24	0.001828
33.95813	151.042	15:40:24	0.002766
33.95812	151.042	15:41:24	0.00228
33.95811	151.042	15:42:24	0.001547
33.9581	151.042	15:43:24	0.001299
33.9581	151.042	15:44:24	0.001772
33.95809	151.042	15:45:24	0.001686
33.95808	151.0421	15:46:24	0.001676
33.95807	151.0421	15:47:24	0.001739
33.95807	151.0421	15:48:24	0.000786
33.95806	151.0421	15:49:24	0.001456
33.95806	151.0421	15:50:24	0.002003
33.95806	151.0421	15:51:24	0.0013
33.95806	151.0421	15:52:24	0.002389
33.95806	151.0421	15:53:24	0.001498
33.95807	151.0421	15:54:24	0.003089
33.95808	151.0421	15:55:24	0.002981
33.95809	151.0421	15:56:24	0.004246
33.9581	151.0421	15:57:24	0.00275
33.95812	151.0422	15:58:24	0.003267
33.95814	151.0422	15:59:24	0.002774
33.95817	151.0422	16:00:24	0.002973
33.95821	151.0422	16:01:24	0.002892
33.95825	151.0422	16:02:24	0.002918
33.95829	151.0422	16:03:24	0.003432
33.95834	151.0422	16:04:24	0.002759
33.95839	151.0423	16:05:24	0.003456
33.95844	151.0423	16:06:24	0.002499
33.95848	151.0423	16:07:24	0.002951
33.95853	151.0423	16:08:24	0.003373
33.95857	151.0423	16:09:24	0.00291
33.95863	151.0423	16:10:24	0.003856
33.95868	151.0423	16:11:24	0.003648
33.95874	151.0423	16:12:24	0.003256
33.9588	151.0423	16:13:24	0.003835
33.95886	151.0423	16:14:24	0.003965
33.95893	151.0423	16:15:24	0.004207
33.95898	151.0423	16:16:24	0.003533
33.95904	151.0423	16:17:24	0.003002
33.95911	151.0423	16:18:24	0.003419
33.95917	151.0423	16:19:24	0.002641
33.95923	151.0423	16:20:24	0.003424
33.95929	151.0423	16:21:24	0.003751
33.95982	151.0414	16:30:24	0.0483
33.95986	151.0413	16:31:24	0.110155
33.95992	151.0413	16:32:24	0.127148

33.95998	151.0413	16:33:24	0.127256
33.96003	151.0412	16:34:24	0.120954
33.96008	151.0412	16:35:24	0.126443
33.96015	151.0412	16:36:24	0.079953
33.9602	151.0411	16:37:24	0.139838
33.96027	151.0411	16:38:24	0.085601
33.96032	151.0411	16:39:24	0.114663
33.96038	151.0411	16:40:24	0.164511
33.96046	151.0411	16:41:24	0.041872
33.96053	151.041	16:42:24	0.11015
33.9606	151.041	16:43:24	0.150276
33.96068	151.041	16:44:24	0.161462
33.96076	151.041	16:45:24	0.232374
33.96084	151.0409	16:46:24	0.088164
33.96093	151.0409	16:47:24	0.092892
33.96102	151.0409	16:48:24	0.183542
33.96112	151.0409	16:49:24	0.173406
33.96121	151.0409	16:50:24	0.181352
33.96131	151.0409	16:51:24	0.136099
33.96142	151.0409	16:52:24	0.181141
33.96151	151.0409	16:53:24	0.015071
33.96155	151.0409	16:54:24	0.035587
33.96157	151.0408	16:55:24	0.030404
33.96158	151.0408	16:56:24	0.022168
33.96162	151.0408	16:57:24	0.026902
33.96164	151.0408	16:58:24	0.032154
33.96174	151.0408	16:59:24	0.022103
33.96189	151.0409	17:00:24	0.022323
33.96239	151.041	17:01:24	0.271235
33.96289	151.0412	17:02:24	0.281555
33.9631	151.0413	17:03:24	0.252561
33.96323	151.0413	17:04:24	0.276936
33.96331	151.0414	17:05:24	0.142616
33.96339	151.0416	17:06:24	0.279045

Salt Pan Creek Velocity 2

Latitude	Longitude	Time AEST	Speed M/Sec
33.96132	151.0412	15:21:10	0.001883
33.96132	151.0412	15:21:15	0.001059
33.96132	151.0412	15:21:20	0.001731
33.96132	151.0412	15:21:25	0.000465
33.96132	151.0412	15:21:30	0.001625
33.96132	151.0412	15:21:35	0.001096
33.96132	151.0412	15:21:40	0.002114
33.96132	151.0412	15:21:45	0.001451
33.96132	151.0412	15:21:50	0.00039
33.96132	151.0412	15:21:55	0.000104
33.96132	151.0412	15:22:00	0.001666
33.96132	151.0412	15:22:05	0.001205
33.96132	151.0412	15:22:10	0.000481
33.96132	151.0412	15:22:15	0.000545
33.96132	151.0412	15:22:20	0.001961
33.96132	151.0412	15:22:25	0.001041
33.96132	151.0412	15:22:30	0.001393
33.96132	151.0412	15:22:35	0.001815
33.96132	151.0412	15:22:40	0.001039
33.96132	151.0412	15:22:45	0.000372
33.96132	151.0412	15:22:50	0.002293

33.96132	151.0412	15:22:55	0.000843
33.96132	151.0412	15:23:00	0.001035
33.96132	151.0412	15:23:05	0.002102
33.96132	151.0412	15:23:10	0.001348
33.96132	151.0412	15:23:15	0.000669
33.96132	151.0412	15:23:20	0.000693
33.96132	151.0412	15:23:25	0.000541
33.96132	151.0412	15:23:30	0.000608
33.96132	151.0412	15:23:35	0.001156
33.96132	151.0412	15:23:40	0.001976
33.96132	151.0412	15:23:45	0.000702
33.96132	151.0412	15:23:50	0.001441
33.96132	151.0412	15:23:55	0.001619
33.96132	151.0412	15:24:00	0.000911
33.96132	151.0412	15:24:05	9.39E-05
33.96132	151.0412	15:24:10	0.000448
33.96132	151.0412	15:24:15	0.0018
33.96132	151.0412	15:24:20	0.001157
33.96132	151.0412	15:24:25	0.000678
33.96132	151.0412	15:24:30	0.002526
33.96132	151.0412	15:24:35	0.00224
33.96132	151.0412	15:24:40	0.00034
33.96132	151.0412	15:24:45	0.001786
33.96132	151.0412	15:24:50	0.002195
33.96132	151.0412	15:24:55	0.001468
33.96132	151.0412	15:25:00	0.000835
33.96132	151.0412	15:25:05	0.002077
33.96132	151.0412	15:25:10	0.002137
33.96132	151.0412	15:25:15	0.00136
33.96132	151.0412	15:25:20	0.002671
33.96132	151.0412	15:25:25	0.001184
33.96132	151.0412	15:25:30	0.001102
33.96131	151.0412	15:25:35	0.001708
33.96131	151.0412	15:25:40	0.002192
33.96131	151.0412	15:25:45	0.002713
33.96131	151.0412	15:25:50	0.001099
33.96131	151.0412	15:25:55	0.000355
33.96131	151.0412	15:26:00	0.000882
33.96131	151.0412	15:26:05	0.001507
33.96131	151.0412	15:26:10	0.002239
33.96131	151.0412	15:26:15	0.001148
33.96131	151.0412	15:26:20	0.001168
33.96131	151.0412	15:26:25	0.002556
33.96131	151.0412	15:26:30	0.002216
33.96131	151.0412	15:26:35	0.001031
33.96131	151.0412	15:26:40	0.002014
33.96131	151.0412	15:26:45	0.000737
33.96131	151.0412	15:26:50	0.00193
33.96131	151.0412	15:26:55	0.001731
33.96131	151.0412	15:27:00	0.000983
33.96131	151.0412	15:27:05	0.001588
33.96131	151.0412	15:27:10	0.001854
33.96131	151.0412	15:27:15	0.000967
33.96131	151.0412	15:27:20	0.002228
33.96131	151.0412	15:27:25	0.002203
33.96131	151.0412	15:27:30	0.001449
33.96131	151.0412	15:27:35	0.001709
33.96131	151.0412	15:27:40	0.002202
33.96131	151.0412	15:27:45	0.001698
33.96131	151.0412	15:27:50	0.001291
33.9613	151.0412	15:27:55	0.001283

33.9613	151.0412	15:28:00	0.001764
33.9613	151.0412	15:28:05	0.000591
33.9613	151.0412	15:28:10	0.0003
33.9613	151.0412	15:28:15	0.001714
33.9613	151.0412	15:28:20	0.00161
33.9613	151.0412	15:28:25	0.000838
33.9613	151.0412	15:28:30	0.001596
33.9613	151.0412	15:28:35	0.000825
33.9613	151.0412	15:28:40	0.002213
33.9613	151.0412	15:28:45	0.002043
33.9613	151.0412	15:28:50	0.000521
33.9613	151.0412	15:28:55	0.001796
33.9613	151.0412	15:29:00	0.001064
33.9613	151.0412	15:29:05	0.001181
33.9613	151.0412	15:29:10	0.002931
33.9613	151.0412	15:29:15	0.001032
33.9613	151.0412	15:29:20	0.001042
33.9613	151.0412	15:29:25	0.001649
33.9613	151.0412	15:29:30	0.000541
33.9613	151.0412	15:29:35	0.002001
33.9613	151.0412	15:29:40	0.001312
33.9613	151.0412	15:29:45	0.001656
33.9613	151.0412	15:29:50	0.002164
33.9613	151.0412	15:29:55	0.000611
33.96129	151.0412	15:30:00	0.00268
33.96129	151.0412	15:30:05	0.001426
33.96129	151.0412	15:30:10	0.001441
33.96129	151.0412	15:30:15	0.002014
33.96129	151.0412	15:30:20	0.000398
33.96129	151.0412	15:30:25	0.000966
33.96129	151.0412	15:30:30	0.001623
33.96129	151.0412	15:30:35	0.001109
33.96129	151.0412	15:30:40	0.001168
33.96129	151.0412	15:30:45	0.001023
33.96129	151.0412	15:30:50	0.001489
33.96129	151.0412	15:30:55	0.000761
33.96129	151.0412	15:31:00	0.000583
33.96129	151.0412	15:31:05	0.000745
33.96129	151.0412	15:31:10	0.000945
33.96129	151.0412	15:31:15	0.000959
33.96129	151.0412	15:31:20	0.000981
33.96129	151.0412	15:31:25	0.000506
33.96129	151.0412	15:31:30	0.000905
33.96129	151.0412	15:31:35	0.001331
33.96129	151.0412	15:31:40	0.000851
33.96129	151.0412	15:31:45	0.001274
33.96129	151.0412	15:31:50	0.001149
33.96129	151.0412	15:31:55	0.001216
33.96129	151.0412	15:32:00	0.001403
33.96129	151.0412	15:32:05	0.001622
33.96128	151.0412	15:32:10	0.000219
33.96128	151.0412	15:32:15	0.000251
33.96128	151.0412	15:32:20	0.001134
33.96128	151.0412	15:32:25	0.001388
33.96128	151.0412	15:32:30	0.000985
33.96128	151.0412	15:32:35	0.001178
33.96128	151.0412	15:32:40	0.001386
33.96128	151.0412	15:32:45	0.001069
33.96128	151.0412	15:32:50	0.000237
33.96128	151.0412	15:32:55	0.00139
33.96128	151.0412	15:33:00	0.001073

33.96128	151.0412	15:33:05	0.001013
33.96128	151.0412	15:33:10	0.00136
33.96128	151.0412	15:33:15	0.001396
33.96128	151.0412	15:33:20	0.001399
33.96128	151.0412	15:33:25	0.00019
33.96128	151.0412	15:33:30	0.000542
33.96128	151.0412	15:33:35	0.001973
33.96128	151.0412	15:33:40	0.000813
33.96128	151.0412	15:33:45	0.001311
33.96128	151.0412	15:33:50	0.001171
33.96128	151.0412	15:33:55	0.001264
33.96128	151.0412	15:34:00	0.000211
33.96128	151.0412	15:34:05	0.000481
33.96128	151.0412	15:34:10	0.001397
33.96128	151.0412	15:34:15	0.001407
33.96128	151.0412	15:34:20	0.000707
33.96128	151.0412	15:34:25	0.000584
33.96128	151.0412	15:34:30	0.000729
33.96128	151.0412	15:34:35	0.00185
33.96128	151.0412	15:34:40	0.000643
33.96128	151.0412	15:34:45	0.000998
33.96128	151.0412	15:34:50	0.000677
33.96128	151.0412	15:34:55	0.001027
33.96128	151.0412	15:35:00	0.000993
33.96128	151.0412	15:35:05	0.000679
33.96128	151.0412	15:35:10	0.001372
33.96128	151.0412	15:35:15	0.000821
33.96128	151.0412	15:35:20	0.000877
33.96128	151.0412	15:35:25	0.000749
33.96128	151.0412	15:35:30	0.000668
33.96128	151.0412	15:35:35	0.001024
33.96128	151.0412	15:35:40	0.000771
33.96128	151.0412	15:35:45	0.000908
33.96128	151.0412	15:35:50	0.001075
33.96128	151.0412	15:35:55	0.001677
33.96128	151.0412	15:36:00	0.000562
33.96127	151.0412	15:36:05	0.001141
33.96127	151.0412	15:36:10	0.001411
33.96127	151.0412	15:36:15	0.000883
33.96127	151.0412	15:36:20	0.001999
33.96127	151.0412	15:36:25	0.001257
33.96127	151.0412	15:36:30	0.000972
33.96127	151.0412	15:36:35	0.001471
33.96127	151.0412	15:36:40	0.000977
33.96127	151.0412	15:36:45	0.000699
33.96127	151.0412	15:36:50	0.000784
33.96127	151.0412	15:36:55	0.000708
33.96127	151.0412	15:37:00	0.001057
33.96127	151.0412	15:37:05	0.001063
33.96127	151.0412	15:37:10	0.001231
33.96127	151.0412	15:37:15	0.001207
33.96127	151.0412	15:37:20	0.00084
33.96127	151.0412	15:37:25	0.000208
33.96127	151.0412	15:37:30	0.000574
33.96127	151.0412	15:37:35	0.001373
33.96127	151.0412	15:37:40	0.001896
33.96127	151.0412	15:37:45	0.001295
33.96127	151.0412	15:37:50	0.001099
33.96127	151.0412	15:37:55	0.000904
33.96127	151.0412	15:38:00	0.002032
33.96127	151.0412	15:38:05	0.001606

33.96127	151.0412	15:38:10	0.002186
33.96127	151.0412	15:38:15	0.000861
33.96127	151.0412	15:38:20	0.000494
33.96127	151.0412	15:38:25	4.44E-06
33.96127	151.0412	15:38:30	0.001414
33.96127	151.0412	15:38:35	0.000963
33.96127	151.0412	15:38:40	0.000851
33.96127	151.0412	15:38:45	0.00234
33.96127	151.0412	15:38:50	0.001374
33.96128	151.0412	15:38:55	0.001954
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33.9622	151.0415	16:09:25	0.005258
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33.96221	151.0415	16:09:35	0.003958
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33.96223	151.0415	16:09:50	0.004632
33.96223	151.0415	16:09:55	0.004288
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33.96224	151.0415	16:10:05	0.005046
33.96225	151.0415	16:10:10	0.004771
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33.96226	151.0415	16:10:20	0.004108
33.96227	151.0415	16:10:25	0.005418
33.96227	151.0415	16:10:30	0.006116
33.96228	151.0415	16:10:35	0.004528
33.96229	151.0415	16:10:40	0.004631
33.96229	151.0415	16:10:45	0.004653
33.9623	151.0415	16:10:50	0.005244
33.9623	151.0415	16:10:55	0.002659
33.96231	151.0415	16:11:00	0.003916
33.96232	151.0415	16:11:05	0.004358
33.96232	151.0415	16:11:10	0.002768
33.96233	151.0415	16:11:15	0.004454
33.96234	151.0415	16:11:20	0.004987
33.96234	151.0415	16:11:25	0.004814
33.96235	151.0415	16:11:30	0.004524
33.96236	151.0415	16:11:35	0.004925
33.96236	151.0415	16:11:40	0.005608
33.96237	151.0415	16:11:45	0.005864
33.96238	151.0415	16:11:50	0.003694
33.96239	151.0415	16:11:55	0.005058
33.96239	151.0415	16:12:00	0.005244
33.9624	151.0415	16:12:05	0.006135
33.96241	151.0415	16:12:10	0.004736
33.96241	151.0415	16:12:15	0.004557
33.96242	151.0415	16:12:20	0.006756
33.96243	151.0415	16:12:25	0.005055
33.96243	151.0415	16:12:30	0.004108
33.96244	151.0415	16:12:35	0.005941
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33.96249	151.0415	16:13:05	0.004656
33.96249	151.0415	16:13:10	0.005979
33.9625	151.0415	16:13:15	0.005177
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33.96252	151.0415	16:13:25	0.003186
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33.96314	151.0417	16:17:25	0.363456
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33.96337	151.0418	16:18:25	0.376669
33.96339	151.0418	16:18:30	0.186999
33.9634	151.0418	16:18:35	0.262148
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33.96351	151.0419	16:19:25	0.207724
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33.96357	151.042	16:20:05	0.239398
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33.96363	151.0421	16:20:40	0.242601
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33.96367	151.0421	16:21:10	0.261791
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33.9637	151.0422	16:21:40	0.253904
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33.96405	151.0426	16:25:05	0.27805
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33.96437	151.043	16:28:30	0.217557
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33.96439	151.043	16:28:45	0.249109
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33.96444	151.0431	16:29:25	0.126574
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33.96446	151.0431	16:29:35	0.174242
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33.96449	151.0431	16:30:00	0.146657
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33.96463	151.0433	16:32:30	0.161047
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33.96494	151.0438	16:38:10	0.17891
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33.96502	151.0438	16:39:20	0.174002
33.96503	151.0438	16:39:25	0.132227
33.96503	151.0438	16:39:30	0.191907
33.96504	151.0438	16:39:35	0.125418
33.96504	151.0438	16:39:40	0.26698
33.96505	151.0439	16:39:45	0.086286
33.96505	151.0439	16:39:50	0.182563
33.96506	151.0439	16:39:55	0.126034
33.96507	151.0439	16:40:00	0.221408
33.96508	151.0439	16:40:05	0.172992
33.96509	151.0439	16:40:10	0.138248
33.96509	151.0439	16:40:15	0.220614
33.96509	151.0439	16:40:20	0.16474
33.9651	151.0439	16:40:25	0.062581
33.96512	151.0439	16:40:30	0.134149
33.96513	151.0439	16:40:35	0.109072
33.96513	151.0439	16:40:40	0.123491
33.96513	151.0439	16:40:45	0.073664
33.96514	151.0439	16:40:50	0.214459
33.96516	151.0439	16:40:55	0.141584
33.96517	151.0439	16:41:00	0.181966
33.96517	151.0439	16:41:05	0.24059
33.96518	151.0439	16:41:10	0.136
33.9652	151.0439	16:41:15	0.185126
33.96521	151.0439	16:41:20	0.19162
33.96521	151.0439	16:41:25	0.148148
33.96522	151.0439	16:41:30	0.196453
33.96522	151.0439	16:41:35	0.094564
33.96523	151.0439	16:41:40	0.232203
33.96523	151.0439	16:41:45	0.161609
33.96525	151.0439	16:41:50	0.097448
33.96526	151.0439	16:41:55	0.220372
33.96526	151.0439	16:42:00	0.029241
33.96526	151.0439	16:42:05	0.210301
33.96527	151.0439	16:42:10	0.133947
33.96527	151.0439	16:42:15	0.084009
33.96528	151.0439	16:42:20	0.304099
33.96528	151.0439	16:42:25	0.247243
33.96529	151.0439	16:42:30	0.172093
33.96529	151.044	16:42:35	0.214997
33.9653	151.044	16:42:40	0.172895
33.9653	151.044	16:42:45	0.179941
33.96531	151.044	16:42:50	0.146209
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33.96532	151.044	16:43:10	0.151181
33.96533	151.044	16:43:15	0.110256
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33.96534	151.044	16:43:30	0.100468
33.96534	151.044	16:43:35	0.148553
33.96535	151.044	16:43:40	0.130555
33.96535	151.044	16:43:45	0.075687
33.96536	151.044	16:43:50	0.131274
33.96536	151.044	16:43:55	0.159151
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33.96537	151.0441	16:44:05	0.217218
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33.9654	151.0441	16:44:35	0.169889
33.9654	151.0441	16:44:40	0.101538
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33.96542	151.0441	16:44:55	0.179797
33.96542	151.0441	16:45:00	0.145829
33.96543	151.0441	16:45:05	0.161294
33.96543	151.0441	16:45:10	0.157819
33.96543	151.0441	16:45:15	0.172906
33.96544	151.0441	16:45:20	0.176586
33.96544	151.0442	16:45:25	0.159521
33.96545	151.0442	16:45:30	0.145169
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33.96546	151.0442	16:45:40	0.140965
33.96546	151.0442	16:45:45	0.176591
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33.96547	151.0442	16:45:55	0.222455
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33.96548	151.0442	16:46:05	0.129441
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33.96557	151.0443	16:47:45	0.131887
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33.96558	151.0443	16:47:55	0.169773
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33.96559	151.0443	16:48:05	0.163106
33.96559	151.0443	16:48:10	0.164986
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33.96568	151.0445	16:49:40	0.175845
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33.9657	151.0445	16:50:00	0.119307
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33.96571	151.0445	16:50:15	0.222327
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33.96582	151.0446	16:52:05	0.148025
33.96583	151.0446	16:52:10	0.141497
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33.9659	151.0447	16:53:30	0.138791
33.96591	151.0448	16:53:35	0.155477
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33.96597	151.0448	16:54:45	0.159285
33.96598	151.0448	16:54:50	0.169292
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33.96603	151.0449	16:55:45	0.149586
33.96604	151.0449	16:55:50	0.117696
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33.96611	151.045	16:57:10	0.170561
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33.96614	151.0451	16:57:40	0.179453
33.96615	151.0451	16:57:45	0.160022
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33.9662	151.0451	16:58:45	0.137798
33.96621	151.0451	16:58:50	0.132935
33.96621	151.0452	16:58:55	0.149944
33.96621	151.0452	16:59:00	0.175833
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33.96622	151.0452	16:59:10	0.169186
33.96623	151.0452	16:59:15	0.157238
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33.96624	151.0452	16:59:25	0.144267

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33.96625	151.0452	16:59:45	0.133346
33.96626	151.0452	16:59:50	0.146132
33.96626	151.0452	16:59:55	0.150644
33.96627	151.0452	17:00:00	0.167867
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33.96629	151.0452	17:00:15	0.183282
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33.96636	151.0453	17:01:25	0.134392
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33.96637	151.0453	17:01:35	0.127813
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33.96638	151.0453	17:01:45	0.179523
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33.96642	151.0453	17:02:25	0.129719
33.96643	151.0453	17:02:30	0.177821
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33.96646	151.0453	17:02:55	0.177406
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33.96649	151.0453	17:03:20	0.102479
33.9665	151.0453	17:03:25	0.212238
33.9665	151.0453	17:03:30	0.176556
33.96651	151.0453	17:03:35	0.170739
33.96652	151.0453	17:03:40	0.107009
33.96652	151.0454	17:03:45	0.174801
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33.96654	151.0454	17:03:55	0.177813
33.96654	151.0454	17:04:00	0.151476
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33.96655	151.0454	17:04:10	0.132392
33.96656	151.0454	17:04:15	0.152391
33.96657	151.0454	17:04:20	0.167485
33.96657	151.0454	17:04:25	0.144686
33.96658	151.0454	17:04:30	0.14014

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33.96663	151.0454	17:05:10	0.162487
33.96664	151.0454	17:05:15	0.174275
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33.96666	151.0454	17:05:35	0.103739
33.96667	151.0454	17:05:40	0.168156
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33.96668	151.0454	17:05:50	0.169495
33.96669	151.0454	17:05:55	0.114384
33.96669	151.0454	17:06:00	0.156942
33.9667	151.0454	17:06:05	0.168289
33.96671	151.0454	17:06:10	0.075924
33.96671	151.0454	17:06:15	0.155845
33.96672	151.0454	17:06:20	0.194372
33.96673	151.0454	17:06:25	0.158581
33.96673	151.0454	17:06:30	0.171462
33.96674	151.0454	17:06:35	0.140909
33.96675	151.0454	17:06:40	0.168989
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33.9668	151.0455	17:07:25	0.160069
33.96681	151.0455	17:07:30	0.089023
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33.96686	151.0455	17:08:10	0.143842
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33.9669	151.0455	17:08:35	0.138314
33.96691	151.0455	17:08:40	0.173237
33.96691	151.0455	17:08:45	0.120785
33.96692	151.0455	17:08:50	0.117692
33.96693	151.0455	17:08:55	0.14183
33.96694	151.0455	17:09:00	0.150847
33.96694	151.0455	17:09:05	0.149946
33.96695	151.0455	17:09:10	0.125374
33.96696	151.0455	17:09:15	0.113372
33.96696	151.0455	17:09:20	0.146183

Salt Pan Creek velocity 3

Longitude	Latitude	Time AEST	M/Sec
151.044	33.9675	15:23:59	0.002778
151.044	33.9675	15:24:29	0.002341
151.044	33.9675	15:24:59	0.001718
151.044	33.9675	15:25:29	0.002384
151.044	33.9675	15:25:59	0.005022
151.044	33.9675	15:26:29	0.002588
151.044	33.9675	15:26:59	0.005045
151.044	33.96749	15:27:29	0.004214
151.044	33.96749	15:27:59	0.003339
151.044	33.96749	15:28:29	0.00307
151.044	33.96749	15:28:59	0.003825
151.044	33.96749	15:29:29	0.00417
151.044	33.96748	15:29:59	0.002872
151.0439	33.96748	15:30:29	0.00261
151.0439	33.96748	15:30:59	0.002542
151.0439	33.96748	15:31:29	0.00245
151.0439	33.96748	15:31:59	0.003223
151.0439	33.96748	15:32:29	0.001688
151.0439	33.96748	15:32:59	0.002878
151.0439	33.96748	15:33:29	0.002121
151.0439	33.96748	15:33:59	0.001944
151.0439	33.96748	15:34:29	0.00535
151.0439	33.96748	15:34:59	0.001877
151.0439	33.96748	15:35:29	0.002016
151.0439	33.96748	15:35:59	0.001284
151.0439	33.96748	15:36:29	0.003729
151.0439	33.96748	15:36:59	0.0019
151.0439	33.96748	15:37:29	0.002106
151.0439	33.96749	15:37:59	0.00301
151.0438	33.96749	15:38:29	0.001695
151.0438	33.96749	15:38:59	0.002708
151.0438	33.96749	15:39:29	0.001982
151.0438	33.96749	15:39:59	0.001641
151.0438	33.96749	15:40:29	0.003038
151.0438	33.9675	15:40:59	0.001845
151.0438	33.9675	15:41:29	0.001804
151.0438	33.9675	15:41:59	0.002597
151.0438	33.96751	15:42:29	0.001594
151.0438	33.96751	15:42:59	0.003083
151.0438	33.96751	15:43:29	0.002797
151.0438	33.96752	15:43:59	0.002418
151.0438	33.96752	15:44:29	0.00282
151.0438	33.96753	15:44:59	0.00311
151.0438	33.96753	15:45:29	0.001468
151.0438	33.96753	15:45:59	0.001739
151.0438	33.96754	15:46:29	0.00163
151.0438	33.96754	15:46:59	0.001277
151.0438	33.96754	15:47:29	0.000931
151.0438	33.96755	15:47:59	0.002514
151.0438	33.96755	15:48:29	0.001847
151.0438	33.96756	15:48:59	0.002048
151.0437	33.96756	15:49:29	0.001391
151.0437	33.96756	15:49:59	0.000464
151.0437	33.96757	15:50:29	0.002878
151.0437	33.96757	15:50:59	0.003848
151.0437	33.96758	15:51:29	0.002899
151.0437	33.96758	15:51:59	0.001086

151.0437	33.96759	15:52:29	0.002648
151.0437	33.96759	15:52:59	0.004003
151.0437	33.9676	15:53:29	0.001399
151.0437	33.9676	15:53:59	0.003373
151.0437	33.96761	15:54:29	0.001652
151.0437	33.96761	15:54:59	0.002535
151.0437	33.96762	15:55:29	0.004694
151.0437	33.96762	15:55:59	0.00166
151.0437	33.96763	15:56:29	0.002812
151.0437	33.96763	15:56:59	0.002665
151.0437	33.96764	15:57:29	0.003069
151.0437	33.96764	15:57:59	0.004189
151.0437	33.96765	15:58:29	0.003954
151.0437	33.96765	15:58:59	0.001304
151.0437	33.96766	15:59:29	0.002771
151.0437	33.96766	15:59:59	0.002373
151.0437	33.96767	16:00:29	0.003504
151.0437	33.96767	16:00:59	0.002528
151.0437	33.96768	16:01:29	0.003033
151.0437	33.96768	16:01:59	0.002473
151.0437	33.96769	16:02:29	0.001845
151.0437	33.96769	16:02:59	0.001244
151.0437	33.9677	16:03:29	0.003593
151.0437	33.96771	16:03:59	0.001799
151.0437	33.96771	16:04:29	0.002974
151.0437	33.96772	16:04:59	0.002164
151.0438	33.96773	16:05:29	0.003282
151.0438	33.96773	16:05:59	0.002801
151.0438	33.96774	16:06:29	0.000495
151.0438	33.96776	16:06:59	0.001961
151.0438	33.96776	16:07:29	0.003148
151.0438	33.96778	16:07:59	0.003499
151.0438	33.96779	16:08:29	0.002133
151.0438	33.9678	16:08:59	0.003138
151.0438	33.96783	16:09:29	0.001938
151.0438	33.96784	16:09:59	0.003349
151.0438	33.96785	16:10:29	0.002511
151.0438	33.96787	16:10:59	0.001818
151.0439	33.96789	16:11:29	0.003585
151.0439	33.96791	16:11:59	0.001989
151.0439	33.96793	16:12:29	0.002071
151.0439	33.96794	16:12:59	0.002315
151.0439	33.96795	16:13:29	0.001456
151.0439	33.96796	16:13:59	0.001149
151.0439	33.96797	16:14:29	0.005982
151.044	33.968	16:14:59	0.093148
151.0441	33.96812	16:16:59	0.068263
151.0441	33.96814	16:17:29	0.072658
151.0441	33.96816	16:17:59	0.049886
151.0441	33.96817	16:18:29	0.048816
151.0441	33.96819	16:18:59	0.062979
151.0441	33.9682	16:19:29	0.055451
151.0441	33.96822	16:19:59	0.068424
151.0442	33.96824	16:20:29	0.064452
151.0442	33.96826	16:20:59	0.087113
151.0442	33.96828	16:21:29	0.07068
151.0442	33.9683	16:21:59	0.069379
151.0442	33.96832	16:22:29	0.075094
151.0442	33.96834	16:22:59	0.047156
151.0442	33.96834	16:23:29	0.036252
151.0442	33.96835	16:23:59	0.060281

151.0442	33.96836	16:24:29	0.037348
151.0442	33.96836	16:24:59	0.047761
151.0442	33.96838	16:25:29	0.115887
151.0442	33.96839	16:25:59	0.041136
151.0442	33.96839	16:26:29	0.009194
151.045	33.96829	16:27:59	0.214527
151.0451	33.9683	16:28:29	0.169326
151.0451	33.96831	16:28:59	0.18407
151.0451	33.96832	16:29:29	0.233265
151.0452	33.96833	16:29:59	0.153063
151.0452	33.96836	16:30:29	0.319096
151.0452	33.96844	16:30:59	0.160568
151.0452	33.96845	16:31:29	0.122701
151.0452	33.96846	16:31:59	0.118404
151.0453	33.96847	16:32:29	0.088841
151.0453	33.96848	16:32:59	0.088608
151.0453	33.96849	16:33:29	0.167674
151.0453	33.9685	16:33:59	0.1048
151.0454	33.96852	16:34:29	0.129716
151.0454	33.96853	16:34:59	0.153711
151.0454	33.96854	16:35:29	0.173743
151.0454	33.96856	16:35:59	0.154471
151.0454	33.96857	16:36:29	0.141579
151.0455	33.9686	16:36:59	0.086756
151.0455	33.96862	16:37:29	0.140025
151.0455	33.96865	16:37:59	0.150833
151.0456	33.96869	16:38:29	0.134629
151.0456	33.96873	16:38:59	0.13184
151.0456	33.96877	16:39:29	0.121962
151.0456	33.96881	16:39:59	0.112157
151.0456	33.96885	16:40:29	0.106155
151.0457	33.96889	16:40:59	0.148382
151.0457	33.96893	16:41:29	0.143442
151.0457	33.96896	16:41:59	0.121674
151.0457	33.969	16:42:29	0.144521
151.0457	33.96904	16:42:59	0.155124
151.0458	33.96908	16:43:29	0.120207
151.0458	33.96911	16:43:59	0.104627
151.0458	33.96915	16:44:29	0.14472
151.0458	33.96918	16:44:59	0.084109
151.0458	33.96922	16:45:29	0.170893
151.0458	33.96926	16:45:59	0.110815
151.0458	33.9693	16:46:29	0.183293
151.0458	33.96935	16:46:59	0.234619
151.0458	33.96939	16:47:29	0.086388
151.0458	33.96943	16:47:59	0.102854
151.0458	33.96947	16:48:29	0.093465
151.0458	33.96951	16:48:59	0.200324
151.0458	33.96954	16:49:29	0.141736
151.0458	33.96958	16:49:59	0.175414
151.0458	33.96962	16:50:29	0.171136
151.0458	33.96966	16:50:59	0.151867
151.0458	33.96971	16:51:29	0.20341
151.0458	33.96975	16:51:59	0.163994
151.0458	33.96979	16:52:29	0.108044
151.0458	33.96983	16:52:59	0.136893
151.0458	33.96987	16:53:29	0.013641
151.0458	33.96991	16:53:59	0.146243
151.0458	33.96995	16:54:29	0.15292
151.0458	33.97	16:54:59	0.148086
151.0458	33.97004	16:55:29	0.11296

151.0458	33.97008	16:55:59	0.162636
151.0457	33.97012	16:56:29	0.13249
151.0457	33.97017	16:56:59	0.171759
151.0457	33.97021	16:57:29	0.112588
151.0457	33.97025	16:57:59	0.15166
151.0457	33.97029	16:58:29	0.116672
151.0456	33.97033	16:58:59	0.139069
151.0456	33.97036	16:59:29	0.138093
151.0456	33.9704	16:59:59	0.16352
151.0456	33.97044	17:00:29	0.132297
151.0456	33.97047	17:00:59	0.13091
151.0455	33.97051	17:01:29	0.151975
151.0455	33.97055	17:01:59	0.147359
151.0455	33.97058	17:02:29	0.154913
151.0455	33.97061	17:02:59	0.117234
151.0454	33.97065	17:03:29	0.159512
151.0454	33.97068	17:03:59	0.13298
151.0454	33.97072	17:04:29	0.15056
151.0453	33.97076	17:04:59	0.142968
151.0453	33.97079	17:05:29	0.140364
151.0453	33.97083	17:05:59	0.078553
151.0452	33.97086	17:06:29	0.089724
151.0452	33.9709	17:06:59	0.124604
151.0452	33.97094	17:07:29	0.129989
151.0451	33.97098	17:07:59	0.146306
151.0451	33.97101	17:08:29	0.150274
151.0451	33.97105	17:08:59	0.143143
151.045	33.97108	17:09:29	0.182782
151.045	33.97111	17:09:59	0.146596
151.0449	33.97114	17:10:29	0.168102
151.0449	33.97116	17:10:59	0.189561

Gunnamatta Bay velocity 1

Latitude	Longitud e	Time AEST	Speed M/Sec
34.05536	151.1485	11:01:52	0.001068
34.05543	151.1484	11:02:52	0.096542
34.05545	151.1484	11:03:52	0.001468
34.05545	151.1484	11:04:52	0.000751
34.05546	151.1484	11:05:52	0.003723
34.05546	151.1484	11:06:52	0.005518
34.05547	151.1484	11:07:52	0.004923
34.05548	151.1484	11:08:52	0.000715
34.05548	151.1484	11:09:52	0.001361
34.05549	151.1484	11:10:52	0.002692
34.0555	151.1484	11:11:52	0.003616
34.05551	151.1483	11:12:52	0.002573
34.05552	151.1483	11:13:52	0.003202
34.05554	151.1483	11:14:52	0.003937
34.05556	151.1483	11:15:52	0.010515
34.05559	151.1482	11:16:52	0.002816
34.05562	151.1482	11:17:52	0.006383
34.05564	151.1481	11:18:52	0.003792
34.05584	151.1478	11:22:52	0.077628
34.05589	151.1478	11:23:52	0.117487
34.05595	151.1477	11:24:52	0.136591
34.05602	151.1476	11:25:52	0.167667
34.05608	151.1475	11:26:52	0.159797
34.05614	151.1474	11:27:52	0.152867

34.05619	151.1473	11:28:52	0.15599
34.05626	151.1473	11:29:52	0.149184
34.05631	151.1472	11:30:52	0.115879
34.05634	151.1471	11:31:52	0.123148
34.05639	151.147	11:32:52	0.147067
34.05644	151.147	11:33:52	0.182691
34.05648	151.1469	11:34:52	0.124983
34.05652	151.1468	11:35:52	0.141729
34.05666	151.1466	11:39:52	0.172099
34.05671	151.1465	11:40:52	0.125381
34.05677	151.1464	11:41:52	0.241792
34.05682	151.1464	11:42:52	0.113264
34.05686	151.1463	11:43:52	0.103607
34.05689	151.1462	11:44:52	0.176097
34.05693	151.1462	11:45:52	0.056853
34.05698	151.1461	11:46:52	0.128232
34.05702	151.146	11:47:52	0.012642
34.05704	151.1458	11:49:52	0.096062
34.05706	151.1458	11:50:52	0.160066
34.05712	151.1457	11:51:52	0.165827
34.05717	151.1456	11:52:52	0.185787
34.05723	151.1456	11:53:52	0.129941
34.05723	151.1457	12:01:52	0.716032
34.05738	151.1455	12:02:52	0.068659
34.05738	151.1454	12:03:52	0.18338
34.05741	151.1454	12:04:52	0.056665
34.05746	151.1453	12:05:52	0.110973
34.0575	151.1453	12:06:52	0.123412
34.05753	151.1453	12:07:52	0.20451
34.05757	151.1452	12:08:52	0.155063
34.05762	151.1452	12:09:52	0.104814
34.05766	151.1452	12:10:52	0.18134
34.05771	151.1451	12:11:52	0.299763
34.05773	151.1451	12:12:52	0.0622
34.05775	151.1451	12:13:52	0.138254
34.05781	151.145	12:14:52	0.045537
34.05787	151.145	12:15:52	0.149448
34.05792	151.145	12:16:52	0.180851
34.05796	151.1449	12:17:52	0.173324
34.05801	151.1449	12:18:52	0.230272
34.05807	151.1448	12:19:52	0.138114
34.05812	151.1448	12:20:52	0.112596
34.05815	151.1447	12:21:52	0.200465
34.05822	151.1447	12:22:52	0.460841
34.05828	151.1446	12:23:52	0.125445
34.05832	151.1446	12:24:52	0.106859
34.05837	151.1446	12:25:52	0.128718
34.05843	151.1445	12:26:52	0.074796
34.0585	151.1445	12:27:52	0.396776
34.05855	151.1444	12:28:52	0.177005
34.05861	151.1444	12:29:52	0.244414
34.05866	151.1444	12:30:52	0.343644
34.05869	151.1444	12:31:52	0.170994
34.05875	151.1443	12:32:52	0.141452
34.05883	151.1442	12:33:52	0.111171
34.05888	151.1442	12:34:52	0.256957
34.05894	151.1442	12:35:52	0.08695

Gunnamatta Bay velocity 2

Latitud e	Longitud e	Time AEST	Speed M/Sec
34.05889	151.1449	11:04:29	0.146396
34.0589	151.1448	11:04:34	0.134637
34.0589	151.1448	11:04:39	0.121663
34.05891	151.1448	11:04:44	0.267158
34.05892	151.1448	11:04:49	0.193468
34.05892	151.1448	11:04:54	0.151299
34.05892	151.1448	11:04:59	0.059276
34.05892	151.1448	11:05:04	0.046681
34.05893	151.1448	11:05:09	0.164331
34.05893	151.1448	11:05:14	0.130126
34.05893	151.1448	11:05:19	0.131393
34.05894	151.1448	11:05:24	0.249406
34.05894	151.1448	11:05:29	0.302379
34.05894	151.1448	11:05:34	0.107477
34.05895	151.1448	11:05:39	0.035762
34.05895	151.1448	11:05:44	0.122439
34.05896	151.1448	11:05:49	0.255429
34.05896	151.1447	11:05:54	0.147199
34.05897	151.1447	11:05:59	0.09691
34.05897	151.1447	11:06:04	0.127674
34.05898	151.1447	11:06:09	0.326591
34.05898	151.1447	11:06:14	0.396355
34.05899	151.1447	11:06:19	0.220855
34.059	151.1447	11:06:24	0.15074
34.059	151.1447	11:06:29	0.058253
34.05901	151.1447	11:06:34	0.106031
34.05901	151.1447	11:06:39	0.044011
34.05901	151.1447	11:06:44	0.065392
34.05902	151.1447	11:06:49	0.03045
34.05902	151.1447	11:06:54	0.069048
34.05902	151.1447	11:06:59	0.126814
34.05903	151.1447	11:07:04	0.290296
34.05903	151.1447	11:07:09	0.070142
34.05904	151.1447	11:07:14	0.152158
34.05904	151.1447	11:07:19	0.215619
34.05905	151.1447	11:07:24	0.176639
34.05905	151.1447	11:07:29	0.114367
34.05906	151.1447	11:07:34	0.083233
34.05906	151.1447	11:07:39	0.040326
34.05906	151.1447	11:07:44	0.136162
34.05907	151.1447	11:07:49	0.143556
34.05907	151.1447	11:07:54	0.229334
34.05908	151.1447	11:07:59	0.198959
34.05908	151.1447	11:08:04	0.070692
34.05908	151.1447	11:08:09	0.057886
34.05909	151.1447	11:08:14	0.133352
34.05909	151.1447	11:08:19	0.082002
34.05909	151.1447	11:08:24	0.088927
34.0591	151.1447	11:08:29	0.184618
34.0591	151.1447	11:08:34	0.07182
34.0591	151.1447	11:08:39	0.175838
34.05911	151.1447	11:08:44	0.161582
34.05912	151.1446	11:08:49	0.156084
34.05912	151.1446	11:08:54	0.175585
34.05913	151.1446	11:08:59	0.073361
34.05913	151.1446	11:09:04	0.157065
34.05914	151.1446	11:09:09	0.154505

34.05914	151.1446	11:09:14	0.151785
34.05915	151.1446	11:09:19	0.209075
34.05916	151.1446	11:09:24	0.131354
34.05916	151.1446	11:09:29	0.091356
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34.06093	151.1432	11:39:49	0.177966
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34.06095	151.1432	11:39:59	0.054572
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34.06096	151.1432	11:40:09	0.204793
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34.06097	151.1432	11:40:19	0.15811
34.06098	151.1432	11:40:24	0.249516
34.06098	151.1432	11:40:29	0.436513
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34.06102	151.1431	11:41:04	0.122098
34.06103	151.1431	11:41:09	0.096536
34.06103	151.1431	11:41:14	0.182417
34.06104	151.1431	11:41:19	0.249706
34.06106	151.1431	11:41:24	0.398018
34.06106	151.1431	11:41:29	0.094897
34.06106	151.1431	11:41:34	0.11519
34.06106	151.1431	11:41:39	0.202001
34.06106	151.1431	11:41:44	0.068694
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34.06108	151.1431	11:41:54	0.07855
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34.0611	151.1431	11:42:04	0.160552
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34.06112	151.1431	11:42:24	0.389248
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34.06244	151.1418	12:09:59	0.184572
34.06245	151.1418	12:10:04	0.109879
34.06245	151.1418	12:10:09	0.134343

34.06246	151.1418	12:10:14	0.206232
34.06247	151.1418	12:10:19	0.218112
34.06248	151.1418	12:10:24	0.198778
34.06248	151.1418	12:10:29	0.137836
34.06249	151.1418	12:10:34	0.038205
34.06249	151.1418	12:10:39	0.038525
34.06249	151.1418	12:10:44	0.001661
34.06249	151.1418	12:10:49	0.001041
34.06249	151.1418	12:10:54	0.001111
34.06249	151.1418	12:10:59	0.002151
34.06249	151.1418	12:11:04	0.003286
34.06249	151.1418	12:11:09	0.00427
34.06249	151.1418	12:11:14	0.001311
34.06249	151.1418	12:11:19	0.002251
34.06248	151.1418	12:11:24	0.002865
34.06248	151.1418	12:11:29	0.004132
34.06248	151.1418	12:11:34	0.001316
34.06248	151.1418	12:11:39	0.002352
34.06248	151.1418	12:11:44	0.000966
34.06248	151.1418	12:11:49	0.002653
34.06248	151.1418	12:11:54	0.000488
34.06248	151.1418	12:11:59	0.002219
34.06248	151.1418	12:12:04	0.001038
34.06248	151.1418	12:12:09	0.002707
34.06248	151.1418	12:12:14	0.001604
34.06248	151.1418	12:12:19	0.000742
34.06248	151.1418	12:12:24	0.005214
34.06248	151.1418	12:12:29	0.002554
34.06248	151.1418	12:12:34	0.0017
34.06248	151.1418	12:12:39	0.004306
34.06248	151.1418	12:12:44	0.002339
34.06248	151.1418	12:12:49	0.00255
34.06248	151.1418	12:12:54	0.001906
34.06248	151.1418	12:12:59	0.004278
34.06248	151.1418	12:13:04	0.004592
34.06248	151.1418	12:13:09	0.00513
34.06248	151.1418	12:13:14	0.002793
34.06248	151.1418	12:13:19	0.000892
34.06248	151.1418	12:13:24	0.002349
34.06248	151.1418	12:13:29	0.00194
34.06248	151.1418	12:13:34	0.003065
34.06248	151.1418	12:13:39	0.001824
34.06248	151.1418	12:13:44	0.001366
34.06248	151.1418	12:13:49	0.004109
34.06248	151.1418	12:13:54	0.003719
34.06248	151.1418	12:13:59	0.002437
34.06248	151.1418	12:14:04	0.001849
34.06248	151.1418	12:14:09	0.004263
34.06248	151.1418	12:14:14	0.003114
34.06248	151.1418	12:14:19	0.003319
34.06247	151.1418	12:14:24	0.001519
34.06247	151.1418	12:14:29	0.000301
34.06247	151.1418	12:14:34	0.007638
34.06247	151.1418	12:14:39	0.003217
34.06247	151.1418	12:14:44	0.005843
34.06247	151.1418	12:14:49	0.004148
34.06247	151.1418	12:14:54	0.002471
34.06247	151.1418	12:14:59	0.001695
34.06247	151.1418	12:15:04	0.000911
34.06247	151.1418	12:15:09	0.001689
34.06247	151.1418	12:15:14	0.003541

34.06247	151.1418	12:15:19	0.001396
34.06247	151.1418	12:15:24	0.003723
34.06247	151.1418	12:15:29	0.003428
34.06247	151.1418	12:15:34	0.002104
34.06247	151.1418	12:15:39	0.000648
34.06247	151.1418	12:15:44	0.003037
34.06247	151.1418	12:15:49	0.002062
34.06247	151.1418	12:15:54	0.000861
34.06247	151.1418	12:15:59	0.001321
34.06247	151.1418	12:16:04	0.002803
34.06247	151.1418	12:16:09	0.001124
34.06247	151.1418	12:16:14	0.001416
34.06247	151.1418	12:16:19	0.001353
34.06247	151.1418	12:16:24	0.002249
34.06247	151.1418	12:16:29	0.001874
34.06247	151.1418	12:16:34	0.000802
34.06247	151.1418	12:16:39	0.001118
34.06247	151.1418	12:16:44	0.002111
34.06247	151.1418	12:16:49	0.003908
34.06247	151.1418	12:16:54	0.002576
34.06247	151.1418	12:16:59	0.005443
34.06247	151.1418	12:17:04	0.003248
34.06247	151.1418	12:17:09	0.002181
34.06247	151.1418	12:17:14	0.001311
34.06247	151.1418	12:17:19	0.000498
34.06247	151.1418	12:17:24	0.000459
34.06247	151.1418	12:17:29	0.000962
34.06247	151.1418	12:17:34	0.000613
34.06247	151.1418	12:17:39	0.001063
34.06247	151.1418	12:17:44	0.007262
34.06247	151.1418	12:17:49	0.00249
34.06247	151.1418	12:17:54	0.001274
34.06247	151.1418	12:17:59	0.003134
34.06247	151.1418	12:18:04	0.001061
34.06247	151.1418	12:18:09	0.002322
34.06247	151.1418	12:18:14	0.003688
34.06247	151.1418	12:18:19	0.001952
34.06247	151.1418	12:18:24	0.001682
34.06247	151.1418	12:18:29	0.000821
34.06247	151.1418	12:18:34	0.001687
34.06247	151.1418	12:18:39	0.001405
34.06247	151.1418	12:18:44	0.003756
34.06247	151.1418	12:18:49	0.002933
34.06247	151.1418	12:18:54	0.001111
34.06247	151.1418	12:18:59	0.000449
34.06247	151.1418	12:19:04	0.002037
34.06247	151.1418	12:19:09	0.002362
34.06248	151.1418	12:19:14	0.003993
34.06248	151.1418	12:19:19	0.002647
34.06248	151.1418	12:19:24	0.001107
34.06248	151.1418	12:19:29	0.000264
34.06248	151.1418	12:19:34	0.002245
34.06248	151.1418	12:19:39	0.002131
34.06248	151.1418	12:19:44	0.005062
34.06248	151.1418	12:19:49	0.080889
34.06248	151.1418	12:19:54	0.137312
34.06249	151.1418	12:19:59	0.102233
34.06249	151.1418	12:20:04	0.109002
34.06249	151.1418	12:20:09	0.096688
34.0625	151.1418	12:20:14	0.024552
34.06249	151.1418	12:20:19	0.037086

34.06249	151.1418	12:20:24	0.001785
34.06249	151.1418	12:20:29	0.00363
34.06249	151.1418	12:20:34	0.002627
34.06249	151.1418	12:20:39	0.001557
34.06249	151.1418	12:20:44	0.001944
34.06249	151.1418	12:20:49	0.001207
34.0625	151.1418	12:20:54	0.004866
34.0625	151.1418	12:20:59	0.001216
34.0625	151.1418	12:21:04	0.002095
34.0625	151.1418	12:21:09	0.000566
34.0625	151.1418	12:21:14	0.001115
34.0625	151.1418	12:21:19	0.00125
34.0625	151.1418	12:21:24	0.000548
34.0625	151.1418	12:21:29	0.002807
34.0625	151.1418	12:21:34	0.00148
34.0625	151.1418	12:21:39	0.003476
34.06249	151.1418	12:21:44	0.002009
34.0625	151.1418	12:21:49	0.001451
34.06249	151.1418	12:21:54	0.003084
34.0625	151.1418	12:21:59	0.000468
34.0625	151.1418	12:22:04	0.001497
34.0625	151.1418	12:22:09	0.000307
34.0625	151.1418	12:22:14	0.001606
34.0625	151.1418	12:22:19	0.001988
34.0625	151.1418	12:22:24	0.002196
34.0625	151.1418	12:22:29	0.001061
34.0625	151.1418	12:22:34	0.000524
34.0625	151.1418	12:22:39	0.001821
34.0625	151.1418	12:22:44	0.003651
34.0625	151.1418	12:22:49	0.002558
34.0625	151.1418	12:22:54	0.003096
34.0625	151.1418	12:22:59	0.001198
34.0625	151.1418	12:23:04	0.003323
34.0625	151.1418	12:23:09	0.002263
34.0625	151.1418	12:23:14	0.001959
34.06249	151.1418	12:23:19	0.002734
34.06249	151.1418	12:23:24	0.001204
34.06249	151.1418	12:23:29	0.001479
34.0625	151.1418	12:23:34	0.002191
34.0625	151.1418	12:23:39	0.000995
34.0625	151.1418	12:23:44	0.002731
34.0625	151.1418	12:23:49	0.000362
34.06249	151.1418	12:23:54	0.002283
34.06249	151.1418	12:23:59	0.002171
34.0625	151.1418	12:24:04	0.001644
34.06249	151.1418	12:24:09	0.002284
34.06249	151.1418	12:24:14	0.000824
34.06249	151.1418	12:24:19	0.005063
34.06249	151.1418	12:24:24	0.002824
34.06249	151.1418	12:24:29	0.001242
34.0625	151.1418	12:24:34	0.003184
34.0625	151.1418	12:24:39	0.000392
34.06249	151.1418	12:24:44	0.002028
34.06249	151.1418	12:24:49	0.002765
34.06249	151.1418	12:24:54	0.002623
34.06249	151.1418	12:24:59	0.001733
34.06249	151.1418	12:25:04	0.000876
34.06249	151.1418	12:25:09	0.00137
34.06249	151.1418	12:25:14	0.004118
34.06249	151.1418	12:25:19	0.004269
34.06249	151.1418	12:25:24	0.00156

34.06249	151.1418	12:25:29	0.000161
34.06249	151.1418	12:25:34	0.001427
34.06249	151.1418	12:25:39	0.001465
34.06249	151.1418	12:25:44	0.001489
34.06249	151.1418	12:25:49	0.002174
34.06249	151.1418	12:25:54	0.001812
34.06249	151.1418	12:25:59	0.000926
34.06249	151.1418	12:26:04	0.002417
34.06249	151.1418	12:26:09	0.00106
34.06249	151.1418	12:26:14	0.001362
34.06249	151.1418	12:26:19	0.002859
34.06249	151.1418	12:26:24	0.000579
34.06249	151.1418	12:26:29	0.002468
34.06249	151.1418	12:26:34	0.001309
34.06249	151.1418	12:26:39	0.001899
34.06249	151.1418	12:26:44	0.001178
34.06249	151.1418	12:26:49	0.001142
34.06249	151.1418	12:26:54	0.000491
34.06249	151.1418	12:26:59	0.000869
34.06249	151.1418	12:27:04	0.001786
34.06249	151.1418	12:27:09	0.003921
34.06249	151.1418	12:27:14	0.002648
34.0625	151.1418	12:27:19	0.001314
34.0625	151.1418	12:27:24	0.002054
34.0625	151.1418	12:27:29	0.002667
34.0625	151.1418	12:27:34	0.00079
34.0625	151.1418	12:27:39	0.002343
34.06249	151.1418	12:27:44	0.00345
34.06249	151.1418	12:27:49	0.001828
34.0625	151.1418	12:27:54	0.000511
34.0625	151.1418	12:27:59	0.003721
34.0625	151.1418	12:28:04	0.002059
34.06249	151.1418	12:28:09	0.005404
34.06249	151.1418	12:28:14	0.003969
34.0625	151.1418	12:28:19	0.003174
34.0625	151.1418	12:28:24	0.00142
34.0625	151.1418	12:28:29	0.001946
34.0625	151.1418	12:28:34	0.002962
34.0625	151.1418	12:28:39	0.001919
34.0625	151.1418	12:28:44	0.002205
34.0625	151.1418	12:28:49	0.000271
34.0625	151.1418	12:28:54	0.001958
34.06249	151.1418	12:28:59	0.001407
34.06249	151.1418	12:29:04	0.001634
34.06249	151.1418	12:29:09	0.004346
34.06249	151.1418	12:29:14	0.000912
34.06249	151.1418	12:29:19	0.002045
34.06249	151.1418	12:29:24	0.00357
34.06249	151.1418	12:29:29	0.002299
34.06249	151.1418	12:29:34	0.000692
34.06249	151.1418	12:29:39	0.005633
34.06249	151.1418	12:29:44	0.005114
34.06249	151.1418	12:29:49	0.011015

Gunnamatta Bay velocity 3

Latitu de	Longitu de	Time AEST	Speed M/Sec
34.06357	151.145	11:10:40	0.083591
34.06363	151.145	11:11:10	0.261636
34.06366	151.1449	11:11:40	0.206432
34.0637	151.1449	11:12:10	0.14759
34.06374	151.1449	11:12:40	0.110366
34.06378	151.1449	11:13:10	0.140989
34.06382	151.1448	11:13:40	0.112003
34.06386	151.1448	11:14:10	0.227531
34.06389	151.1448	11:14:40	0.004414
34.06393	151.1448	11:15:10	0.313393
34.06396	151.1448	11:15:40	0.197318
34.06397	151.1447	11:16:10	0.279467
34.06397	151.1447	11:16:40	0.13076
34.064	151.1447	11:17:10	0.04739
34.06403	151.1447	11:17:40	0.127814
34.06407	151.1447	11:18:10	0.165282
34.06409	151.1447	11:18:40	0.06401
34.06413	151.1447	11:19:10	0.40327
34.06416	151.1446	11:19:40	0.108836
34.06419	151.1446	11:20:10	0.125608
34.06423	151.1446	11:20:40	0.13291
34.06427	151.1446	11:21:10	0.089528
34.06428	151.1446	11:21:40	0.168894
34.06432	151.1446	11:22:10	0.134931
34.06435	151.1445	11:22:40	0.024641
34.06437	151.1445	11:23:10	0.249864
34.06441	151.1445	11:23:40	0.118697
34.06444	151.1445	11:24:10	0.214325
34.0645	151.1445	11:24:40	0.207377
34.06454	151.1445	11:25:10	0.216735
34.06457	151.1444	11:25:40	0.204624
34.0646	151.1444	11:26:10	0.102573
34.06463	151.1444	11:26:40	0.027609
34.06466	151.1444	11:27:10	0.297279
34.0647	151.1443	11:27:40	0.146592
34.06474	151.1443	11:28:10	0.212157
34.06477	151.1443	11:28:40	0.243394
34.06481	151.1443	11:29:10	0.046187
34.06484	151.1443	11:29:40	0.177433
34.06486	151.1443	11:30:10	0.141794
34.06489	151.1443	11:30:40	0.186407
34.06491	151.1442	11:31:10	0.315729
34.06496	151.1442	11:31:40	0.175571
34.06499	151.1442	11:32:10	0.048366
34.06502	151.1442	11:32:40	0.256724
34.06505	151.1442	11:33:10	0.041255
34.06507	151.1442	11:33:40	0.213179
34.06511	151.1441	11:34:10	0.206481
34.06514	151.1441	11:34:40	0.030889
34.06517	151.1441	11:35:10	0.104481
34.06521	151.1441	11:35:40	0.171209
34.06525	151.1441	11:36:10	0.190292
34.06527	151.144	11:36:40	0.283126
34.06529	151.144	11:37:10	0.20074
34.06532	151.144	11:37:40	0.031132
34.06535	151.144	11:38:10	0.128323
34.06539	151.144	11:38:40	0.145663

34.06541	151.1439	11:39:10	0.336507
34.06545	151.1439	11:39:40	0.363636
34.06547	151.1439	11:40:10	0.126553
34.06549	151.1439	11:40:40	0.139704
34.06553	151.1439	11:41:10	0.032259
34.06556	151.1439	11:41:40	0.196867
34.06561	151.1439	11:42:10	0.146903
34.06563	151.1439	11:42:40	0.227044
34.06569	151.1438	11:43:10	0.328381
34.06574	151.1438	11:43:40	0.235102
34.06576	151.1438	11:44:10	0.560947
34.06577	151.1438	11:44:40	0.362387
34.06578	151.1437	11:45:10	0.28014
34.06582	151.1437	11:45:40	0.270798
34.06587	151.1437	11:46:10	0.147336
34.0659	151.1437	11:46:40	0.487983
34.06591	151.1437	11:47:10	0.146941
34.06595	151.1437	11:47:40	0.319047
34.06598	151.1436	11:48:10	0.254244
34.06601	151.1436	11:48:40	0.161768
34.06605	151.1436	11:49:10	0.469683
34.06608	151.1436	11:49:40	0.106242
34.06611	151.1436	11:50:10	0.216472
34.06614	151.1435	11:50:40	0.312047
34.06617	151.1435	11:51:10	0.055055
34.06622	151.1435	11:51:40	0.273737
34.06626	151.1435	11:52:10	0.245122
34.06628	151.1435	11:52:40	0.191496
34.06634	151.1435	11:53:10	0.168099
34.06637	151.1434	11:53:40	0.052487
34.06639	151.1434	11:54:10	0.154431
34.06644	151.1434	11:54:40	0.158056
34.06647	151.1434	11:55:10	0.198897
34.0665	151.1434	11:55:40	0.172367
34.06653	151.1434	11:56:10	0.299798
34.06659	151.1433	11:56:40	0.022456
34.06663	151.1433	11:57:10	0.055793
34.06668	151.1433	11:57:40	0.049481
34.06671	151.1433	11:58:10	0.052423
34.06675	151.1432	11:58:40	0.214672
34.06678	151.1432	11:59:10	0.242734
34.06682	151.1432	11:59:40	0.276857
34.06686	151.1432	12:00:10	0.140911
34.06689	151.1432	12:00:40	0.217983
34.06695	151.1432	12:01:10	0.210156
34.06699	151.1431	12:01:40	0.355074
34.06703	151.1431	12:02:10	0.08023
34.06709	151.1431	12:02:40	0.180374
34.06712	151.1431	12:03:10	0.05312
34.06715	151.1431	12:03:40	0.125153
34.06718	151.1431	12:04:10	0.375666
34.06722	151.1431	12:04:40	0.265941
34.06724	151.1431	12:05:10	0.116171
34.06727	151.143	12:05:40	0.209957
34.06731	151.143	12:06:10	0.217049
34.06734	151.143	12:06:40	0.076726
34.06736	151.143	12:07:10	0.194801
34.06739	151.143	12:07:40	0.218455
34.06743	151.143	12:08:10	0.058884
34.06745	151.143	12:08:40	0.105993
34.06747	151.1429	12:09:10	0.239564

34.06749	151.1429	12:09:40	0.160334
34.06752	151.1429	12:10:10	0.04655
34.06754	151.1429	12:10:40	0.065023

Gymea Bay velocity 1

Latitude	Longitude	Time AEST	Speed M/Sec
34.05006	151.0937	12:28:18	0.004665
34.05006	151.0937	12:29:18	0.007388
34.05006	151.0937	12:30:18	0.007051
34.05006	151.0937	12:31:18	0.001922
34.05006	151.0937	12:32:18	0.002595
34.05007	151.0937	12:33:18	0.004232
34.05007	151.0937	12:34:18	0.005251
34.05007	151.0937	12:35:18	0.001856
34.05007	151.0937	12:36:18	0.00044
34.05007	151.0937	12:37:18	0.00083
34.05007	151.0937	12:38:18	0.002473
34.05006	151.0937	12:39:18	0.001693
34.05006	151.0937	12:40:18	0.002902
34.05006	151.0936	12:41:18	0.005809
34.05006	151.0936	12:42:18	0.003287
34.05006	151.0936	12:43:18	0.002561
34.05006	151.0936	12:44:18	0.003017
34.05006	151.0936	12:45:18	0.003055
34.05006	151.0936	12:46:18	0.004281
34.05006	151.0936	12:47:18	0.003378
34.05006	151.0936	12:48:18	0.005244
34.05006	151.0935	12:49:18	0.002684
34.05006	151.0935	12:50:18	0.00266
34.05006	151.0935	12:51:18	0.00269
34.05006	151.0935	12:52:18	0.001625
34.05006	151.0935	12:53:18	0.002184
34.05006	151.0935	12:54:18	0.001189
34.05006	151.0935	12:55:18	0.002438
34.05006	151.0935	12:56:18	0.006835
34.05006	151.0934	12:57:18	0.001308
34.05006	151.0934	12:58:18	0.000171
34.05006	151.0934	12:59:18	0.002331
34.05006	151.0934	13:00:18	0.00389
34.05006	151.0934	13:01:18	0.003879
34.05006	151.0934	13:02:18	0.001868
34.05006	151.0934	13:03:18	0.00385
34.05006	151.0934	13:04:18	0.000394
34.05006	151.0934	13:05:18	0.001731
34.05006	151.0934	13:06:18	0.001293
34.05006	151.0933	13:07:18	0.009029
34.05006	151.0933	13:08:18	0.003416
34.05006	151.0933	13:09:18	0.002545
34.05006	151.0933	13:10:18	0.002
34.05006	151.0933	13:11:18	0.001466
34.05006	151.0933	13:12:18	0.004872
34.05006	151.0933	13:13:18	0.003455
34.05006	151.0933	13:14:18	0.004451
34.05006	151.0933	13:15:18	0.004241
34.05006	151.0932	13:16:18	0.006776
34.05006	151.0932	13:17:18	0.004236
34.05006	151.0932	13:18:18	0.00453
34.05006	151.0932	13:19:18	0.002078

34.05006	151.0932	13:20:18	0.003259
34.05006	151.0932	13:21:18	0.001736
34.05006	151.0932	13:22:18	0.004215
34.05007	151.0932	13:23:18	0.004795
34.05007	151.0932	13:24:18	0.002297
34.05007	151.0932	13:25:18	0.004264
34.05007	151.0932	13:26:18	0.003161
34.05007	151.0931	13:27:18	0.00629
34.05007	151.0931	13:28:18	0.00301
34.05007	151.0931	13:29:18	0.004466
34.05007	151.0931	13:30:18	0.004825
34.05007	151.0931	13:31:18	0.002979

Gymea Bay velocity 2

Latitude	Longitude	Time AEST	Speed M/Sec
34.04877	151.0981	12:18:33	0.00428
34.04877	151.0981	12:18:38	0.001621
34.04877	151.0981	12:18:43	0.00092
34.04877	151.0981	12:18:48	0.001723
34.04877	151.0981	12:18:53	0.001701
34.04877	151.0981	12:18:58	0.000216
34.04877	151.0981	12:19:03	0.001532
34.04877	151.0981	12:19:08	0.0034
34.04877	151.0981	12:19:13	0.003335
34.04877	151.0981	12:19:18	0.000931
34.04877	151.0981	12:19:23	0.001479
34.04878	151.0981	12:19:28	0.005868
34.04878	151.0981	12:19:33	0.002348
34.04878	151.0981	12:19:38	0.003881
34.04878	151.0981	12:19:43	0.002953
34.04878	151.0981	12:19:48	0.006129
34.04878	151.0981	12:19:53	0.002574
34.04878	151.0981	12:19:58	0.004448
34.04878	151.0981	12:20:03	0.003431
34.04878	151.0981	12:20:08	0.001224
34.04878	151.0981	12:20:13	0.002487
34.04878	151.0981	12:20:18	0.005367
34.04878	151.0981	12:20:23	0.004149
34.04878	151.0981	12:20:28	0.003904
34.04878	151.0981	12:20:33	0.003699
34.04878	151.0981	12:20:38	0.000334
34.04878	151.0981	12:20:43	0.000656
34.04878	151.0981	12:20:48	0.004646
34.04878	151.0981	12:20:53	0.001894
34.04878	151.0981	12:20:58	0.009345
34.04878	151.0981	12:21:03	0.006384
34.04878	151.0981	12:21:08	0.002089
34.04878	151.0981	12:21:13	0.003327
34.04878	151.0981	12:21:18	0.001509
34.04878	151.0981	12:21:23	0.001692
34.04878	151.0981	12:21:28	0.000148
34.04878	151.0981	12:21:33	0.000977
34.04878	151.0981	12:21:38	0.004355
34.04878	151.0981	12:21:43	0.003189
34.04878	151.0981	12:21:48	0.003216
34.04878	151.0981	12:21:53	0.006292
34.04878	151.0981	12:21:58	0.004683
34.04878	151.0981	12:22:03	0.005512

34.04878	151.0981	12:22:08	0.001266
34.04878	151.0981	12:22:13	0.006917
34.04878	151.0981	12:22:18	0.009627
34.04878	151.0981	12:22:28	0.003539
34.04878	151.0981	12:22:33	0.00572
34.04878	151.0981	12:22:38	0.004421
34.04878	151.0981	12:22:43	0.006707
34.04878	151.0981	12:22:48	0.004886
34.04878	151.0981	12:22:53	0.00295
34.04878	151.0981	12:22:58	0.015401
34.04878	151.0981	12:23:03	0.00544
34.04878	151.0981	12:23:08	0.007345
34.04878	151.0981	12:23:13	0.002395
34.04878	151.0981	12:23:18	0.002493
34.04878	151.0981	12:23:23	0.006869
34.04878	151.0981	12:23:28	0.00482
34.04878	151.0981	12:23:33	0.002198
34.04878	151.0981	12:23:38	0.007043
34.04878	151.0981	12:23:43	0.001847
34.04878	151.0981	12:23:48	0.005218
34.04878	151.0981	12:23:53	0.007252
34.04878	151.0981	12:23:58	0.002164
34.04878	151.0981	12:24:03	0.003444
34.04878	151.0981	12:24:08	0.002594
34.04878	151.0981	12:24:13	0.005784
34.04879	151.0981	12:24:18	0.005766
34.04879	151.0981	12:24:23	0.001961
34.04879	151.0981	12:24:28	0.005899
34.04879	151.0981	12:24:33	0.003192
34.04879	151.0981	12:24:38	0.003781
34.04879	151.0981	12:24:43	0.001177
34.04879	151.0981	12:24:48	0.001071
34.04879	151.0981	12:24:53	0.00545
34.04879	151.0981	12:24:58	0.007443
34.04879	151.0981	12:25:03	0.001699
34.04879	151.0981	12:25:08	0.002351
34.04879	151.0981	12:25:13	0.002406
34.04879	151.0981	12:25:18	0.003514
34.04879	151.0981	12:25:23	0.004568
34.04879	151.0981	12:25:28	0.004596
34.04879	151.0981	12:25:33	0.002393
34.04879	151.0981	12:25:38	0.002906
34.04879	151.0981	12:25:43	0.001611
34.04879	151.0981	12:25:48	0.00346
34.04879	151.0981	12:25:53	0.005529
34.04879	151.0981	12:25:58	0.010631
34.04879	151.0981	12:26:03	0.004859
34.04879	151.0981	12:26:08	0.003993
34.04879	151.0981	12:26:13	0.002778
34.04879	151.0981	12:26:18	0.005007
34.04879	151.0981	12:26:23	0.004159
34.04879	151.0981	12:26:28	0.00332
34.04879	151.0981	12:26:33	0.004534
34.04879	151.0981	12:26:38	0.005155
34.04879	151.0981	12:26:43	0.001697
34.04879	151.0981	12:26:48	0.005562
34.04879	151.0981	12:26:53	0.00478
34.04879	151.0981	12:26:58	0.003483
34.04879	151.0981	12:27:03	0.002384
34.04879	151.0981	12:27:08	0.0037
34.04879	151.0981	12:27:13	0.002196

34.04879	151.0981	12:27:18	0.000804
34.04879	151.0981	12:27:23	0.002765
34.04879	151.0981	12:27:28	0.001134
34.04879	151.0981	12:27:33	0.001343
34.04879	151.0981	12:27:38	0.002937
34.04879	151.0981	12:27:43	0.002034
34.04879	151.0981	12:27:48	0.003057
34.04879	151.0981	12:27:53	0.000752
34.04879	151.0981	12:27:58	0.001963
34.04879	151.0981	12:28:03	0.003416
34.04879	151.0981	12:28:08	0.003313
34.04879	151.0981	12:28:13	0.002481
34.04879	151.0981	12:28:18	0.002319
34.04879	151.0981	12:28:23	0.002119
34.04879	151.0981	12:28:28	0.006362
34.04879	151.0981	12:28:33	0.003357
34.04879	151.0981	12:28:38	0.003754
34.04879	151.0981	12:28:43	0.002047
34.04879	151.0981	12:28:48	0.005124
34.04879	151.0981	12:28:53	0.004076
34.04879	151.0981	12:28:58	0.003259
34.04879	151.0981	12:29:03	0.003656
34.04879	151.0981	12:29:08	0.001391
34.04879	151.0981	12:29:13	0.003941
34.04879	151.0981	12:29:18	0.002799
34.04879	151.0981	12:29:23	0.003692
34.0488	151.0981	12:29:28	0.002411
34.0488	151.0981	12:29:33	0.002917
34.0488	151.0981	12:29:38	0.003382
34.0488	151.0981	12:29:43	0.001618
34.0488	151.0981	12:29:48	0.002499
34.0488	151.0981	12:29:53	0.003621
34.0488	151.0981	12:29:58	0.002973
34.0488	151.0981	12:30:03	0.00292
34.0488	151.0981	12:30:08	0.002312
34.0488	151.0981	12:30:13	0.000528
34.0488	151.0981	12:30:18	0.004211
34.0488	151.0981	12:30:23	0.001827
34.0488	151.0981	12:30:28	0.003327
34.0488	151.0981	12:30:33	0.001744
34.0488	151.0981	12:30:38	0.001424
34.0488	151.0981	12:30:43	0.003316
34.0488	151.0981	12:30:48	0.002466
34.0488	151.0981	12:30:53	0.001571
34.0488	151.0981	12:30:58	0.001724
34.0488	151.0981	12:31:03	0.00316
34.0488	151.0981	12:31:08	0.002743
34.0488	151.0981	12:31:13	0.001693
34.0488	151.0981	12:31:18	0.003261
34.0488	151.0981	12:31:23	0.004091
34.0488	151.0981	12:31:28	0.004198
34.0488	151.0981	12:31:33	0.002005
34.0488	151.0981	12:31:38	0.001019
34.0488	151.0981	12:31:43	0.002952
34.0488	151.0981	12:31:48	0.00232
34.0488	151.0981	12:31:53	0.007249
34.0488	151.0981	12:31:58	0.002373
34.0488	151.0981	12:32:03	0.006254
34.0488	151.0981	12:32:08	0.005817
34.0488	151.0981	12:32:13	0.002243
34.0488	151.0981	12:32:18	0.003973

34.0488	151.0981	12:32:23	0.00113
34.0488	151.0981	12:32:28	0.006668
34.0488	151.0981	12:32:33	0.003361
34.0488	151.0981	12:32:38	0.004217
34.0488	151.0981	12:32:43	0.005164
34.0488	151.0981	12:32:48	0.003049
34.0488	151.0981	12:32:53	0.004786
34.0488	151.0981	12:32:58	0.007193
34.0488	151.0981	12:33:03	0.003762
34.0488	151.0981	12:33:08	0.003139
34.0488	151.0981	12:33:13	0.004548
34.0488	151.0981	12:33:18	0.001657
34.0488	151.0981	12:33:23	0.003301
34.04881	151.0981	12:33:28	0.002148
34.04881	151.0981	12:33:33	0.002427
34.04881	151.0981	12:33:38	0.002537
34.04881	151.0981	12:33:43	0.003277
34.04881	151.0981	12:33:48	0.002317
34.04881	151.0981	12:33:53	0.002979
34.04881	151.0981	12:33:58	0.003394
34.04881	151.0981	12:34:03	0.003993
34.04881	151.0981	12:34:08	0.001443
34.04881	151.0981	12:34:13	0.000756
34.04881	151.0981	12:34:18	0.002745
34.04881	151.0981	12:34:23	0.000983
34.04881	151.0981	12:34:28	0.000629
34.04881	151.0981	12:34:33	0.002734
34.04881	151.0981	12:34:38	0.006483
34.04881	151.0981	12:34:43	0.00396
34.04881	151.0981	12:34:48	0.001311
34.04881	151.0981	12:34:53	0.002083
34.04881	151.0981	12:34:58	0.004694
34.04881	151.0981	12:35:03	0.004438
34.04881	151.0981	12:35:08	0.002998
34.04881	151.0981	12:35:13	0.002668
34.04881	151.0981	12:35:18	0.002072
34.04881	151.0981	12:35:23	0.001406
34.04881	151.0981	12:35:28	0.005536
34.04881	151.0981	12:35:33	0.007907
34.04881	151.0981	12:35:38	0.001019
34.04881	151.0981	12:35:43	0.002073
34.04881	151.0981	12:35:48	0.004238
34.04881	151.0981	12:35:53	0.001559
34.04881	151.0981	12:35:58	0.003096
34.04881	151.0981	12:36:03	0.003829
34.04881	151.0981	12:36:08	0.001712
34.04881	151.0981	12:36:13	0.004475
34.04881	151.0981	12:36:18	0.005545
34.04881	151.0981	12:36:23	0.000569
34.04881	151.0981	12:36:28	0.003123
34.04881	151.0981	12:36:33	0.004548
34.04882	151.0981	12:36:38	0.003105
34.04882	151.0981	12:36:43	0.002959
34.04882	151.0981	12:36:48	0.001851
34.04882	151.0981	12:36:53	0.006552
34.04882	151.0981	12:36:58	0.005034
34.04882	151.0981	12:37:03	0.004166
34.04882	151.0981	12:37:08	0.001133
34.04882	151.0981	12:37:13	0.000744
34.04882	151.0981	12:37:18	0.001266
34.04882	151.0981	12:37:23	0.004671

34.04882	151.0981	12:37:28	0.003818
34.04882	151.0981	12:37:33	0.001174
34.04882	151.0981	12:37:38	0.00553
34.04882	151.0981	12:37:43	0.000663
34.04882	151.0981	12:37:48	0.003683
34.04882	151.0981	12:37:53	0.001508
34.04882	151.0981	12:37:58	0.001032
34.04882	151.0982	12:38:03	0.002212
34.04882	151.0982	12:38:08	0.001864
34.04882	151.0982	12:38:13	0.004287
34.04882	151.0982	12:38:18	0.000314
34.04882	151.0982	12:38:23	0.004032
34.04882	151.0982	12:38:28	0.00168
34.04883	151.0982	12:38:33	0.000579
34.04883	151.0982	12:38:38	0.008035
34.04883	151.0982	12:38:43	0.004505
34.04883	151.0982	12:38:48	0.004924
34.04883	151.0982	12:38:53	0.002694
34.04883	151.0982	12:38:58	0.001684
34.04883	151.0982	12:39:03	0.000447
34.04883	151.0982	12:39:08	0.003539
34.04883	151.0982	12:39:13	0.005832
34.04883	151.0982	12:39:18	0.000404
34.04883	151.0982	12:39:23	0.000365
34.04883	151.0982	12:39:28	0.002523
34.04883	151.0982	12:39:33	0.002654
34.04883	151.0982	12:39:38	0.002848
34.04883	151.0982	12:39:43	0.001638
34.04883	151.0982	12:39:48	0.00266
34.04883	151.0982	12:39:53	0.00232
34.04883	151.0982	12:39:58	0.002461
34.04883	151.0982	12:40:03	0.004734
34.04883	151.0982	12:40:08	0.003397
34.04883	151.0982	12:40:13	0.001663
34.04883	151.0982	12:40:18	0.006114
34.04883	151.0982	12:40:23	0.002626
34.04884	151.0982	12:40:28	0.003207
34.04884	151.0982	12:40:33	0.002218
34.04884	151.0982	12:40:38	0.003166
34.04884	151.0982	12:40:43	0.000375
34.04884	151.0982	12:40:48	0.002449
34.04884	151.0982	12:40:53	0.003753
34.04884	151.0982	12:40:58	0.000877
34.04884	151.0982	12:41:03	0.003476
34.04884	151.0982	12:41:08	0.001831
34.04884	151.0982	12:41:13	0.004859
34.04884	151.0982	12:41:18	0.002094
34.04884	151.0982	12:41:23	0.006654
34.04884	151.0982	12:41:28	0.002528
34.04884	151.0982	12:41:33	0.003316
34.04884	151.0982	12:41:38	0.002538
34.04884	151.0982	12:41:43	0.000597
34.04884	151.0982	12:41:48	0.005344
34.04884	151.0982	12:41:53	0.005366
34.04884	151.0982	12:41:58	0.003268
34.04885	151.0982	12:42:03	0.003836
34.04885	151.0982	12:42:08	0.000322
34.04885	151.0982	12:42:13	0.001813
34.04885	151.0982	12:42:18	0.003237
34.04885	151.0982	12:42:23	0.002472
34.04885	151.0982	12:42:28	0.006044

34.04885	151.0982	12:42:33	0.001416
34.04885	151.0982	12:42:38	0.001791
34.04885	151.0982	12:42:43	0.003351
34.04885	151.0982	12:42:48	0.001445
34.04885	151.0982	12:42:53	0.002751
34.04885	151.0982	12:42:58	0.004281
34.04885	151.0982	12:43:03	0.001726
34.04885	151.0982	12:43:08	0.002021
34.04885	151.0982	12:43:13	0.004718
34.04885	151.0982	12:43:18	0.003961
34.04885	151.0982	12:43:23	0.000479
34.04885	151.0982	12:43:28	0.003476
34.04885	151.0982	12:43:33	0.002758
34.04885	151.0982	12:43:38	0.003224
34.04885	151.0982	12:43:43	0.002499
34.04885	151.0982	12:43:48	0.001539
34.04885	151.0982	12:43:53	0.002058
34.04885	151.0982	12:43:58	0.002081
34.04885	151.0982	12:44:03	0.001861
34.04885	151.0982	12:44:08	0.002555
34.04885	151.0982	12:44:13	0.002073
34.04885	151.0982	12:44:18	0.003237
34.04886	151.0982	12:44:23	0.001637
34.04886	151.0982	12:44:28	0.003123
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34.04898	151.0985	13:15:18	0.003455
34.04898	151.0985	13:15:23	0.001796
34.04898	151.0985	13:15:28	0.002612
34.04898	151.0985	13:15:33	0.005579
34.04898	151.0985	13:15:38	0.004386
34.04898	151.0985	13:15:43	0.00203
34.04898	151.0985	13:15:48	0.001711
34.04898	151.0985	13:15:53	0.002108
34.04898	151.0985	13:15:58	0.001011
34.04898	151.0985	13:16:03	0.002417
34.04898	151.0985	13:16:08	0.004386
34.04898	151.0985	13:16:13	0.003374
34.04898	151.0985	13:16:18	0.003138
34.04898	151.0985	13:16:23	0.00409
34.04898	151.0985	13:16:28	0.001524
34.04898	151.0985	13:16:33	0.002554
34.04899	151.0985	13:16:38	0.0035
34.04899	151.0985	13:16:43	0.000487
34.04899	151.0985	13:16:48	0.003109
34.04899	151.0985	13:16:53	0.002299
34.04899	151.0985	13:16:58	0.002233
34.04899	151.0985	13:17:03	0.00232
34.04899	151.0985	13:17:08	0.003037
34.04899	151.0985	13:17:13	0.004799
34.04899	151.0985	13:17:18	0.003071
34.04899	151.0985	13:17:23	0.000933
34.04899	151.0985	13:17:28	0.002853
34.04899	151.0985	13:17:33	0.002728
34.04899	151.0985	13:17:38	0.002024
34.04899	151.0985	13:17:43	0.002289
34.04899	151.0985	13:17:48	0.004089
34.04899	151.0985	13:17:53	0.004034
34.04899	151.0985	13:17:58	0.001601
34.04899	151.0985	13:18:03	0.003122

34.04899	151.0985	13:18:08	0.002963
34.04899	151.0985	13:18:13	0.002509
34.04899	151.0985	13:18:18	0.001516
34.04899	151.0985	13:18:23	0.002131
34.04899	151.0985	13:18:28	0.003566
34.04899	151.0985	13:18:33	0.003945
34.04899	151.0985	13:18:38	0.005158
34.04899	151.0985	13:18:43	0.004053
34.04899	151.0985	13:18:48	0.004204
34.04899	151.0985	13:18:53	0.001347
34.04899	151.0985	13:18:58	0.003429
34.04899	151.0985	13:19:03	0.003609
34.04899	151.0985	13:19:08	0.002263
34.04899	151.0985	13:19:13	0.002639
34.04899	151.0985	13:19:18	0.00513
34.04899	151.0985	13:19:23	0.000939
34.04899	151.0985	13:19:28	0.002594
34.04899	151.0985	13:19:33	0.002832
34.04899	151.0985	13:19:38	0.003094
34.04899	151.0985	13:19:43	0.001939
34.04899	151.0985	13:19:48	0.002354
34.04899	151.0985	13:19:53	0.002916
34.04899	151.0985	13:19:58	0.002191
34.04899	151.0985	13:20:03	0.002492
34.04899	151.0985	13:20:08	0.0072
34.04899	151.0985	13:20:13	0.002952
34.04899	151.0985	13:20:18	0.005392
34.04899	151.0985	13:20:23	0.00067
34.049	151.0985	13:20:28	0.006722
34.049	151.0985	13:20:33	0.002226
34.049	151.0985	13:20:38	0.004409
34.049	151.0985	13:20:43	0.001299
34.049	151.0985	13:20:48	0.002886
34.049	151.0985	13:20:53	0.003805
34.049	151.0985	13:20:58	0.0036
34.049	151.0985	13:21:03	0.002984
34.049	151.0985	13:21:08	0.00292
34.049	151.0985	13:21:13	0.00112
34.049	151.0985	13:21:18	0.003775
34.049	151.0985	13:21:23	0.003226
34.049	151.0985	13:21:28	0.004434
34.049	151.0985	13:21:33	0.004539
34.049	151.0985	13:21:38	0.00128
34.049	151.0985	13:21:43	0.002764
34.049	151.0985	13:21:48	0.002107
34.049	151.0985	13:21:53	0.003767
34.049	151.0985	13:21:58	0.003852
34.049	151.0985	13:22:03	0.002181
34.049	151.0985	13:22:08	0.000927
34.049	151.0986	13:22:13	0.004327
34.049	151.0986	13:22:18	0.00258
34.049	151.0986	13:22:23	0.00401
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34.049	151.0986	13:22:33	0.002112
34.049	151.0986	13:22:38	0.0039
34.049	151.0986	13:22:43	0.004178
34.049	151.0986	13:22:48	0.002336
34.049	151.0986	13:22:53	0.003266
34.049	151.0986	13:22:58	0.001759
34.049	151.0986	13:23:03	0.003686
34.049	151.0986	13:23:08	0.000481

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34.049	151.0986	13:23:18	0.001506
34.049	151.0986	13:23:23	0.004116
34.049	151.0986	13:23:28	0.000885
34.04901	151.0986	13:23:33	0.006402
34.04901	151.0986	13:23:38	0.006041
34.04901	151.0986	13:23:43	0.002169
34.04901	151.0986	13:23:48	0.000585
34.04901	151.0986	13:23:53	0.002651
34.04901	151.0986	13:23:58	0.00249
34.04901	151.0986	13:24:03	0.000892
34.04901	151.0986	13:24:08	0.004371
34.04901	151.0986	13:24:13	0.003519
34.04901	151.0986	13:24:18	0.002059
34.04901	151.0986	13:24:23	0.003381
34.04901	151.0986	13:24:28	0.001481
34.04901	151.0986	13:24:33	0.002969
34.04901	151.0986	13:24:38	0.003099
34.04901	151.0986	13:24:43	0.00285
34.04901	151.0986	13:24:48	0.004696
34.04901	151.0986	13:24:53	0.003511
34.04901	151.0986	13:24:58	0.000462
34.04901	151.0986	13:25:03	0.002747
34.04901	151.0986	13:25:08	0.001861
34.04901	151.0986	13:25:13	0.004152
34.04901	151.0986	13:25:18	0.000849
34.04901	151.0986	13:25:23	0.006375
34.04901	151.0986	13:25:28	0.002681
34.04901	151.0986	13:25:33	0.005489
34.04901	151.0986	13:25:38	0.001017
34.04901	151.0986	13:25:43	0.002198
34.04901	151.0986	13:25:48	0.001695
34.04901	151.0986	13:25:53	0.002469
34.04901	151.0986	13:25:58	0.00313
34.04901	151.0986	13:26:03	0.001593
34.04901	151.0986	13:26:08	0.004184
34.04901	151.0986	13:26:13	0.003416
34.04901	151.0986	13:26:18	0.003607
34.04901	151.0986	13:26:23	0.004603
34.04901	151.0986	13:26:28	0.003388
34.04901	151.0986	13:26:33	0.001944
34.04901	151.0986	13:26:38	0.003311
34.04901	151.0986	13:26:43	0.001489
34.04901	151.0986	13:26:48	0.003187
34.04901	151.0986	13:26:53	0.001663
34.04901	151.0986	13:26:58	0.003942
34.04901	151.0986	13:27:03	0.003114
34.04902	151.0986	13:27:08	0.004714
34.04902	151.0986	13:27:13	0.002876
34.04902	151.0986	13:27:18	0.00396
34.04902	151.0986	13:27:23	0.000858
34.04902	151.0986	13:27:28	0.002864
34.04902	151.0986	13:27:33	0.002772
34.04902	151.0986	13:27:38	0.001476
34.04902	151.0986	13:27:43	0.000466
34.04902	151.0986	13:27:48	0.002114
34.04902	151.0986	13:27:53	0.001333
34.04902	151.0986	13:27:58	0.002069
34.04902	151.0986	13:28:03	0.001952
34.04902	151.0986	13:28:08	0.001813
34.04902	151.0986	13:28:13	0.003617

34.04902	151.0986	13:28:18	0.001953
34.04902	151.0986	13:28:23	0.001086
34.04902	151.0986	13:28:28	0.002433
34.04902	151.0986	13:28:33	0.00088
34.04902	151.0986	13:28:38	0.003301
34.04902	151.0986	13:28:43	0.003725
34.04902	151.0986	13:28:48	0.001953
34.04902	151.0986	13:28:53	0.002144
34.04902	151.0986	13:28:58	0.002428
34.04902	151.0986	13:29:03	0.002237
34.04902	151.0986	13:29:08	0.002364
34.04902	151.0986	13:29:13	0.001584
34.04902	151.0986	13:29:18	0.00201
34.04902	151.0986	13:29:23	0.001121
34.04902	151.0986	13:29:28	0.002587
34.04902	151.0986	13:29:33	0.003113
34.04902	151.0986	13:29:38	0.000721
34.04902	151.0986	13:29:43	0.004329
34.04902	151.0986	13:29:48	0.00275
34.04902	151.0986	13:29:53	0.003649
34.04902	151.0986	13:29:58	0.003337
34.04902	151.0986	13:30:03	0.00349
34.04902	151.0986	13:30:08	0.004361
34.04902	151.0986	13:30:13	0.003514
34.04902	151.0986	13:30:18	0.001503
34.04902	151.0986	13:30:23	0.001855
34.04902	151.0986	13:30:28	0.005197
34.04902	151.0986	13:30:33	0.002615
34.04902	151.0986	13:30:38	0.003629
34.04902	151.0986	13:30:43	0.004621
34.04902	151.0986	13:30:48	0.003229
34.04902	151.0986	13:30:53	0.002395
34.04902	151.0986	13:30:58	0.00098
34.04902	151.0987	13:31:03	0.003198
34.04902	151.0987	13:31:08	0.001743
34.04902	151.0987	13:31:13	0.004816
34.04902	151.0987	13:31:18	0.004803
34.04902	151.0987	13:31:23	0.004245
34.04902	151.0987	13:31:28	0.006011
34.04902	151.0987	13:31:33	0.002313
34.04902	151.0987	13:31:38	0.000624
34.04902	151.0987	13:31:43	0.000654
34.04902	151.0987	13:31:48	0.003764
34.04902	151.0987	13:31:53	0.001965
34.04902	151.0987	13:31:58	0.001245
34.04902	151.0987	13:32:03	0.002602
34.04902	151.0987	13:32:08	0.002536
34.04902	151.0987	13:32:13	0.003648
34.04902	151.0987	13:32:18	0.00352
34.04902	151.0987	13:32:23	0.001713
34.04902	151.0987	13:32:28	0.001347
34.04903	151.0987	13:32:33	0.002484
34.04903	151.0987	13:32:38	0.001478
34.04903	151.0987	13:32:43	0.002319
34.04903	151.0987	13:32:48	0.001919
34.04903	151.0987	13:32:53	0.002509
34.04903	151.0987	13:32:58	0.005765
34.04903	151.0987	13:33:03	0.003736
34.04903	151.0987	13:33:08	0.002393
34.04903	151.0987	13:33:13	0.003713
34.04903	151.0987	13:33:18	0.000632

34.04903	151.0987	13:33:23	0.001014
34.04903	151.0987	13:33:28	0.001393
34.04903	151.0988	13:36:38	0.000823
34.04903	151.0988	13:36:43	0.00444
34.04903	151.0988	13:36:48	0.002554
34.04903	151.0988	13:36:53	0.001751
34.04903	151.0988	13:36:58	0.001072
34.04903	151.0988	13:37:03	0.002179
34.04903	151.0988	13:37:08	0.002247
34.04903	151.0988	13:37:13	0.002883
34.04903	151.0988	13:37:18	0.002895
34.04903	151.0988	13:37:23	0.000227
34.04903	151.0988	13:37:28	0.001335
34.04903	151.0988	13:37:33	0.000926
34.04903	151.0988	13:37:38	0.001548
34.04903	151.0988	13:37:43	0.001799
34.04903	151.0988	13:37:48	0.001068
34.04903	151.0988	13:37:53	0.003439
34.04903	151.0988	13:37:58	0.002389
34.04903	151.0988	13:38:03	0.000371
34.04903	151.0988	13:38:08	0.00075
34.04904	151.0988	13:38:13	0.002907
34.04904	151.0988	13:38:18	0.000731
34.04904	151.0988	13:38:23	0.000918
34.04904	151.0988	13:38:28	0.005331
34.04904	151.0988	13:38:33	0.007428
34.04904	151.0988	13:38:38	0.001893
34.04904	151.0988	13:38:43	0.007601

Gymea Bay velocity 3

Latitude	Longitude	Time AEST	Speed M/Sec
34.05334	151.0977	12:14:38	0.163615
34.05336	151.0977	12:15:08	0.049598
34.05337	151.0977	12:15:38	0.089835
34.05338	151.0977	12:16:08	0.22978
34.05338	151.0977	12:16:38	0.25024
34.05339	151.0977	12:17:08	0.181147
34.05344	151.0977	12:17:38	0.235661
34.05346	151.0977	12:18:08	0.091133
34.05345	151.0976	12:18:38	0.182597
34.05348	151.0976	12:19:08	0.141241
34.05348	151.0976	12:19:38	0.126699
34.05347	151.0976	12:20:08	0.183609
34.05348	151.0976	12:20:38	0.253228
34.0535	151.0976	12:21:08	0.251004
34.05351	151.0976	12:21:38	0.083666
34.05352	151.0976	12:22:08	0.062083
34.05354	151.0975	12:22:38	0.056659
34.05354	151.0975	12:23:08	0.190764
34.05357	151.0975	12:23:38	0.162044
34.05358	151.0975	12:24:08	0.061704
34.05357	151.0975	12:24:38	0.134082
34.05358	151.0975	12:25:08	0.190709
34.05359	151.0975	12:25:38	0.143188
34.05359	151.0975	12:26:08	0.246915
34.05359	151.0975	12:26:38	0.121938
34.0536	151.0975	12:27:08	0.085683
34.0536	151.0975	12:27:38	0.208615

34.05362	151.0975	12:28:08	0.210864
34.05363	151.0974	12:28:38	0.112723
34.05365	151.0974	12:29:08	0.170055
34.05366	151.0974	12:29:38	0.149081
34.05366	151.0974	12:30:08	0.185134
34.05367	151.0974	12:30:38	0.203561
34.05369	151.0974	12:31:08	0.100206
34.05369	151.0974	12:31:38	0.126805
34.0537	151.0974	12:32:08	0.051704
34.0537	151.0974	12:32:38	0.241276
34.05371	151.0974	12:33:08	0.150497
34.05372	151.0973	12:33:38	0.224793
34.05373	151.0973	12:34:08	0.056009
34.05374	151.0973	12:34:38	0.005893
34.05374	151.0973	12:35:08	0.009002
34.05374	151.0973	12:35:38	0.005926
34.05374	151.0973	12:36:08	0.003833
34.05374	151.0973	12:36:38	0.002863
34.05374	151.0973	12:37:08	0.002328
34.05374	151.0973	12:37:38	0.002642
34.05374	151.0973	12:38:08	0.002106
34.05375	151.0973	12:38:38	0.010037
34.05375	151.0973	12:39:08	0.005494
34.05375	151.0973	12:39:38	0.002506
34.05376	151.0973	12:40:08	0.100828
34.05379	151.0973	12:40:38	0.033198
34.05383	151.0972	12:41:08	0.191275
34.05385	151.0972	12:41:38	0.26579
34.05387	151.0972	12:42:08	0.090687
34.05389	151.0972	12:42:38	0.084
34.0539	151.0972	12:43:08	0.035194
34.05391	151.0972	12:43:38	0.003218
34.05391	151.0972	12:44:08	0.005169
34.05391	151.0972	12:44:38	0.002633
34.05391	151.0972	12:45:08	0.001447
34.05392	151.0972	12:45:38	0.005093
34.05392	151.0972	12:46:08	0.002071
34.05392	151.0972	12:46:38	0.001995
34.05392	151.0972	12:47:08	0.008921
34.05393	151.0972	12:47:38	0.006609
34.05393	151.0972	12:48:08	0.005468
34.05394	151.0971	12:48:38	0.004937
34.05395	151.0971	12:49:08	0.179298
34.05399	151.0971	12:49:38	0.084003
34.05401	151.0971	12:50:08	0.250674
34.05404	151.0971	12:50:38	0.205346
34.05406	151.0971	12:51:08	0.083524
34.05407	151.097	12:51:38	0.00603
34.05407	151.097	12:52:08	0.002462
34.05407	151.097	12:52:38	0.008513
34.05408	151.097	12:53:08	0.08548
34.05411	151.097	12:53:38	0.155165
34.05414	151.097	12:54:08	0.005534
34.05415	151.097	12:54:38	0.055851
34.05418	151.097	12:55:08	0.181974
34.0542	151.097	12:55:38	0.127091
34.05422	151.097	12:56:08	0.088822
34.05422	151.097	12:56:38	0.006406
34.05422	151.097	12:57:08	0.002621
34.05422	151.097	12:57:38	0.00947
34.05425	151.097	12:58:08	0.104536

34.05427	151.097	12:58:38	0.119184
34.0543	151.097	12:59:08	0.070129
34.05431	151.097	12:59:38	0.005022
34.05431	151.097	13:00:08	0.00634
34.05431	151.097	13:00:38	0.006495
34.05432	151.097	13:01:08	0.002535
34.05432	151.097	13:01:38	0.006292
34.05432	151.097	13:02:08	0.005785
34.05433	151.097	13:02:38	0.062923
34.05434	151.097	13:03:08	0.000704
34.05434	151.097	13:03:38	0.009488
34.05434	151.097	13:04:08	0.088145
34.05436	151.097	13:04:38	0.133044
34.05439	151.097	13:05:08	0.054156
34.0544	151.097	13:05:38	0.175189
34.05442	151.097	13:06:08	0.034189
34.05442	151.097	13:06:38	0.007123
34.05442	151.0969	13:07:08	0.094368
34.05443	151.0969	13:07:38	0.008031
34.05443	151.0969	13:08:08	0.004527
34.05444	151.0969	13:08:38	0.004081
34.05444	151.0969	13:09:08	0.111196
34.05446	151.0969	13:09:38	0.158263
34.05448	151.0969	13:10:08	0.007048
34.05448	151.0969	13:10:38	0.002538
34.05448	151.0969	13:11:08	0.006414
34.05448	151.0969	13:11:38	0.003374
34.05448	151.0969	13:12:08	0.005269
34.05449	151.0969	13:12:38	0.169289
34.05452	151.0969	13:13:08	0.086681
34.05453	151.0969	13:13:38	0.12232
34.05453	151.0969	13:14:08	0.077652
34.05453	151.0968	13:14:38	0.135201
34.05454	151.0968	13:15:08	0.006341
34.05454	151.0968	13:15:38	0.006378
34.05454	151.0968	13:16:08	0.004626
34.05454	151.0968	13:16:38	0.113662
34.05454	151.0968	13:17:08	0.00217
34.05454	151.0968	13:17:38	0.004563
34.05455	151.0968	13:18:08	0.008097
34.05455	151.0968	13:18:38	0.002443
34.05455	151.0968	13:19:08	0.005333
34.05455	151.0968	13:19:38	0.009765
34.05458	151.0968	13:20:08	0.133993
34.05459	151.0968	13:20:38	0.039779
34.0546	151.0968	13:21:08	0.001193
34.0546	151.0968	13:21:38	0.093094
34.05462	151.0968	13:22:08	0.049474
34.05464	151.0968	13:22:38	0.101645
34.05466	151.0967	13:23:08	0.071505
34.05467	151.0967	13:23:38	0.085409
34.05467	151.0967	13:24:08	0.053345
34.05467	151.0967	13:24:38	0.004194
34.05468	151.0967	13:25:08	0.004107
34.05468	151.0967	13:25:38	0.008327
34.05468	151.0967	13:26:08	0.007427
34.05471	151.0967	13:26:38	0.142252
34.05474	151.0967	13:27:08	0.21588
34.05476	151.0967	13:27:38	0.081248
34.05477	151.0967	13:28:08	0.064738
34.05477	151.0967	13:28:38	0.004228

34.05479	151.0967	13:29:08	0.100953
34.05481	151.0966	13:29:38	0.029019
34.05482	151.0966	13:30:08	0.004799
34.05483	151.0966	13:30:38	0.002477
34.05484	151.0966	13:31:08	0.049842
34.05485	151.0966	13:31:38	0.061235
34.05486	151.0966	13:32:08	0.009129
34.05486	151.0966	13:32:38	0.070877
34.05488	151.0966	13:33:08	0.171523
34.05491	151.0966	13:33:38	0.195651
34.05492	151.0966	13:34:08	0.017025
34.05492	151.0966	13:34:38	0.005022
34.05493	151.0966	13:35:08	0.162844
34.05496	151.0966	13:35:38	0.126489

Yowie Bay velocity 1

Latitude	Longitude	Time AEST	Speed M/Sec
34.0447	151.111	10:34:20	0.001308
34.04461	151.1109	10:35:20	0.003035
34.04459	151.1109	10:36:20	0.003528
34.04459	151.1109	10:37:20	0.000964
34.04459	151.1109	10:38:20	0.000186
34.0446	151.1109	10:39:20	0.000993
34.0446	151.1109	10:40:20	0.000791
34.0446	151.1109	10:41:20	0.001886
34.0446	151.1109	10:42:20	0.004156
34.04461	151.1109	10:43:20	0.002975
34.04462	151.1109	10:44:20	0.000969
34.04462	151.1109	10:45:20	0.002458
34.04463	151.1109	10:46:20	0.002698
34.04464	151.1109	10:47:20	0.001784
34.04464	151.1109	10:48:20	0.003573
34.04465	151.1109	10:49:20	0.004242
34.04466	151.1109	10:50:20	0.001751
34.04466	151.1109	10:51:20	0.001725
34.04467	151.1109	10:52:20	0.002452
34.04468	151.1109	10:53:20	0.001959
34.04468	151.1109	10:54:20	0.003936
34.04469	151.1109	10:55:20	0.002693
34.0447	151.1109	10:56:20	0.002098
34.04471	151.1109	10:57:20	0.001881
34.04472	151.1109	10:58:20	0.00483
34.04473	151.1109	10:59:20	0.003116
34.04474	151.1109	11:00:20	0.004764
34.04475	151.1109	11:01:20	0.003638
34.04477	151.1109	11:02:20	0.003854
34.04478	151.1109	11:03:20	0.004212
34.04479	151.1109	11:04:20	0.001671
34.0448	151.1109	11:05:20	0.005263
34.04481	151.1109	11:06:20	0.002174
34.04483	151.1109	11:07:20	0.004734
34.04484	151.1109	11:08:20	0.004105
34.04485	151.1109	11:09:20	0.002343
34.04486	151.1109	11:10:20	0.002218
34.04487	151.1109	11:11:20	0.00373
34.04488	151.1109	11:12:20	0.003257
34.0449	151.1109	11:13:20	0.00217
34.04491	151.1109	11:14:20	0.002461

34.04492	151.1109	11:15:20	0.003428
34.04493	151.1109	11:16:20	0.002531
34.04494	151.1109	11:17:20	0.003731
34.04495	151.1109	11:18:20	0.00219
34.04496	151.1109	11:19:20	0.002489
34.04497	151.1109	11:20:20	0.003243
34.04499	151.1109	11:21:20	0.002262
34.04501	151.1109	11:22:20	0.001995
34.04502	151.1109	11:23:20	0.002252
34.04504	151.1109	11:24:20	0.00345
34.04506	151.1108	11:25:20	0.004685
34.04508	151.1108	11:26:20	0.004644
34.04511	151.1108	11:27:20	0.005558
34.04513	151.1108	11:28:20	0.002845
34.04515	151.1108	11:29:20	0.005675
34.04517	151.1108	11:30:20	0.00569
34.0452	151.1108	11:31:20	0.0033
34.04523	151.1108	11:32:20	0.002643
34.04525	151.1108	11:33:20	0.003529
34.04528	151.1107	11:34:20	0.004398
34.04531	151.1107	11:35:20	0.003249
34.04534	151.1107	11:36:20	0.002828
34.04536	151.1107	11:37:20	0.002622
34.04538	151.1107	11:38:20	0.003357
34.0454	151.1107	11:39:20	0.004035
34.04543	151.1107	11:40:20	0.000801
34.04546	151.1106	11:41:20	0.003329
34.04549	151.1106	11:42:20	0.004503
34.04552	151.1106	11:43:20	0.001783
34.04555	151.1106	11:44:20	0.004571
34.04558	151.1106	11:45:20	0.004694
34.04562	151.1105	11:46:20	0.002178
34.04565	151.1105	11:47:20	0.005627
34.0457	151.1105	11:48:20	0.003122
34.04574	151.1105	11:49:20	0.000654
34.04577	151.1105	11:50:20	0.004327
34.04581	151.1104	11:51:20	0.004302
34.04584	151.1104	11:52:20	0.001562
34.04588	151.1104	11:53:20	0.004901
34.04592	151.1104	11:54:20	0.002874
34.04597	151.1103	11:55:20	0.004161
34.04602	151.1103	11:56:20	0.002947
34.04604	151.1103	11:57:20	0.003793
34.04607	151.1103	11:58:20	0.006403
34.04611	151.1102	11:59:20	0.006011
34.04615	151.1102	12:00:20	0.003253
34.04618	151.1102	12:01:20	0.006031
34.04623	151.1102	12:02:20	0.001151
34.04627	151.1101	12:03:20	0.004567

Yowie Bay velocity 2

Latitude	Longitude	Time AEST	Speed M/Sec
34.04457	151.1077	10:39:31	0.002458
34.04457	151.1077	10:39:36	0.001435
34.04457	151.1077	10:39:41	0.000739
34.04457	151.1077	10:39:46	0.00089
34.04457	151.1077	10:39:51	0.004005
34.04457	151.1078	10:39:56	0.001862

34.04457	151.1078	10:40:01	0.001235
34.04457	151.1078	10:40:06	0.002001
34.04457	151.1078	10:40:11	0.00395
34.04457	151.1078	10:40:16	0.00274
34.04457	151.1078	10:40:21	0.001294
34.04457	151.1078	10:40:26	0.002304
34.04457	151.1078	10:40:31	0.000663
34.04457	151.1078	10:40:36	0.002397
34.04457	151.1078	10:40:41	0.000269
34.04457	151.1078	10:40:46	0.002926
34.04458	151.1078	10:40:51	0.001035
34.04458	151.1078	10:40:56	0.002927
34.04458	151.1078	10:41:01	0.001409
34.04458	151.1078	10:41:06	0.000753
34.04458	151.1078	10:41:11	0.003309
34.04458	151.1078	10:41:16	0.004102
34.04458	151.1078	10:41:21	0.003037
34.04458	151.1078	10:41:26	0.002037
34.04458	151.1078	10:41:31	0.001898
34.04458	151.1078	10:41:36	0.001351
34.04458	151.1078	10:41:41	0.002143
34.04458	151.1078	10:41:46	0.004038
34.04458	151.1078	10:41:51	0.000661
34.04458	151.1078	10:41:56	0.004175
34.04458	151.1078	10:42:01	0.004687
34.04458	151.1078	10:42:06	0.003071
34.04462	151.1078	10:42:21	0.000278
34.04463	151.1078	10:42:26	0.001961
34.04464	151.1078	10:42:31	0.00033
34.04465	151.1078	10:42:36	0.002431
34.04465	151.1078	10:42:41	0.002111
34.04465	151.1078	10:42:46	0.001484
34.04466	151.1078	10:42:51	0.001781
34.04466	151.1078	10:42:56	0.003269
34.04466	151.1078	10:43:01	0.003179
34.04466	151.1078	10:43:06	0.001426
34.04466	151.1078	10:43:11	0.00324
34.04466	151.1078	10:43:16	0.002808
34.04466	151.1078	10:43:21	0.003114
34.04466	151.1078	10:43:26	0.002241
34.04466	151.1078	10:43:31	0.001079
34.04466	151.1078	10:43:36	0.001114
34.04466	151.1078	10:43:41	0.003953
34.04466	151.1078	10:43:46	0.002919
34.04466	151.1078	10:43:51	0.002594
34.04466	151.1078	10:43:56	0.002671
34.04466	151.1078	10:44:01	0.003562
34.04466	151.1078	10:44:06	0.002812
34.04466	151.1078	10:44:11	0.000522
34.04466	151.1078	10:44:16	0.0021
34.04466	151.1078	10:44:21	0.001915
34.04466	151.1078	10:44:26	0.003198
34.04466	151.1078	10:44:31	0.001479
34.04466	151.1078	10:44:36	0.002279
34.04466	151.1078	10:44:41	0.001572
34.04466	151.1078	10:44:46	0.001714
34.04466	151.1078	10:44:51	0.000646
34.04466	151.1078	10:44:56	0.001816
34.04466	151.1078	10:45:01	0.001622
34.04466	151.1078	10:45:06	0.001046
34.04466	151.1078	10:45:11	0.001837

34.04466	151.1078	10:45:16	0.002617
34.04466	151.1078	10:45:21	0.000415
34.04466	151.1078	10:45:26	0.001104
34.04466	151.1078	10:45:31	0.002669
34.04466	151.1078	10:45:36	0.001367
34.04466	151.1078	10:45:41	0.001559
34.04466	151.1078	10:45:46	0.002646
34.04466	151.1078	10:45:51	0.000728
34.04466	151.1078	10:45:56	0.002032
34.04466	151.1078	10:46:01	0.002551
34.04466	151.1078	10:46:06	0.000516
34.04466	151.1078	10:46:11	0.000524
34.04466	151.1078	10:46:16	0.002319
34.04466	151.1078	10:46:21	0.002406
34.04466	151.1078	10:46:26	0.002381
34.04466	151.1078	10:46:31	0.001859
34.04466	151.1078	10:46:36	0.001861
34.04466	151.1078	10:46:41	0.001006
34.04466	151.1078	10:46:46	0.001954
34.04466	151.1078	10:46:51	0.002189
34.04466	151.1078	10:46:56	0.002585
34.04466	151.1078	10:47:01	0.000952
34.04466	151.1078	10:47:06	0.004485
34.04466	151.1078	10:47:11	0.001743
34.04466	151.1078	10:47:16	0.004808
34.04466	151.1078	10:47:21	0.002249
34.04466	151.1078	10:47:26	0.000369
34.04466	151.1078	10:47:31	0.000933
34.04466	151.1078	10:47:36	0.001654
34.04466	151.1078	10:47:41	0.00139
34.04466	151.1078	10:47:46	0.00047
34.04466	151.1078	10:47:51	0.003062
34.04466	151.1078	10:47:56	0.004008
34.04466	151.1078	10:48:01	0.001674
34.04466	151.1078	10:48:06	0.000835
34.04466	151.1078	10:48:11	0.003511
34.04466	151.1078	10:48:16	0.00208
34.04466	151.1078	10:48:21	0.003893
34.04466	151.1078	10:48:26	0.001416
34.04466	151.1078	10:48:31	0.001046
34.04466	151.1078	10:48:36	0.002052
34.04466	151.1078	10:48:41	0.002141
34.04466	151.1078	10:48:46	0.002862
34.04466	151.1078	10:48:51	0.003167
34.04466	151.1078	10:48:56	0.00151
34.04466	151.1078	10:49:01	0.001043
34.04466	151.1078	10:49:06	0.002222
34.04466	151.1078	10:49:11	0.003633
34.04466	151.1078	10:49:16	0.001148
34.04466	151.1078	10:49:21	0.003011
34.04466	151.1078	10:49:26	0.001462
34.04466	151.1078	10:49:31	0.001724
34.04466	151.1078	10:49:36	0.00214
34.04466	151.1078	10:49:41	0.001179
34.04466	151.1078	10:49:46	0.002102
34.04466	151.1078	10:49:51	0.001176
34.04466	151.1078	10:49:56	0.001437
34.04466	151.1078	10:50:01	0.000345
34.04466	151.1078	10:50:06	0.001535
34.04466	151.1078	10:50:11	0.001397
34.04466	151.1078	10:50:16	0.002724

34.04467	151.1078	10:50:21	6.86E-05
34.04467	151.1078	10:50:26	0.0028
34.04467	151.1078	10:50:31	0.000446
34.04467	151.1078	10:50:36	0.002669
34.04467	151.1078	10:50:41	0.005094
34.04467	151.1078	10:50:46	0.002133
34.04467	151.1078	10:50:51	0.000448
34.04467	151.1078	10:50:56	0.002424
34.04467	151.1078	10:51:01	0.001995
34.04467	151.1078	10:51:06	0.001552
34.04467	151.1078	10:51:11	0.004964
34.04467	151.1078	10:51:16	0.003442
34.04467	151.1078	10:51:21	0.003656
34.04467	151.1078	10:51:26	0.002567
34.04467	151.1078	10:51:31	0.001852
34.04467	151.1078	10:51:36	0.00042
34.04467	151.1078	10:51:41	0.003731
34.04467	151.1078	10:51:46	0.000533
34.04467	151.1078	10:51:51	0.003066
34.04467	151.1078	10:51:56	0.003699
34.04467	151.1078	10:52:01	0.002353
34.04467	151.1078	10:52:06	0.001529
34.04467	151.1078	10:52:11	0.000684
34.04467	151.1078	10:52:16	0.003034
34.04467	151.1078	10:52:21	0.002622
34.04467	151.1078	10:52:26	0.00286
34.04467	151.1078	10:52:31	0.001162
34.04467	151.1078	10:52:36	0.001878
34.04467	151.1078	10:52:41	0.002369
34.04467	151.1078	10:52:46	0.003323
34.04467	151.1078	10:52:51	0.001599
34.04467	151.1078	10:52:56	0.002668
34.04467	151.1078	10:53:01	0.000511
34.04467	151.1078	10:53:06	0.000925
34.04467	151.1078	10:53:11	0.00066
34.04468	151.1078	10:53:16	0.000331
34.04468	151.1078	10:53:21	0.001083
34.04468	151.1078	10:53:26	0.000777
34.04468	151.1078	10:53:31	0.001674
34.04468	151.1078	10:53:36	0.001233
34.04468	151.1078	10:53:41	0.002043
34.04468	151.1078	10:53:46	0.002111
34.04468	151.1078	10:53:51	0.001461
34.04468	151.1078	10:53:56	0.002856
34.04468	151.1078	10:54:01	0.001369
34.04468	151.1078	10:54:06	0.002615
34.04468	151.1078	10:54:11	0.00176
34.04468	151.1078	10:54:16	0.001224
34.04468	151.1078	10:54:21	0.000703
34.04468	151.1078	10:54:26	0.000398
34.04468	151.1078	10:54:31	0.001001
34.04468	151.1078	10:54:36	0.002435
34.04468	151.1078	10:54:41	0.001859
34.04468	151.1078	10:54:46	0.000511
34.04468	151.1078	10:54:51	0.001146
34.04468	151.1078	10:54:56	0.000959
34.04468	151.1078	10:55:01	0.001845
34.04468	151.1078	10:55:06	0.000749
34.04468	151.1078	10:55:11	0.001462
34.04468	151.1078	10:55:16	0.001179
34.04468	151.1078	10:55:21	0.002636

34.04468	151.1078	10:55:26	0.002779
34.04468	151.1078	10:55:31	0.00169
34.04468	151.1078	10:55:36	0.0014
34.04468	151.1078	10:55:41	0.002732
34.04468	151.1078	10:55:46	0.003108
34.04468	151.1078	10:55:51	0.000493
34.04468	151.1078	10:55:56	0.004509
34.04468	151.1078	10:56:01	0.000807
34.04468	151.1078	10:56:06	0.003403
34.04468	151.1078	10:56:11	0.000777
34.04468	151.1078	10:56:16	0.001734
34.04468	151.1078	10:56:21	0.001952
34.04468	151.1078	10:56:26	0.000948
34.04468	151.1078	10:56:31	0.001951
34.04468	151.1078	10:56:36	0.000594
34.04468	151.1078	10:56:41	0.0032
34.04468	151.1078	10:56:46	0.001491
34.04468	151.1078	10:56:51	0.001998
34.04468	151.1078	10:56:56	0.002253
34.04468	151.1078	10:57:01	0.001763
34.04468	151.1078	10:57:06	0.000763
34.04468	151.1078	10:57:11	0.000417
34.04468	151.1078	10:57:16	0.004957
34.04468	151.1078	10:57:21	0.000453
34.04468	151.1078	10:57:26	0.002857
34.04468	151.1078	10:57:31	0.002755
34.04468	151.1078	10:57:36	0.000749
34.04468	151.1078	10:57:41	0.002065
34.04468	151.1078	10:57:46	0.002291
34.04468	151.1078	10:57:51	0.001655
34.04468	151.1078	10:57:56	0.000469
34.04468	151.1078	10:58:01	0.001889
34.04468	151.1078	10:58:06	0.003381
34.04468	151.1078	10:58:11	0.001062
34.04468	151.1078	10:58:16	0.002645
34.04468	151.1078	10:58:21	0.002424
34.04468	151.1078	10:58:26	0.000992
34.04468	151.1078	10:58:31	0.001644
34.04468	151.1078	10:58:36	0.001746
34.04468	151.1078	10:58:41	0.001564
34.04468	151.1078	10:58:46	0.003613
34.04468	151.1078	10:58:51	0.001957
34.04468	151.1078	10:58:56	0.000238
34.04468	151.1078	10:59:01	0.000885
34.04468	151.1078	10:59:06	0.000286
34.04468	151.1078	10:59:11	0.002252
34.04468	151.1078	10:59:16	0.004155
34.04468	151.1078	10:59:21	0.001559
34.04468	151.1078	10:59:26	0.001004
34.04468	151.1078	10:59:31	0.00129
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34.04465	151.1079	11:30:21	0.003237
34.04465	151.1079	11:30:26	0.000751
34.04465	151.1079	11:30:31	0.001982
34.04465	151.1079	11:30:36	0.000752
34.04465	151.1079	11:30:41	0.005493
34.04465	151.1079	11:30:46	0.001501
34.04465	151.1079	11:30:51	0.002545
34.04465	151.1079	11:30:56	0.006022

34.04465	151.1079	11:31:01	0.000974
34.04465	151.1079	11:31:06	0.004936
34.04465	151.1079	11:31:11	0.003032
34.04465	151.1079	11:31:16	0.000437
34.04465	151.1079	11:31:21	0.000788
34.04465	151.1079	11:31:26	0.001763
34.04465	151.1079	11:31:31	0.003322
34.04465	151.1079	11:31:36	0.003743
34.04465	151.1079	11:31:41	0.000726
34.04465	151.1079	11:31:46	0.00497
34.04465	151.1079	11:31:51	0.001334
34.04465	151.1079	11:31:56	0.003317
34.04465	151.1079	11:32:01	0.002462
34.04465	151.1079	11:32:06	0.001004
34.04465	151.1079	11:32:11	0.004376
34.04465	151.1079	11:32:16	0.002547
34.04465	151.1079	11:32:21	0.003444
34.04465	151.1079	11:32:26	0.003656
34.04466	151.1079	11:32:31	0.004051
34.04466	151.1079	11:32:36	0.001123
34.04466	151.1079	11:32:41	0.001048
34.04466	151.1079	11:32:46	0.003966
34.04466	151.1079	11:32:51	0.004373
34.04466	151.1079	11:32:56	0.002073
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34.04466	151.1079	11:33:06	0.000201
34.04466	151.1079	11:33:11	0.004804
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34.04466	151.1079	11:33:26	0.001128
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34.04466	151.1079	11:33:36	0.004049
34.04466	151.1079	11:33:41	0.003719
34.04466	151.1079	11:33:46	0.004514
34.04466	151.1079	11:33:51	0.000371
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34.04466	151.1079	11:34:26	0.000616
34.04466	151.1079	11:34:31	0.004993
34.04466	151.1079	11:34:36	0.002933
34.04466	151.1079	11:34:41	0.003409
34.04466	151.1079	11:34:46	0.003281
34.04466	151.1079	11:34:51	0.003182
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34.04466	151.1079	11:35:01	0.001037
34.04466	151.1079	11:35:06	0.002297
34.04466	151.1079	11:35:11	0.001184
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34.04466	151.1079	11:35:21	0.002644
34.04466	151.1079	11:35:26	0.002067
34.04466	151.1079	11:35:31	0.003266
34.04466	151.1079	11:35:36	0.001713
34.04466	151.1079	11:35:41	0.005141
34.04466	151.1079	11:35:46	0.002842
34.04466	151.1079	11:35:51	0.002237
34.04466	151.1079	11:35:56	0.000786
34.04466	151.1079	11:36:01	0.004029

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34.04466	151.1079	11:36:16	0.001062
34.04466	151.1079	11:36:21	0.00183
34.04466	151.1079	11:36:26	0.002108
34.04466	151.1079	11:36:31	0.003373
34.04466	151.1079	11:36:36	0.001234
34.04466	151.1079	11:36:41	0.002876
34.04466	151.1079	11:36:46	0.001736
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34.04466	151.1079	11:36:56	0.000586
34.04466	151.1079	11:37:01	0.001666
34.04466	151.1079	11:37:06	0.003147
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34.04467	151.1079	11:37:16	0.003893
34.04467	151.1079	11:37:21	0.00031
34.04467	151.1079	11:37:26	0.001315
34.04467	151.1079	11:37:31	0.002633
34.04467	151.1079	11:37:36	0.00268
34.04467	151.1079	11:37:41	0.002014
34.04467	151.1079	11:37:46	0.00104
34.04467	151.1079	11:37:51	0.001585
34.04467	151.1079	11:37:56	0.002445
34.04467	151.1079	11:38:01	0.002363
34.04467	151.1079	11:38:06	0.002563
34.04467	151.1079	11:38:11	0.002017
34.04467	151.1079	11:38:16	0.00334
34.04467	151.1079	11:38:21	0.000134
34.04467	151.1079	11:38:26	0.001802
34.04467	151.1079	11:38:31	0.003278
34.04467	151.1079	11:38:36	0.000348
34.04467	151.1079	11:38:41	0.004848
34.04467	151.1079	11:38:46	0.002027
34.04467	151.1079	11:38:51	0.001895
34.04467	151.1079	11:38:56	0.001389
34.04467	151.1079	11:39:01	0.001109
34.04467	151.1079	11:39:06	0.003904
34.04467	151.1079	11:39:11	0.00174
34.04467	151.1079	11:39:16	0.004012
34.04467	151.1079	11:39:21	0.001099
34.04467	151.1079	11:39:26	0.001946
34.04467	151.1079	11:39:31	0.002661
34.04467	151.1079	11:39:36	0.000442
34.04467	151.1079	11:39:41	0.001105
34.04467	151.1079	11:39:46	0.002581
34.04467	151.1079	11:39:51	0.002767
34.04467	151.1079	11:39:56	0.002582
34.04467	151.1079	11:40:01	0.00097
34.04467	151.1079	11:40:06	0.012225
34.04467	151.1079	11:40:11	0.005679
34.04468	151.1079	11:40:56	0.005555
34.04468	151.1079	11:41:01	0.005258
34.04468	151.1079	11:41:06	0.005304
34.04468	151.1079	11:41:11	0.002
34.04468	151.1079	11:41:31	0.006254
34.04468	151.1079	11:41:36	0.003252
34.04468	151.1079	11:41:41	0.004592
34.04468	151.1079	11:41:46	0.004373
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34.04468	151.1079	11:42:01	0.00452

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34.04468	151.1079	11:42:11	0.003735
34.04468	151.1079	11:42:16	0.004851
34.04468	151.1079	11:42:21	0.001815
34.04468	151.1079	11:42:26	0.002117
34.04468	151.1079	11:42:31	0.001154
34.04468	151.1079	11:42:36	0.001367
34.04468	151.1079	11:42:41	0.003324
34.04468	151.1079	11:42:46	0.001985
34.04468	151.1079	11:42:51	0.001028
34.04468	151.1079	11:42:56	0.007164
34.04468	151.1079	11:43:01	0.000386
34.04468	151.1079	11:43:06	0.004349
34.04468	151.1079	11:43:11	0.005663
34.04468	151.1079	11:43:16	0.002495
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34.04468	151.1079	11:43:26	0.002347
34.04468	151.1079	11:43:31	0.003183
34.04468	151.1079	11:43:36	0.003907
34.04468	151.1079	11:43:41	0.001362
34.04468	151.1079	11:43:46	0.002755
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34.04468	151.1079	11:43:56	0.000354
34.04468	151.1079	11:44:01	0.003368
34.04468	151.1079	11:44:06	0.000687
34.04468	151.1079	11:44:11	0.002319
34.04468	151.1079	11:44:16	0.004203
34.04468	151.1079	11:44:21	0.00274
34.04468	151.1079	11:44:26	0.001019
34.04468	151.1079	11:44:31	0.000306
34.04468	151.1079	11:44:36	0.001948
34.04468	151.1079	11:44:41	0.002213
34.04468	151.1079	11:44:46	0.001427
34.04468	151.1079	11:44:51	0.001137
34.04468	151.1079	11:44:56	0.003056
34.04468	151.1079	11:45:01	0.004004
34.04468	151.1079	11:45:06	0.002429
34.04468	151.1079	11:45:11	0.001162
34.04468	151.1079	11:45:16	0.003333
34.04468	151.1079	11:45:21	0.001236
34.04468	151.1079	11:45:26	0.001404
34.04468	151.1079	11:45:31	0.001313
34.04469	151.1079	11:45:36	0.004389
34.04469	151.1079	11:45:41	0.002202
34.04469	151.1079	11:45:46	0.002359
34.04469	151.1079	11:45:51	0.002945
34.04469	151.1079	11:45:56	0.003267
34.04469	151.1079	11:46:01	0.002381
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34.04469	151.1079	11:46:11	0.001046
34.04469	151.1079	11:46:16	0.001734
34.04469	151.1079	11:46:21	0.001664
34.04469	151.1079	11:46:26	0.000287
34.04469	151.1079	11:46:31	0.001033
34.04469	151.1079	11:46:36	0.002754
34.04469	151.1079	11:46:41	0.001879
34.04469	151.1079	11:46:46	0.001341
34.04469	151.1079	11:46:51	0.001376
34.04469	151.1079	11:46:56	0.00076
34.04469	151.1079	11:47:01	0.001842
34.04469	151.1079	11:47:06	0.001754

34.04469	151.1079	11:47:11	0.001036
34.04469	151.1079	11:47:16	0.001172
34.04469	151.1079	11:47:21	0.002119
34.04469	151.1079	11:47:26	0.003269
34.04469	151.1079	11:47:31	0.002661
34.04469	151.1079	11:47:36	0.002938
34.04469	151.1079	11:47:41	0.001609
34.04469	151.1079	11:47:46	0.000151
34.04469	151.1079	11:47:51	0.001834
34.04469	151.1079	11:47:56	0.000959
34.04469	151.1079	11:48:01	0.000952
34.04469	151.1079	11:48:06	0.001867
34.04469	151.1079	11:48:11	0.001099
34.04469	151.1079	11:48:16	0.001923
34.04469	151.1079	11:48:21	0.003722
34.04469	151.1079	11:48:26	0.002479
34.04469	151.1079	11:48:31	0.000713
34.04469	151.1079	11:48:36	0.000329
34.04469	151.1079	11:48:41	0.000907
34.04469	151.1079	11:48:46	0.003988
34.04469	151.1079	11:48:51	0.000707
34.04469	151.1079	11:48:56	0.000693
34.04469	151.1079	11:49:01	0.002161
34.04469	151.1079	11:49:06	0.002111
34.04469	151.1079	11:49:11	0.001971
34.04469	151.1079	11:49:16	0.001398
34.04469	151.1079	11:49:21	0.000587
34.04469	151.1079	11:49:26	0.000603
34.04469	151.1079	11:49:31	0.001491
34.04469	151.1079	11:49:36	0.00399
34.04469	151.1079	11:49:41	0.004166
34.04469	151.1079	11:49:46	0.004683
34.04469	151.1079	11:49:51	0.001661
34.04469	151.1079	11:49:56	0.003149
34.04469	151.1079	11:50:01	0.003664
34.04469	151.1079	11:50:06	0.002761
34.04469	151.1079	11:50:11	0.002743
34.04469	151.1079	11:50:16	0.002264
34.04469	151.1079	11:50:21	0.001326
34.04469	151.1079	11:50:26	0.001064
34.04469	151.1079	11:50:31	0.002493
34.04469	151.1079	11:50:36	0.001752
34.04469	151.1079	11:50:41	0.002401
34.04469	151.1079	11:50:46	0.004064
34.04469	151.1079	11:50:51	0.00084
34.04469	151.1079	11:50:56	0.001617
34.04469	151.1079	11:51:01	0.002428
34.04469	151.1079	11:51:06	0.002783
34.04469	151.1079	11:51:11	0.004299
34.04469	151.1079	11:51:16	0.002779
34.04469	151.1079	11:51:21	0.000421
34.04469	151.1079	11:51:26	0.003657
34.04469	151.1079	11:51:31	0.003708
34.04469	151.1079	11:51:36	0.005032
34.04469	151.1079	11:51:41	0.001415
34.04469	151.1079	11:51:46	0.002682
34.04469	151.1079	11:51:51	0.00292
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34.0447	151.1079	11:52:01	0.003226
34.0447	151.1079	11:52:06	0.003513
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34.0447	151.1079	11:52:16	0.005434
34.0447	151.1079	11:52:21	0.001263
34.0447	151.1079	11:52:26	0.002756
34.0447	151.1079	11:52:31	0.000802
34.0447	151.1079	11:52:36	0.003018
34.0447	151.1079	11:52:41	0.000792
34.0447	151.1079	11:52:46	0.001047
34.0447	151.1079	11:52:51	0.002601
34.0447	151.1079	11:52:56	0.002004
34.0447	151.1079	11:53:01	0.002538
34.0447	151.1079	11:53:06	0.000672
34.0447	151.1079	11:53:11	0.002263
34.0447	151.1079	11:53:16	0.002768
34.0447	151.1079	11:53:21	0.001655
34.0447	151.1079	11:53:26	0.001984
34.0447	151.1079	11:53:31	0.003974
34.0447	151.1079	11:53:36	0.001538
34.0447	151.1079	11:53:41	0.000777
34.0447	151.1079	11:53:46	0.001054
34.0447	151.1079	11:53:51	0.001294
34.0447	151.1079	11:53:56	0.000732
34.0447	151.1079	11:54:01	0.002289
34.0447	151.1079	11:54:06	0.001647
34.0447	151.1079	11:54:11	0.001166
34.0447	151.1079	11:54:16	0.001662
34.0447	151.1079	11:54:21	0.000552
34.0447	151.1079	11:54:26	0.002357
34.0447	151.1079	11:54:31	5.64E-05
34.0447	151.1079	11:54:36	0.002942
34.0447	151.1079	11:54:41	0.001361
34.0447	151.1079	11:54:46	0.001483
34.0447	151.1079	11:54:51	0.001981
34.0447	151.1079	11:54:56	0.000593
34.0447	151.1079	11:55:01	0.000856
34.0447	151.1079	11:55:06	0.00115
34.0447	151.1079	11:55:11	0.000994
34.0447	151.1079	11:55:16	0.002843
34.0447	151.1079	11:55:21	0.000845
34.0447	151.1079	11:55:26	0.001482
34.0447	151.1079	11:55:31	0.001113
34.0447	151.1079	11:55:36	0.001092
34.0447	151.1079	11:55:41	0.002226
34.0447	151.1079	11:55:46	0.00199
34.0447	151.1079	11:55:51	0.001887
34.0447	151.1079	11:55:56	0.002347
34.0447	151.1079	11:56:01	0.002775
34.0447	151.1079	11:56:06	0.001336
34.0447	151.1079	11:56:11	0.000394
34.0447	151.1079	11:56:16	0.000851
34.0447	151.1079	11:56:21	0.002429
34.0447	151.1078	11:56:26	0.001225
34.0447	151.1078	11:56:31	0.000866
34.0447	151.1078	11:56:36	0.000789
34.0447	151.1079	11:56:41	0.002257
34.0447	151.1078	11:56:46	0.000471
34.0447	151.1078	11:56:51	0.001837
34.0447	151.1078	11:56:56	0.000447
34.0447	151.1078	11:57:01	0.001094
34.0447	151.1078	11:57:06	0.001333
34.0447	151.1078	11:57:11	0.000847
34.0447	151.1078	11:57:16	0.003723

34.0447	151.1078	11:57:21	0.001569
34.0447	151.1078	11:57:26	0.000805
34.0447	151.1078	11:57:31	0.001597
34.0447	151.1078	11:57:36	0.001736
34.0447	151.1078	11:57:41	0.001875
34.0447	151.1078	11:57:46	0.001478
34.0447	151.1078	11:57:51	0.002106
34.0447	151.1078	11:57:56	0.003131
34.0447	151.1078	11:58:01	0.001736
34.0447	151.1078	11:58:06	0.004054
34.0447	151.1078	11:58:11	0.001164
34.0447	151.1078	11:58:16	0.00154
34.0447	151.1078	11:58:21	0.001723
34.0447	151.1078	11:58:26	0.003161
34.0447	151.1078	11:58:31	0.00035
34.0447	151.1078	11:58:36	0.001456
34.0447	151.1078	11:58:41	0.00229
34.0447	151.1078	11:58:46	0.000811
34.0447	151.1078	11:58:51	0.006008
34.0447	151.1078	11:58:56	0.001744
34.0447	151.1078	11:59:01	0.001482
34.0447	151.1078	11:59:06	0.002371
34.0447	151.1078	11:59:11	0.003185
34.0447	151.1078	11:59:16	0.005293
34.0447	151.1078	11:59:21	0.002741
34.0447	151.1078	11:59:26	0.001014
34.0447	151.1078	11:59:31	0.001339
34.0447	151.1078	11:59:36	0.003431
34.0447	151.1078	11:59:41	0.002536
34.0447	151.1078	11:59:46	0.001906
34.0447	151.1078	11:59:51	0.00286
34.0447	151.1078	11:59:56	0.004227
34.0447	151.1078	12:00:01	0.001185
34.0447	151.1078	12:00:06	0.000694
34.0447	151.1078	12:00:11	0.001272
34.0447	151.1078	12:00:16	0.001932
34.0447	151.1078	12:00:21	0.002147
34.0447	151.1078	12:00:26	0.001055
34.0447	151.1078	12:00:31	0.002101
34.0447	151.1078	12:00:36	0.000591

Yowie Bay Velocity 3

Latitude	Longitude	Time AEST	Speed M/Sec
34.05036	151.1081	10:45:41	0.154553
34.05036	151.1081	10:46:11	0.178685
34.05039	151.1081	10:46:41	0.135316
34.0504	151.1081	10:47:11	0.100217
34.05042	151.1081	10:47:41	0.017273
34.05041	151.1081	10:48:11	0.237176
34.05042	151.1081	10:48:41	0.044277
34.05045	151.1081	10:49:11	0.165249
34.05046	151.1081	10:49:41	0.098342
34.05047	151.1081	10:50:11	0.152761
34.05049	151.1081	10:50:41	0.003495
34.0505	151.1081	10:51:11	0.006468
34.0505	151.1081	10:51:41	0.005997
34.0505	151.1081	10:52:11	0.00211
34.0505	151.1081	10:52:41	0.004273
34.05051	151.1081	10:53:11	0.003983
34.05051	151.1081	10:53:41	0.008084
34.05052	151.1081	10:54:11	0.006757
34.05052	151.1081	10:54:41	0.005344
34.05053	151.1081	10:55:11	0.006642
34.05053	151.108	10:55:41	0.002015
34.05054	151.108	10:56:11	0.002654
34.05054	151.108	10:56:41	0.002879
34.05055	151.108	10:57:11	0.009418
34.05055	151.108	10:57:41	0.008428
34.05056	151.108	10:58:11	0.004513
34.05057	151.108	10:58:41	0.003383
34.05057	151.108	10:59:11	0.008017
34.05058	151.108	10:59:41	0.003024
34.05058	151.108	11:00:11	0.00433
34.05059	151.108	11:00:41	0.007259
34.0506	151.108	11:01:11	0.005724
34.05061	151.108	11:01:41	0.008389
34.05064	151.108	11:02:11	0.001611
34.05065	151.108	11:02:41	0.005058
34.05067	151.108	11:03:11	0.004626
34.05068	151.108	11:03:41	0.004588
34.0507	151.108	11:04:11	0.004062
34.05071	151.108	11:04:41	0.003982
34.05073	151.108	11:05:11	0.00232
34.05075	151.1079	11:05:41	0.002552
34.05078	151.1079	11:06:11	0.00329
34.05081	151.1079	11:06:41	0.000968
34.05083	151.1079	11:07:11	0.008822
34.05085	151.1079	11:07:41	0.006513
34.05086	151.1079	11:08:11	0.002571
34.05088	151.1079	11:08:41	0.004633
34.0509	151.1079	11:09:11	0.005709
34.05092	151.1079	11:09:41	0.004327
34.05094	151.1079	11:10:11	0.007182
34.05096	151.1079	11:10:41	0.004663
34.05099	151.1079	11:11:11	0.005463
34.05101	151.1078	11:11:41	0.00504
34.05103	151.1078	11:12:11	0.002125
34.05106	151.1078	11:12:41	0.000392
34.05108	151.1078	11:13:11	0.006069
34.05109	151.1078	11:13:41	0.008793

34.05112	151.1078	11:14:11	0.116114
34.05115	151.1078	11:14:41	0.08381
34.05118	151.1078	11:15:11	0.14816
34.05123	151.1078	11:15:41	0.091296
34.05128	151.1078	11:16:11	0.158783
34.05132	151.1078	11:16:41	0.062146
34.05135	151.1078	11:17:11	0.067724
34.05138	151.1077	11:17:41	0.099571
34.05142	151.1077	11:18:11	0.063011
34.05145	151.1077	11:18:41	0.121772
34.05148	151.1077	11:19:11	0.183701
34.05152	151.1077	11:19:41	0.079865
34.05155	151.1077	11:20:11	0.113429
34.05158	151.1077	11:20:41	0.078763
34.05161	151.1077	11:21:11	0.133633
34.05165	151.1077	11:21:41	0.148183
34.05168	151.1076	11:22:11	0.051043
34.05171	151.1076	11:22:41	0.062385
34.05173	151.1076	11:23:11	0.167497
34.05176	151.1076	11:23:41	0.127458
34.05179	151.1076	11:24:11	0.173101
34.05182	151.1076	11:24:41	0.087555
34.05184	151.1076	11:25:11	0.168076
34.05188	151.1075	11:25:41	0.15209
34.05192	151.1075	11:26:11	0.074237
34.05194	151.1075	11:26:41	0.149256
34.05198	151.1075	11:27:11	0.085874
34.05202	151.1075	11:27:41	0.274578
34.05205	151.1074	11:28:11	0.455885
34.05208	151.1074	11:28:41	0.231031
34.05211	151.1074	11:29:11	0.02284
34.05212	151.1074	11:29:41	0.284927
34.05214	151.1074	11:30:11	0.097116
34.05217	151.1074	11:30:41	0.081444
34.0522	151.1074	11:31:11	0.159018
34.05222	151.1074	11:31:41	0.258245
34.05222	151.1074	11:32:11	0.126311
34.05224	151.1073	11:32:41	0.089399
34.05226	151.1074	11:33:11	0.395143
34.0523	151.1073	11:33:41	0.10795
34.05232	151.1073	11:34:11	0.234159
34.05233	151.1073	11:34:41	0.265049
34.05235	151.1073	11:35:11	0.197969
34.05238	151.1073	11:35:41	0.205059
34.0524	151.1073	11:36:11	0.118009
34.05242	151.1073	11:36:41	0.219418
34.05244	151.1073	11:37:11	0.145959
34.05249	151.1072	11:37:41	0.128328
34.05253	151.1072	11:38:11	0.190012
34.05256	151.1072	11:38:41	0.215759
34.0526	151.1072	11:39:11	0.106036
34.05263	151.1072	11:39:41	0.110122
34.05266	151.1072	11:40:11	0.118809
34.05268	151.1072	11:40:41	0.179007
34.0527	151.1072	11:41:11	0.179386
34.05272	151.1072	11:41:41	0.158096
34.05274	151.1072	11:42:11	0.122466
34.05276	151.1071	11:42:41	0.205486
34.05277	151.1071	11:43:11	0.071088
34.05278	151.1071	11:43:41	0.006351
34.05278	151.1071	11:44:11	0.005793

34.05279	151.1071	11:44:41	0.003585
34.05279	151.1071	11:45:11	0.008573
34.0528	151.1071	11:45:41	0.008469
34.0528	151.1071	11:46:11	0.001977
34.05281	151.1071	11:46:41	0.011376
34.05281	151.1071	11:47:11	0.005897
34.05282	151.1071	11:47:41	0.056539
34.05283	151.1071	11:48:11	0.363215
34.05287	151.1071	11:48:41	0.213499
34.05299	151.107	11:49:11	0.246502
34.05306	151.107	11:49:41	0.091556
34.05309	151.107	11:50:11	0.132931
34.05313	151.107	11:50:41	0.330646
34.05317	151.107	11:51:11	0.213479
34.05321	151.107	11:51:41	0.140219
34.05323	151.107	11:52:11	0.159684
34.05325	151.107	11:52:41	0.028351
34.05329	151.1069	11:53:11	0.125359
34.05331	151.1069	11:53:41	0.293411
34.05335	151.1069	11:54:11	0.146563
34.05338	151.1069	11:54:41	0.200264
34.05342	151.1069	11:55:11	0.109313
34.05346	151.1069	11:55:41	0.156553
34.05348	151.1069	11:56:11	0.155458
34.05351	151.1069	11:56:41	0.172199
34.05355	151.1069	11:57:11	0.087197
34.05359	151.1068	11:57:41	0.124021
34.05363	151.1068	11:58:11	0.055795
34.05365	151.1068	11:58:41	0.047671
34.05368	151.1068	11:59:11	0.18675
34.05371	151.1068	11:59:41	0.120714
34.05373	151.1068	12:00:11	0.028446
34.05375	151.1068	12:00:41	0.08161
34.05378	151.1068	12:01:11	0.008215
34.0538	151.1068	12:01:41	0.177292
34.05383	151.1068	12:02:11	0.400233
34.05387	151.1068	12:02:41	0.165453
34.05392	151.1068	12:03:11	0.220911
34.05395	151.1068	12:03:41	0.114781
34.05398	151.1068	12:04:11	0.324529
34.05402	151.1068	12:04:41	0.171976
34.05406	151.1068	12:05:11	0.11848
34.05409	151.1068	12:05:41	0.054363
34.05411	151.1068	12:06:11	0.077134
34.05414	151.1068	12:06:41	0.138647
34.05419	151.1068	12:07:11	0.096171

4. Additional Geochemical results

4.1 Normalization results of Kogarah Bay, all results in ppm except Sand particles wt%.

Sample No	Sand%	Cr	Co	Ni	Cu	Zn	As	Br	Rb	Sr	Cd	Sn	Ba	Pb
KO1	37.24	76.8	10.5	27.4	38.7	311.7	27.4	295.6	73.6	206.7	0.8	16.4	180.2	98.3
KO2	4	12.6	3.5	14.2	28.2	202.4	21.3	152.5	80.2	166.9	2.1	9.1	182.4	107.9
KO3	7.48	25.8	6.7	17.9	38.2	231.2	17.7	217.8	88.2	181.4	0.2	16.1	194.9	118.7
KO4	35.66	53.2	14	15.5	41	181.1	11.5	190.9	53.3	135.4	3.1	18.2	129.3	62
KO5	6.67	70.4	14.4	24.5	61.9	292.7	17.8	402.6	87.5	173.4	2.1	14.1	185.3	101.9
KO6	10.85	50.4	13	11.7	89.4	166.1	8.9	206.8	38.9	98.1	0.4	14.1	108	48.7
KO7	3.85	14.8	8.1	15.5	39.6	208.6	20.6	169.8	85.9	157.7	0.8	13	200.3	119.2
KO8	9.63	30.9	8.7	14.6	43.5	174.7	16.3	175.4	64.6	120.8	2.2	13.5	152.7	100.1
KO9	52.69	41.9	8.9	11	22.4	104.6	12.5	244.6	38.7	96.2	4.2	17.5	139.5	38.9
KO10	77.46	67.4	28.4	21.3	40.8	122	21.7	432.6	43.9	127.3	1.3	27.1	214.7	45.7
KO11	91.97	123.3	62.3	22.4	69.7	145.7	24.9	171.9	156.9	184.3	5	82.2	691.2	67.2
KO12	15.52	96.5	18.1	31.3	63	333	22.6	390.4	101.2	159.9	2.4	14.7	209.5	114.2
KO13	4.95	15	8.6	16.2	36.3	190.1	23	128.7	85.2	140	0.5	14.8	200.9	138.3
KO14	13.93	64.4	5.7	18.2	55.2	206.3	14.3	193.3	59.7	99	0.3	12.7	137.2	84.7
KO15	24.93	57.7	7.3	17.5	56.5	212.6	15.3	194.5	64.1	101.8	2.7	13.9	170.9	88.1
KO16	0.19	25.4	8.7	18.2	85.7	245.2	20.2	191.7	83.6	132.9	2	13.6	195.9	156.8
KO17	3.43	12.2	8.9	12.9	30.8	169.4	22	143.7	77.5	128.1	2.1	12.9	174.8	128.1
KO18	91.7	126.5	36.1	21.7	77.1	183.1	26.5	654.8	112	238.6	10.8	109.6	501.2	104.8
KO19	28.84	24.5	12.6	19	56.6	300.9	27.7	179.3	95.8	169.6	2.8	19	257.6	253.2
KO20	20.35	61.9	15.8	15.2	57	265.5	9.8	444.6	44.6	127.7	2.5	13.7	161.7	92
KO21	93.52	175.9	54	40.1	88	354.9	29.3	628.1	166.7	450.6	30.9	126.5	645.1	228.4
KO22	2.63	30.7	7.6	17.3	35.6	197.4	19.2	171.3	79.7	121.5	2.1	12.7	184.5	126.3
KO23	64.08	105.5	9.7	15.6	61.2	181.2	13.9	202.1	45.7	90.5	2.2	24.5	157.9	89.1
KO24	28.47	81.2	9.2	21.8	62.5	266.6	16.2	316	75.2	126.2	0.3	14.4	196.3	126.2
KO25	3.02	26	6.7	16.3	41.5	205.3	27	162.3	80.7	135.7	0.9	12.5	192.2	187.3
KO26	3.16	12.1	8.3	15.6	46.3	231.7	28.4	116.3	90.1	146.4	0.5	12.5	222	242.9
KO27	99.26	2067.6	2810.8	513.5	1473	1432.4	202.7	3567.6	1486.5	5391.9	270.3	2486.5	12689.2	2418.9
KO28	94.16	207.2	51.4	66.8	161	669.5	30.8	500	226	729.5	12	416.1	1335.6	357.9
KO29	40.35	97.1	5.9	26	124.9	622	13.2	219.3	62.7	218.6	1.8	25.1	277.3	201.2
KO30	89.08	242.7	31.1	87	440.5	1081.5	25.6	206	272.9	1185.9	18.3	136.4	1652.9	250.9
KO31	94.62	494.4	109.7	135.7	630.1	1803	44.6	425.7	423.8	1879.2	20.4	278.8	3011.2	1011.2
KO32	22.98	20.5	6.5	14	41.9	205.4	23.2	227.6	72.2	133.1	0.8	16.6	205.4	221
KO33	16.71	46.6	4.2	13.1	39	157	13.1	127.5	49.2	87.3	0.5	14	142.4	91.8
KO34	48.78	62.3	8.6	15.2	48	177.9	11.9	246	48.2	101.1	3.9	19.5	145.5	82.6
KO35	92.83	110.2	41.8	18.1	106	184.1	22.3	446.3	43.2	217.6	27.9	140.9	410	107.4
KO36	21.73	112.8	8.2	25.2	60.3	288.4	18.1	186.9	80.9	172.7	2.6	16.1	181	145.8
KO37	94.02	192.3	50.2	62.7	104.5	337.8	25.1	234.1	234.1	428.1	33.4	107	871.2	178.9
KO38	76.11	74.5	12.6	19.7	49.4	186.7	11.7	102.1	59.4	136.5	2.1	44.4	213.5	114.7
KO39	2.26	86	14.6	23.8	75.6	345.3	18.6	545.8	76.5	141.8	0.1	10.1	172.6	143.2
KO40	2.58	28.4	3.7	7	22.9	98	7.4	195.2	23.2	53	1.5	9.8	86.8	47.5
KO41	17.35	106.8	11.5	29.8	109.4	481.4	22.3	311.2	93.5	170.2	2.4	18.6	232.3	204.2
KO42	85.92	79.5	28.4	20.6	79.5	264.2	17.8	769.2	54	378.6	14.2	61.8	477.3	174.7
KO43	93.09	577.4	260.5	267.7	1442.1	2069.5	65.1	831.4	797.4	4688.1	15.2	34	6046.3	1006.5

KO44	56.12	137	6.8	34.2	125.3	577	19.8	425.5	79.8	232	0.5	31.7	317.5	270.1
KO45	5.65	96.9	11.4	29.6	99.9	459	18.7	261.2	90.5	154.3	2.1	13.9	207.7	205.3
KO46	26.6	94.6	8.6	26.4	81.7	345.9	21.3	151.5	81.2	167	0.7	17.7	191.3	157.5
KO47	80.82	75.6	15.6	16.7	57.4	158.5	17.2	99.6	59.4	113.1	10.4	34.9	319.1	80.3
KO48	11.84	17.7	4.5	14.9	44.2	227.7	21.3	124.5	78.9	144.3	2.3	11.6	215.4	197.8
KO49	1.54	15.4	5.5	15.3	39.6	194.8	21.6	99.2	75	135.4	0.4	11.9	193.6	157.4
KO50	90.48	118.7	31.5	15.8	50.4	203.8	39.9	416	90.3	693.3	10.5	96.6	446.4	121.8
KO51	4.26	19.5	11	18.3	43.7	218.8	25.7	124.9	89.8	161.9	2.1	13.6	202.3	147.9
KO52	7.25	8.4	7.1	12.8	29.6	166.9	25.7	123.2	80.5	144.8	0.4	14.2	202.9	171.5
KO53	5.47	70.3	14.3	21.8	82.3	257.8	20.5	201.1	65.3	218.9	2.1	12.3	163.8	96.9
KO54	4.29	6.9	7.4	12	28.1	155.4	26.2	117.5	74.7	131.3	2.1	12	186	170.1
KO55	1.38	18.7	3.9	15.5	40.6	197.2	22.5	137.3	83.9	141.9	2	12.2	205.1	154.9
KO56	31.94	69.5	11.6	14.7	27.9	144.3	12.8	105.9	47.2	76.3	0.1	13.7	125.2	47.5
KO57	50.85	53.3	10.8	11.6	22.6	113.1	13.8	99.1	48.4	90.7	0.2	16.3	163	38
KO58	14	37.2	9	18.4	34.5	238.4	17.9	221.6	87.8	196.3	2.3	13.1	225.8	130.6
KO59	9.41	53.6	8.7	14.8	30.1	190.9	14.2	203.4	48.9	295	0.7	10.4	126	56.5
Mean	36.10085	118.3	68.2	36.1	122.3	337.9	24.2	319.2	124.7	393.7	9.4	82.1	637.8	203.9

4.2. Contamination factor (CF), Pollution load index (PLI), Degree of contamination (C_d) and Modified degree of contamination (mC_d). A- Botany Bay: Kogarah Bay

Sample No	CF Cr	CF Co	CF Ni	CF Cu	CF Zn	CF Pb	CF As	CF Sn	PLI	C _d	mC _d
KO1	1.44	1.83	1.37	2.67	4.66	2.64	0.89	10.30	2.49	23.95	3.42
KO2	0.36	0.94	1.08	2.98	4.63	4.43	1.05	8.70	2.16	23.22	3.32
KO3	0.71	1.72	1.32	3.88	5.09	4.69	0.85	14.90	2.72	31.44	4.49
KO4	1.02	2.50	0.79	2.90	2.77	1.71	0.38	11.70	1.75	21.28	3.04
KO5	1.96	3.72	1.82	6.35	6.50	4.06	0.86	13.20	3.52	34.75	4.96
KO6	1.34	3.22	0.83	8.76	3.53	1.85	0.41	12.60	2.28	29.31	4.19
KO7	0.42	2.17	1.18	4.19	4.78	4.90	1.02	12.50	2.51	28.99	4.14
KO8	0.83	2.19	1.05	4.32	3.76	3.87	0.76	12.20	2.43	26.78	3.83
KO9	0.59	1.17	0.41	1.16	1.18	0.79	0.30	8.30	0.94	12.74	1.82
KO10	0.45	1.78	0.38	1.01	0.65	0.44	0.25	6.10	0.69	9.29	1.33
KO11	0.30	1.39	0.14	0.62	0.28	0.23	0.10	6.60	0.38	8.27	1.18
KO12	2.43	4.25	2.10	5.85	6.70	4.12	0.98	12.40	3.73	34.58	4.94
KO13	0.43	2.28	1.22	3.79	4.30	5.62	1.13	14.10	2.58	30.59	4.37
KO14	1.65	1.36	1.25	5.22	4.23	3.12	0.63	10.90	2.67	27.00	3.86
KO15	1.29	1.53	1.04	4.66	3.80	2.82	0.59	10.40	2.37	24.61	3.52
KO16	0.76	2.42	1.44	9.40	5.83	6.69	1.04	13.60	3.44	38.75	5.54
KO17	0.35	2.39	0.99	3.26	3.90	5.29	1.09	12.50	2.28	27.38	3.91
KO18	0.31	0.83	0.14	0.70	0.36	0.37	0.11	9.10	0.46	11.11	1.59
KO19	0.52	2.50	1.07	4.43	5.10	7.70	1.02	13.50	2.79	33.33	4.76
KO20	1.47	3.50	0.96	4.99	5.04	3.13	0.40	10.90	2.42	26.89	3.84
KO21	0.34	0.97	0.21	0.63	0.55	0.63	0.10	8.20	0.53	10.65	1.52
KO22	0.89	2.06	1.33	3.81	4.58	5.26	0.96	12.40	2.79	29.24	4.18
KO23	1.13	0.97	0.44	2.42	1.55	1.37	0.26	8.80	1.29	15.97	2.28
KO24	1.73	1.83	1.24	4.91	4.54	3.86	0.60	10.30	2.73	27.18	3.88
KO25	0.75	1.81	1.25	4.42	4.74	7.76	1.35	12.10	3.06	32.38	4.63
KO26	0.35	2.22	1.20	4.92	5.34	10.05	1.42	12.10	2.94	35.38	5.05
KO27	0.46	5.78	0.30	1.20	0.25	0.76	0.08	18.40	0.64	21.45	3.06
KO28	0.36	0.83	0.31	1.03	0.93	0.89	0.09	24.30	0.80	27.92	3.99
KO29	1.73	0.97	1.23	8.19	8.83	5.13	0.41	15.00	3.36	40.51	5.79
KO30	0.79	0.94	0.75	5.29	2.81	1.17	0.14	14.90	1.56	25.86	3.69
KO31	0.79	1.64	0.58	3.73	2.31	2.32	0.12	15.00	1.50	24.86	3.55
KO32	0.47	1.39	0.86	3.55	3.77	7.27	0.92	12.80	2.40	29.64	4.23
KO33	1.16	0.97	0.87	3.57	3.11	3.27	0.56	11.70	2.19	24.24	3.46
KO34	0.95	1.22	0.62	2.70	2.17	1.81	0.31	10.00	1.53	18.57	2.65
KO35	0.24	0.83	0.10	0.84	0.31	0.33	0.08	10.10	0.40	12.00	1.71
KO36	2.64	1.78	1.56	5.19	5.37	4.88	0.73	12.60	3.39	32.97	4.71
KO37	0.34	0.83	0.30	0.69	0.48	0.46	0.08	6.40	0.50	8.74	1.25
KO38	0.53	0.83	0.37	1.30	1.06	1.17	0.14	10.60	0.90	15.18	2.17
KO39	2.51	3.97	1.85	8.12	8.04	5.98	0.94	9.90	4.02	37.34	5.33
KO40	0.83	1.00	0.54	2.45	2.27	1.98	0.37	9.50	1.50	17.94	2.56
KO41	2.64	2.64	1.95	9.93	9.47	7.21	0.95	15.40	4.70	47.56	6.79
KO42	0.33	1.11	0.23	1.23	0.89	1.05	0.13	8.70	0.72	12.56	1.79
KO43	1.19	5.00	1.47	10.95	3.40	2.97	0.23	2.35	1.95	22.57	3.22
KO44	1.79	0.83	1.19	6.04	6.03	5.06	0.45	13.90	3.05	34.47	4.92
KO45	2.73	3.00	2.21	10.36	10.31	8.28	0.91	13.10	4.85	47.90	6.84
KO46	2.07	1.75	1.54	6.59	6.05	4.94	0.80	13.00	3.51	34.99	5.00
KO47	0.43	0.83	0.25	1.21	0.72	0.66	0.17	6.70	0.69	10.15	1.45
KO48	0.47	1.11	1.04	4.29	4.78	7.45	0.97	10.20	2.56	29.19	4.17
KO49	0.45	1.50	1.20	4.29	4.57	6.62	1.10	11.70	2.64	29.93	4.28
KO50	0.34	0.83	0.12	0.53	0.46	0.50	0.20	9.20	0.51	11.34	1.62
KO51	0.56	2.92	1.39	4.59	4.99	6.05	1.27	13.00	2.91	31.85	4.55
KO52	0.23	1.83	0.94	3.02	3.69	6.80	1.23	13.20	2.22	29.11	4.16
KO53	1.99	3.75	1.63	8.55	5.80	3.91	1.00	11.60	3.56	34.49	4.93
KO54	0.20	1.97	0.91	2.96	3.54	6.96	1.29	11.50	2.12	27.36	3.91
KO55	0.55	1.06	1.21	4.40	4.63	6.53	1.14	12.00	2.76	30.46	4.35
KO56	1.41	2.19	0.79	2.09	2.34	1.38	0.45	9.30	1.64	17.76	2.54
KO57	0.78	1.47	0.45	1.22	1.32	0.80	0.35	8.00	1.04	12.93	1.85
KO58	0.96	2.14	1.25	3.26	4.88	4.80	0.79	11.30	2.61	27.25	3.89
KO59	1.45	2.19	1.06	3.00	4.12	2.19	0.66	9.40	2.21	21.88	3.13
Min	0.20	0.83	0.10	0.53	0.25	0.23	0.08	2.35	0.38	8.27	1.18
Max	2.73	5.78	2.21	10.95	10.31	10.05	1.42	24.30	4.85	47.90	6.84

Woollooware Bay

Samples No	CF Cr	CF Co	CF Ni	CF Cu	CF Zn	CF As	CF Sn	CF Pb	PLI	C _d	mC _d
WO1	0.61	0.70	0.29	0.86	0.92	0.20	7.90	0.60	0.74	12.08	1.51
WO2	1.33	0.82	0.81	1.88	2.65	0.52	9.00	1.43	1.53	18.43	2.30
WO3	2.94	2.32	2.06	4.98	7.49	1.03	9.50	3.80	3.44	34.12	4.27
WO4	0.43	1.40	1.19	3.11	4.51	0.88	12.40	4.45	2.17	28.37	3.55
WO5	0.97	0.98	0.59	1.38	1.65	0.33	7.30	0.93	1.14	14.14	1.77
WO6	0.26	1.26	0.50	0.73	0.21	0.10	7.80	0.18	0.50	11.05	1.38
WO7	0.18	0.62	0.18	0.55	0.18	0.07	6.70	0.17	0.33	8.66	1.08
WO8	2.94	3.02	2.07	4.86	6.71	1.10	8.40	3.30	3.41	32.40	4.05
WO9	1.75	1.00	1.19	3.29	4.07	0.68	9.40	2.29	2.12	23.67	2.96
WO10	0.98	0.68	0.47	1.65	1.58	0.30	8.60	0.86	1.07	15.11	1.89
WO11	1.96	1.26	1.38	6.37	5.35	0.72	14.40	2.67	2.75	34.12	4.27
WO12	0.73	0.60	0.37	2.14	1.26	0.26	10.50	0.63	0.96	16.48	2.06
WO13	1.64	1.36	1.10	3.00	3.85	0.65	7.70	1.96	2.02	21.25	2.66
WO14	1.93	1.42	1.56	3.90	5.10	1.01	8.90	2.78	2.60	26.60	3.32
WO15	0.44	0.90	0.70	2.03	2.84	0.65	9.50	2.48	1.49	19.54	2.44
WO16	0.20	0.78	0.09	0.34	0.22	0.07	6.40	0.18	0.31	8.28	1.04
WO17	0.21	0.98	0.37	0.56	0.22	0.06	6.25	0.14	0.39	8.81	1.10
WO18	1.80	2.18	1.12	2.52	3.20	0.66	8.80	1.67	2.07	21.94	2.74
WO19	1.29	2.18	0.80	2.03	2.10	0.47	10.40	1.13	1.65	20.42	2.55
WO20	2.50	2.50	1.73	4.05	5.00	0.75	4.90	2.62	2.60	24.05	3.01
WO21	2.34	3.14	1.75	4.02	5.26	1.12	11.90	2.71	3.16	32.25	4.03
WO22	0.67	3.04	0.66	1.98	1.79	0.49	3.00	1.21	1.31	12.83	1.60
WO23	1.76	1.74	1.79	3.84	5.16	1.15	9.00	3.08	2.77	27.51	3.44
WO24	0.80	0.76	0.62	1.56	2.05	0.40	10.40	1.36	1.27	17.95	2.24
WO25	0.17	0.66	0.10	0.31	0.25	0.07	7.80	0.15	0.30	9.51	1.19
WO26	0.27	0.70	0.14	0.44	0.39	0.10	4.90	0.22	0.39	7.17	0.90
WO27	1.13	0.74	0.72	1.70	2.20	0.35	8.30	1.23	1.30	16.37	2.05
WO28	1.81	4.02	1.02	2.45	2.33	0.52	9.20	1.35	2.02	22.70	2.84
WO29	1.77	3.34	1.63	3.59	4.65	1.13	10.30	2.61	2.89	29.03	3.63
WO30	1.67	3.00	1.37	2.75	3.69	0.96	8.10	1.89	2.38	23.43	2.93
WO31	1.52	1.92	0.90	2.25	3.02	0.66	9.40	1.40	1.88	21.07	2.63
WO32	1.64	3.10	1.14	2.45	2.32	0.66	7.40	1.29	1.95	20.00	2.50
WO33	2.27	4.00	1.50	2.76	3.30	0.74	7.30	1.81	2.43	23.69	2.96
WO34	1.52	0.76	1.42	3.04	4.10	0.86	8.10	2.46	2.08	22.27	2.78
WO35	1.68	1.78	1.17	2.56	3.10	0.64	11.10	1.56	2.05	23.59	2.95
WO36	1.65	2.44	1.16	2.48	3.13	0.61	10.70	1.62	2.10	23.80	2.97
WO37	1.67	1.60	1.07	2.36	2.97	0.50	10.80	1.57	1.90	22.54	2.82
WO38	1.12	1.32	0.56	1.27	1.50	0.30	9.70	0.84	1.18	16.61	2.08
WO39	0.84	1.26	0.63	1.41	1.75	0.33	10.40	0.97	1.24	17.59	2.20
WO40	1.27	2.00	0.94	2.05	2.30	0.44	10.80	1.22	1.68	21.02	2.63
WO41	1.04	1.56	0.88	1.63	1.60	0.35	7.80	0.91	1.32	15.77	1.97
WO42	0.67	1.78	0.75	1.53	1.38	0.32	8.40	0.88	1.20	15.70	1.96
WO43	1.90	3.92	1.24	2.79	3.18	0.69	6.70	1.86	2.27	22.28	2.78
WO44	0.61	0.70	0.25	0.67	1.35	0.52	4.40	0.89	0.82	9.39	1.17
WO45	1.38	1.62	0.88	2.25	2.83	0.50	6.20	1.47	1.66	17.14	2.14
Min	0.17	0.60	0.09	0.31	0.18	0.06	3.00	0.14	0.30	7.17	0.90
Max	2.94	4.02	2.07	6.37	7.49	1.15	14.40	4.45	3.44	34.12	4.27

Oyster Bay

Sample No	Cr CF	Ni CF	Cu CF	Zn CF	As CF	Sn CF	Pb CF	PLI	C _d	mC _d
OY1	1.00	1.10	3.42	3.76	0.94	11.40	4.05	2.50	25.66	3.67
OY2	0.35	0.95	3.23	3.51	1.22	12.30	5.22	2.25	26.78	3.83
OY3	1.72	1.31	3.70	4.78	0.80	14.00	3.85	2.90	30.16	4.31
OY4	0.58	0.64	1.32	1.35	0.26	10.35	0.91	1.07	15.42	2.20
OY5	0.64	1.04	3.26	3.88	0.97	9.10	4.31	2.28	23.20	3.31
OY6	0.30	0.98	3.03	3.52	1.25	15.20	6.62	2.34	30.89	4.41
OY7	1.40	1.02	2.46	3.20	0.53	10.30	1.94	1.98	20.86	2.98
OY8	2.39	1.63	4.13	4.72	0.68	12.10	2.65	2.88	28.31	4.04
OY9	1.43	1.07	3.04	3.39	0.54	11.00	2.14	2.13	22.62	3.23
OY10	2.65	2.10	5.40	6.82	0.94	12.80	4.12	3.74	34.83	4.98
OY11	1.33	1.40	4.33	5.18	0.89	11.10	4.20	2.90	28.42	4.06
OY12	0.29	0.97	3.07	3.50	1.31	12.80	7.31	2.32	29.24	4.18
OY13	0.73	1.37	3.87	4.77	1.01	11.90	5.44	2.76	29.09	4.16
OY14	1.01	0.58	1.56	1.70	0.29	7.80	1.01	1.20	13.95	1.99
OY15	0.58	1.15	3.29	3.44	1.16	12.10	6.06	2.52	27.78	3.97
OY16	1.56	1.77	4.22	5.97	0.88	14.50	4.92	3.31	33.82	4.83
OY17	2.49	2.14	5.33	7.08	0.81	14.70	4.50	3.77	37.05	5.29
OY18	2.16	1.93	4.96	6.58	0.79	13.50	4.53	3.51	34.43	4.92
OY19	2.82	2.28	5.59	7.94	0.91	13.90	4.50	4.00	37.94	5.42
OY20	0.41	1.21	3.52	4.59	1.32	12.50	8.47	2.72	32.01	4.57
OY21	0.32	0.87	2.67	3.74	0.99	10.20	6.17	2.08	24.95	3.56
OY22	0.90	1.39	4.16	5.73	1.06	14.00	6.99	3.15	34.23	4.89
OY23	0.27	0.94	3.03	3.81	1.18	11.60	7.88	2.27	28.73	4.10
OY24	0.43	1.12	3.71	4.69	1.30	14.30	7.83	2.76	33.38	4.77
OY25	0.53	1.10	3.58	4.74	1.30	11.90	7.35	2.73	30.51	4.36
OY26	0.64	1.45	4.12	5.57	1.16	12.70	6.75	2.99	32.40	4.63
OY27	0.45	1.13	3.27	4.49	0.97	12.40	5.15	2.40	27.87	3.98
OY28	0.59	1.17	3.56	4.77	0.87	9.70	5.27	2.45	25.94	3.71
OY29	2.71	2.23	5.67	7.72	0.97	10.80	4.57	3.85	34.66	4.95
OY30	1.10	1.62	4.51	6.23	0.96	11.50	5.85	3.17	31.77	4.54
OY31	2.26	1.56	3.89	5.71	0.75	10.00	3.18	2.93	27.36	3.91
OY32	2.03	1.36	3.15	4.25	0.57	10.45	2.51	2.46	24.32	3.47
OY33	0.74	1.40	4.12	5.71	1.08	11.50	6.41	2.95	30.96	4.42
OY34	1.73	1.41	2.74	3.38	0.42	9.85	1.96	2.11	21.49	3.07
OY35	1.60	1.05	3.10	3.85	0.39	10.50	2.22	2.10	22.70	3.24
OY36	1.05	0.88	1.93	2.20	0.30	10.15	1.36	1.49	17.87	2.55
OY37	0.79	0.59	1.34	1.34	0.24	7.90	0.85	1.04	13.03	1.86
OY38	0.53	0.56	1.07	1.03	0.10	8.75	0.60	0.77	12.64	1.81
OY39	1.18	0.86	1.85	2.06	0.24	9.15	1.37	1.42	16.71	2.39
OY40	0.92	0.75	1.73	1.75	0.18	8.65	1.20	1.21	15.18	2.17
OY41	2.19	1.50	3.75	4.49	0.52	11.50	2.72	2.64	26.67	3.81
OY42	2.70	2.17	6.16	8.68	0.88	11.40	4.77	3.95	36.77	5.25
OY43	2.85	2.21	5.82	7.94	0.93	12.70	4.68	3.99	37.14	5.31
OY44	3.32	2.57	6.41	8.19	0.98	9.10	5.05	4.12	35.62	5.09
OY45	2.17	1.58	3.45	4.73	0.57	10.55	2.79	2.66	25.84	3.69
OY46	2.53	1.79	5.38	6.31	0.75	12.00	3.71	3.39	32.47	4.64
OY47	2.58	1.91	5.97	8.11	0.75	11.70	4.58	3.71	35.60	5.09
OY48	2.54	1.83	4.48	5.75	0.66	11.00	3.58	3.15	29.85	4.26
OY49	2.21	2.08	3.51	4.56	0.51	9.65	2.69	2.67	25.20	3.60
OY50	2.63	1.90	4.02	5.18	0.76	8.10	2.83	2.92	25.44	3.63
OY51	1.09	1.69	4.44	6.38	0.94	11.60	6.25	3.21	32.39	4.63
OY52	3.33	2.58	6.55	8.16	0.73	12.90	4.81	4.14	39.05	5.58
OY53	2.17	1.99	3.53	4.58	0.34	9.65	2.15	2.43	24.41	3.49
OY54	3.79	3.08	6.89	9.19	0.99	11.80	4.67	4.55	40.41	5.77
OY55	1.73	1.73	2.57	2.80	0.26	10.20	1.81	1.94	21.10	3.01
Min	0.27	0.56	1.07	1.03	0.10	7.80	0.60	0.69	11.43	1.63
Max	3.79	3.08	6.89	9.19	1.32	15.20	8.47	5.35	47.93	6.85

Woronora River

Samples No	CF Ni	CF Cu	CF Zn	CF As	CF Pb	PLI	C _d	mC _d
WOR1	0.6	1.5	1.2	0.2	0.7	0.7	4.1	0.83
WOR2	0.3	0.9	0.8	0.2	0.5	0.4	2.6	0.51
WOR3	0.7	1.6	1.4	0.3	0.9	0.9	4.9	0.99
WOR4	0.3	1.0	1.1	0.2	0.6	0.6	3.4	0.67
WOR5	0.7	1.5	1.3	0.2	0.8	0.7	4.5	0.89
WOR6	0.2	0.5	0.5	0.1	0.3	0.3	1.6	0.31
WOR7	0.6	1.2	1.1	0.2	0.7	0.7	3.8	0.77
WOR8	1.4	0.8	0.7	0.1	0.3	0.5	3.3	0.67
WOR9	0.9	2.5	2.7	0.5	1.6	1.3	8.1	1.63
WOR10	1.3	3.6	3.5	0.6	2.3	1.8	11.3	2.25
WOR11	0.7	1.6	1.4	0.3	0.9	0.8	4.9	0.97
WOR12	0.2	0.7	0.4	0.1	0.3	0.3	1.6	0.32
WOR13	0.2	0.6	0.3	0.1	0.3	0.2	1.5	0.30
WOR14	1.7	4.5	4.9	0.8	3.0	2.4	14.9	2.98
WOR15	0.1	0.6	0.2	0.1	0.2	0.2	1.2	0.23
WOR16	0.2	0.8	0.5	0.1	0.3	0.3	2.0	0.39
WOR17	0.2	0.5	0.5	0.1	0.4	0.3	1.7	0.34
WOR18	0.4	1.3	1.1	0.2	0.7	0.6	3.6	0.72
WOR19	0.1	0.4	0.3	0.1	0.2	0.2	1.1	0.21
WOR20	0.9	2.0	2.0	0.4	1.2	1.1	6.5	1.30
WOR21	1.5	2.7	3.1	0.5	1.7	1.6	9.5	1.90
WOR22	0.7	2.2	2.6	0.4	1.6	1.2	7.5	1.49
WOR23	0.1	0.4	0.3	0.1	0.2	0.2	1.2	0.23
WOR24	0.1	0.3	0.3	0.1	0.3	0.2	1.2	0.23
WOR25	0.4	0.8	0.6	0.1	0.3	0.4	2.3	0.46
WOR26	0.1	0.5	0.6	0.1	0.4	0.3	1.7	0.34
WOR27	1.8	5.7	6.1	0.9	3.7	2.9	18.2	3.65
WOR28	1.4	4.2	4.5	0.8	2.7	2.3	13.7	2.74
WOR29	1.5	4.2	4.4	1.0	2.6	2.3	13.7	2.74
WOR30	1.6	5.1	5.1	0.7	3.1	2.5	15.5	3.10
WOR31	1.5	4.2	4.7	0.8	2.5	2.3	13.7	2.74
WOR32	0.1	0.6	0.3	0.1	0.2	0.2	1.3	0.26
WOR33	0.6	1.2	1.1	0.2	0.7	0.7	3.9	0.78
WOR34	0.6	0.8	0.5	0.1	0.3	0.4	2.3	0.46
WOR35	0.5	0.9	0.4	0.1	0.2	0.3	2.2	0.44
WOR36	0.9	1.7	2.1	0.3	1.7	1.1	6.7	1.34
WOR37	0.8	2.4	2.6	0.3	1.4	1.1	7.5	1.50
WOR38	1.9	6.0	7.8	0.9	4.5	3.2	21.1	4.21
WOR39	0.1	0.5	0.3	0.0	0.2	0.2	1.1	0.22
WOR40	0.8	2.1	2.1	0.3	1.3	1.0	6.6	1.31
WOR41	0.8	1.2	1.0	0.2	0.8	0.7	4.0	0.80
WOR42	1.2	2.9	3.1	0.3	1.9	1.5	9.4	1.87
WOR43	1.9	6.1	7.1	0.7	4.3	3.0	20.0	4.01
WOR44	1.0	2.5	2.6	0.3	1.4	1.2	7.8	1.56
WOR45	1.8	6.0	7.3	0.7	4.2	3.0	20.1	4.02
WOR46	0.1	0.3	0.2	0.1	0.2	0.1	0.9	0.18
WOR47	0.7	2.0	2.1	0.4	1.2	1.0	6.3	1.27
Min	0.1	0.3	0.2	0.0	0.2	0.1	0.9	0.18
Max	1.9	6.1	7.8	1.0	4.5	3.2	21.1	4.21

Georges River and Salt Pan Creek

Sample No	CF Cr	CF Co	CF Ni	CF Cu	CF Zn	CF As	CF Sn	CF Pb	PLI	C _d	mC _d
GE1	0.27	1.14	1.25	4.29	5.60	1.01	10.90	5.53	2.21	29.99	3.75
GE2	2.03	1.35	1.96	6.24	9.34	0.64	8.30	4.24	3.03	34.10	4.26
GE3	1.92	1.82	2.11	6.58	9.10	0.61	11.00	3.74	3.20	36.86	4.61
GE4	0.43	0.33	0.27	0.93	0.87	0.14	7.90	0.46	0.59	11.32	1.41
GE5	0.62	0.08	0.36	1.31	1.26	0.14	8.00	0.60	0.61	12.37	1.55
GE6	0.26	0.33	0.10	0.35	0.36	0.09	7.70	0.21	0.34	9.41	1.18
GE7	0.74	0.33	0.69	1.41	1.62	0.21	5.00	0.85	0.87	10.83	1.35
GE8	1.11	0.33	0.84	2.09	2.50	0.20	7.60	1.18	1.14	15.85	1.98
GE9	1.19	0.33	0.67	2.02	1.96	0.37	9.20	1.40	1.22	17.15	2.14
GE10	1.41	0.88	1.16	3.38	4.23	0.50	10.50	1.91	1.95	23.97	3.00
GE11	0.54	0.33	0.13	0.36	0.35	0.10	9.90	0.24	0.40	11.95	1.49
GE12	0.87	1.35	1.27	4.64	5.99	0.96	12.90	5.62	2.71	33.60	4.20
GE13	0.87	0.95	1.10	3.59	5.37	0.53	10.70	3.03	2.04	26.14	3.27
GE14	1.67	1.02	1.44	3.62	4.39	0.43	10.90	2.44	2.14	25.90	3.24
GE15	0.49	0.33	0.25	0.64	0.70	0.08	5.20	0.43	0.48	8.11	1.01
GE16	0.26	0.43	0.92	3.52	4.37	0.74	12.70	5.13	1.72	28.07	3.51
GE17	1.57	0.66	1.42	4.36	5.87	0.44	8.20	2.28	2.05	24.81	3.10
GE18	0.96	0.66	1.25	2.23	2.10	0.41	9.60	0.98	1.40	18.19	2.27
GE19	0.16	0.33	0.13	0.34	0.42	0.09	6.40	0.28	0.34	8.16	1.02
GE20	0.33	0.33	0.17	0.48	0.66	0.15	7.00	0.29	0.46	9.42	1.18
GE21	0.27	0.33	0.22	0.60	0.70	0.11	7.80	0.36	0.47	10.39	1.30
GE22	0.18	0.33	0.17	0.55	0.45	0.10	5.90	0.25	0.37	7.93	0.99
GE23	1.16	0.33	1.08	3.62	5.04	0.49	13.00	3.24	1.88	27.96	3.50
GE24	1.11	0.33	0.69	1.81	2.34	0.17	10.60	1.09	1.10	18.14	2.27
GE25	0.76	0.43	1.28	4.35	5.56	0.68	12.80	4.20	2.10	30.07	3.76
GE26	1.30	1.52	1.87	6.53	10.26	0.66	10.50	4.83	3.09	37.47	4.68
GE27	1.59	0.41	1.13	3.12	3.70	0.58	10.50	1.97	1.79	23.02	2.88
GE28	1.69	0.91	1.12	3.54	3.99	0.43	9.50	2.07	1.95	23.25	2.91
GE29	0.78	0.60	1.12	3.51	4.00	0.77	13.00	3.12	1.97	26.90	3.36
GE30	2.03	1.21	1.83	4.52	5.51	0.85	9.00	3.12	2.68	28.06	3.51
GE31	1.29	0.86	0.81	2.19	2.55	0.25	9.10	1.25	1.40	18.31	2.29
GE32	0.11	0.37	0.11	0.29	0.27	0.10	11.10	0.16	0.30	12.51	1.56
GE33	0.64	1.53	1.37	4.49	6.52	0.55	10.80	4.51	2.39	30.42	3.80
GE34	0.94	1.17	1.58	4.47	5.82	0.78	11.00	4.11	2.52	29.88	3.73
GE35	0.36	0.46	0.85	3.78	4.34	0.87	13.70	6.03	1.89	30.39	3.80
GE36	0.37	0.67	1.12	4.93	5.39	0.98	14.70	6.56	2.27	34.73	4.34
GE37	2.11	0.95	2.03	10.69	12.21	0.77	15.40	7.35	3.83	51.52	6.44
GE38	0.71	0.71	1.43	9.14	10.33	1.35	15.10	11.44	3.35	50.21	6.28
GE39	0.89	0.74	1.40	8.10	8.32	0.96	14.70	8.49	3.05	43.59	5.45
GE40	0.16	0.66	0.16	0.46	0.31	0.18	7.00	0.17	0.39	9.10	1.14
GE41	0.63	0.33	0.43	1.13	1.37	0.24	9.00	0.82	0.84	13.95	1.74
GE42	0.15	0.34	0.34	0.93	0.55	0.19	8.20	0.81	0.57	11.50	1.44
GE43	0.21	0.33	0.22	0.48	0.64	0.22	7.25	0.37	0.48	9.72	1.21
GE44	1.50	0.33	0.78	1.88	2.29	0.50	8.70	1.25	1.31	17.21	2.15
GE45	0.74	0.33	1.20	1.23	1.30	0.41	7.75	0.62	0.99	13.56	1.70
GE46	0.31	0.42	0.22	0.40	0.48	0.18	10.40	0.20	0.46	12.62	1.58
GE47	0.19	0.37	0.17	0.41	0.46	0.19	5.90	0.29	0.41	7.98	1.00
GE48	0.19	0.33	0.17	0.64	0.41	0.16	6.75	0.28	0.41	8.93	1.12
GE49	1.95	1.12	2.05	13.46	17.11	0.67	16.70	7.39	4.13	60.46	7.56
GE50	2.57	1.34	2.37	15.20	15.63	0.86	17.50	8.31	4.71	63.77	7.97
GE51	1.88	1.71	2.09	11.99	18.78	0.67	17.40	7.85	4.39	62.36	7.80
GE52	1.88	1.43	1.96	11.80	14.00	0.56	15.70	6.45	3.86	53.78	6.72
GE53	2.45	1.27	2.10	11.81	12.12	0.76	12.50	5.91	3.89	48.92	6.12
GE54	1.03	0.92	1.32	8.55	10.56	0.85	15.70	9.03	3.29	47.97	6.00
Min	0.11	0.08	0.10	0.29	0.27	0.08	5.00	0.16	0.30	7.93	0.99
Max	2.57	1.82	2.37	15.20	18.78	1.35	17.50	11.44	4.71	63.77	7.97

Oatley Bay

Sample No	CF Cr	CF Cu	CF Zn	CF As	CF Pb	PLI	C _d	mC _d
OBu1	0.76	0.73	0.90	0.82	0.60	0.75	3.80	0.76
OBu2	0.90	2.70	2.78	0.75	1.99	1.59	9.12	1.82
OBu3	1.18	3.01	2.82	0.58	2.24	1.67	9.83	1.97
OBu4	1.83	10.19	9.03	1.13	6.25	4.12	28.43	5.69
OBu5	0.81	2.96	3.05	1.25	2.25	1.83	10.31	2.06
OBu6	1.50	4.42	4.48	1.27	3.23	2.61	14.90	2.98
OBu7	1.00	8.27	6.67	1.47	7.19	3.57	24.61	4.92
OBu8	0.65	5.86	5.85	1.85	7.98	3.19	22.19	4.44
OBu9	0.85	5.86	6.51	1.52	7.87	3.29	22.60	4.52
OBu10	2.53	3.08	3.37	1.26	4.31	2.70	14.55	2.91
OBu11	1.29	3.68	4.38	1.16	3.13	2.37	13.64	2.73
OBu12	0.24	3.87	4.55	2.03	10.04	2.43	20.73	4.15
OBu13	0.76	6.71	7.66	1.70	9.23	3.61	26.06	5.21
OBu14	1.31	7.74	8.97	1.35	6.74	3.83	26.10	5.22
OBu15	1.98	2.35	2.27	0.31	2.08	1.47	8.99	1.80
OBu16	3.15	2.25	2.75	1.19	2.59	2.27	11.94	2.39
OBu17	0.69	6.18	6.52	1.50	7.74	3.18	22.62	4.52
OBu18	1.03	3.67	3.92	0.65	4.22	2.10	13.49	2.70
OBu19	1.44	9.16	7.70	1.45	8.03	4.12	27.78	5.56
OBu20	0.79	6.82	6.79	1.47	6.44	3.21	22.30	4.46
OBu21	1.01	7.07	7.70	1.48	7.16	3.58	24.42	4.88
OBu22	1.50	8.79	9.09	1.32	7.26	4.09	27.96	5.59
OBu23	1.93	9.27	10.81	1.45	9.32	4.82	32.78	6.56
OBu24	3.87	6.24	8.06	0.90	5.93	4.02	25.01	5.00
OBu25	1.03	2.90	2.74	0.65	1.91	1.59	9.23	1.85
OBu26	0.74	5.35	5.64	1.68	7.41	3.08	20.82	4.16
OBu27	0.99	2.92	2.81	0.70	2.06	1.64	9.49	1.90
OBu28	1.11	5.55	6.03	1.14	5.47	2.98	19.31	3.86
OBu29	0.33	5.53	5.07	1.57	6.46	2.48	18.96	3.79
OBu30	1.17	3.74	4.07	1.12	3.29	2.31	13.40	2.68
OBu31	0.48	6.21	5.44	1.73	7.46	2.91	21.32	4.26
OBu32	1.34	1.91	1.50	0.31	1.54	1.13	6.61	1.32
OBu33	1.03	1.24	0.93	0.72	0.63	0.89	4.56	0.91
OBu34	0.90	2.23	2.20	1.10	2.68	1.67	9.12	1.82
OBu35	0.46	4.04	4.49	1.50	6.53	2.41	17.02	3.40
OBu36	1.50	2.02	2.15	0.59	1.78	1.47	8.06	1.61
OBu37	0.63	3.32	3.97	1.42	4.98	2.26	14.31	2.86
OBu38	1.04	1.98	2.33	0.74	1.73	1.44	7.83	1.57
OBu39	0.60	3.20	3.33	1.37	5.17	2.14	13.67	2.73
OBu40	0.99	1.63	1.72	1.12	1.76	1.40	7.22	1.44
OBu41	0.39	3.86	4.06	1.48	5.83	2.21	15.62	3.12
OBu42	0.77	2.58	2.15	0.58	1.53	1.31	7.61	1.52
OBu43	1.31	3.41	4.15	1.52	5.79	2.77	16.18	3.24
OBu44	0.91	2.32	2.15	0.58	1.47	1.31	7.42	1.48
OBu45	0.79	3.64	3.65	1.02	4.00	2.12	13.10	2.62
OBu46	0.57	3.66	4.13	1.28	4.56	2.19	14.20	2.84
OBu47	1.24	2.85	3.68	0.97	4.17	2.21	12.91	2.58
OBu48	2.45	3.04	2.91	1.26	4.06	2.56	13.73	2.75
OBu49	0.57	3.40	4.19	1.28	4.90	2.19	14.33	2.87
OBu50	0.88	3.09	4.07	1.17	4.29	2.23	13.50	2.70
OBu51	1.37	2.40	1.84	0.30	1.14	1.16	7.05	1.41
OBu52	2.06	2.08	2.33	1.05	3.23	2.02	10.75	2.15
OBu53	2.12	3.00	3.57	1.52	5.62	2.87	15.84	3.17
OBu54	0.64	3.03	3.15	1.20	3.90	1.96	11.93	2.39
OBu55	1.35	3.38	3.43	0.96	3.62	2.23	12.75	2.55
OBu56	1.87	3.25	3.16	1.34	3.99	2.52	13.60	2.72
OBu57	1.07	3.14	3.83	1.07	4.34	2.27	13.45	2.69
OBu58	0.84	4.14	4.15	1.67	6.52	2.75	17.32	3.46
OBu59	0.88	3.04	3.73	1.31	5.10	2.32	14.06	2.81
OBu60	0.93	3.95	3.70	1.61	7.02	2.73	17.20	3.44
OBu61	0.87	4.20	4.57	1.42	6.18	2.71	17.23	3.45
OBu62	0.54	3.60	4.74	1.43	6.24	2.42	16.56	3.31
OBu63	1.28	3.40	3.56	1.61	5.55	2.68	15.39	3.08
OBu64	1.02	2.43	2.57	0.54	1.79	1.44	8.34	1.67
OBu65	0.79	1.85	1.56	1.08	1.61	1.31	6.88	1.38
Min	0.24	0.73	0.90	0.30	0.60	0.75	3.80	0.76
Max	3.87	10.19	10.81	2.03	10.04	4.82	32.78	6.56

B- Port Hacking / Gunnamatta Bay

Samples No	CF Cr	CF Ni	CF Cu	CF Zn	CF As	CF Pb	PLI	C _d	mC _d
GU1	0.25	0.24	0.55	0.28	0.10	0.21	0.24	1.63	0.27
GU2	0.17	0.12	0.62	0.35	0.20	0.28	0.25	1.73	0.29
GU3	0.30	0.18	0.46	0.22	0.11	0.18	0.22	1.45	0.24
GU4	0.55	0.47	0.88	0.33	0.16	0.23	0.38	2.63	0.44
GU5	0.19	0.23	0.53	0.18	0.08	0.09	0.17	1.29	0.22
GU6	0.21	0.18	0.32	0.18	0.08	0.10	0.16	1.08	0.18
GU7	0.23	0.16	0.32	0.13	0.06	0.06	0.13	0.97	0.16
GU8	0.31	0.13	0.60	0.30	0.07	0.31	0.24	1.73	0.29
GU9	0.23	0.19	0.42	0.21	0.07	0.14	0.18	1.26	0.21
GU10	0.34	0.14	1.06	0.40	0.22	0.51	0.36	2.67	0.44
GU11	0.70	0.51	4.34	1.81	0.21	1.05	0.92	8.62	1.44
GU12	0.17	0.27	0.43	0.16	0.10	0.07	0.17	1.20	0.20
GU13	0.29	0.19	0.38	0.24	0.07	0.22	0.21	1.40	0.23
GU14	0.32	0.03	0.85	0.41	0.11	0.40	0.23	2.12	0.35
GU15	1.86	0.88	8.22	3.29	0.39	2.47	1.87	17.11	2.85
GU16	1.03	0.94	7.36	3.27	0.42	2.76	1.73	15.77	2.63
GU17	1.02	0.80	6.88	2.95	0.41	2.46	1.60	14.52	2.42
GU18	1.78	1.24	10.55	4.50	0.59	3.59	2.46	22.26	3.71
GU19	1.53	0.57	4.57	1.93	0.34	1.58	1.27	10.52	1.75
GU20	0.82	0.28	6.70	1.65	0.23	1.28	0.95	10.96	1.83
GU21	1.13	1.28	12.90	5.51	0.59	4.59	2.56	25.99	4.33
GU22	0.29	0.08	0.73	0.32	0.07	0.43	0.23	1.92	0.32
GU23	0.18	0.21	0.57	0.26	0.06	0.22	0.21	1.51	0.25
GU24	0.26	0.16	0.55	0.37	0.13	0.28	0.26	1.76	0.29
GU25	2.93	1.57	16.36	5.88	0.57	4.78	3.26	32.10	5.35
GU26	0.25	0.21	0.99	0.30	0.16	0.38	0.31	2.29	0.38
GU27	2.26	1.14	9.86	4.00	0.55	2.95	2.35	20.76	3.46
GU28	0.50	0.24	1.31	0.60	0.15	0.50	0.44	3.30	0.55
GU29	0.31	0.25	1.37	0.41	0.11	0.42	0.36	2.88	0.48
GU30	2.91	0.89	8.49	3.21	0.42	2.37	2.03	18.29	3.05
GU31	0.61	0.57	4.93	0.96	0.26	1.40	0.92	8.73	1.46
GU32	0.43	0.20	3.48	1.57	0.13	0.69	0.58	6.49	1.08
GU33	0.39	0.20	3.48	0.63	0.13	0.69	0.49	5.50	0.92
GU34	0.24	0.17	1.05	0.25	0.06	0.34	0.24	2.11	0.35
GU35	0.24	0.18	2.34	1.08	0.05	0.59	0.39	4.49	0.75
GU36	0.93	0.35	6.63	1.95	0.20	1.90	1.08	11.95	1.99
GU37	0.27	0.31	1.60	0.29	0.15	0.29	0.35	2.91	0.49
GU38	0.43	0.26	2.37	0.49	0.12	1.00	0.50	4.67	0.78
GU39	2.74	1.06	11.15	4.37	0.53	3.98	2.58	23.83	3.97
GU40	2.27	0.85	8.60	3.60	0.46	2.97	2.08	18.75	3.13
GU41	0.11	0.15	0.69	0.27	0.11	0.27	0.21	1.59	0.27
GU42	0.44	0.19	1.92	0.60	0.14	0.79	0.47	4.08	0.68
GU43	0.23	0.23	1.48	0.36	0.06	0.33	0.28	2.70	0.45
GU44	2.13	0.56	4.99	2.01	0.32	2.05	1.41	12.05	2.01
GU45	1.85	1.28	14.52	4.34	0.54	4.35	2.65	26.88	4.48
GU46	0.28	0.25	1.56	0.53	0.13	0.73	0.42	3.48	0.58
GU47	0.38	0.21	2.80	0.81	0.07	0.92	0.48	5.19	0.86
GU48	0.13	0.17	0.69	0.16	0.09	0.16	0.18	1.39	0.23
GU49	0.39	0.21	1.12	0.31	0.10	0.26	0.30	2.38	0.40
GU50	0.41	0.30	3.38	0.92	0.12	1.06	0.60	6.17	1.03
GU51	0.54	0.34	1.60	0.54	0.26	0.79	0.56	4.08	0.68
GU52	0.65	0.36	3.84	1.37	0.23	1.82	0.89	8.27	1.38
GU53	0.86	0.62	3.60	1.82	0.31	1.87	1.13	9.09	1.51
GU54	1.75	0.56	4.40	1.93	0.21	1.94	1.23	10.80	1.80
GU55	3.19	1.13	43.77	9.83	0.40	8.68	4.18	66.99	11.16
GU56	0.77	0.64	7.84	2.43	0.17	2.08	1.23	13.93	2.32
GU57	0.73	0.62	3.93	1.63	0.16	2.02	0.99	9.09	1.51
GU58	0.50	0.32	5.27	1.74	0.27	2.07	0.97	10.17	1.69
GU59	0.47	0.21	1.75	0.62	0.29	0.79	0.54	4.12	0.69
Min	0.11	0.03	0.32	0.13	0.05	0.06	0.13	0.97	0.16
Max	3.19	1.57	43.77	9.83	0.59	8.68	4.18	66.99	11.16

GyMEA Bay

Samples No	CF Cr	CF Ni	CF Cu	CF Zn	CF As	CF Sn	CF Pb	PIL	C _d	mC _d
GY1	1.87	1.61	5.84	4.41	0.54	10.60	4.07	2.92	28.95	4.14
GY2	2.68	1.83	6.64	4.99	0.70	10.80	4.33	3.41	31.97	4.57
GY3	0.34	0.38	0.63	0.34	0.18	6.10	0.41	0.53	8.38	1.20
GY4	0.54	0.23	0.58	0.70	0.36	4.15	0.55	0.63	7.10	1.01
GY5	2.80	1.98	6.68	5.34	0.68	9.80	4.78	3.49	32.06	4.58
GY6	0.34	0.34	0.84	0.45	0.37	6.05	0.43	0.63	8.81	1.26
GY7	0.23	0.23	0.71	0.42	0.18	6.90	0.49	0.52	9.16	1.31
GY8	2.48	1.74	5.71	4.38	0.59	6.90	4.01	2.91	25.81	3.69
GY9	0.94	1.44	5.32	4.00	0.66	12.60	4.83	2.74	29.78	4.25
GY10	0.40	0.27	0.88	0.39	0.24	7.40	0.64	0.64	10.22	1.46
GY11	0.69	0.44	1.14	0.94	0.41	5.25	1.03	0.96	9.90	1.41
GY12	2.51	1.90	6.01	4.90	0.63	12.70	4.51	3.38	33.16	4.74
GY13	1.88	1.49	5.12	4.28	0.54	8.10	4.10	2.72	25.52	3.65
GY14	0.17	0.39	0.53	0.29	0.17	3.90	0.21	0.39	5.66	0.81
GY15	0.30	0.29	0.46	0.25	0.05	6.30	0.21	0.36	7.88	1.13
GY16	0.63	0.38	0.62	0.39	0.06	8.50	0.36	0.53	10.94	1.56
GY17	0.33	0.32	1.09	0.54	0.07	7.30	0.44	0.54	10.09	1.44
GY18	0.31	0.25	0.49	0.33	0.06	8.30	0.24	0.40	9.98	1.43
GY19	1.76	1.09	2.89	1.76	0.44	9.55	2.38	1.92	19.86	2.84
GY20	0.33	0.26	0.43	0.32	0.13	11.70	0.37	0.49	13.54	1.93
GY21	0.56	0.27	0.93	0.47	0.27	6.30	0.72	0.70	9.53	1.36
GY22	0.33	0.24	0.70	0.85	0.33	8.80	0.97	0.75	12.21	1.74
GY23	0.64	0.13	1.14	0.68	0.43	0.60	0.77	0.54	4.39	0.63
GY24	0.53	0.45	0.92	0.96	0.07	11.60	0.39	0.67	14.92	2.13
GY25	0.35	0.25	0.65	0.97	0.09	10.25	0.42	0.58	12.98	1.85
GY26	0.55	0.16	0.87	0.51	0.13	7.80	0.41	0.55	10.43	1.49
GY27	0.33	0.34	0.76	0.49	0.05	9.30	0.47	0.52	11.74	1.68
GY28	0.99	0.46	1.84	1.78	0.30	10.90	1.57	1.33	17.83	2.55
GY29	0.41	0.27	1.13	1.97	0.10	20.85	1.06	0.92	25.79	3.68
GY30	0.53	0.42	2.35	0.68	0.10	21.28	0.48	0.87	25.83	3.69
GY31	0.53	0.41	0.92	0.44	0.10	5.05	0.25	0.52	7.70	1.10
GY32	0.30	0.20	0.59	0.49	0.15	9.45	0.29	0.49	11.48	1.64
Min	0.17	0.13	0.43	0.25	0.05	0.60	0.21	0.36	4.39	0.63
Max	2.80	1.98	6.68	5.34	0.70	21.28	4.83	3.49	33.16	4.74

Mansion Bay and Hacking River

Samples No	CF Cu	CF Zn	CF Pb	PLI	C _d	mC _d
MA1	0.22	0.15	0.06	0.13	0.43	0.14
MA2	0.58	0.25	0.18	0.30	1.01	0.34
MA3	0.43	0.15	0.07	0.16	0.65	0.22
MA4	0.32	0.28	0.21	0.27	0.81	0.27
MA5	0.46	0.17	0.12	0.21	0.75	0.25
MA6	0.53	0.38	0.26	0.37	1.16	0.39
MA7	0.39	0.20	0.10	0.20	0.69	0.23
MA8	0.42	0.26	0.18	0.27	0.86	0.29
MA9	0.34	0.24	0.14	0.22	0.71	0.24
MA10	0.75	0.37	0.27	0.42	1.39	0.46
MA11	1.89	1.33	1.02	1.37	4.24	1.41
MA12	0.22	0.17	0.07	0.14	0.46	0.15
MA13	0.64	0.21	0.19	0.29	1.04	0.35
MA14	0.54	0.19	0.08	0.20	0.81	0.27
MA15	0.36	0.22	0.18	0.24	0.77	0.26
MA16	0.89	0.68	0.47	0.66	2.04	0.68
MA17	0.51	0.34	0.23	0.34	1.07	0.36
MA18	0.40	0.14	0.07	0.16	0.61	0.20
MA19	0.56	0.36	0.21	0.34	1.12	0.37
MA20	0.56	0.47	0.38	0.47	1.42	0.47
MA21	5.27	3.54	2.84	3.76	11.66	3.89
MA22	5.77	4.22	3.63	4.46	13.62	4.54
MA23	0.93	0.36	0.41	0.52	1.71	0.57
MA24	0.40	0.24	0.20	0.27	0.83	0.28
MA25	5.40	3.85	3.23	4.06	12.48	4.16
MA26	1.14	0.50	0.36	0.59	2.00	0.67
MA27	0.55	0.25	0.24	0.32	1.04	0.35
MA28	0.78	0.33	0.21	0.38	1.32	0.44
Min	0.22	0.14	0.06	0.13	0.43	0.14
Max	5.77	4.22	3.63	4.46	13.62	4.54

Yowie Bay

Samples No	CF Ni	CF Cu	CF Zn	CF As	CF Pb	PLI	C _d	mC _d
YO1	0.23	1.79	1.32	0.31	1.72	0.78	5.38	1.08
YO2	0.90	5.01	3.30	0.26	2.96	1.63	12.42	2.48
YO3	0.38	2.16	1.90	0.27	1.78	0.94	6.49	1.30
YO4	0.87	6.00	4.32	0.49	4.89	2.22	16.57	3.31
YO5	1.17	6.62	4.71	0.52	6.18	2.59	19.20	3.84
YO6	0.26	1.37	1.00	0.18	1.21	0.60	4.03	0.81
YO7	0.54	1.49	0.55	0.21	0.62	0.57	3.41	0.68
YO8	1.58	11.80	7.24	0.75	7.54	3.77	28.92	5.78
YO9	0.56	1.95	1.18	0.37	1.61	0.95	5.67	1.13
YO10	0.56	1.85	0.92	0.41	1.35	0.88	5.08	1.02
YO11	1.52	8.68	5.46	0.87	5.48	3.21	22.00	4.40
YO12	0.14	0.65	0.36	0.10	0.39	0.27	1.65	0.33
YO13	0.13	0.51	0.39	0.08	0.29	0.23	1.40	0.28
YO14	0.18	0.97	1.05	0.22	1.02	0.53	3.43	0.69
YO15	0.19	0.49	0.38	0.13	0.42	0.29	1.62	0.32
YO16	0.73	0.81	0.40	0.13	0.27	0.39	2.35	0.47
YO17	1.57	6.52	4.58	0.53	4.38	2.55	17.57	3.51
YO18	1.39	4.08	3.17	0.62	2.71	1.97	11.95	2.39
YO19	1.07	5.32	3.45	0.56	3.70	2.10	14.10	2.82
YO20	1.25	6.66	4.54	0.63	6.12	2.71	19.20	3.84
YO21	1.29	6.59	4.66	0.59	4.01	2.49	17.15	3.43
Mean	0.79	3.87	2.61	0.39	2.79	1.51	10.46	2.09
Min	0.13	0.49	0.36	0.08	0.27	0.23	1.40	0.28
Max	1.58	11.80	7.24	0.87	7.54	3.77	28.92	5.78

South West Arm

Samples No	CF Cu	CF Zn	CF Pb	PLI	C _d	mC _d
SWA1	1.44	0.80	0.90	1.01	3.14	1.05
SWA2	0.58	0.15	0.11	0.21	0.85	0.28
SWA3	0.54	0.17	0.15	0.24	0.85	0.28
SWA4	0.74	0.17	0.10	0.23	1.01	0.34
SWA5	0.47	0.11	0.02	0.10	0.60	0.20
SWA6	0.30	0.26	0.17	0.23	0.72	0.24
SWA7	0.71	0.11	0.05	0.16	0.87	0.29
SWA8	0.41	0.09	0.04	0.11	0.53	0.18
SWA9	0.59	0.14	0.08	0.19	0.81	0.27
SWA10	0.39	0.07	0.03	0.09	0.48	0.16
SWA11	0.47	0.07	0.03	0.10	0.58	0.19
SWA12	0.42	0.07	0.01	0.07	0.50	0.17
SWA13	0.58	0.11	0.03	0.13	0.72	0.24
SWA14	0.44	0.08	0.03	0.10	0.55	0.18
SWA15	0.43	0.07	0.03	0.09	0.53	0.18
SWA16	0.42	0.07	0.03	0.10	0.52	0.17
SWA17	5.52	3.90	3.10	4.05	12.51	4.17
SWA18	0.23	0.20	0.16	0.19	0.59	0.20
SWA19	1.23	0.80	0.62	0.85	2.65	0.88
SWA20	1.62	1.21	1.06	1.27	3.88	1.29

North West Arm

Samples No	CF Cu	CF Zn	CF Pb	PLI	C _d	mC _d
NWA1	6.45	6.08	4.82	5.74	17.35	5.78
NWA2	0.65	0.83	0.72	0.73	2.20	0.73
NWA3	7.19	7.82	6.03	6.97	21.04	7.01
NWA4	8.42	9.94	6.79	8.28	25.14	8.38
NWA5	6.48	8.31	5.53	6.68	20.33	6.78
NWA6	1.13	0.99	0.50	0.82	2.62	0.87
NWA7	0.73	0.81	0.55	0.69	2.09	0.70
NWA8	0.46	0.64	0.47	0.52	1.57	0.52

Burraneer Bay

Sample No	CF Cu	CF Zn	CF Pb	PLI	Cd	mC _d
gh 1	0.27	0.22	0.25	0.29	4.74	0.79
gh 2	0.45	0.22	0.28	0.29	4.09	0.68
gh 3	0.46	0.19	0.21	0.30	4.39	0.73
gh 4	0.36	0.20	0.22	0.33	7.44	1.24
gh 5	0.40	0.23	0.26	0.29	4.69	0.78
gh 6	0.32	0.26	0.30	0.39	9.63	1.61
gh 7	0.36	0.14	0.14	0.29	9.67	1.61
gh 8	2.56	2.52	1.99	1.73	14.98	2.50
gh 9	0.80	0.37	0.41	0.60	9.58	1.60
gh 10	2.68	2.24	1.85	1.73	16.44	2.74
gh 11	0.97	0.50	0.56	0.65	11.79	1.96
gh 12	0.44	0.39	0.35	0.34	6.74	1.12
gh 13	1.10	0.76	0.66	0.60	8.38	1.40
gh 14	0.80	0.42	0.45	0.76	11.83	1.97
gh 15	1.67	0.90	0.73	0.66	9.32	1.55
gh 16	1.60	0.86	0.92	0.87	13.26	2.21
gh 17	4.15	0.91	0.80	1.12	14.47	2.41
gh 18	11.16	3.30	4.32	2.88	34.38	5.73
gh 19	2.10	0.70	0.96	1.35	18.08	3.01
gh 20	2.31	2.35	0.97	1.46	32.43	5.40
gh 21	4.81	2.45	2.57	1.96	21.18	3.53
gh 22	2.71	1.02	1.01	0.97	13.75	2.29
gh 23	2.22	1.17	1.18	1.42	17.89	2.98
gh 24	10.64	3.59	2.39	2.39	25.63	4.27
gh 25	25.47	1.41	2.46	1.88	37.26	6.21
gh 26	1.40	0.56	0.57	0.68	10.54	1.76
gh 27	1.88	0.62	1.38	0.95	13.44	2.24
gh 28	1.63	1.09	1.06	0.98	10.45	1.74
gh 29	0.99	0.55	0.54	0.66	10.60	1.77
gh 30	1.12	0.40	0.61	0.63	10.28	1.71
gh 31	3.07	0.90	0.95	1.30	14.88	2.48
gh 32	1.20	0.80	1.07	0.70	11.61	1.93
gh 33	1.14	1.07	2.54	0.99	13.92	2.32
gh 34	3.05	1.07	1.29	1.10	21.86	3.64
gh 35	16.84	4.25	4.14	2.50	45.24	7.54
gh 36	2.76	1.33	1.62	1.25	14.59	2.43
gh 37	0.60	0.27	0.39	0.43	9.10	1.52
gh 38	1.53	0.99	1.13	1.14	16.95	2.83
gh 39	0.21	0.19	0.11	0.22	5.12	0.85
gh 40	0.40	0.12	0.06	0.26	5.40	0.90
gh 41	0.44	0.15	0.14	0.37	7.85	1.31
gh 42	0.22	0.12	0.15	0.29	6.63	1.11
gh 43	0.51	0.34	0.23	0.54	5.08	0.85
gh 44	0.44	0.21	0.19	0.29	5.36	0.89
gh 45	0.46	0.17	0.15	0.25	7.62	1.27
gh 46	0.46	0.24	0.31	0.35	9.63	1.61
gh 47	4.65	2.90	2.59	2.29	18.29	3.05
gh 48	5.03	3.00	2.54	2.31	18.70	3.12
gh 49	3.66	2.17	2.15	1.88	17.23	2.87
gh 50	1.84	1.09	1.29	1.13	11.90	1.98
gh 51	0.84	0.34	0.41	0.43	8.52	1.42
gh 52	5.62	2.57	3.18	2.33	23.03	3.84
gh 53	0.49	0.26	0.36	0.32	7.46	1.24
gh 54	1.26	0.55	0.79	0.55	7.44	1.24
gh 55	5.53	2.47	2.03	2.54	23.72	3.95
gh 56	2.53	0.91	1.01	0.78	8.04	1.34
gh 57	2.02	1.24	1.32	1.11	10.68	1.78
gh 58	2.54	1.43	1.54	1.34	15.11	2.52
gh 59	1.13	0.65	0.99	0.62	9.71	1.62
gh 60	1.57	0.71	0.83	0.76	9.98	1.66
gh 61	0.69	0.38	0.65	0.48	8.76	1.46
gh 62	2.71	1.12	1.24	1.21	14.01	2.34
gh 63	6.88	3.86	3.50	2.96	26.44	4.41
gh 64	2.99	1.61	1.64	1.43	12.62	2.10
gh 65	0.88	0.55	0.87	0.61	11.99	2.00
Mean	2.68	1.09	1.14	1.02	13.57	2.26
Min	0.21	0.12	0.06	0.22	4.09	0.68
Max	25.47	4.25	4.32	2.96	45.24	7.54

4.3. Correlation coefficients for trace elements in the study areas.

1- Kogarah Bay

Correlations																
	Depth	Sand	Silt	Clay	Cr	Ni	Cu	Zn	As	Br	Rb	Sr	Cd	Sn	Ba	Pb
Depth	1.0000	-0.7398	0.7127	0.8061	0.0903	0.5284	0.1788	0.4429	0.7169	0.4468	0.7132	0.6054	-0.0408	0.0660	0.4017	0.4751
Sand	-0.7398	1.0000	-0.9973	-0.9575	-0.3186	-0.7220	-0.4777	-0.7073	-0.8698	-0.6372	-0.8454	-0.5232	-0.0095	-0.1939	-0.4845	-0.7466
Silt	0.7127	-0.9973	1.0000	0.9337	0.3390	0.7351	0.5044	0.7307	0.8681	0.6641	0.8468	0.5174	0.0103	0.2032	0.4926	0.7611
Clay	0.8061	-0.9575	0.9337	1.0000	0.2217	0.6325	0.3480	0.5784	0.8306	0.4982	0.7951	0.5181	0.0057	0.1476	0.4273	0.6500
Cr	0.0903	-0.3186	0.3390	0.2217	1.0000	0.7178	0.6809	0.6983	0.1389	0.6508	0.2891	0.3433	-0.0295	0.1178	0.2180	0.2065
Ni	0.5284	-0.7220	0.7351	0.6325	0.7178	1.0000	0.8190	0.9332	0.7156	0.7191	0.8538	0.7343	0.0626	0.2441	0.7189	0.7222
Cu	0.1788	-0.4777	0.5044	0.3480	0.6809	0.8190	1.0000	0.8272	0.4212	0.5575	0.5975	0.6663	0.0545	0.1939	0.7063	0.5707
Zn	0.4429	-0.7073	0.7307	0.5784	0.6983	0.9332	0.8272	1.0000	0.6748	0.7184	0.7864	0.6444	0.0595	0.3275	0.6393	0.7735
As	0.7169	-0.8698	0.8681	0.8306	0.1389	0.7156	0.4212	0.6748	1.0000	0.4697	0.9318	0.5844	0.0342	0.2349	0.6235	0.8908
Br	0.4468	-0.6372	0.6641	0.4982	0.6508	0.7191	0.5575	0.7184	0.4697	1.0000	0.5549	0.4068	0.0216	0.1165	0.3188	0.4406
Rb	0.7132	-0.8454	0.8468	0.7951	0.2891	0.8538	0.5975	0.7864	0.9318	0.5549	1.0000	0.7130	0.0927	0.2636	0.7792	0.8781
Sr	0.6054	-0.5232	0.5174	0.5181	0.3433	0.7343	0.6663	0.6444	0.5844	0.4068	0.7130	1.0000	0.0454	0.0706	0.8538	0.5662
Cd	-0.0408	-0.0095	0.0103	0.0057	-0.0295	0.0626	0.0545	0.0595	0.0342	0.0216	0.0927	0.0454	1.0000	0.0345	0.0710	0.0424
Sn	0.0660	-0.1939	0.2032	0.1476	0.1178	0.2441	0.1939	0.3275	0.2349	0.1165	0.2636	0.0706	0.0345	1.0000	0.1377	0.3248
Ba	0.4017	-0.4845	0.4926	0.4273	0.2180	0.7189	0.7063	0.6393	0.6235	0.3188	0.7792	0.8538	0.0710	0.1377	1.0000	0.7124
Pb	0.4751	-0.7466	0.7611	0.6500	0.2065	0.7222	0.5707	0.7735	0.8908	0.4406	0.8781	0.5662	0.0424	0.3248	0.7124	1.0000

Woolooware Bay

Correlations															
	Depth	Sand	Silt	Clay	Cr	Ni	Cu	Zn	As	Br	Rb	Sr	Sn	Ba	Pb
Depth	1.0000	-0.4779	0.4669	0.5000	0.3914	0.5302	0.5171	0.6474	0.6297	0.4338	0.6136	0.4440	0.2109	0.6117	0.7607
Sand	-0.4779	1.0000	-0.9978	-0.9435	-0.7726	-0.8534	-0.8220	-0.8409	-0.8479	-0.7353	-0.8710	-0.4081	-0.4472	-0.8262	-0.8168
Silt	0.4669	-0.9978	1.0000	0.9193	0.7762	0.8624	0.8198	0.8414	0.8608	0.7493	0.8794	0.4068	0.4277	0.8354	0.8160
Clay	0.5000	-0.9435	0.9193	1.0000	0.7029	0.7514	0.7770	0.7815	0.7264	0.6160	0.7700	0.3875	0.5137	0.7245	0.7654
Cr	0.3914	-0.7726	0.7762	0.7029	1.0000	0.9073	0.8403	0.8609	0.7932	0.7015	0.7981	0.2660	0.2598	0.6978	0.6764
Ni	0.5302	-0.8534	0.8624	0.7514	0.9073	1.0000	0.9017	0.9456	0.9246	0.8205	0.9545	0.3006	0.3247	0.8820	0.8610
Cu	0.5171	-0.8220	0.8198	0.7770	0.8403	0.9017	1.0000	0.9431	0.8477	0.7544	0.8568	0.2974	0.4562	0.7771	0.8585
Zn	0.6474	-0.8409	0.8414	0.7815	0.8609	0.9456	0.9431	1.0000	0.9276	0.8234	0.9386	0.3261	0.3845	0.8659	0.9375
As	0.6297	-0.8479	0.8608	0.7264	0.7932	0.9246	0.8477	0.9276	1.0000	0.7844	0.9385	0.4244	0.3181	0.8662	0.9002
Br	0.4338	-0.7353	0.7493	0.6160	0.7015	0.8205	0.7544	0.8234	0.7844	1.0000	0.8150	0.3219	0.1044	0.7548	0.7880
Rb	0.6136	-0.8710	0.8794	0.7700	0.7981	0.9545	0.8568	0.9386	0.9385	0.8150	1.0000	0.3244	0.3772	0.9601	0.9366
Sr	0.4440	-0.4081	0.4068	0.3875	0.2660	0.3006	0.2974	0.3261	0.4244	0.3219	0.3244	1.0000	-0.3036	0.2666	0.3707
Sn	0.2109	-0.4472	0.4277	0.5137	0.2598	0.3247	0.4562	0.3845	0.3181	0.1044	0.3772	-0.3036	1.0000	0.3960	0.4076
Ba	0.6117	-0.8262	0.8354	0.7245	0.6978	0.8820	0.7771	0.8659	0.8662	0.7548	0.9601	0.2666	0.3960	1.0000	0.8970
Pb	0.7607	-0.8168	0.8160	0.7654	0.6764	0.8610	0.8585	0.9375	0.9002	0.7880	0.9366	0.3707	0.4076	0.8970	1.0000

Oyster Bay

Correlations

	Depth	Sand	Silt	Clay	Cr	Ni	Cu	Zn	As	Br	Rb	Sr	Sn	Ba	Pb
Depth	1.0000	-0.1878	0.1621	0.2779	-0.1029	-0.0081	0.1116	0.0389	0.4069	0.3986	0.3827	0.3373	0.3740	0.2739	0.2194
Sand	-0.1878	1.0000	-0.9949	-0.8915	-0.1208	-0.4034	-0.6731	-0.6848	-0.7965	-0.5676	-0.8822	-0.8794	-0.5839	-0.8759	-0.7858
Silt	0.1621	-0.9949	1.0000	0.8411	0.1187	0.4040	0.6794	0.6940	0.7993	0.5787	0.8836	0.8855	0.5752	0.8781	0.7971
Clay	0.2779	-0.8915	0.8411	1.0000	0.1143	0.3479	0.5567	0.5537	0.6796	0.4432	0.7598	0.7368	0.5462	0.7509	0.6321
Cr	-0.1029	-0.1208	0.1187	0.1143	1.0000	0.8693	0.7205	0.7006	-0.1915	0.3055	0.1350	0.0902	0.0183	0.0046	-0.2644
Ni	-0.0081	-0.4034	0.4040	0.3479	0.8693	1.0000	0.9002	0.8926	0.1896	0.4124	0.4908	0.4786	0.2748	0.4156	0.1537
Cu	0.1116	-0.6731	0.6794	0.5567	0.7205	0.9002	1.0000	0.9846	0.4694	0.6342	0.7424	0.7214	0.4621	0.6439	0.4227
Zn	0.0389	-0.6848	0.6940	0.5537	0.7006	0.8926	0.9846	1.0000	0.4658	0.6425	0.7467	0.7196	0.4537	0.6558	0.4376
As	0.4069	-0.7965	0.7993	0.6796	-0.1915	0.1896	0.4694	0.4658	1.0000	0.4169	0.8696	0.8957	0.6290	0.8961	0.9478
Br	0.3986	-0.5676	0.5787	0.4432	0.3055	0.4124	0.6342	0.6425	0.4169	1.0000	0.6587	0.5859	0.5255	0.5324	0.3610
Rb	0.3827	-0.8822	0.8836	0.7598	0.1350	0.4908	0.7424	0.7467	0.8696	0.6587	1.0000	0.9507	0.7031	0.9369	0.8316
Sr	0.3373	-0.8794	0.8855	0.7368	0.0902	0.4786	0.7214	0.7196	0.8957	0.5859	0.9507	1.0000	0.6375	0.9637	0.8715
Sn	0.3740	-0.5839	0.5752	0.5462	0.0183	0.2748	0.4621	0.4537	0.6290	0.5255	0.7031	0.6375	1.0000	0.6319	0.6331
Ba	0.2739	-0.8759	0.8781	0.7509	0.0046	0.4156	0.6439	0.6558	0.8961	0.5324	0.9369	0.9637	0.6319	1.0000	0.9067
Pb	0.2194	-0.7858	0.7971	0.6321	-0.2644	0.1537	0.4227	0.4376	0.9478	0.3610	0.8316	0.8715	0.6331	0.9067	1.0000

Woronora River

Correlations

	Depth	Sand	Silt	Clay	Cr	Ni	Cu	Zn	As	Br	Rb	Sr	Sn	Ba	Pb
Depth	1.0000	0.0522	-0.0258	-0.1637	0.0411	-0.0509	0.0430	0.1062	-0.0649	0.2190	0.0546	0.1078	-0.1764	0.0552	0.0796
Sand	0.0522	1.0000	-0.9955	-0.9078	-0.5250	-0.9110	-0.9010	-0.8826	-0.8990	-0.7402	-0.8762	-0.8654	-0.7037	-0.8615	-0.8826
Silt	-0.0258	-0.9955	1.0000	0.8641	0.5311	0.9121	0.9131	0.8961	0.8995	0.7658	0.8871	0.8843	0.6830	0.8758	0.8955
Clay	-0.1637	-0.9078	0.8641	1.0000	0.4388	0.8040	0.7465	0.7239	0.7964	0.5441	0.7299	0.6843	0.7170	0.7016	0.7268
Cr	0.0411	-0.5250	0.5311	0.4388	1.0000	0.4687	0.4205	0.4042	0.3971	0.3146	0.3898	0.3920	0.1866	0.3638	0.4281
Ni	-0.0509	-0.9110	0.9121	0.8040	0.4687	1.0000	0.9343	0.9208	0.9090	0.7661	0.9068	0.9012	0.6296	0.8829	0.9204
Cu	0.0430	-0.9010	0.9131	0.7465	0.4205	0.9343	1.0000	0.9909	0.9459	0.8465	0.9898	0.9795	0.6361	0.9784	0.9895
Zn	0.1062	-0.8826	0.8961	0.7239	0.4042	0.9208	0.9909	1.0000	0.9339	0.8734	0.9868	0.9779	0.6097	0.9760	0.9956
As	-0.0649	-0.8990	0.8995	0.7964	0.3971	0.9090	0.9459	0.9339	1.0000	0.8249	0.9481	0.9374	0.6051	0.9286	0.9325
Br	0.2190	-0.7402	0.7658	0.5441	0.3146	0.7661	0.8465	0.8734	0.8249	1.0000	0.8624	0.9033	0.3929	0.8623	0.8495
Rb	0.0546	-0.8762	0.8871	0.7299	0.3898	0.9068	0.9898	0.9868	0.9481	0.8624	1.0000	0.9803	0.6021	0.9902	0.9854
Sr	0.1078	-0.8654	0.8843	0.6843	0.3920	0.9012	0.9795	0.9779	0.9374	0.9033	0.9803	1.0000	0.5918	0.9711	0.9724
Sn	-0.1764	-0.7037	0.6830	0.7170	0.1866	0.6296	0.6361	0.6097	0.6051	0.3929	0.6021	0.5918	1.0000	0.6089	0.6254
Ba	0.0552	-0.8615	0.8758	0.7016	0.3638	0.8829	0.9784	0.9760	0.9286	0.8623	0.9902	0.9711	0.6089	1.0000	0.9742
Pb	0.0796	-0.8826	0.8955	0.7268	0.4281	0.9204	0.9895	0.9956	0.9325	0.8495	0.9854	0.9724	0.6254	0.9742	1.0000

Georges River

Correlations

	Depth	Sand	Silt	Clay	Cr	Ni	Cu	Zn	As	Br	Rb	Sr	Sn	Ba	Pb
Depth	1.0000	0.0725	-0.1102	0.1099	-0.1471	-0.1719	-0.3346	-0.3090	-0.2160	-0.0838	-0.1409	-0.0371	-0.2980	-0.2160	-0.3138
Sand	0.0725	1.0000	-0.9974	-0.9418	-0.6104	-0.8508	-0.7196	-0.7330	-0.8688	-0.7659	-0.9372	-0.7626	-0.7073	-0.9207	-0.8064
Silt	-0.1102	-0.9974	1.0000	0.9153	0.6054	0.8492	0.7361	0.7472	0.8811	0.7634	0.9382	0.7579	0.7269	0.9279	0.8241
Clay	0.1099	-0.9418	0.9153	1.0000	0.5911	0.7989	0.5912	0.6145	0.7499	0.7236	0.8668	0.7310	0.5653	0.8220	0.6665
Cr	-0.1471	-0.6104	0.6054	0.5911	1.0000	0.8380	0.7384	0.7302	0.4137	0.5436	0.5559	0.4004	0.4728	0.5493	0.4562
Ni	-0.1719	-0.8508	0.8492	0.7989	0.8380	1.0000	0.8785	0.8905	0.7498	0.7959	0.8630	0.6694	0.6918	0.8559	0.7602
Cu	-0.3346	-0.7196	0.7361	0.5912	0.7384	0.8785	1.0000	0.9784	0.7068	0.6851	0.7527	0.6004	0.8303	0.8245	0.8764
Zn	-0.3090	-0.7330	0.7472	0.6145	0.7302	0.8905	0.9784	1.0000	0.6885	0.7477	0.7778	0.6205	0.8142	0.8442	0.8610
As	-0.2160	-0.8688	0.8811	0.7499	0.4137	0.7498	0.7068	0.6885	1.0000	0.6338	0.8828	0.6722	0.7513	0.8946	0.8957
Br	-0.0838	-0.7659	0.7634	0.7236	0.5436	0.7959	0.6851	0.7477	0.6338	1.0000	0.8515	0.6512	0.5777	0.8244	0.6765
Rb	-0.1409	-0.9372	0.9382	0.8668	0.5559	0.8630	0.7527	0.7778	0.8828	0.8515	1.0000	0.7407	0.7069	0.9655	0.8379
Sr	-0.0371	-0.7626	0.7579	0.7310	0.4004	0.6694	0.6004	0.6205	0.6722	0.6512	0.7407	1.0000	0.5024	0.7401	0.6748
Sn	-0.2980	-0.7073	0.7269	0.5653	0.4728	0.6918	0.8303	0.8142	0.7513	0.5777	0.7069	0.5024	1.0000	0.8020	0.8704
Ba	-0.2160	-0.9207	0.9279	0.8220	0.5493	0.8559	0.8245	0.8442	0.8946	0.8244	0.9655	0.7401	0.8020	1.0000	0.9138
Pb	-0.3138	-0.8064	0.8241	0.6665	0.4562	0.7602	0.8764	0.8610	0.8957	0.6765	0.8379	0.6748	0.8704	0.9138	1.0000

Gunnamatta Bay

Correlations

	Depth	Sand	Silt	Clay	Cr	Ni	Cu	Zn	As	Br	Rb	Sr	Sn	Ba	Pb
Depth	1.0000	-0.7256	0.7169	0.7504	0.4979	0.5514	0.2416	0.4072	0.6932	0.6939	0.5608	0.5669	-0.0436	0.3575	0.3767
Sand	-0.7256	1.0000	-0.9991	-0.9710	-0.8016	-0.8817	-0.6197	-0.7979	-0.9209	-0.9157	-0.8361	-0.3586	-0.3414	-0.7151	-0.7736
Silt	0.7169	-0.9991	1.0000	0.9601	0.8042	0.8847	0.6269	0.8039	0.9206	0.9184	0.8386	0.3605	0.3436	0.7202	0.7777
Clay	0.7504	-0.9710	0.9601	1.0000	0.7600	0.8345	0.5578	0.7367	0.8914	0.8694	0.7935	0.3358	0.3176	0.6620	0.7241
Cr	0.4979	-0.8016	0.8042	0.7600	1.0000	0.8556	0.7726	0.8662	0.8278	0.7661	0.7385	0.2081	0.4401	0.7881	0.8483
Ni	0.5514	-0.8817	0.8847	0.8345	0.8556	1.0000	0.7384	0.8910	0.9242	0.8245	0.8921	0.2088	0.4897	0.8866	0.8723
Cu	0.2416	-0.6197	0.6269	0.5578	0.7726	0.7384	1.0000	0.9449	0.6505	0.6358	0.6193	0.0611	0.6036	0.7453	0.9500
Zn	0.4072	-0.7979	0.8039	0.7367	0.8662	0.8910	0.9449	1.0000	0.8268	0.7755	0.7863	0.1777	0.5755	0.8573	0.9843
As	0.6932	-0.9209	0.9206	0.8914	0.8278	0.9242	0.6505	0.8268	1.0000	0.8528	0.8656	0.3737	0.3759	0.7964	0.8121
Br	0.6939	-0.9157	0.9184	0.8694	0.7661	0.8245	0.6358	0.7755	0.8528	1.0000	0.7943	0.4878	0.2533	0.7039	0.7474
Rb	0.5608	-0.8361	0.8386	0.7935	0.7385	0.8921	0.6193	0.7863	0.8656	0.7943	1.0000	0.3693	0.3464	0.8737	0.7635
Sr	0.5669	-0.3586	0.3605	0.3358	0.2081	0.2088	0.0611	0.1777	0.3737	0.4878	0.3693	1.0000	-0.4856	0.2798	0.1099
Sn	-0.0436	-0.3414	0.3436	0.3176	0.4401	0.4897	0.6036	0.5755	0.3759	0.2533	0.3464	-0.4856	1.0000	0.4426	0.6431
Ba	0.3575	-0.7151	0.7202	0.6620	0.7881	0.8866	0.7453	0.8573	0.7964	0.7039	0.8737	0.2798	0.4426	1.0000	0.8461
Pb	0.3767	-0.7736	0.7777	0.7241	0.8483	0.8723	0.9500	0.9843	0.8121	0.7474	0.7635	0.1099	0.6431	0.8461	1.0000

GyMEA Bay

Correlations

	Depth	Sand	Silt	Clay	Cr	Ni	Cu	Zn	As	Br	Rb	Sr	Sn	Ba	Pb
Depth	1.0000	-0.8752	0.8743	0.8680	0.8014	0.8590	0.8517	0.8394	0.9458	0.8367	0.8572	0.5489	-0.0575	0.8194	0.8871
Sand	-0.8752	1.0000	-0.9997	-0.9866	-0.8825	-0.9051	-0.9023	-0.8872	-0.8716	-0.8689	-0.8977	-0.2947	-0.1231	-0.8909	-0.9328
Silt	0.8743	-0.9997	1.0000	0.9822	0.8822	0.9061	0.9036	0.8886	0.8697	0.8755	0.8990	0.2934	0.1265	0.8929	0.9339
Clay	0.8680	-0.9866	0.9822	1.0000	0.8706	0.8843	0.8804	0.8640	0.8713	0.8122	0.8750	0.2989	0.0987	0.8638	0.9114
Cr	0.8014	-0.8825	0.8822	0.8706	1.0000	0.9495	0.9371	0.9265	0.8352	0.8349	0.9089	0.3039	0.1394	0.8897	0.9071
Ni	0.8590	-0.9051	0.9061	0.8843	0.9495	1.0000	0.9806	0.9646	0.8445	0.8767	0.9698	0.2516	0.1985	0.9573	0.9660
Cu	0.8517	-0.9023	0.9036	0.8804	0.9371	0.9806	1.0000	0.9777	0.8619	0.8667	0.9750	0.3069	0.2575	0.9684	0.9768
Zn	0.8394	-0.8872	0.8886	0.8640	0.9265	0.9646	0.9777	1.0000	0.8529	0.8672	0.9722	0.2962	0.2780	0.9635	0.9794
As	0.9458	-0.8716	0.8697	0.8713	0.8352	0.8445	0.8619	0.8529	1.0000	0.7922	0.8637	0.6366	-0.0475	0.8262	0.8990
Br	0.8367	-0.8689	0.8755	0.8122	0.8349	0.8767	0.8667	0.8672	0.7922	1.0000	0.8720	0.3346	0.0561	0.8471	0.8796
Rb	0.8572	-0.8977	0.8990	0.8750	0.9089	0.9698	0.9750	0.9722	0.8637	0.8720	1.0000	0.2949	0.1753	0.9905	0.9784
Sr	0.5489	-0.2947	0.2934	0.2989	0.3039	0.2516	0.3069	0.2962	0.6366	0.3346	0.2949	1.0000	-0.3836	0.2346	0.3396
Sn	-0.0575	-0.1231	0.1265	0.0987	0.1394	0.1985	0.2575	0.2780	-0.0475	0.0561	0.1753	-0.3836	1.0000	0.2246	0.2160
Ba	0.8194	-0.8909	0.8929	0.8638	0.8897	0.9573	0.9684	0.9635	0.8262	0.8471	0.9905	0.2346	0.2246	1.0000	0.9698
Pb	0.8871	-0.9328	0.9339	0.9114	0.9071	0.9660	0.9768	0.9794	0.8990	0.8796	0.9784	0.3396	0.2160	0.9698	1.0000

South West Arm

Correlations

	Depth	Sand	Silt	Clay	Ni	Cu	Zn	As	Br	Rb	Sr	Sn	Ba	Pb
Depth	1.0000	-0.7463	0.7385	0.7981	0.4873	0.4432	0.4847	0.6125	0.5014	0.5084	0.9121	-0.3973	0.5567	0.5276
Sand	-0.7463	1.0000	-0.9998	-0.9880	-0.8748	-0.8880	-0.9118	-0.9325	-0.8995	-0.9179	-0.9172	0.4685	-0.8915	-0.9373
Silt	0.7385	-0.9998	1.0000	0.9848	0.8762	0.8922	0.9153	0.9326	0.9033	0.9207	0.9112	-0.4630	0.8915	0.9406
Clay	0.7981	-0.9880	0.9848	1.0000	0.8513	0.8419	0.8717	0.9187	0.8569	0.8829	0.9522	-0.5052	0.8789	0.8980
Ni	0.4873	-0.8748	0.8762	0.8513	1.0000	0.9359	0.9182	0.9207	0.8812	0.8688	0.7079	-0.4091	0.7932	0.9111
Cu	0.4432	-0.8880	0.8922	0.8419	0.9359	1.0000	0.9903	0.9585	0.9687	0.9487	0.6610	-0.3887	0.8561	0.9841
Zn	0.4847	-0.9118	0.9153	0.8717	0.9182	0.9903	1.0000	0.9663	0.9686	0.9764	0.7080	-0.4728	0.8892	0.9952
As	0.6125	-0.9325	0.9326	0.9187	0.9207	0.9585	0.9663	1.0000	0.9285	0.9394	0.7988	-0.5070	0.9093	0.9645
Br	0.5014	-0.8995	0.9033	0.8569	0.8812	0.9687	0.9686	0.9285	1.0000	0.9244	0.6867	-0.3490	0.8268	0.9755
Rb	0.5084	-0.9179	0.9207	0.8829	0.8688	0.9487	0.9764	0.9394	0.9244	1.0000	0.7391	-0.5385	0.9215	0.9797
Sr	0.9121	-0.9172	0.9112	0.9522	0.7079	0.6610	0.7080	0.7988	0.6867	0.7391	1.0000	-0.5403	0.7907	0.7443
Sn	-0.3973	0.4685	-0.4630	-0.5052	-0.4091	-0.3887	-0.4728	-0.5070	-0.3490	-0.5385	-0.5403	1.0000	-0.5661	-0.4638
Ba	0.5567	-0.8915	0.8915	0.8789	0.7932	0.8561	0.8892	0.9093	0.8268	0.9215	0.7907	-0.5661	1.0000	0.8957
Pb	0.5276	-0.9373	0.9406	0.8980	0.9111	0.9841	0.9952	0.9645	0.9755	0.9797	0.7443	-0.4638	0.8957	1.0000

Mansion Bay and Hacking River

Correlations

	Depth	Sand	Silt	Clay	Ni	Cu	Zn	As	Br	Rb	Sr	Sn	Ba	Pb
Depth	1.0000	-0.5315	0.5308	0.5353	0.5321	0.5134	0.5546	0.5671	0.5883	0.5139	0.5948	0.2932	0.5154	0.5433
Sand	-0.5315	1.0000	-1.0000	-0.9985	-0.8897	-0.9589	-0.9634	-0.9600	-0.8967	-0.9479	-0.9433	-0.6116	-0.9517	-0.9627
Silt	0.5308	-1.0000	1.0000	0.9980	0.8903	0.9598	0.9643	0.9607	0.8966	0.9487	0.9438	0.6098	0.9525	0.9633
Clay	0.5353	-0.9985	0.9980	1.0000	0.8839	0.9512	0.9561	0.9540	0.8954	0.9413	0.9384	0.6218	0.9449	0.9572
Ni	0.5321	-0.8897	0.8903	0.8839	1.0000	0.8969	0.8815	0.8855	0.8091	0.8562	0.8546	0.3654	0.8582	0.8767
Cu	0.5134	-0.9589	0.9598	0.9512	0.8969	1.0000	0.9912	0.9740	0.9407	0.9844	0.9771	0.5982	0.9753	0.9939
Zn	0.5546	-0.9634	0.9643	0.9561	0.8815	0.9912	1.0000	0.9856	0.9299	0.9889	0.9765	0.6137	0.9880	0.9951
As	0.5671	-0.9600	0.9607	0.9540	0.8855	0.9740	0.9856	1.0000	0.9036	0.9747	0.9629	0.5846	0.9776	0.9799
Br	0.5883	-0.8967	0.8966	0.8954	0.8091	0.9407	0.9299	0.9036	1.0000	0.9123	0.9528	0.6816	0.9098	0.9479
Rb	0.5139	-0.9479	0.9487	0.9413	0.8562	0.9844	0.9889	0.9747	0.9123	1.0000	0.9586	0.6074	0.9863	0.9911
Sr	0.5948	-0.9433	0.9438	0.9384	0.8546	0.9771	0.9765	0.9629	0.9528	0.9586	1.0000	0.6645	0.9581	0.9759
Sn	0.2932	-0.6116	0.6098	0.6218	0.3654	0.5982	0.6137	0.5846	0.6816	0.6074	0.6645	1.0000	0.6398	0.6289
Ba	0.5154	-0.9517	0.9525	0.9449	0.8582	0.9753	0.9880	0.9776	0.9098	0.9863	0.9581	0.6398	1.0000	0.9858
Pb	0.5433	-0.9627	0.9633	0.9572	0.8767	0.9939	0.9951	0.9799	0.9479	0.9911	0.9759	0.6289	0.9858	1.0000

North West Arm

Correlations

	Depth	Sand	Silt	Clay	Ni	Cu	Zn	As	Br	Rb	Sn	Ba	Pb
Depth	1.0000	-0.9195	0.9159	0.9356	0.9041	0.8646	0.8089	0.9731	0.9142	0.9054	0.0000	-0.8834	0.8624
Sand	-0.9195	1.0000	-0.9999	-0.9980	-0.9714	-0.9819	-0.9466	-0.9827	-0.9378	-0.9840	0.0000	0.7805	-0.9741
Silt	0.9159	-0.9999	1.0000	0.9971	0.9714	0.9839	0.9498	0.9813	0.9373	0.9832	0.0000	-0.7786	0.9760
Clay	0.9356	-0.9980	0.9971	1.0000	0.9689	0.9690	0.9276	0.9872	0.9377	0.9859	0.0000	-0.7883	0.9618
Ni	0.9041	-0.9714	0.9714	0.9689	1.0000	0.9477	0.9018	0.9556	0.9093	0.9324	0.0000	-0.8040	0.9272
Cu	0.8646	-0.9819	0.9839	0.9690	0.9477	1.0000	0.9874	0.9521	0.9328	0.9604	0.0000	-0.7467	0.9955
Zn	0.8089	-0.9466	0.9498	0.9276	0.9018	0.9874	1.0000	0.9112	0.8826	0.9146	0.0000	-0.7366	0.9934
As	0.9731	-0.9827	0.9813	0.9872	0.9556	0.9521	0.9112	1.0000	0.9418	0.9633	0.0000	-0.8536	0.9478
Br	0.9142	-0.9378	0.9373	0.9377	0.9093	0.9328	0.8826	0.9418	1.0000	0.9575	0.0000	-0.6938	0.9175
Rb	0.9054	-0.9840	0.9832	0.9859	0.9324	0.9604	0.9146	0.9633	0.9575	1.0000	0.0000	-0.6907	0.9519
Sn	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ba	-0.8834	0.7805	-0.7786	-0.7883	-0.8040	-0.7467	-0.7366	-0.8536	-0.6938	-0.6907	0.0000	1.0000	-0.7596
Pb	0.8624	-0.9741	0.9760	0.9618	0.9272	0.9955	0.9934	0.9478	0.9175	0.9519	0.0000	-0.7596	1.0000

Yowie Bay

Correlations

	Depth	Sand	Silt	Clay	Ni	Cu	Zn	As	Br	Rb	Sr	Pb
Depth	1.0000	-0.7949	0.7899	0.8139	0.6927	0.4851	0.5123	0.7166	0.8573	0.7852	0.9019	0.4746
Sand	-0.7949	1.0000	-0.9997	-0.9910	-0.9430	-0.8810	-0.8965	-0.9198	-0.8463	-0.9312	-0.6032	-0.8504
Silt	0.7899	-0.9997	1.0000	0.9874	0.9463	0.8836	0.8990	0.9172	0.8441	0.9332	0.5990	0.8503
Clay	0.8139	-0.9910	0.9874	1.0000	0.9150	0.8571	0.8735	0.9237	0.8489	0.9104	0.6199	0.8418
Ni	0.6927	-0.9430	0.9463	0.9150	1.0000	0.8932	0.8938	0.8886	0.7503	0.8522	0.4497	0.8415
Cu	0.4851	-0.8810	0.8836	0.8571	0.8932	1.0000	0.9902	0.8915	0.5730	0.8210	0.2779	0.9638
Zn	0.5123	-0.8965	0.8990	0.8735	0.8938	0.9902	1.0000	0.8909	0.6112	0.8447	0.3148	0.9720
As	0.7166	-0.9198	0.9172	0.9237	0.8886	0.8915	0.8909	1.0000	0.6945	0.8473	0.5505	0.8737
Br	0.8573	-0.8463	0.8441	0.8489	0.7503	0.5730	0.6112	0.6945	1.0000	0.8122	0.7031	0.5114
Rb	0.7852	-0.9312	0.9332	0.9104	0.8522	0.8210	0.8447	0.8473	0.8122	1.0000	0.6118	0.8098
Sr	0.9019	-0.6032	0.5990	0.6199	0.4497	0.2779	0.3148	0.5505	0.7031	0.6118	1.0000	0.2639
Pb	0.4746	-0.8504	0.8503	0.8418	0.8415	0.9638	0.9720	0.8737	0.5114	0.8098	0.2639	1.0000

4.4. Enrichment factor (EF) of trace elements in subsurface sediments (cores)

Kogarah Bay 1

Depth (cm)	EF=Cu	EF=Zn	EF=Pb
0	4.2	3.2	3.0
5	3.3	2.6	2.7
10	2.7	2.1	2.4
20	3.0	2.3	2.1
30	2.3	1.9	1.7
40	1.4	1.2	0.9
150	1	1	1

Kogarah Bay 2

Depth (cm)	EF=Cu	EF=Zn	EF=Pb
0	3.6	3.0	4.2
5	3.6	2.2	3.8
10	2.6	1.7	2.2
20	2.6	0.9	1.1
30	1.9	1.0	1.4
34	1.8	1.1	1.9
150	1.0	1.0	1.0

Woollooware Bay 3

Depth (cm)	EF=Cu	EF=Zn	EF=Pb
0	3.4	3.9	2.2
5	3.1	3.9	2.2
10	2.9	3.5	2.1
20	1.7	1.8	1.1
30	1.0	1.0	0.6
150	1	1	1

Oyster Bay 4

Depth (cm)	EF=Cu	EF=Zn	EF=Pb
0	3.9	4.2	2.9
5	3.8	3.9	2.7
10	4.1	4.1	2.9
20	4.1	4.3	3.1
30	2.5	2.9	2.0
40	1.2	1.1	0.8
45	0.9	0.8	0.7
150	1	1	1

Woronora River 5

Depth (cm)	EF=Cu	EF=Zn	EF=Pb
0	3.0	0.7	0.5
5	1.0	0.4	0.3
10	1.1	0.6	0.4
20	1.3	0.6	0.4
30	1.2	0.6	0.4
40	0.7	0.4	0.3
47	1.0	0.6	0.3
150	1.0	1.0	1.0

Salt Pan Creek 6

Depth (cm)	EF=Cu	EF=Zn	EF=Pb
0	5.9	7.8	2.6
5	9.3	8.1	4.4
10	10.7	5.0	4.0
20	19.2	3.2	7.8
30	2.2	1.6	1.2
40	1.8	1.1	0.8
50	2.1	1.3	1.1
150	1	1	1

Gunnamatta Bay 7

Depth (cm)	EF=Cu	EF=Zn	EF=Pb
0	288.4	29.8	18.9
5	210.6	23.6	22.0
10	145.5	18.5	16.7
20	135.6	18.2	16.1
30	131.9	22.6	22.5
40	108.0	10.8	21.4
48	19.8	6.5	19.8
150	1	1	1

Mansion Bay & Hacking River 8

Depth (cm)	EF=Cu	EF=Zn	EF=Pb
0	0.7	0.2	0.2
5	0.4	0.2	0.2
10	0.6	0.2	0.2
20	0.6	0.1	0.1
30	0.9	0.2	0.1
40	0.6	0.1	0.1
150	0.1	0.1	0.1

Previous data / Oatley Bay

Depth (cm)	EF=Cu	EF=Zn	EF=Pb
0	5.2	3.8	5.7
10	5.3	3.8	6.1
20	4.1	2.9	4.8
30	2.8	2.5	6.9
40	3.2	3.5	12.1
50	1.5	1.5	2.1
60	2.2	2.8	7.6
70	2.5	2.8	6.5
80	1.3	1.2	1.6
90	1.4	1.4	1.3
100	2.1	2.2	4.1
120	1.2	1.4	1.3
140	1.0	1.2	1.3
160	1.4	1.2	1.3
180	1.3	1.1	1.3
200	1.4	0.9	0.9
250	1.0	1.0	1.0

5. Full papers arising from this thesis

Spatial and Temporal Distribution and Pollution Assessment of Trace Metals in Marine Sediments in Oyster Bay, NSW, Australia

Yasir M. Alyazichi · Brian G. Jones ·
Errol McLean

Received: 23 March 2014 / Accepted: 24 November 2014
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Abstract The disposal of untreated urban and industrial wastewater has a deleterious effect on both the water and sediment quality of Oyster Bay located in south Sydney, Australia. The present investigation was undertaken to evaluate the potential pollution of marine sediments in Oyster Bay. The results of metals were compared with adverse biological effect values effect range low (ERL) and effect range median (ERM). Spatial distribution of trace metals was estimated by applying geographic information system. The results indicated that the sediments were polluted with Cu, Zn, As and Pb, which exceeded ERL levels. However, these metals were still below ERM values, and other metals Cr and Ni were below ERL. Moreover, the highest concentrations of metals were around discharge points and in the inner bay. Further, trace metals could be attributed to human activities within the bay as they declined in concentrations with increasing sediment depth.

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Alyazichi, YM, Jones, BG, & McLean, E 2015, 'Spatial and Temporal Distribution and Pollution Assessment of Trace Metals in Marine Sediments in Oyster Bay, NSW, Australia', *Bulletin of Environmental Contamination and Toxicology*, vol. 94, no. 1, pp. 52-57. Available from: 10.1007/s00128-014-1434-z.
Final manuscript can be accessed from Research Online

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Source identification and assessment of sediment contamination of trace metals in Kogarah Bay, NSW, Australia

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Received: 26 July 2014 / Accepted: 17 December 2014 / Published online: 28 January 2015
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Abstract The distribution of trace metals (spatial and temporal) and sedimentary fractions were investigated to identify the concentrations and sources of trace metals within Kogarah Bay, NSW, Australia. A total of 59 surface sediments and six subsurface samples from core of the sediment were collected. The contamination factor and pollution load index indices used to evaluate environmental effects of trace metals. The study area was found to be uncontaminated with Cr and Ni, moderately contaminated with As and considerably contaminated with Cu, Zn and Pb. The concentrations of Cr and Ni were below both effect range low and effect range median, while As, Cu, Zn and Pb were slightly above effect range low. The highest concentrations of these trace metals such as Cu, Zn and Pb were found in the north, northwest and southeast of the bay, close to discharge points, stormwater outlets and around boatyards and watercrafts. The spatial distributions of metals were strongly related to muddy particles and organic matter. The temporal sediments of metals declined with increased sediment depth, which reflects accumulation of trace metals since European settlement in this area. Furthermore, the source of the trace metals was found to

be stormwater outlets, gasoline fumes, boatyards and other human activities.

Article removed for copyright reasons, please refer to citation: Alyazichi, Y, Jones, B, & McLean, E 2015, 'Source identification and assessment of sediment contamination of trace metals in Kogarah Bay, NSW, Australia', *Environmental Monitoring and Assessment*, vol. 187, no. 2, p. 10p. Available from doi: 10.1007/s10661-014-4238-z

Final manuscript can be accessed from Research Online

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2015

Spatial distribution of heavy metal contaminations in Yowie Bay sediments and their environmental impacts

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Publication Details

Alyazichi, Y. M., Jones, B. G. & McLean, E. (2015). Spatial distribution of heavy metal contaminations in Yowie Bay sediments and their environmental impacts. In C. A. Brebbia (Eds.), *Water Resources Management VIII: WIT Transactions on Ecology and the Environment*, Volume 196 (pp. 363-374). United Kingdom: WIT Press.

Spatial distribution of heavy metal contaminations in Yowie Bay sediments and their environmental impacts

Abstract

We investigated the distribution of heavy metals Ni, Cu, Zn, As, Cd and Pb in marine sediments in order to evaluate the pollution status in Yowie Bay, in the Port Hacking Estuary, NSW, Australia. Twenty one surface sediments were collected in this study and hydrodynamic parameters (current track and velocity) were also measured in order to explain the distribution of the heavy metals in the bay. Effect Range Low and Effect Range Median statistics were used to assess the environmental effect in order to offer measures to protect the ecosystem from pollution by the accumulation of heavy metals in the bay. The results showed that the heavy metals Ni, Cu, Zn, As, Cd and Pb had similar distribution patterns in surface sediments. The surface sediments were considerably contaminated by copper, cadmium and lead. The highest concentrations of the metals were found to be in the northeast of the bay, which is in close proximity to discharge points and moored watercraft, with the highest reading (sample YO8) having concentrations of 20, 107.4, 304.2, 15, 12.3 and 176.5 ppm, respectively. The heavy metal pollution was concentrated in the inner bay, which has greater depth and contains organic matter and muddy particles (illite, kaolinite and chlorite). The sources of pollution by heavy metals were found to be discharge points and human activities (gasoline fumes, watercraft and boatyards) and this pollution began with European settlement which now surrounds the bay.

Disciplines

Medicine and Health Sciences | Social and Behavioral Sciences

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Spatial distribution of heavy metal contaminations in Yowie Bay sediments and their environmental impacts

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Abstract

We investigated the distribution of heavy metals Ni, Cu, Zn, As, Cd and Pb in marine sediments in order to evaluate the pollution status in Yowie Bay, in the Port Hacking Estuary, NSW, Australia. Twenty one surface sediments were collected in this study and hydrodynamic parameters (current track and velocity) were also measured in order to explain the distribution of the heavy metals in the bay. Effect Range Low and Effect Range Median statistics were used to assess the environmental effect in order to offer measures to protect the ecosystem from pollution by the accumulation of heavy metals in the bay. The results showed that the heavy metals Ni, Cu, Zn, As, Cd and Pb had similar distribution patterns in surface sediments. The surface sediments were considerably contaminated by copper, cadmium and lead. The highest concentrations of the metals were found to be in the northeast of the bay, which is in close proximity to discharge points and moored watercraft, with the highest reading (sample YO8) having concentrations of 20, 107.4, 304.2, 15, 12.3 and 176.5ppm, respectively. The heavy metal pollution was concentrated in the inner bay, which has greater depth and contains organic matter and muddy particles (illite, kaolinite and chlorite). The sources of pollution by heavy metals were found to be discharge points and human activities (gasoline fumes, watercraft and boatyards) and this pollution began with European settlement which now surrounds the bay.

Keywords: Yowie Bay, Sediments, Heavy metals, Contamination, Hydrodynamic, Statistical techniques.

1 Introduction

Heavy metals in marine sediments are originated from both natural processes such as soil erosion and atmospheric inputs, and anthropogenic activity. Heavy metals in ecosystems causes serious environmental problems around

the world because of the toxicity, non-biodegradable properties, and resistant and accumulation behaviors of heavy metals [1]. Because of rapid urbanization and industrialization around marine coastal ecosystems, concentrations of heavy metals have increased and heavy metals are being discharged into environmentally sensitive estuaries and bays around the world [2].

Once heavy metals are present in the aquatic environment, they can accumulate in the fine sediment particles via physical, chemical and biological processes [3 and 4]. In addition, ebb tidal currents have the capability to transport fine and very fine particles within the estuary, distributing the chemical pollution away from the discharge source. Tide data are considered useful information for both civil and hydraulic engineers who provide hydraulic descriptions, information for water quality model management and frameworks for evaluating sediment and chemical dynamics in bays [5, 6, and 7]. Furthermore, heavy metals can be released again into the water column from sediments as free ions, and/or complex compounds when environmental conditions are changed [8]. These heavy metals can have deleterious effects on fauna, flora and aquatic micro-organisms, and can enter into human bodies via the food chain, inhalation or dermal absorption, potentially leading to critical health disorders that affect the nervous system, endocrine system and/or the immune system [2, 9, and 10].

The major objective of this study was to investigate the spatial distribution and toxicology of heavy metals in the marine sediments of Yowie Bay, and their relationship with sediment fractions. The study also evaluates the effect of current and tidal hydrodynamics on the concentration and dispersal of heavy metal pollutants within a typical estuarine bay system.

2 Experiments

2.1 Study area

Yowie Bay, which is located 30 km south of Sydney Harbour, is one of several bays belonging to the Port Hacking estuary (Fig.1). Overall, the inner area of the bay has deeper depths (>7 m), and the foreshores have been substantially modified [11]. Yowie Bay provides a significant environmental shelter and habitat for flora and fauna, breeding and nursery habitats for several species, and is of economic and social value (e.g. tourism, business enterprises, fisheries and aquaculture). The main freshwater discharge points for the catchment areas are shown in Fig1, which shows catchment model segments for Yowie Bay and the adjacent Gympsea Bay in yellow. These were determined by Sydney Water (the statutory authority responsible for water supply and management across Sydney). The catchment areas of Yowie Bay are urbanized with a population of approximately 40,240 in the local government area. The sources of contamination are mainly from the catchment areas (1658 ha; Fig.1), and from recreational activities along the coastline such as watercraft, boat yards and fishing, which can in turn affect the water quality of the bay.

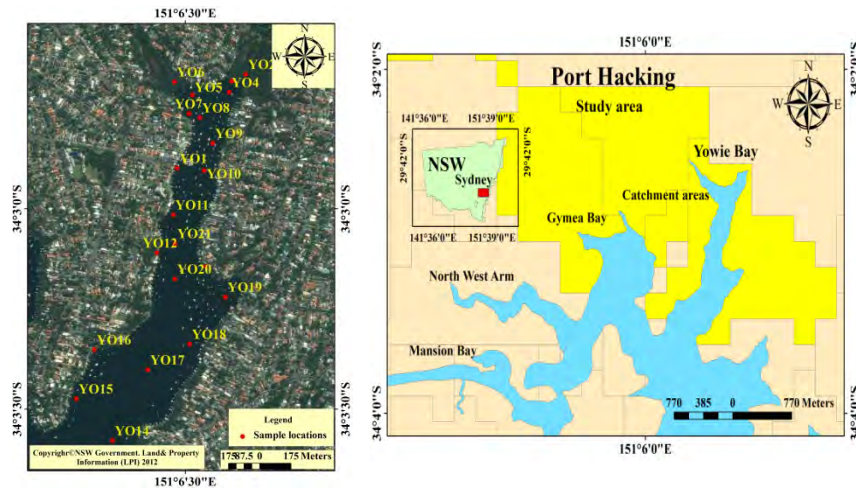


Figure 1: Catchment area and surface sediment sample locations for Yowie Bay, off Port Hacking, NSW, Australia.

2.2 Sample collections and preparations

During the summer of 2012, a total of 21 surface sediment samples were collected using a grab sampler by boat (Fig.1). The sediment samples were reserved for analysis. At each site the water depth and location were recorded using sonar and a Global Positioning System (GPS) respectively. Grain size measurements were performed for all sediment samples using a Malvern Mastersizer 2000. Further analyses were used to obtain the details of the source of sediments, distribution of grain size (sand, silt and clay), and to interpret geochemical results. Heavy metals were measured by X-ray fluorescence spectrometer with a SPECTRO-analytical instrument (XEPOS), following [12] procedure. Hierarchical cluster analysis [13] was applied to distinguish characteristics of the samples. This statistical analysis was achieved using JMP software to include all variables.

Arc GIS desktop software was used to plot the sample sites within the study areas, and to provide advanced geostatistical analysis to create maps. The Kriging method of geostatistical analysis was used [14].

2.3 Hydrodynamic measurements

Hydrodynamic conditions including currents and tides in the study area were measured by drogues (Fig.2). Three drogues were modified from a previous design to permit deployment in estuarine water. These were constructed in the workshop at the University of Wollongong. The height of each drogue was 70 cm, and each drogue consisted of a buoy (ball), with a waterproof enclosure to hold a small GPS and a flashing light. A software program was used to plot the movement directions of the drogues and data from each site measured, and the data was uploaded onto Google earth and kmz files. Data from the GPS has been smoothed to gain an estimate of average velocities over the drogue track.

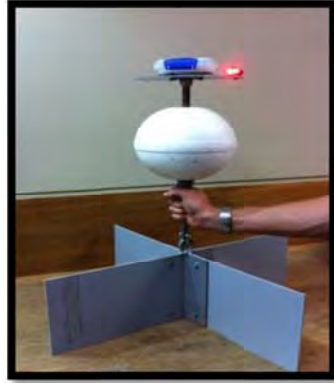


Figure 2: Modified design of the drogue to measure tides and currents.

3 Results and discussion

3.1 Hydrodynamic measurements

Three drogues were deployed at each site in Yowie Bay at about the same time of day (with a difference of only a few minutes between deployments of each drogue). The drogues were deployed just after high tide in order to capture typical ebb-tidal flow patterns and velocities for the larger tides associated with spring tidal ranges. The drogues were deployed at discharge points and stormwater outlets (numbers 1 and 2) for the catchment areas, and in the middle of the bay (Fig.3).

The drogue in the middle of the bay (number 3) had a faster speed compared with the other drogues (1 and 2) because of increased current velocities due to a larger tidal storage above these locations. Field methodology was designed so that the current track and velocity data would be compatible with both a descriptive explanation of spatial distribution of sediments and pollutants movement and the data needs of any future hydrodynamic modelling. For this paper only descriptive measures are used to assess the main trajectory of currents and pollutants. Current speeds in the bay had enough capability to transport the fine and very fine particles, including heavy metals, from the edges, shoreline and catchment areas via discharge points, and then to gradually deposit them in deeper areas [15]. This fact accords with the observations in previous research from other areas [15 and 16]. Hydrodynamic circulation in Yowie Bay is controlled by several factors such as catchment area flows, entry points, wind effects (speed and directions) and tidal velocities. These results correspond with previous studies in different places conducted by [17 and 18]. Wind waves are influential in the resuspension and carriage of fine particles along shallow estuarine margins. Main discharge points carry materials from catchment areas, which are pushed into the bays. The sediment pathway into the bay is in the form of a jet since water velocity decreases gradually when entering the bay, causing deposition of coarse materials close to discharge points and then fine particles further into the bay [19 and 20]. Local waves, generated by wind, become more influential in the shallow waters close to the discharge points, leading to resuspension and transport of fine particles into deeper

sites, where the current and waves become less active and cannot disturb the bottom sediments. The currents have complex circulations in shallower water, and wind-driven current can cause subsequent return flows around the edges of the bay. The fine sediment particles and heavy metals are transported by current and tidal activity and then gradually settle-out at deeper sites in the central part of the bay.

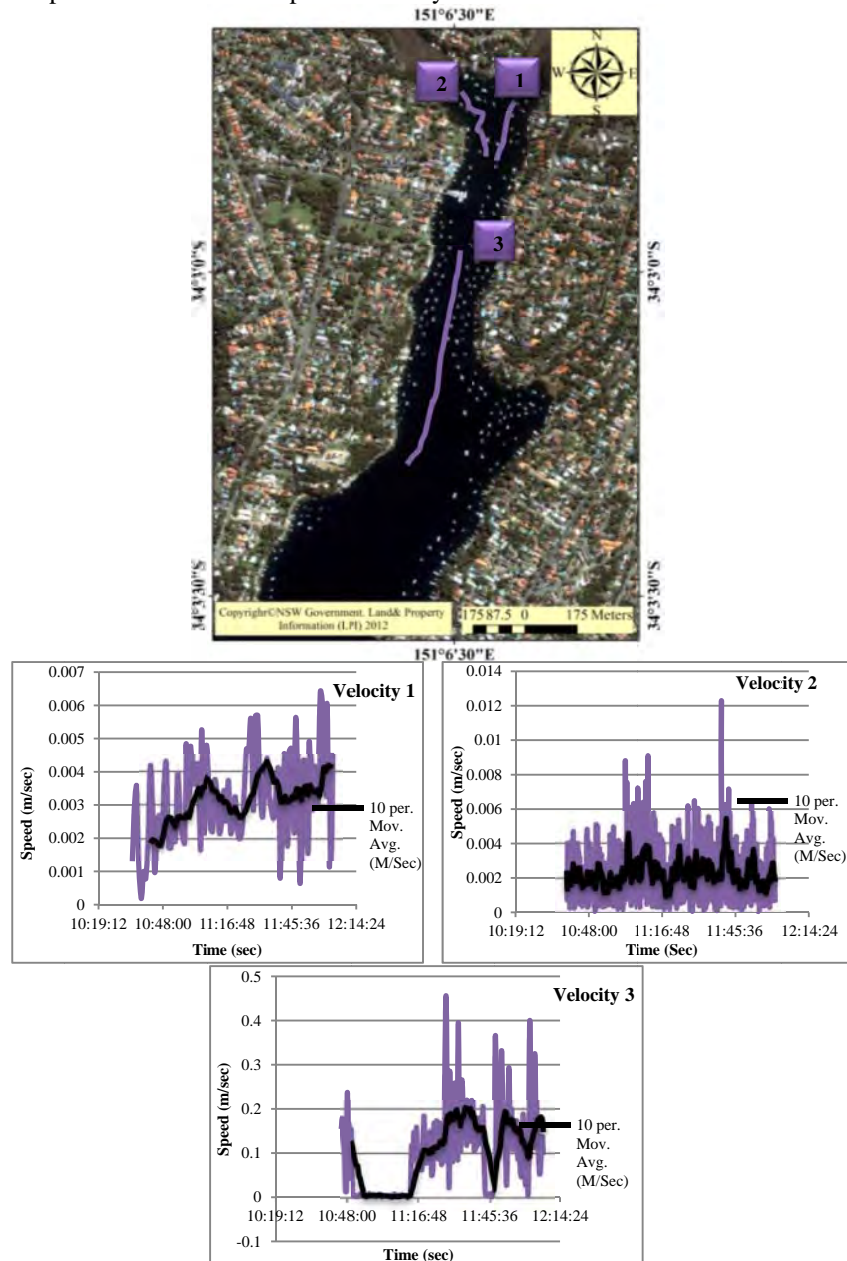


Figure 3: Current track velocities for three drogues in Yowie Bay.

3.2 Sediments and water depth distribution

Sediment grain size and water depth varied within the bay. As illustrated in Fig.4a, a high percentage of sand was found to be located at the shoreline and edge of the bay, which has a shallow water depth (<2 m, Fig.4b). The waves and residual currents at these sites are highly active and can disturb the fine particles, which may transport them into deeper areas (inner bay). However, muddy (silt and clay) percentages are dominant within the inner and north-east areas of the bay (Fig.4c), where the water depth is deep and ranges between 5 m and 20 m and the waves have slightly lower effects on the bottom sediments. Therefore, fine and very fine particles can settle and accumulate within the inner bay.

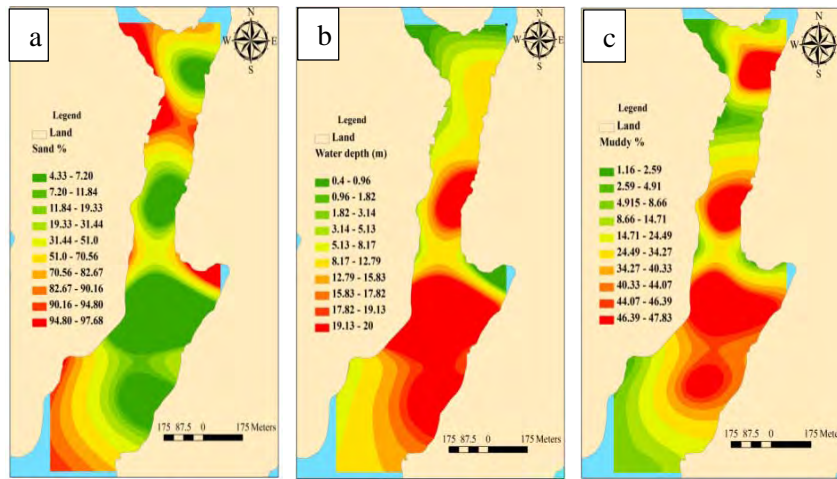


Figure 4: Spatial distribution of **a** sand percentages, **b** water depth (m) and **c** muddy percentages in Yowie Bay.

3.3 Spatial distribution of heavy metal pollution

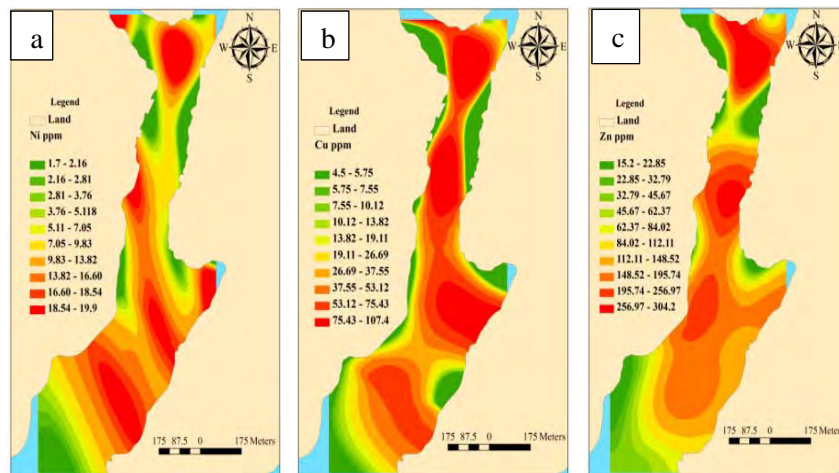
Heavy metals are analyzed in this study and the minimum, maximum and mean values are presented in Table 1. Prediction maps of heavy metals Ni, Cu, Zn, As, Cd and Pb are shown in Fig.5. The concentration of these metals generally exhibited similar spatial distribution patterns. On the one hand, the highest concentrations of these metals are located in the north and north-west of the bay, because they are close to the discharge points and stormwater outlets from catchment areas. Notably, the concentration of heavy metals also increased around boat moorings and boatyards. Heavy metals were also concentrated within the inner bay which was dominated by muddy particles (silt and clay) and organic matter that can absorb and accumulate heavy metals in clay minerals at these sites. The concentration of heavy metals decreases toward the edges and shoreline of the bay for two reasons. First, the edges of the bay are dominated by the sand fractions. Second, the currents and waves become more active at the edges and can disturb fine particles, which are then transported and gradually deposited in deeper areas.

Furthermore, the level of these metals varied in the inner part of the bay, based on mobility of each metal, sediment types and environmental conditions. On the other hand, the variation of these metals at the edges and mouth of the bay was found to be relatively small. Heavy metal levels in this study are compared with harmful biological effect values, which comprise the effect range low (ERL) and effect range median (ERM) in estuarine and marine sediments suggested by U.S. National Oceanic and Atmospheric Administration (NOAA) [21]. The concentrations of these metals in Yowie Bay were less than ERM values. Also, the concentrations of heavy metals Ni, Zn and As were less than ERL values, which show low pollution within bay's sediments. The concentration of heavy metals Cu and Pb that were above the ERL value, which were considered to be moderate pollution for Yowie Bay, were found in the northern, north-western and inner parts of the bay, as shown in Fig.5. This concentration is a result of discharge points, as well as gasoline fumes from cars and boats.

Table 1: Basic statistics of metals with ERL (effect range low) and ERM (effect range median) values in ppm.

Heavy metals	Ni	Cu	Zn	As	Cd	Pb
Minimum	1.7	4.5	15.2	1.6	5.5	6.3
Maximum	20	107.4	304.2	17	12.3	176.5
Mean±SD	10±6.5	35.2±29	110±87	7.7±4.4	9±2.1	65.4±53
ERL	20.9 (6)	34 (31)	150 (36)	8.2 (34)	1.2 (21)	46.7 (39)
ERM	51.6 (-)	270 (-)	410 (-)	70 (-)	9.6 (7)	218 (-)

Values enclosed in parentheses are the numbers of samples are exessed ERL and ERM.



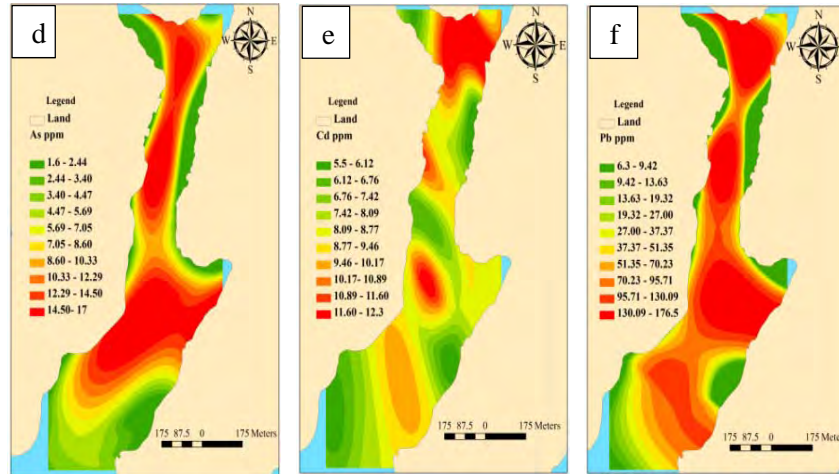


Figure 5: Spatial distribution of heavy metals **a** Ni, **b** Cu, **c** Zn, **d** As, **e** Cd and **f** Pb in sediments in Yowie Bay.

3.4 Statistical techniques

Fig.6 and Table 2 demonstrate the results of hierarchical cluster analysis (HCA). Three clusters of variables can be recognized from these statistics. Based on similar characteristics, sediment fractions and heavy metals can be classified. Cluster A (red) contains samples from deep water and has low percentages of sand, high percentages of mud (silt and clay), and the highest concentration of heavy metals. Samples in this cluster, which are located close to discharge points in the inner bay and around sites that have watercrafts (Fig.6), reflect anoxic condition. These sites may have high percentages of organic matter and clay minerals, which can be a trap for heavy metals, according to [22]. Cluster B (green) samples have higher percentages of sand lower percentages of mud, and lower levels of heavy metals than cluster A.

In contrast, cluster C (blue) consists of samples from shallow water, with the highest percentages of sand, lowest percentages of mud, and lowest concentration of heavy metals. These samples are located at the edges of the bay and in sites that have lower concentrations of pollutants in the bay, and indicate an oxic condition. The concentration patterns of Ni, Cu, Zn, As, Cd and Pb in surface sediments in Yowie Bay suggest that the sources of pollution had emerged from the catchment area, which includes residential, industrial, road sides, as well as boatyards and watercraft. The presence of these heavy metals has deleterious environmental effects on both local fauna and flora. Heavy metals can enter humans via the food chain or by inhalation or dermal absorption, and this may lead to critical health disorders that affect the nervous system, endocrine system and/or the immune system [9 and 10].

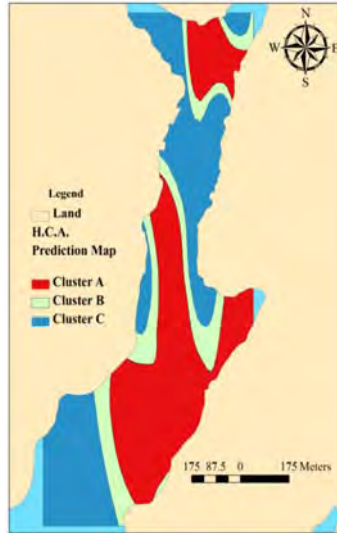


Table 2: Percentages and concentrations of variables in three clusters based on HCA.

Variables	Cluster A	Cluster B	Cluster C
Depth (m)	16.53	3.30	4.81
Sand%	9.83	49.47	85.84
Silt%	76.40	42.99	11.93
Clay%	13.78	7.54	2.22
Ni	17.40	12.33	4.48
Cu	64.54	53.47	11.62
Zn	198.54	172.57	36.11
As	12.69	8.27	4.29
Cd	9.00	11.33	7.95
Pb	113.46	109.40	22.73

Figure 6: Cluster analysis of variables and environmental depositions.

3.5 Comparisons with other areas

The heavy metal concentrations that were measured in Yowie Bay were compared with the concentrations of heavy metals from marine sediments in previous Australian studies [23 and 24] and around the world [25 and 26]. The Huon estuary is essentially a non-industrialized zone and might contain a low level of potentially toxic heavy metals. In contrast, the Port Jackson estuary, Tyne estuary and Avilés estuary have high concentrations of heavy metals and would be expected to contain toxic metals due to the large amounts of waste, including solid and liquid, organic and inorganic, discharged into these bays from residential and industrial areas as well as boat yards and watercraft [23, 26, and 27].

In addition, limited treatment of waste in these bays also leads to higher concentrations of toxic metals. As Table 3 illustrates, the sediments in Yowie Bay are polluted with heavy metals such as Cu, Zn and Pb, while the sediments in the Huon estuary have fewer pollutants than the sediments in the Port Jackson estuary, Tyne estuary and Avilés estuary.

The main anthropogenic pollution sources of heavy metals in the samples of the study area can be attributed to discharge points and stormwater drains from roadways and residential areas, as well as the number of marine services and the large numbers of moored watercraft. Yowie Bay, which is deemed to be a partly-sheltered environment exposed to the open sea and to high winds from the north and north-west, provides a useful example of the distribution of pollutant concentrations by current and wave activity. As a consequence, the heavy metals are gradually precipitated within deeper sites to the inner and west of the Bay (Fig.6).

Table 3: Comparison of heavy metals (ppm) from the study area with other estuaries in Australia and the worldwide.

Location	Country	Ni	Cu	Zn	As	Cd	Pb
Huon [24]							
Range	Australia	2-28	7-32	2-66	4-25	<10	2-48
Mean		20	17	40	16	<10	25
Port Jackson [27]							
Range	Australia	5-24	9-1053	108-7622	BDL	BDL-24	38-3604
Mean		22	188	651		0.8	364
Tyne Estuary [25]							
Mean	UK	34	92	421	NA	2.2	187
Avilés estuary [26]							
Mean	Spain	6.9	34.9	1437.2	18.8	5.9	176.06
Yowie Bay This study							
Range	Australia	2-20	5-107	15-304	2-17	6-12	6-117
Mean±SD		10±7	35±3	110±9	8±4	9±2	65±5

Where: BDL is below detection limit and NA is not available.

4 Conclusions

To evaluate the environmental status of Yowie Bay in NSW, Australia, and to identify potential sources of pollution of marine sediments, heavy metals were analyzed in surface sediments. The heavy metals of interest were Ni, Cu, Zn, As, Cd and Pb. Track current velocities of ebb tides were measured to determine pollutant pathways under tidal flows. Hierarchical cluster analysis (HCA) was applied, and the mean concentrations of heavy metals were compared with deleterious biological effect values. The results indicate that the bay has low contamination of Ni, Zn and As, whereas there is moderate to considerable contamination from Cu, Cd and Pb. Statistical analysis of sediment samples recognized three clusters of environments. The first and second cluster represent moderately to considerably polluted environments. The third cluster shows unpolluted environments. Stormwater outlets and discharge points, as well as watercraft and boatyards, are considered to be the sources of heavy metals in Yowie Bay, together with emissions such as gasoline fumes from vehicle and boat exhausts which have accumulated over time since European settlement. In further studies, there is a need to analyze water and organisms to determine acceptable levels of heavy metals in order to protect aquatic organisms from heavy metal pollution. Physical, chemical and biological treatment methods are recommended to remove and/or reduce contamination from stormwater outlets before discharge into the bay.

Acknowledgements

This paper is a part of the first author PhD. thesis undertaken at the School of Earth and Environmental Sciences, University of Wollongong. It was financially supported by the Ministry of Higher Education and Scientific Research, Iraqi and GeoQuEST Research Centre, University of Wollongong, Australia.

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Contents lists available at ScienceDirect

Regional Studies in Marine Science

journal homepage: www.elsevier.com/locate/rsma



Spatial distribution of sediment particles and trace element pollution within Gunnamatta Bay, Port Hacking, NSW, Australia



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ARTICLE INFO

Article history:

Received 21 July 2015

Received in revised form

4 September 2015

Accepted 13 September 2015

Available online 15 September 2015

Keywords:

Gunnamatta Bay

Hydrodynamic measurements

Trace element pollution

Sediment particles

Potential ecological risk assessments

ABSTRACT

A combination of geochemical analysis and hydrodynamic measuring has been established in order to provide an explanation for the spatial distribution of both sediment particles and trace element pollution Gunnamatta Bay, NSW, Australia. Fifty nine samples of surface sediment were collected to determine the spatial concentrations of trace elements in the bay. Moreover, current track pathways and velocities have been measured in the bay. The distribution of trace elements such as chromium, nickel, copper, zinc, arsenic and lead had similar patterns in surface sediments. Trace element pollution is concentrated along the current trajectory in the inner part of the bay, which has deeper sites and higher percentages of mud particles. The highest concentrations of these metals were found to be in sample GU55 from the northeast of the bay, which is close to a surface discharge point and moored boats.

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Article removed for copyright reasons, please refer to citation:

Alyazichi, YM, Jones, BG, & McLean, E 2015, ' Spatial distribution of sediment particles and trace element pollution within Gunnamatta Bay, Port Hacking, NSW, Australia', *Regional Studies in Marine Science*, vol. 2, no. 1, pp. 124-131.

Available from: [10.1016/j.rsma.2015.09.002](https://doi.org/10.1016/j.rsma.2015.09.002).

Final manuscript can be accessed from Research Online

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<http://dx.doi.org/10.1016/j.rsma.2015.09.002>

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2014

Environmental assessment of benthic foraminiferal and pollution in Gunnamatta Bay, NSW, Australia

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Publication Details

Alyazichi, Y. M., Jones, B. & McLean, E. (2014). Environmental assessment of benthic foraminiferal and pollution in Gunnamatta Bay, NSW, Australia. In N. Shimizu, K. Kaneko & J. Kodama (Eds.), *Rock Mechanics for Global Issues - Natural Disasters, Environment and Energy: Proceedings of the 2014 ISRM International Symposium* (pp. 2495-2504). Japan: Japanese Committee for Rock Mechanics.

Environmental assessment of benthic foraminiferal and pollution in Gunnamatta Bay, NSW, Australia

Abstract

We investigated the distribution of trace metals (spatial and temporal) and sedimentary particles in order to identify the relationship between benthic foraminifera and trace metals pollution within Gunnamatta Bay, Port Hacking Estuary, NSW, Australia. Risk assessments of surface sediments were evaluated by using hierarchical cluster analysis (HCA). A total of 59 surface sediment samples and seven subsurface sediment samples were collected, in order to determine the levels of trace metals in spatial and temporal of the bay. Further, six surface sediment samples were examined for existing foraminiferal assemblages in muddy samples, which had high and low concentration of trace metals and sandy samples. The trace metals distribution showed that the trace metals such as chromium, nickel, copper, zinc, arsenic, lead, rubidium and bromine had similar distribution in surface sediments. The results of trace metal concentrations were compared with the deleterious biological effect values in marine sediments. The mean of most trace metals for the Bay were below the Effect Range Low except copper and Effect Range Median. The highest concentrations of these metals were found to be in the north east of the bay sample GU55, which is close to the proximity of discharge points, and craft boats (moored) with concentrations (107, 14, 398, 413, 8, 203, 27 and 182ppm) respectively. Also, this trace metal pollution is concentrated in the inner part of the bay, which is deep, and has organic matter and clay minerals. The benthic foraminiferal assemblages has low species diversity in muddy samples GU25 and GU55 compared to the fine sandy particles in samples GU12 and GU24. Furthermore, the muddy particles that have had high level of trace metals were dominated by species tolerant- pollution such as *Ammonia beccarii*, *Brizalina spathulata* and *Elphidium excavatum*. These have had more opportunity to flourish. In addition, the values of trace metals dramatically decline with increasing depth. This reflects that the potential source of trace metal pollution is from human activity (eg. gasoline fumes and boats), since early European settlement in this area.

Disciplines

Medicine and Health Sciences | Social and Behavioral Sciences

Publication Details

Alyazichi, Y. M., Jones, B. & McLean, E. (2014). Environmental assessment of benthic foraminiferal and pollution in Gunnamatta Bay, NSW, Australia. In N. Shimizu, K. Kaneko & J. Kodama (Eds.), *Rock Mechanics for Global Issues - Natural Disasters, Environment and Energy: Proceedings of the 2014 ISRM International Symposium* (pp. 2495-2504). Japan: Japanese Committee for Rock Mechanics.

Environmental Assessment of Benthic Foraminiferal and Pollution in Gunnamatta Bay, NSW, Australia.

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Abstract

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Keywords: Gunnamatta Bay, Trace metals, Pollution, Sediment particles, Benthic foraminiferal.

1. Introduction

Sediment pollution by trace metals in estuaries and around coastal areas is an international environmental issue. Contamination results from discharge points, source runoff and human activities related to, industry, agriculture, urban development, mining, shipping and other activities. These activities can provide waste containing metal residues. High levels of pollution can have harmful and toxic effects on the marine ecosystem and biotic resources, and is critical to human health (Hosono et al., 2011; Morelli et al., 2012). Trace metals are dispersed in aquatic habitats, and are then deposited in aqueous environments and combined with sediments and soils by mechanisms such as absorption and ion exchange.

Muddy particles are especially considered to be ultimate sinks for accumulated metals. Therefore, the level of trace metals in sediments and soils contribute to the contamination of aquatic environments due to their toxicity, persistence, hard degradation and easy accumulation (Yuan et al., 2004; Dural et al., 2007; Hu et al., 2011).

However, trace metals can also be released again into the water column as free ions and/or complex compounds from sediments under different processes such as physical disturbance, chemical and diagenesis factors. Consequently, increasing levels of trace metals can be harmful for marine flora and fauna such as dwelling micro-organisms such as foraminiferal and ostracods, their growth may be retarded, and because of impaired reproduction and decline of species diversity. Also, trace metals

may enter human bodies via the food chain, resulting in serious health problems such as brain damage, and various other types of illness (Alves et al., 2013; Huang et al., 2013). The main purpose of this paper is: 1- To evaluate the spatial and temporal distribution of trace metals, within sediments. 2-To assess the ecological risk to the sediments. 3- To identify the distribution patterns of benthic foraminiferal assemblages in the bay. 4-To examine the relationship between trace metal pollution and benthic foraminiferal assemblages.

2. Experiments

2.1 Study area

Gunnamatta Bay, which is located 30 km south of Sydney in the State of New South Wales (Fig.1), and is one of several bays that are part of the Port Hacking estuary. It has a well-defined catchment area, and is impacted by activities from the Hacking River catchment area. Water depths in the bay ranged between 0.3-12m. Gunnamatta Bay is tidal, with maximum tides of approximately 2 m. The tides are semi- diurnal, with fresh water discharged from the Georges River (Gray et al., 2001). The catchment area of Gunnamatta Bay is highly urbanised, with the main land use being commercial, light industrial and residential areas. The sources of contamination are mainly from catchment drainage such as stormwater channels that discharge directly into the Bay .

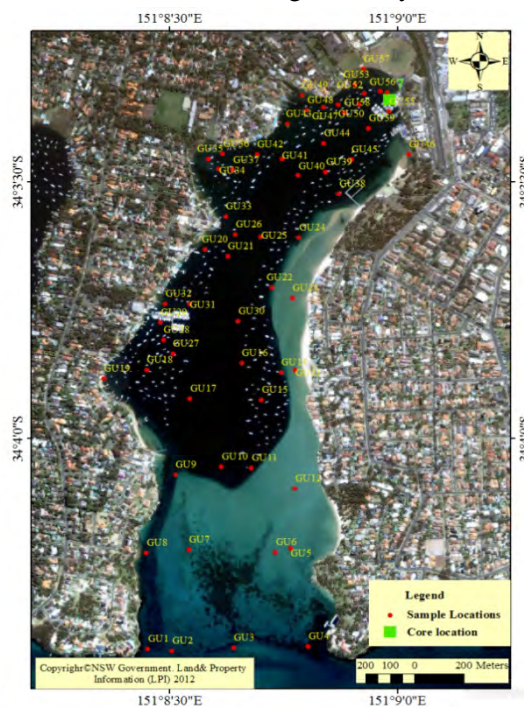


Fig. 1. Sample and core locations in Gunnamatta Bay.

2.2 Sample collections and preparations

Surface sediment samples were collected by a grab sampler. Only the surface 5 cm of sediment was reserved for analysis. A total of 59 samples were collected during the summer of 2012 (Fig.1). Water depth and location were recorded at each site using sonar and Geographical Position System (GPS). Moreover, seven samples from subsurface sediment were collected (from the site with the highest concentrations) of trace metals by using push core.

Grain size measurements were determined for all sediment samples using a Malvern Mastersizer 2000. This analysis was used to obtain the details of distribution of grain size, and to explain the geochemical findings. Percentages of sand, silt and clay contained in each sediment sample were determined.

Trace metals were measured using XRF a SPECTRO - analytical instrument (XEPOS) energy dispersive spectrometer fitted with a Si- docile detector, following an established standard procedure (Norrish and Chappell, 1977).

HCA was applied to distinguish between the sample groups (Zhang et al., 2013). This was achieved using JMP software to present all variables.

Arc GIS (v.10) desktop software was used to plot the sample sites within the study areas, and advanced geostatistical analysis was applied to create maps. This geostatistical analysis is known as the Kriging method. This is a moderately quick interpolator that can be exact or smoothed depending on the measurement error model. It is a flexible means to evaluate graphs of spatial autocorrelation (Li and Heap, 2008). The Kriging method uses statistical models that generate a variety of map outputs, such as predictions, standard errors, and probability. However, Kriging flexibility often requires decision-making. Kriging assumes the data are derived from a stationary stochastic process, while some other methods assume normally distributed data (Chen et al., 2013).

Six sediment surface samples were selected to identify and determine percentages of foraminiferal species. Two samples were selected from three sites with the following characteristics: muddy with high trace metals; muddy with low trace metals; and fine sandy samples. All samples were gently washed through a 63 μ m sieve with tap water to remove muddy particles. The remaining fractions were dried at 60 °C. The total foraminiferal assemblages were counted. The minimum number of specimens used in statistical analysis was approximately 100 for each sample, which was standardised as percentages.

3. Results and Discussion

Sediment grain size and water depth varied within the bay as seen in Table 1. Fig.2a shows that the highest percentages of sand were at the edges, shoreline and mouth of the bay, where the sand barrier and the water depth was shallow at the edges and shoreline (<1.0 m; Fig.2b). These areas had high tidal and current activity, which disturb and transport the fine and very fine particles into deeper areas. The muddy (silt and clay) percentages were concentrated within the inner bay (Fig.2c), where water depths were higher (5.8-12 m; Fig.2b), and the waves slightly less effective on bottom sediments. Therefore, the fine and very fine particles can gradually settle within the inner bay.

Table 1 Range and mean of sediment fractions in Gunnamatta Bay.

Variables	Depth (m)	Sand %	Muddy%
Range (mean)	0.3-12 (5.2)	2.1-100 (72.2)	0-97.8 (27)

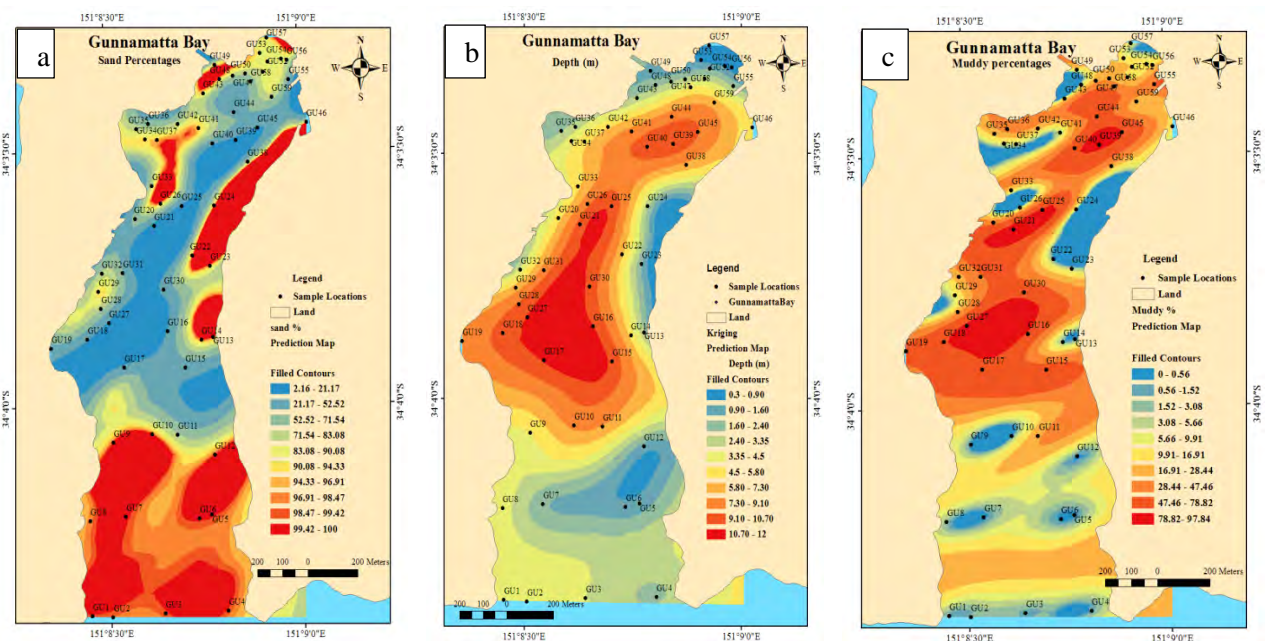


Fig. 2. a - Sand percentages, b- water depth (m) and c- muddy percentages in the Gunnamatta Bay.

As shown in Table 2, trace metal concentrations were compared with the deleterious biological effect values in marine sediments. Effect were measured based on guidelines suggested by the U.S.

National Oceanic and Atmospheric Administration (Long et al., 1995; Ligerio et al., 2002) and ranged from effect range low (ERL) to effect range median (ERM).

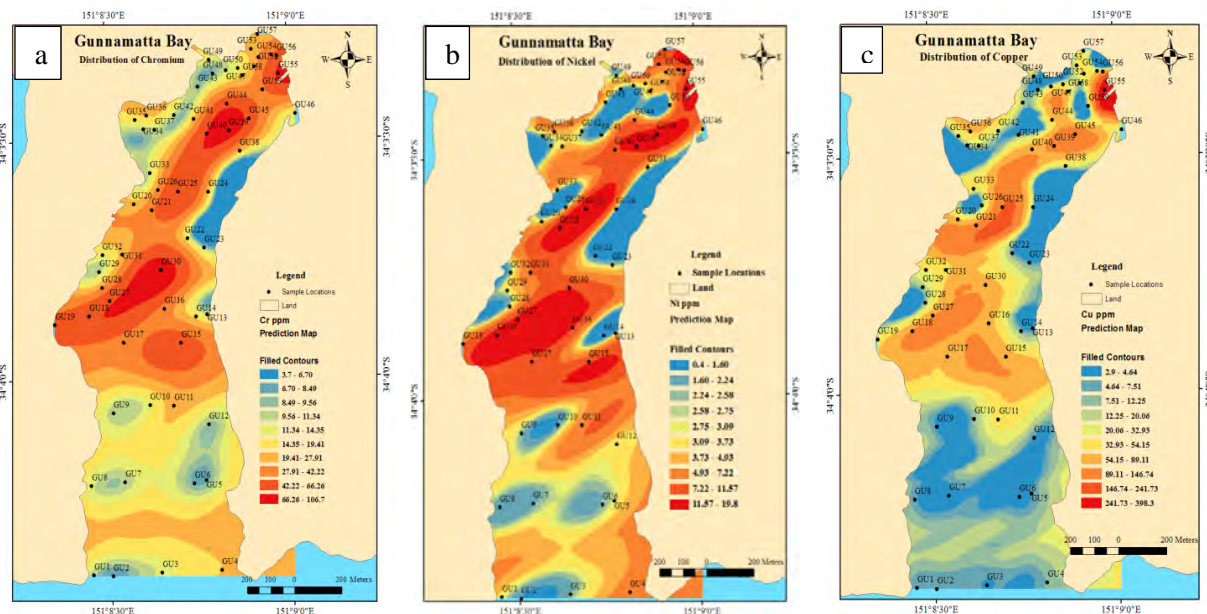
Table 2 Basic statistic range and mean concentrations of trace metals (ppm) in samples of the study area compared with effect range low (ERL) and effect range median (ERM) values.

Trace metals (ppm)	Cr	Ni	Cu	Zn	As	Pb	Rb	Br
Gunnamatta Bay								
Range	4-107	0.4-20	3-398	6-413	1-12	2-203	1.7-48	18-309
Mean \pm SD.	27 \pm 27	6 \pm 5	41 \pm 59	65 \pm 77	4 \pm 3.1	32 \pm 37	14 \pm 11	103 \pm 71
GU25 and GU55								
Mean	102	17	273	330	9	157	37	202
GU44 and GU58								
Mean	44	5	47	79	6	48	15	121
GU12 and GU24								
Mean	7	3	4	11	2	4	10	32
ERL	81	20.9	34	150	8.2	46.7	NA	NA
ERM	270	51.6	270	410	70	218	NA	NA

NA: not available

Overall, the mean concentrations of trace metals were below the ERL and ERM, except copper which was higher than ERL. Samples GU17, GU18, GU21, GU25, GU27, GU30, GU39, GU40, GU45 and GU55), which were located in inner bay, exceeded the ERL for copper, zinc, arsenic and lead. In addition, concentrations of the trace metals such as copper and zinc in sample GU55 exceeded the ERM and lead reach to the ERM value (i.e. 398 ppm for copper, 413 ppm for zinc and 203 ppm for lead). The wide variations in concentrations of trace metals within the bay were, due to sources of pollution (discharge points and stormwater outlets), boatyards, watercraft as well as sediment types (muddy particles and organic matter).

Prediction maps of trace metals chromium, nickel, copper, zinc, arsenic, lead, rubidium and bromine are shown in Fig.3 a-h. The concentration of these metals generally exhibit similar patterns of distribution. The highest concentrations of these metals were in the inner and middle parts of the bay, which also contained high percentages of mud particles (clay minerals), and organic matter. Both muddy particles and organic matter can play important role as a trap for trace metals (Mayer et al., 1981; Fernandes et al., 2011). These metals were also concentrated close to discharge points from the catchment area, while the lowest levels of trace metals were found to be along with the edges and shoreline, as well as in the mouth of the bay, areas with abundant pure coarse sand.



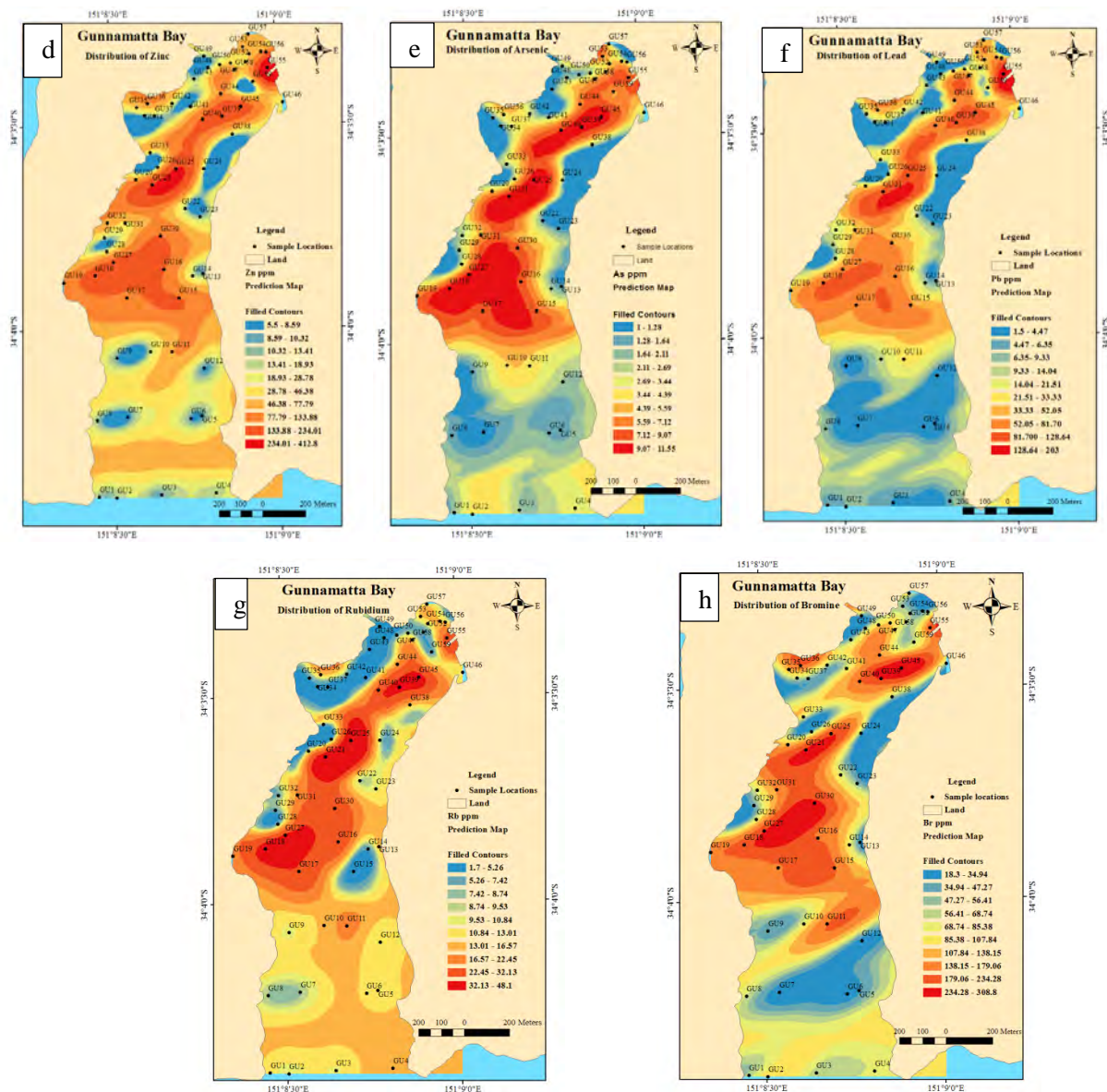


Fig.3. Distribution of metals a- Cr, b- Ni, c- Cu, d-Zn, e- As, f- Pb, g-Rb and h-Br in ppm in the bay.

The concentrations of metals copper and zinc decreased rapidly and lead declined moderately with sediment depth, while chromium remained constant with the increase in sediment depth. The concentrations of copper, zinc and lead in core indicated that the accumulation of these metals started since the first European settlement around these area, whereas chromium does not correlate with pollution, which may be driven from heavy minerals (Johnston and Chrysochoou, 2014; Fig.4).

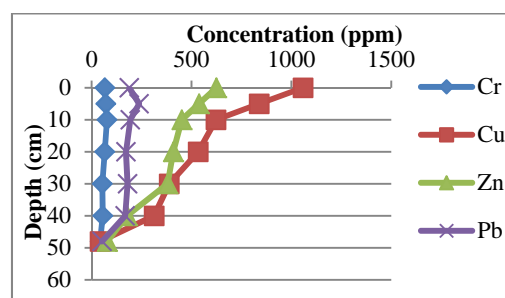


Fig. 4. Variation of trace metals with sediment depth (cm) in Gunnamatta Bay.

The main 38 benthic foraminiferal species were identified in the six samples. Firstly, muddy samples (A) with high concentration of trace metals exceeded ERL for chromium, copper, zinc and lead. Secondly, muddy samples (B) with low concentrations of trace metals and below ERL. Finally, sandy samples (C) Table 3. Species diversity varied between 11-22, was generally higher in the fine sand and muddy with low levels of metals and also below ERL respectively. Species abundance ranged from 1 to 40 individuals per 10g of dry surface sediment. The foraminiferal assemblages in the study area (muddy samples) were composed almost completely of benthic foraminiferal species. This is due to the distance from the open ocean. However, planktonic foraminiferal species are only represented by *Globigerina bulloides* in the sandy samples close to open ocean.

Table 3 Foraminiferal species in surface sediment samples in Gunnamatta Bay.

A- GU55 and GU 25 (Muddy with high level of metals)

Species	Abundances %
<i>Ammonia beccarii</i> (Linne, 1767)	40
<i>Brizalina spathulata</i> (Williamson, 1858)	24
<i>Cellanthus discoidalis multiloculum</i> (Cushman & Ellisor, 1945)	4
<i>Discorbinella bertheloti</i> (d'Orbigny, 1839)	5
<i>Elphidium excavatum</i> (Heron-Allen & Earland, 1913)	11
<i>Elphidium macellum aculeatum</i> (Silvestri, 1901)	2
<i>Parrellina imperatrix</i> (Brady, 1881)	2
<i>Quinqueloculina poeyana</i> (d'Orbigny, 1939)	1
<i>Ramulina globulifera</i> (Brady, 1879)	3
<i>Trichohyalus tropicus</i> (Collins, 1958)	6
<i>Trochammina inflata</i> (Montagu, 1808)	2

B- GU44 and GU58 (Muddy with low level of metals)

Species	Abundances %
<i>Ammonia beccarii</i> (Linne, 1767)	5
<i>Cymbaloperetta bradyi</i> (Cushman, 1915)	4
<i>Dentalina mutsui</i> (Hada, 1931)	2
<i>Elphidium crispum</i> (Linne, 1758)	26
<i>Elphidium jenseni</i> (Cushman, 1924)	3
<i>Guttulina pacifica</i> (Cushman & Ozawa, 1928)	7
<i>Pyrgoella irregularis</i> (d'Orbigny, 1839)	27
<i>Quinqueloculina lamarckiana</i> (d'Orbigny, 1839)	1
<i>Siphogenerina communis</i> (Cushman and Todd, 1944)	5
<i>Spiroloculina canaliculata</i> (d'Orbigny, 1846)	15
<i>Spiroloculina iucida</i> (Cushman & Todd, 1944)	2
<i>Textularia sagittula</i> (Defrance, 1824)	1
<i>Trichohyalus tropicus</i> (Collins, 1958)	2

C- GU12 and GU24 (Sandy)

Species	Abundances %
<i>Bolivina robusta</i> (Brady, 1881)	5
<i>Brizalina spathulata</i> (Williamson, 1858)	3
<i>Cellanthus discoidalis multiloculum</i> (Cushman & Ellisor, 1945)	1
<i>Cribrononion argenteus</i> (Parr, 1945)	3
<i>Discorbinella bertheloti</i> (d'Orbigny, 1839)	2
<i>Elphidium depressulum</i> (Cushman, 1933)	19
<i>Elphidium macellum aculeatum</i> (Silvestri, 1901)	2
<i>Fissurina marginata</i> (Montagu, 1803)	3
<i>Globigerina bulloides</i> (d'Orbigny, 1826)	10
<i>Guttulina pacifica</i> (Cushman & Ozawa, 1928)	2

<i>Loxostomum amygdalaeformis</i> (Brady, 1881)	2
<i>Miliolinella baragwanathi</i> (nov.)	2
<i>Nodosaria perversa</i> (Schwager, 1866)	4
<i>Parrellina verriculata</i> (Brady, 1881)	4
<i>Peneroplis planatus</i> (Fichtel & Moll, 1798)	2
<i>Pyrgoella irregularis</i> (d'Orbigny, 1839)	13
<i>Quinqueloculina anguina arenata</i> (Said, 1949)	3
<i>Quinqueloculina subpolygona</i> (Parr, 1945)	4
<i>Reophax spicalifer</i> (Brady, 1879)	2
<i>Rosalina australis</i> (Parr, 1922)	10
<i>Trochammina ochracea</i> (Williamson, 1858)	2
<i>Vaginulina vertebralis</i> (Parr, 1932)	2

3.1 Distribution patterns of trace metals and sediment fractions

Trace metal pollution once released enter into current and wave circulation and then settle in marine sediments, which have anoxic environmental conditions. The statistical analysis of this study was conducted by hierarchical cluster analysis (Fig. 5, Table 4), and enabled the classification of the samples into three groups.

The main variables that define the red group were the high percentages of mud, low content of sand and high trace metal concentrations. As illustrated in red group (Table 4) rubidium level indicates that the high percentages of mud, and bromine reflects the existence of a high percentage of organic matter in this group, which can play as a trap of trace metals (Mayer et al., 1981; Fernandes et al., 2011). The green group contained less percentage and concentration of variables compared with the red group.

In contrast, the blue group differed completely with high percentages of sand, low percentages of mud and low concentrations of trace metals. Therefore, red was considered to be significant contamination and the green group was considered to be moderately polluted. These samples were located in the middle and inner bay as well as close to discharge points. Nonetheless, the blue group represents areas with low or no pollution and samples were located at the edges and mouth of the bay (Fig. 5).

Table 4: Percentages and concentrations of the variables by HCA.

variables	Cluster A	Cluster B	Cluster C
Depth	9.7	6.9	3.6
Sand	23.2	55.9	91.1
Silt	66.0	37.2	7.7
Clay	10.8	6.9	1.2
Cr	70.4	38.0	13.0
Ni	13.9	6.4	3.2
Cu	124.5	51.9	15.4
Zn	196.5	80.5	25.5
As	9.7	5.4	2.5
Br	220.6	153.4	60.7
Rb	34.9	13.7	8.7
Pb	92.5	40.3	14.3

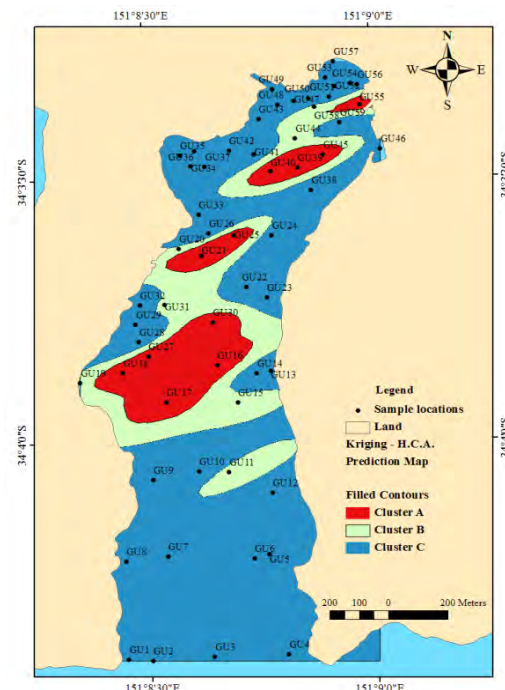


Fig.5. Sketch for classification of all variables in the bay.

3.2 Benthic foraminiferal response to trace metals

Previous research found there was a positive correlation between trace metal pollution and the abundance of benthic foraminiferal species, which made foraminiferal species good bio-indicators of pollution by trace metals (Frontalini and Coccioni, 2008). In addition, foraminiferal species can provide good evidence about any biological change in the past (Alve et al., 2009).

Foraminifera diversity have been deemed indicators of contamination by trace metals and foraminiferal abundance are related to contaminated sites (Bergin et al., 2006). Trace metals can enter into the foraminiferal cell with food and become toxic to benthic species (Yanko et al., 1998). Consequently, a decline tendency in diversity can be indicated as response to trace metals pollution (Debenay and Fernandez, 2009; Alves et al., 2013).

In this research, the lowest foraminiferal diversity was found to be in the muddy samples, having high concentration of trace metals GU25 and GU55 (Table 3), while diversity increases away from discharge points and the middle of the bay toward fine sandy samples GU12 and GU24, which have lowest concentration of trace metals pollution. In other estuaries around the world, foraminiferal diversity has a negative relationship with trace metals (Frontalini and Coccioni, 2008; Li et al., 2013).

Although the availability of community data, the presence or absence of individual foraminiferal species can provide more insight about ecological facts (Debenay and Fernandez, 2009). Previous investigators have found that increasing trace metal pollution can cause an increase in the relative abundance of specific benthic species (Frontalini and Coccioni, 2008; Coccioni et al., 2009), which can be used as a proxy for trace metal pollution. There are several species such as *Ammonia tepida*, *Ammonia parkinsoniana*, *Bolivinelina pseudopunctata*, *Bolivina variabilis*, *Brizalina spathulata*, *Cornuspira involvens*, *Criboelphidium oceanensis*, *Elphidium advena*, *Elphidium excavatum*, *Elphidium magellanicum*, *Haynesina germanica*, *Miliolinella subrotunda*, *Quinqueloculina bicostata* and *Stainforrthia fusiformis* that are known as pollution-resistant and opportunistic species existing in estuary environments contaminated with trace metals (Frontalini and Coccioni, 2008; Romano et al., 2009; Armynot du Châtelet et al., 2011; Foster et al., 2012).

In the present study, *Ammonia tepida*, also reported as *Ammonia beccarii*, *Brizalina spathulata* and *Elphidium excavatum*, are dominant within foraminiferal assemblages in muddy samples. Thus, GU25 and GU55 may reflect the opportunity for this species to withstand contamination by trace metals and tolerant of oxygen deficiency.

As described by (Murray, 2006; Ferraro et al., 2006), some foraminiferal survive and flourish in the most polluted areas, and can exploit chemically and thermally polluted waters, as well as waters with high organic matter. These species were existent in muddy samples GU25 and GU55, which had high concentration of trace metal pollution and organic matter. Consequently, these species can be used as bio-indicators for trace metal pollution in harbours or estuaries.

4. Conclusions

Surface sediments were collected from 59 sites in Gunnamatta Bay, south part of Sydney, Australia, along with subsurface sediments from the identified highest trace metal concentrations. The spatial distribution of trace metals are controlled by discharge points from residential areas, boats and sediment fractions. Sediment samples located in the inner and middle of the bay, as well as vicinity of stormwater outlets have high concentration of trace metals.

Foraminifera species at these sites have low diversity and are recognised by tolerant-pollution *Ammonia beccarii*, *Brizalina spathulata* and *Elphidium excavatum* have more opportunity for survival and thrive in polluted areas, and as such can be used as bio-indicators of trace metal pollution.

Fine sandy samples, have the lowest levels of trace metals, and have the highest foraminiferal diversity including several foraminiferal species.

Trace metal pollution derived from anthropogenic activities including urbanisation, industrialisation and agricultural waste have rapidly increased over time since Europeans settlement around this area.

Acknowledgements

This paper is a part of the first author's PhD. thesis undertaken at School of Earth and Environmental Sciences, University of Wollongong. It was financially supported by the Ministry of Higher Education and Scientific Research, Iraqi Government and GeoQuEST research centre, University of Wollongong, Australia.

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2014

Identification of historical lead sources apportionments in estuary sediments from atmospheric aerosols/ NSW/Australia

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Publication Details

Y. M. Alyazichi, B. Jones & E. McLean (2014). Identification of historical lead sources apportionments in estuary sediments from atmospheric aerosols/ NSW/Australia. presented at the IAC2014: International Aerosol Conference, Busan, Korea, 28 August - 2 September.

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Abstract

Abstract of a poster that presented at the IAC2014 conference.

Disciplines

Medicine and Health Sciences | Social and Behavioral Sciences

Publication Details

Y. M. Alyazichi, B. Jones & E. McLean (2014). Identification of historical lead sources apportionments in estuary sediments from atmospheric aerosols/ NSW/Australia. presented at the IAC2014: International Aerosol Conference, Busan, Korea, 28 August - 2 September.

Identification of historical lead sources apportionments in estuary sediments from atmospheric aerosols/ NSW/Australia.

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Keywords: pollution, lead isotope, marine sediments and atmospheric aerosols

X-Ray fluorescence and stable lead (Pb) isotopic analyses have been determined in surface sediments from urbanized areas in south of Sydney, NSW, Australia. The main objective of this investigation was to determine the histologic record of Pb pollution. Surface and subsurface sediment samples were collected in the study areas. The concentration of lead varied from site to site in the study areas depending on several factors, such as number of discharge points (storm water), population, sediment particles (sand, silt and clay), grain size and mineral composition. The isotope composition found in the sediment samples, expressed here as $^{206}\text{Pb}/^{204}\text{Pb}$, is relatively constant at 18.1 at a depth below 35 cm, whereas, the lead isotope declined with decreasing depth. These results are corresponded with increased lead concentration within surface sediment (Fig. 1).

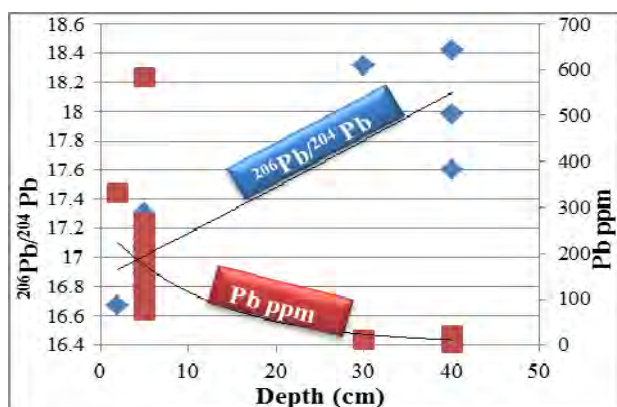


Figure1. Pb concentration and variations of $^{206}\text{Pb}/^{204}\text{Pb}$ ratio with sediment depth of study areas. Where: G, introduction of lead gasoline-air.

In addition, the lead isotope ratio of Botany Bay and Port Hacking sediment samples is represented by $^{207}\text{Pb}/^{206}\text{Pb}$ vs. $^{208}\text{Pb}/^{206}\text{Pb}$ in (Fig.2). The lead isotope ratio of the surface samples lies with and above some samples roof dust samples Chiaradia *et al.* (1997), and below Broken Hill, Mt Isa (the old lead deposited in Australia) and gasoline-air (Gulson, 1986). The lead isotope ratio of the subsurface sediment samples (background) of the study areas was below that of other samples, except the Lake Illawarra samples, which had isotope ratio of 2.1 and 0.85 of $^{208}\text{Pb}/^{206}\text{Pb}$ and $^{207}\text{Pb}/^{206}\text{Pb}$ respectively.

As indicated by these figures the isotope ratio has increased with time since European settlement.

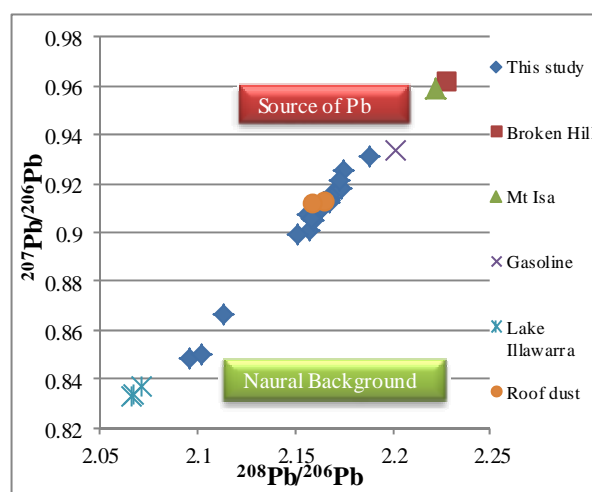


Figure2. $^{207}\text{Pb}/^{206}\text{Pb}$ vs. $^{208}\text{Pb}/^{206}\text{Pb}$ plot for sediment samples from study areas compared with other locations.

The source of lead concentration is derived from atmospheric aerosols from consumption gasoline (cars and boats).

Acknowledgements

This work is a part of the first author's PhD thesis undertaken at School of Earth and Environmental Sciences, University of Wollongong. It was financially supported by the Ministry of Higher Education, Iraqi Government and GeoQuest research Centre, University of Wollongong.

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2015

Risk assessment of trace element pollution in Gymea Bay, NSW, Australia

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Publication Details

Alyazichi, Y. M., Jones, B. G., McLean, E., Altalyan, H. N. & Al-Nasrawi, A. K. M. (2015). Risk assessment of trace element pollution in Gymea Bay, NSW, Australia. *World Academy of Science, Engineering and Technology. Proceedings*, 9 (12), 1286-1292. Melbourne, Australia *International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering. ICEWRE 2015: 17th International Conference on Environmental and Water Resources Engineering*

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Abstract

The main purpose of this study is to assess the sediment quality and potential ecological risk in marine sediments in Gymea Bay located in south Sydney, Australia. A total of 32 surface sediment samples were collected from the bay. Current track trajectories and velocities have also been measured in the bay. The resultant trace elements were compared with the adverse biological effect values Effect Range Low (ERL) and Effect Range Median (ERM) classifications. The results indicate that the average values of chromium, arsenic, copper, zinc, and lead in surface sediments all reveal low pollution levels and are below ERL and ERM values. The highest concentrations of trace elements were found close to discharge points and in the inner bay, and were linked with high percentages of clay minerals, pyrite and organic matter, which can play a significant role in trapping and accumulating these elements. The lowest concentrations of trace elements were found to be on the shoreline of the bay, which contained high percentages of sand fractions. It is postulated that the fine particles and trace elements are disturbed by currents and tides, then transported and deposited in deeper areas. The current track velocities recorded in Gymea Bay had the capability to transport fine particles and trace element pollution within the bay. As a result, hydrodynamic measurements were able to provide useful information and to help explain the distribution of sedimentary particles and geochemical properties. This may lead to knowledge transfer to other bay systems, including those in remote areas. These activities can be conducted at a low cost, and are therefore also transferrable to developing countries. The advent of portable instruments to measure trace elements in the field has also contributed to the development of these lower cost and easily applied methodologies available for use in remote locations and low-cost economies.

Disciplines

Medicine and Health Sciences | Social and Behavioral Sciences

Publication Details

Alyazichi, Y. M., Jones, B. G., McLean, E., Altalyan, H. N. & Al-Nasrawi, A. K. M. (2015). Risk assessment of trace element pollution in Gymea Bay, NSW, Australia. *World Academy of Science, Engineering and Technology. Proceedings*, 9 (12), 1286-1292. Melbourne, Australia International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering. ICEWRE 2015: 17th International Conference on Environmental and Water Resources Engineering

Risk Assessment of Trace Element Pollution in Gymea Bay, NSW, Australia

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Abstract—The main purpose of this study is to assess the sediment quality and potential ecological risk in marine sediments in Gymea Bay located in south Sydney, Australia. A total of 32 surface sediment samples were collected from the bay. Current track trajectories and velocities have also been measured in the bay. The resultant trace elements were compared with the adverse biological effect values Effect Range Low (ERL) and Effect Range Median (ERM) classifications. The results indicate that the average values of chromium, arsenic, copper, zinc, and lead in surface sediments all reveal low pollution levels and are below ERL and ERM values. The highest concentrations of trace elements were found close to discharge points and in the inner bay, and were linked with high percentages of clay minerals, pyrite and organic matter, which can play a significant role in trapping and accumulating these elements. The lowest concentrations of trace elements were found to be on the shoreline of the bay, which contained high percentages of sand fractions. It is postulated that the fine particles and trace elements are disturbed by currents and tides, then transported and deposited in deeper areas. The current track velocities recorded in Gymea Bay had the capability to transport fine particles and trace element pollution within the bay. As a result, hydrodynamic measurements were able to provide useful information and to help explain the distribution of sedimentary particles and geochemical properties. This may lead to knowledge transfer to other bay systems, including those in remote areas. These activities can be conducted at a low cost, and are therefore also transferrable to developing countries. The advent of portable instruments to measure trace elements in the field has also contributed to the development of these lower cost and easily applied methodologies available for use in remote locations and low-cost economies.

Keywords—Current track velocities, Gymea Bay, surface sediments, trace elements.

I. INTRODUCTION

MARINE sediment contamination caused by trace elements in estuaries and bays around coastal areas are considered an international environmental issue because of their toxicity, non-biodegradable and accumulative characteristics. Furthermore, they are not removed from aquatic ecosystems by self-purification [1], [2] and accumulate in sediments and in fine suspended particles. Trace element pollution enters the marine environment from discharge points; source runoff and human activities related to industry, agriculture, urban development, and other activities. These activities result in waste containing element residues. Consequent increased levels of pollution in sediment sinks can

have harmful and toxic effects on the marine ecosystem [3], [4]. Trace elements are dispersed in aquatic habitats and are then deposited in aqueous environments, combining with sediments through mechanisms such as absorption and ion exchange. Muddy particles are considered to be the ultimate sinks for most accumulated chemical pollution, such as trace elements. Thus, trace elements in sediments and soils contribute to the contamination of aquatic environments due to their toxicity, persistence, difficult degradation, and easy accumulation [5]–[7]. Trace elements can also be released again into the water column as free ions and/or complex compounds from sediments due to such as physical disturbance and chemical and diagenetic factors [8], [9]. Although complex and highly technical methodologies have been established in developed countries to assess the spatial distribution of sediment particles and chemical pollution in bays and estuaries [10], [11], these methods have not really addressed the need to provide methodologies applicable to either remote areas or low-cost technologies, especially in countries with less developed economies or remote locations.

Complex and costly methods are appropriate where studies are being completed by organisations with adequate technical and financial support. Application of such technology in countries with less developed economies is difficult for both cost and technical reasons. Field data, such as tidal levels, current track and wind speed and direction, comprise such suitable data [12], [13]. The main objectives of this paper are to investigate the spatial distribution of trace element concentrations in Gymea Bay sediments, to evaluate the influence of current and tide trajectory on these concentrations, and to assess the potential ecological risk of trace elements within these marine sediments by comparing them with deleterious biological effect values.

II. MATERIAL AND METHODS

A. Study Area

Gymea Bay, which is located 30 km south of Sydney Harbour, is one of several bays belonging to the Port Hacking estuary (Fig. 1). Overall, the inner area of the bay has deeper depths (>16 m), and it provides a significant environmental shelter and habitat for flora and fauna, and breeding and nursery habitats for several species, and is of economic and social value (e.g. tourism, business enterprises, fisheries and aquaculture) [14]. The main freshwater discharge points for the catchment areas are shown in Fig. 1, which shows catchment model segments for Yowie Bay and the adjacent Gymea Bay in yellow. These were determined by Sydney

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Water (the statutory authority responsible for water supply and management across Sydney) [15].

The catchment areas of Gymea Bay are urbanized with a population of approximately 40,000 in the local government

area. The sources of contamination are mainly from the catchment areas (Fig. 1), and from recreational activities along the coastline, such as watercraft, boatyards and fishing, which can in turn affect the water quality of the bay [15], [16].

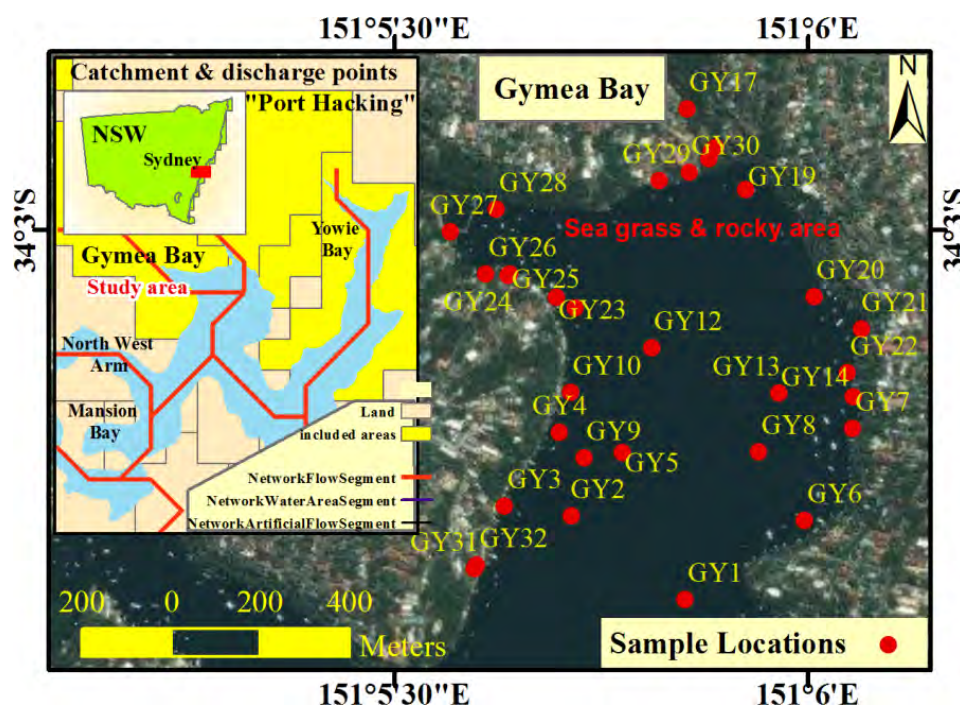


Fig. 1 Geographical locations map showing thirty-two surface sediment samples in Gymea Bay, Port Hacking, NSW, Australia

B. Sample Collection and Preparation

A total of 32 surface sediment samples were collected using a grab sampler during the summer of 2012 (Fig. 1). Only the surface 5 cm of sediment was reserved for analysis. Water depth and location were recorded at each site using sonar and a Geographical Position System (GPS). Sediment grain size measurements and percentages for sand and muddy particles were conducted using a Malvern Mastersizer 2000. Trace elements were measured using an XRF SPECTRO-analytical instrument (XEPOS) energy dispersive spectrometer fitted with a Si-docile detector; following an established standard procedure [17], [18]. ArcGIS desktop software, version 10.2, was applied to create maps for the study area by geostatistical analysis (Kriging method) [19]. The Kriging method uses statistical models that generate a variety of map outputs, such as predictions, standard errors, and probability. However, Kriging flexibility often requires inter-active decision-making. Kriging assumes the data are derived from a stationary stochastic process, while some other methods assume normally distributed data [9].

C. Hydrodynamic Activities

Hydrodynamic parameters comprising current speed and direction in the study area were measured by drogues (Fig. 2). Three drogues were modified from a previous design to permit deployment in estuarine water. These were constructed in a workshop at the University of Wollongong. The height of each drogue was 70 cm, and each one consisted of a buoy (ball),

with a waterproof enclosure to hold a small GPS and a flashing light. An associated GPS software program was used to plot the speed and trajectory of the drogues and the data was uploaded into Google earth and kmz files. Velocity data from the GPS was not differentially corrected and, therefore, has been smoothed to filter out GPS variations and to gain an estimate of average velocities over the drogue track.

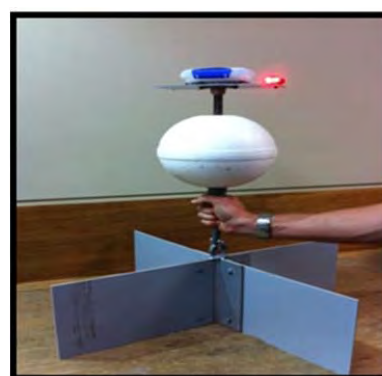


Fig. 2 Modified design of the drogue to measure tides and currents

D. Potential Ecological Risk Index

The potential ecological risk index (RI) was used to assess the effects of the trace element pollution in the study area. The RI was originally defined by [20], and was calculated using [21]:

$$CF^i = C_{\text{sample}} / C_{\text{background}} \quad (1)$$

$$E_r^i = T_r^i \times CF^i \quad (2)$$

$$RI = \sum_i^n E_r^i \quad (3)$$

where, C is the measured concentration of each trace element; $C_{\text{background}}$ concentrations of trace elements in core at 2.5m, which were obtained from [22]; CF^i is the contamination factor; E_r^i is the monomial potential ecological risk factor; T_r^i is the response coefficient for the toxicity of single trace element, which was adopted to be the evaluation criterion i.e. Cr=2, Ni=Cu=Pb= 5, Zn=1 and As=10 [20], [23]; and RI is the sum of all risk factors for trace elements in sediments.

According to [20], the following terminology is designed to be applied for the RI values in Table I.

TABLE I
INDICES AND POTENTIAL ECOLOGICAL RISK OF TRACE ELEMENTS POLLUTION

RI value	Potential ecological risk
RI < 30	Low risk
30 ≤ RI < 60	Moderate risk
60 ≤ RI < 120	Considerable risk
RI ≥ 120	Very high risk

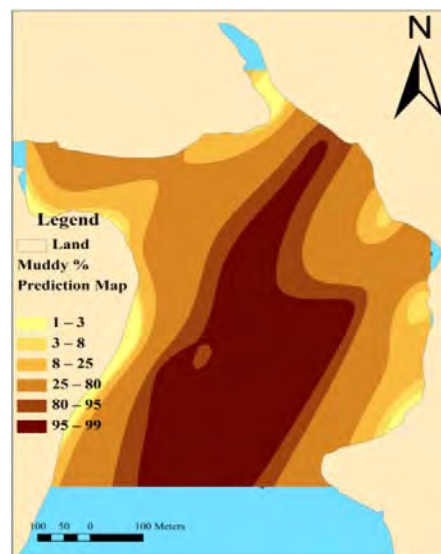
III. RESULT AND DISCUSSION

A. Spatial Distribution of Sediment Particles and Trace Elements

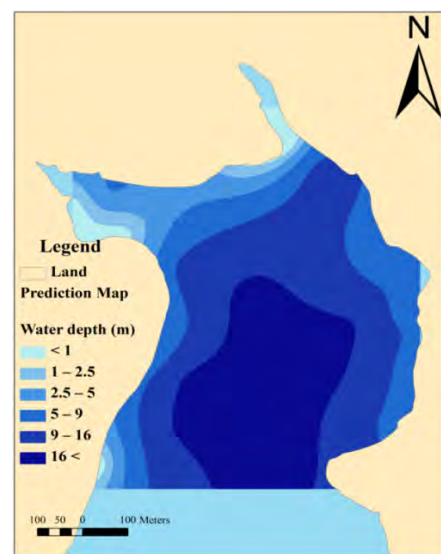
Fine sediments (muddy particles) and water depth varied within the bay. Fig. 3 (a) illustrates that the highest percentages of mud (silt and clay) were concentrated within the inner bay where water depths were greater (> 9m; Fig. 3 (b)) and the waves have less effect on bottom sediments. Therefore, the fine and very fine particles can gradually settle within the inner bay [24]. In contrast, the highest percentages of sand were found to be in the shallow water (< 2.0 m; Fig. 3 (b)) near the shoreline and the edges of the bay. These areas have high local wave activity, which disturbs and transports the fine and very fine particles into deeper areas.

Prediction maps of chromium, arsenic, copper, zinc, lead, rubidium and bromine are displayed in Figs. 4 (a)-(g). The spatial distribution of trace element concentrations generally exhibit similar patterns in the bay. The highest concentrations of these elements were found to be in the inner and middle parts of the bay, because these sites have the highest percentages of mud particles and organic matter, which are indicated by rubidium (Rb) and bromine (Br), Figs. 4 (f), (g), respectively. Muddy particles and organic matter can play important roles in absorbing and accumulating the trace elements. Furthermore, trace elements were concentrated around the harbors and marinas where boats are moored, with associated potential contaminant spills. The surface sample sites are close to areas that contain boatyards where boats are painted to prevent fouling. Consequently, these sites are considered to be a sink for trace elements [23], [25], [26].

However, the lowest concentrations of trace elements were found to be along the shoreline and at the edges of the bay, which are dominated by coarse sand percentages [24], and have the lowest percentages of organic matter Fig. 4 (g).



(a)



(b)

Fig. 3 (a) Muddy percentages and (b) Water depth (m) in Gymea Bay

B. Hydrodynamic Measurements

Estuaries are typically regarded as mixed systems controlled by the combined influences of tides and catchment flows. Nonetheless, many aspects of their dynamics are influenced by wind force. Because wind is inherently variable, determining conventions that apply commonly is a challenge for estuarine physicists [27].

Information on tides and winds were obtained from Manly Hydraulics Laboratory and the BOM (Bureau of Meteorology) and field efforts concentrated on the collection of velocity and track data for the ebb tidal currents. These are plotted in Fig. 5.

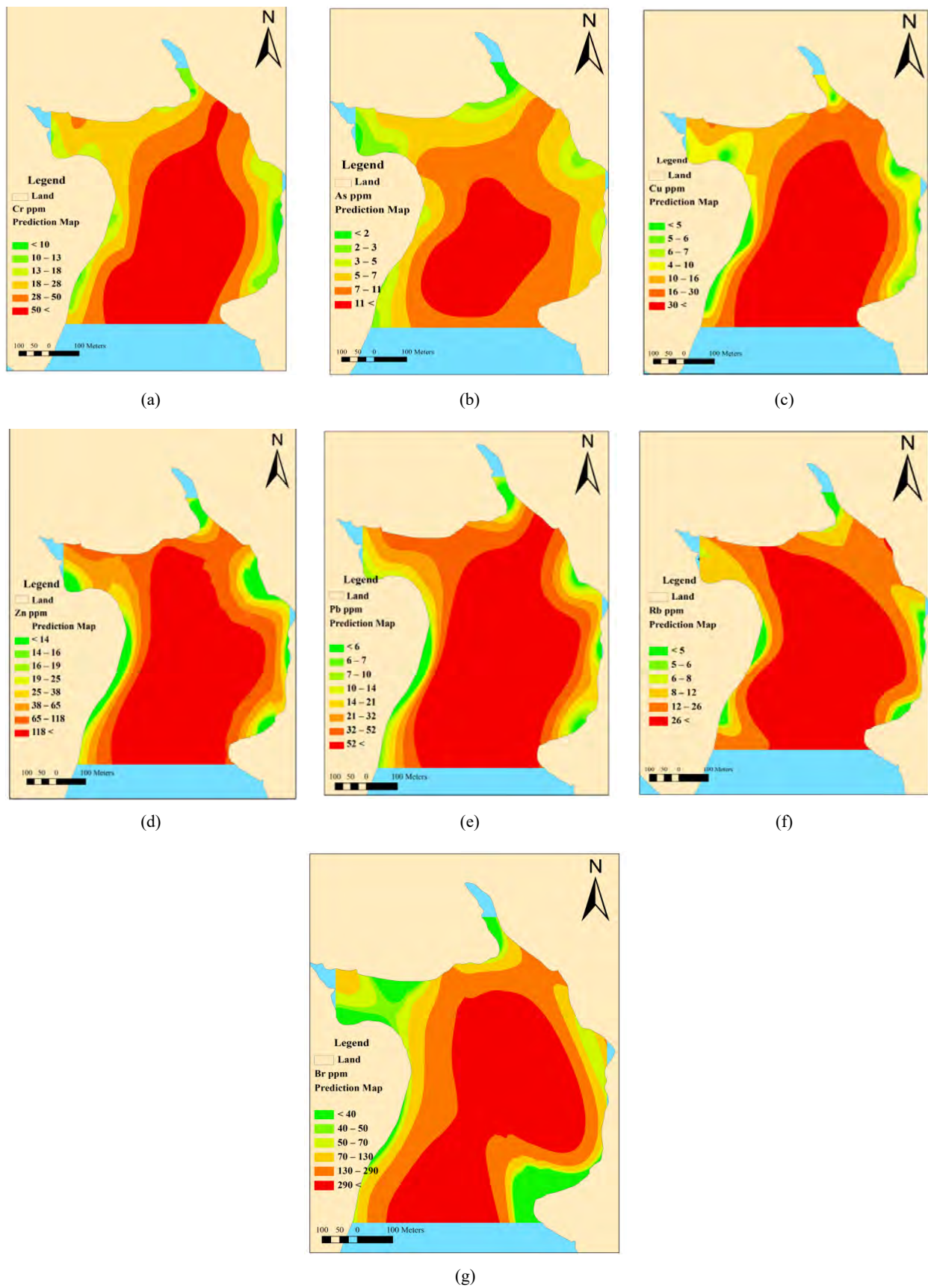


Fig. 4 Spatial distribution of (a) Cr, (b) As, (c) Cu, (d) Zn, (e) Pb, (f) Rb and (g) Br in surface sediments in Gymea Bay

Three drogues were deployed in GyMEA Bay; the first and second drogues were at the head of the bay and the third was placed in the inner and middle bay. As observed able in Fig. 5, velocities 1, 2 and 3 have peaks in velocity; this is because of the effects of boats moving past during measurement.

The current tracks showed that drogues 1 and 2 had low velocities (less than 0.005m/sec) compared to 3, which had a faster velocity since it was influenced by a greater tidal volume. This is due to the upstream tidal storage at these locations. In addition, in the third current track, the velocity has the capability to transport fine particles and trace element pollution (Fig. 5 (d)). The currents showed complex circulations, and wind driven currents caused subsequent return flows to be concentrated around the bay margins. The fine sediment particles and trace elements transported by current and tidal activity then gradually precipitate at deeper sites in the middle bay during low flow conditions. In addition, local waves are also active in the shallow waters, leading to re-suspension and transport of fine particles into deeper sites, where the current and waves are less active and cannot disturb the bottom sediments. This hydrodynamic method using drogues could be used in developed countries but is also applicable in remote locations and is cost-effective for developing countries.

Because of the low tidal current speed in the study area, this bay can be considered to be significantly affected by wind,

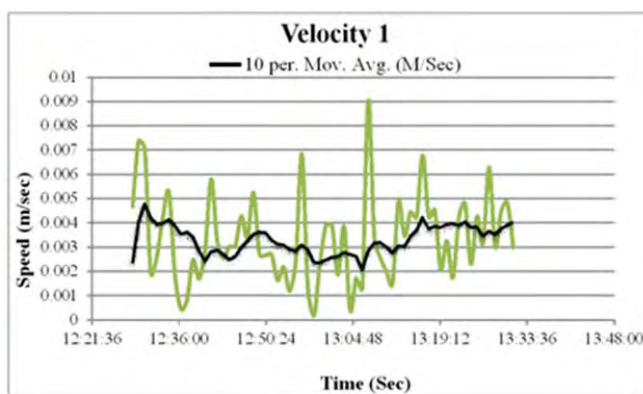
with ebb current tracks being deflected towards the lee shores, depending on wind direction at the time. Thus, movement and subsequent setting of trace elements and suspended sediment particles from catchments will be a result of ebb tidal drainage and dominant wind directions during catchment events.

C. Risk Assessments

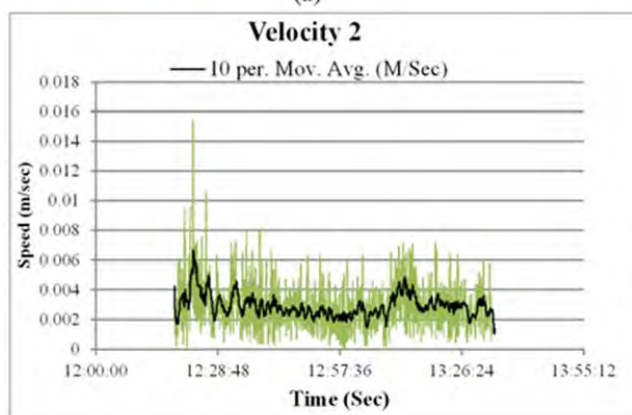
The trace element concentrations were compared with the deleterious biological effect values in marine sediments as shown in Table II. The effect range low (ERL) and effect range median (ERM) in estuarine and marine sediments were measured based on guidelines suggested by the U.S. National Oceanic and Atmospheric Administration [27]-[30]. The mean concentrations of trace elements in GyMEA Bay sediments were less than both ERL and ERM, which shows no contamination for these elements. However, some sites in the bay exceeded the ERL (Table II), which are considered to be moderately to considerably contaminated, whereas these sites are below ERM. The source of contamination may be gasoline fumes from both car and boat exhausts. In addition, the potential ecological risk index (RI) is also calculated. It is considered the method most frequently used in biological toxicology, environmental chemistry and ecology to evaluate the toxicity of the trace elements for both human and environmental ecosystems, which indicates the concentration of trace elements (Table I) [31]-[33].



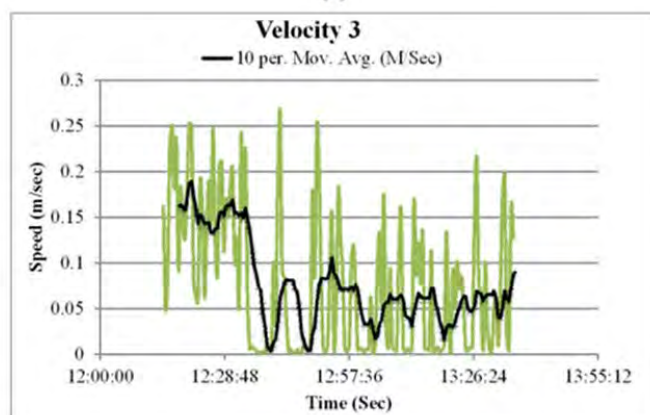
(a)



(b)



(c)



(d)

Fig. 5 Current track velocities for three drogues in GyMEA Bay

TABLE II
COMPARISON BETWEEN CONCENTRATIONS OF TRACE ELEMENTS (PPM)
FROM THE STUDY AREA AND EFFECT RANGE LOW (ERL) AND EFFECT RANGE
MEDIAN (ERM) VALUES

Trace elements	Cr	As	Cu	Zn	Pb
Range	6-94	1-14	4-61	11-224	5-113
Mean	6	7	19	65	34
ERL	81 (4)	8.2 (7)	34 (6)	150 (7)	46.7 (8)
ERM	370 (-)	70 (-)	270 (-)	410 (-)	218 (-)

Values enclosed in parentheses are the number of samples exceeding ERL and ERM.

Generally, the results of RI values indicated that surface sediments in Gymea Bay have considerable to low risk (RI about 26). The highest RI value at some sites (inner) in Gymea Bay ranged between 70 and 85. This is because these sites are close to discharge points - watercraft and boatyards - as well as in sediment types which are dominated by muddy particles (Fig. 6). However, the lowest RI value sites are also indicated in Gymea Bay, located around its edges and northwestern areas, (Fig. 6), where the sediment fractions are dominated by coarse particles (sand and/ or silt) and currents and waves are more active, leading to transportation of fine particles and trace elements to deeper areas.

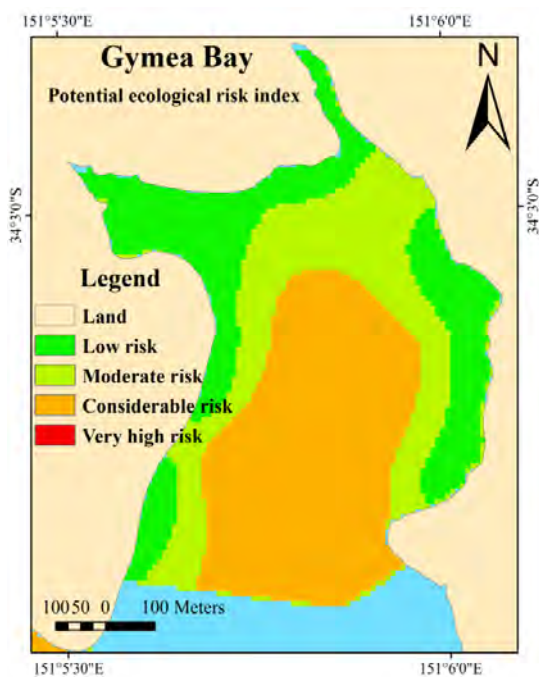


Fig. 6 Potential ecological risk assessment in Gymea Bay, NSW

IV. CONCLUSION

In order to evaluate the environmental status of marine sediments, the trace elements Cr, As, Cu, Zn and Pb, were analysed in surface marine sediments in Gymea Bay, NSW, Australia. Adverse biological effect values and potential ecological risk assessment were used to evaluate contamination of trace elements. Overall, the findings indicate that the bay had low contamination by trace elements. The highest concentrations of trace elements were found to be in

the inner area of the bay, which displays levels with a considerable risk of contamination. This was because the sediments contained higher percentages of mud particles and organic matter. The lowest concentrations of trace elements were found to be at the edges of the bay, which had low risk of contamination, because these areas were dominated by high percentages of sand and low percentages of organic matter. In addition, waves and tides become more active in these sites, which can disturb and transport fine particles and trace elements, depositing them in the inner bay. The trace elements in Gymea Bay have accumulated over time from sources such as discharge points, fuel spillage, and exhaust fumes from vehicles and boats.

ACKNOWLEDGMENT

This paper is a part of the first author's PhD thesis undertaken at the School of Earth and Environmental Sciences, University of Wollongong. It was financially supported by the Ministry of Higher Education and Scientific Research, the Iraqi Government and the University of Wollongong.

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Lead isotope fingerprinting used as a tracer of lead pollution in marine sediments from Botany Bay and Port Hacking estuaries, southern Sydney, Australia.

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Abstract

Concentration of lead was determined in marine sediments from Botany Bay and Port Hacking estuary, south of Sydney. Areas with the highest concentrations of lead in the samples were analysed for lead isotopes to effectively identify the metal contamination source. In addition, other sediment samples were collected from cores at 40 cm depth to represent the natural background composition. The total lead in the tested marine sediments varied from 75.6mg/kg to 582.2mg/kg. The $^{206}\text{Pb}/^{204}\text{Pb}$ shows a decline towards the current surface sediment. Assuming that the natural background source of lead remains the same in terms of both isotopic signature and accumulation rate, the decline in $^{206}\text{Pb}/^{204}\text{Pb}$ indicates a rise in the contribution of old lead to the sediment, mainly from gasoline fumes (car and boat exhausts) and paint. This is because the samples came from close to water discharge points.

Keywords: Estuaries, marine sediments, lead, Pb isotopes, source identification.

1. Introduction

Lead pollution above background concentrations in ecosystems is derived from anthropogenic activities such as industry, mining, coal burning, paint and gasoline-fumes. Lead is considered a poisonous metal that is harmful to the human body and can cause serious diseases such central nervous system disorders, kidney brain damage and high blood pressure (Needleman, 2004). Lead pollution increased in the early 1970s from lead-based paints and gasoline-fumes in developed countries, as well as emissions from industrial activities (Needleman, 2004). It is an important issue in environmental investigation to identify the source of pollution and determine the transport history of pollutants (Cheng and Hu, 2010). A large number of sources of lead pollution occur in ecosystems including major contributions from urbanization, such as gasoline-air emissions, paints and insecticides, as well as from natural sources such as bedrock (Lu et al., 2011). The distributions of total Pb in the sediments were derived from statistical analysis of a large sample dataset to categorize the source and transport of metal pollution. The chemical composition of trace metals can be an

effective method to recognize the source of resources and to compare them by using “fingerprinting” (Qishlaqi and Moore, 2007). Several attempts have been made to fingerprint the isotopic composition and ratios of Pb and other metals, which can play an important and powerful tool in tracking sources of pollution (Chiaradia et al., 1997; Franco-Uriá et al., 2009; Cheng and Hu, 2010). Thus, using isotopic ratios of metals is a more found tracking method than using their concentrations alone to identify sources of contamination (e.g. carbon and chlorine; Sueker, 2001; Philp et al., 2002). In the same way Pb isotopic composition may be used to trace the source and transport history of Pb (Chiaradia et al., 1997; Cheng and Hu, 2010; Lu et al., 2011). The main objective of investigating lead isotopes is to support a source apportionment and historic record of lead pollution in the study areas.

1.1 Study areas

This study covers two coastal areas classified as open estuaries, the Port Hacking and Botany Bay areas in New South Wales, Australia (Fig. 1). The Port Hacking catchment consists of approximately 60% natural bushland with the remainder being urbanised areas. Port Hacking contains several bays and some shallow rivers and creeks. Consequently, these deeper bays form sediment traps for fine and very fine particles and detritus that are discharged from the rivers and creeks (Smith et al., 1990). In contrast, the catchment areas of Botany Bay are urbanised with light industry. It is described as a semi-enclosed estuary with a wide coastal embayment that joins with the open sea. The hydrodynamics of Botany Bay have been changed by anthropogenic constriction, which includes a shipping container port as well as the reclamation effects of Sydney’s main airport on the northern side of Botany Bay (Gray et al., 2001; Fraser et al., 2006).

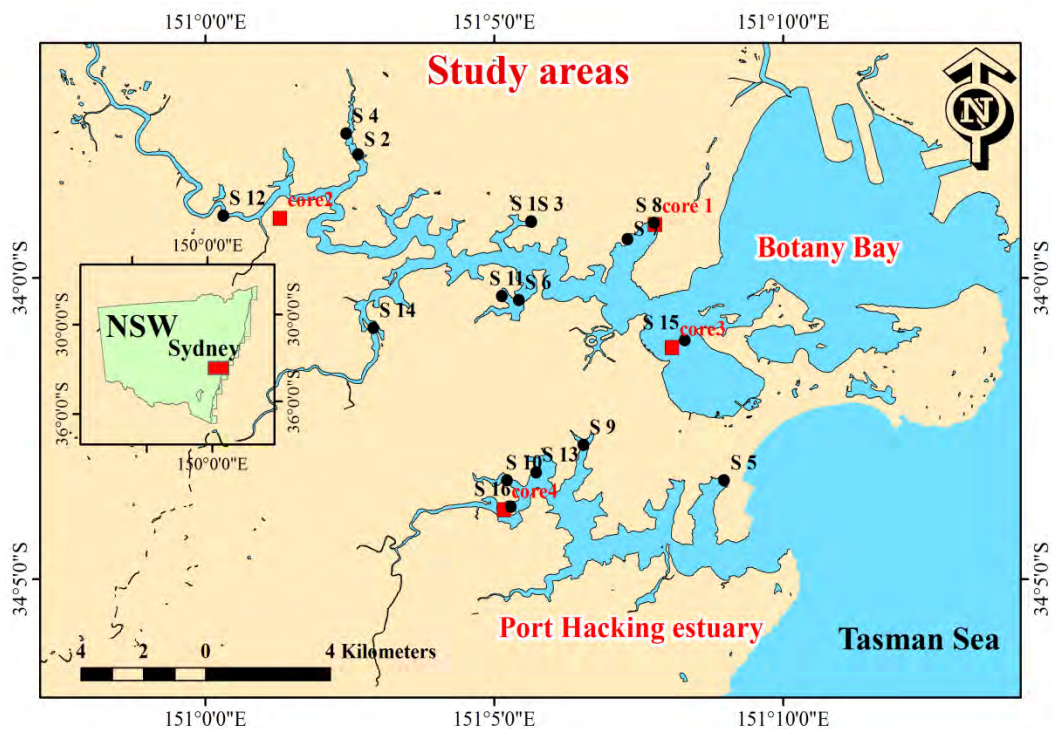


Fig. 1 Surface (dots) and subsurface (red squares) sample locations for lead isotopes in the study areas.

2. Methods and Materials

2.1 Sample collection

Fourteen surface sediment samples from these study areas, which have the highest concentrations of lead, and two from a previous study were selected and analysed for lead isotopes. Also, four subsurface sediment samples from different locations were selected to use as background values (Fig. 1). ArcGIS desktop software, version 10.2, was used to create bay boundaries around the collected plot sediment samples of each bay to produce maps for lead distribution and muddy particles. Spline with Barriers was chosen as the interpolation method for this part of the analysis due to the ability to input a barrier feature when interpolating a raster surface from points using a minimum curvature spline technique (Lin and Chen, 2004; Lark et al., 2006).

2.2 Analytical methods

Powdered samples were analysed ($<4\mu\text{m}$) at the National Measurement Institute (NMI), NSW, Australia. X ray fluorescence was used to measure concentration of total lead in sediments. Furthermore, approximately 2 g of each sample was digested in acid (nitric and hydrochloric) then measured for lead using inductively coupled plasma - mass spectrometry (ICP-MS) using a Perkin Elmer Elan DRCII, 1300 W, which has advantages for the analysis

of lead isotope ratios in environmental samples (O'Connor and Evans, 2007; Komárek et al., 2008). A summary of the tuning parameters for ICP-MS equipment, which is used during measurement of the samples, is presented in Table 1.

Table 1: Tuning parameters and implication of the ICP-MS.

Parameters	Typical value/ range He mode
RF Power	1500w
RE matching	1.75 V
Sample depth	8 mm
Torch- H	0.8 mm
Torch- V	0.4 mm
Carrier gas	0.9 l/min
Makeup gas	0.15 l/min
Nebulizer pump	0.1 rps
Extract 1	4 V
Extract 2	-140 V
Omega Bias-ce	-16 V
Omega Lens-ce	1.8 V
Cell Entrance	-24 V
QP focus	-12 V
QP bias	-16V
Cell exit	-30 V

3. Results and Discussion

3.1 Lead concentration in marine sediments

Lead concentrations in surface sediments from the study areas ranged between 75.6 mg/kg and 582.2 mg/kg. The highest concentrations of lead were found in Salt Pan Creek, close to discharge points and around watercraft within the bays, as well as in the inner parts of bays (Fig. 2). These areas are close to the source of contamination such as stormwater and watercraft, and have high percentages of mud particles (Fig. 3). In contrast, the lowest concentrations of lead were in the South West Arm and Woronora River that drain natural catchments and are mainly free from residential development. Low concentrations also occur in the mouths and along the shorelines of the bays (Fig. 2) because these sites are affected by wave reworking of the sediment that consists predominantly sand (Fig. 3).

Lead concentrations are much lower (4.0 mg/kg to 22.5 mg/kg) within the subsurface sediments. Compared with these background concentrations the significant increase of lead concentrations in the surface sediments indicates contributions from anthropogenic sources of lead.

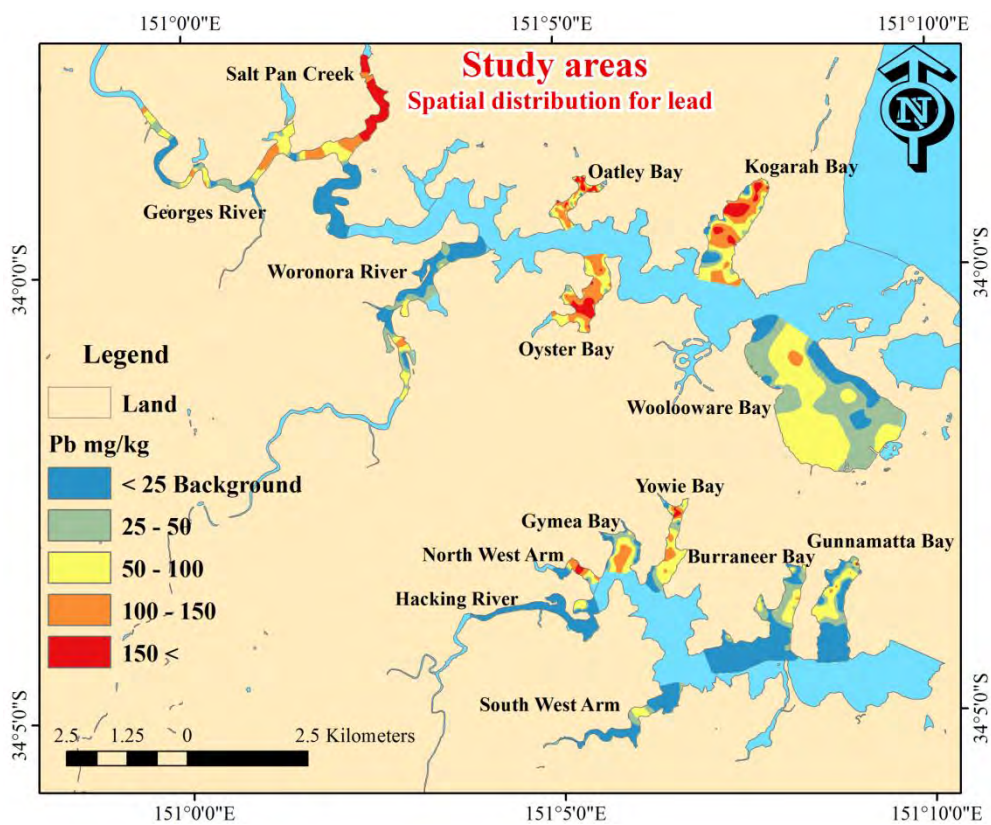


Fig. 2 Spatial distribution of lead concentration (mg/kg) in the study areas.

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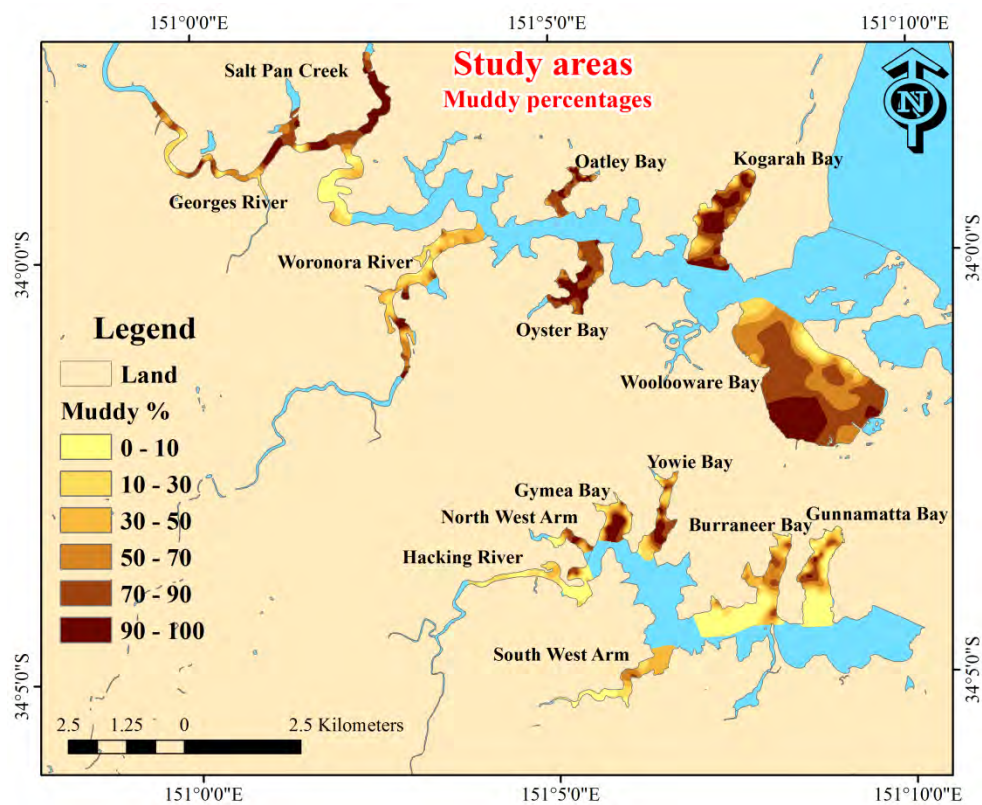


Fig. 3 Spatial distribution of mud percentages in the study areas.

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3.2 Lead source and apportionment

Although no previous data on lead isotopes had been reported in these study areas, lead isotope signatures have now been determined for the surface and subsurface sediment samples. Pb isotopic compositions can identify the contributions from Pb-containing products such as gasoline-fumes, leaded pesticides and leaded paints (Flament et al., 2002; Vallelonga and Mather, 2003; Cheng and Hu, 2010).

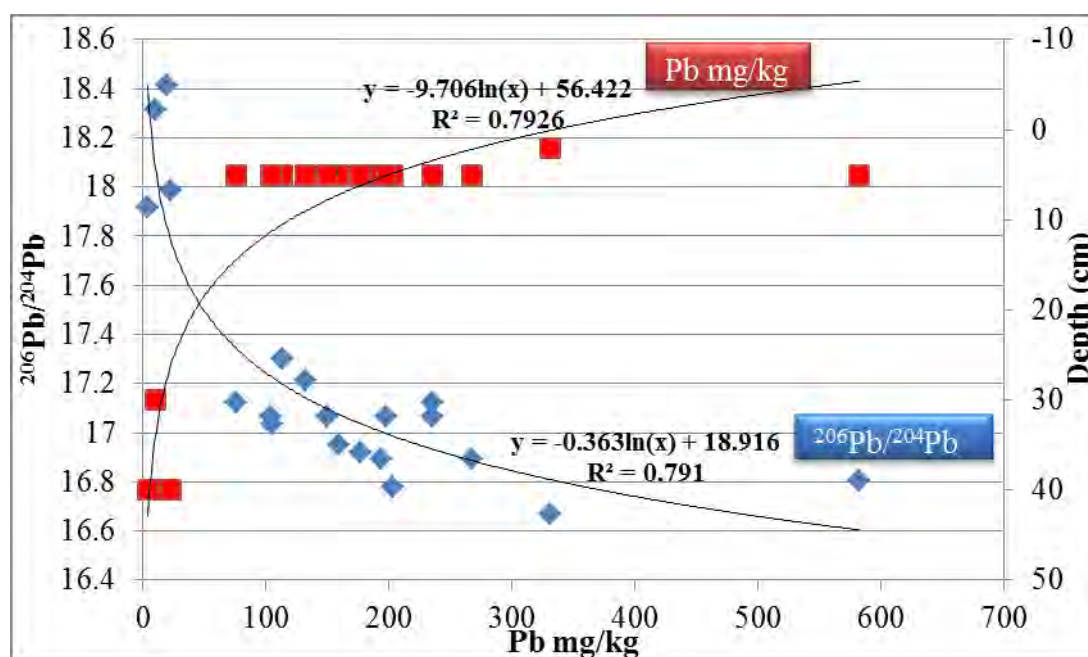


Fig. 4 ■ Pb concentration and variations of ◆ $^{206}\text{Pb}/^{204}\text{Pb}$ ratio with sediments depth in the study areas. The surface and subsurface sediment samples from Botany Bay and Port Hacking show that their isotopic ratios are dependent on the Pb concentrations.

The concentration of lead in the subsurface samples was low at about 15 mg/kg (Alyazichi et al., 2014). The $^{206}\text{Pb}/^{204}\text{Pb}$ ratio in these subsurface sediments, below at least 30 cm depth in cores 1 and 3, represents the natural background (pre-European settlement) isotopic signature of about 18.4. This was reinforced by similar lead isotope ratios measured in pre-industrial sediment in cores from Lake Illawarra some 80 km south of Sydney (Chenhall et al., 1995; Chiaradia et al., 1997). Between 40 cm and 5 cm, the $^{206}\text{Pb}/^{204}\text{Pb}$ ratio demonstrated a decline towards the current surface sediment. Assuming that the natural background source of Pb remains the same in terms of both isotopic signature and accumulation rate of Pb from the source, the decline in $^{206}\text{Pb}/^{204}\text{Pb}$ suggests a rise in the contribution of old lead to the sediment, mainly from gasoline fumes (car and boat exhausts; Fig. 4). This modification of isotopic composition corresponds to a progressive increase in the concentration of lead from 75 mg/kg and 582 mg/kg in the upper sedimentary layers (Fig. 4). These changes correspond

very well with findings from both roof dust and contaminated sediments from the Lake Illawarra area, where the background $^{206}\text{Pb}/^{204}\text{Pb}$ concentrations is about 18.7%.

Table 2 represents lead isotopes, lead concentrations in marine sediments, and the calculated contribution of lead from air emissions (i.e. gasoline fumes), which are sourced from vehicles and boats exhausted, as well as lead-based paint and industries.

Table 2 Lead isotope data from the study areas and calculated percentage contributions from air-lead (i.e. gasoline fumes).

Sample No.	Depth(cm)	Pb mg/kg	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{206}\text{Pb}$	$^{206}\text{Pb}/^{204}\text{Pb}$	Pb air%
S 1*	5	582.2	0.921	2.173	16.81	82.32
S 2	5	267.6	0.918	2.174	16.89	78.61
S 3	5	234.9	0.913	2.168	17.06	71.09
S 4	5	330.7	0.931	2.188	16.67	88.41
S 5	5	203	0.925	2.175	16.78	83.54
S 6	5	198.2	0.909	2.163	17.06	71.09
S 7	5	235.2	0.912	2.168	17.12	68.55
S 8	5	193.7	0.916	2.17	16.89	78.61
S 9	5	176.5	0.914	2.168	16.92	77.37
S 10	5	158.8	0.914	2.168	16.95	76.12
S 11	5	149.9	0.91	2.164	17.06	71.09
S 12	5	131.6	0.906	2.158	17.21	64.71
S 13	5	113	0.91	2.163	17.30	60.82
S 14	5	104.9	0.907	2.156	17.04	72.36
S 15	5	104.1	0.905	2.159	17.06	71.09
S 16	5	75.6	0.901	2.157	17.12	68.55
Core 1-40cm**	40	22.5	0.866	2.113	17.99	31.06
Core 2-40cm	40	20	0.848	2.096	18.42	12.34
Core 3-30cm	30	10.5	0.85	2.102	18.32	16.74
Core 4-40cm	40	4.0	0.899	2.151	17.92	33.87

* Surface sample, ** Subsurface sample.

Other lead isotope ratios in the Botany Bay and Port Hacking sediment samples are represented by $^{207}\text{Pb}/^{206}\text{Pb}$ vs $^{208}\text{Pb}/^{206}\text{Pb}$ in (Fig. 6; Alyazichi et al., 2014). The surface samples lie within and above some samples of roof dust in the Illawarra district (Chiaradia et al., 1997), and below Broken Hill and Mt Isa (old lead deposits in Australia used in the production of leaded petrol), and leaded gasoline fumes. The subsurface sediment samples (background) from the study areas plot below other samples, except for the samples from Lake Illawarra, with isotope ratios of 2.1 and 0.85 for $^{208}\text{Pb}/^{206}\text{Pb}$ and $^{207}\text{Pb}/^{206}\text{Pb}$, respectively (Fig. 5).

The concentration of Pb in subsurface sediments in the study areas ranged between 4.0 mg/kg -22.5 mg/kg and the isotopic composition at cores 1 and 3 represent essentially natural background sediment from a Palaeozoic source (Chiaradia et al., 1997). Two of the samples

from 40 cm show partial contamination by introduced lead probably representing faster sedimentation rates at cores 6 and 11. The lead concentration increased over time towards the surface sediment as a result of anthropogenic contributions. Fig.5 shows isotope modelling demonstrated that the lead concentrations in surface sediments indicate mixing with substantial quantities (60-80%) of older Broken Hill-Mt Isa lead derived from anthropogenic pollution, especially gasoline fumes from both cars and boats.

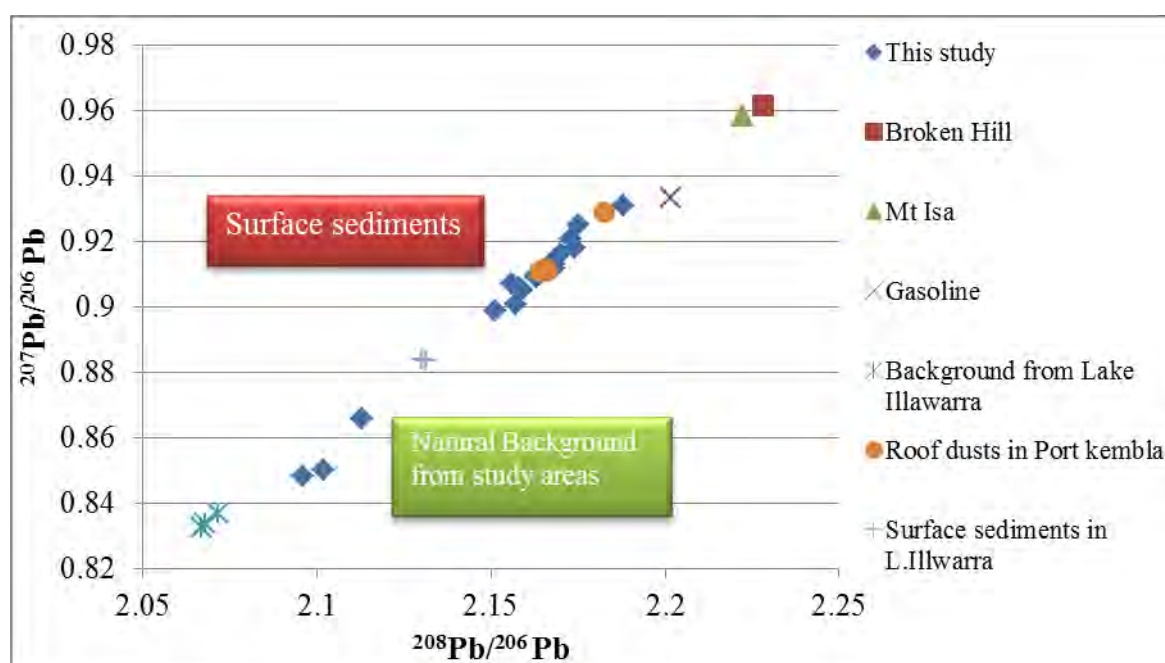


Fig. 5 Comparison between $^{207}\text{Pb}/^{206}\text{Pb}$ and $^{208}\text{Pb}/^{206}\text{Pb}$ in different sites.

Conclusions

Our investigation of lead pollution in marine surface sediments from both Botany Bay and Port Hacking estuary, southern Sydney, indicate a significant increase in surface lead concentrations compared to subsurface sediments. Moreover, the isotopic ratio of $^{206}\text{Pb}/^{204}\text{Pb}$ varied from 16.81 at depth 5 cm to 18.42 at a depth of 40 cm. The latter represent natural background isotopic ratios whereas lead isotope modelling demonstrated that the lead concentrations in surface sediments were derived from anthropogenic pollution, especially gasoline fumes from both cars and boats. Between 60-88% of the lead in the surface sediments consists of old Broken Hill or Mt Isa lead derived mainly from leaded paint and gasoline.

Acknowledgements

This paper is a part of the first author's PhD thesis undertaken at the School of Earth and Environmental Sciences, University of Wollongong. It was financially supported by GeoQuEST Research Centre, University of Wollongong, Australia.

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Geochemical assessment of trace element pollution in surface sediments from the Georges River, southern Sydney, Australia

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Abstract

Measurement of elevated trace elements is an important component of environmental assessment and management of estuarine marine sediments in systems adjacent to concentrated human activity. The present study surveys the estuarine sediments in selected tributary bays, creeks and the upper segments of the Georges River system, NSW, Australia, which flows into the Tasman Sea through Botany Bay. A total of 146 surface sediment samples were analysed by X-ray fluorescence. Potential pollution of sediments was evaluated using potential load index, modified degree of contamination and potential ecological risk index. The spatial distribution of trace elements varies between sites. Variable sources of contamination, including runoff from catchment areas, and emissions from watercraft and boatyards are contributing sources. Bay morphologies and their interactions with catchment and tidal flows play significant roles in the distribution of trace elements. The greatest concentration of trace elements occurs around discharge points, and in the inner parts of bays that have high percentages of mud particles and organic matter. The lowest contamination by trace elements was found to be in sandy sediments along the shoreline and edges of the bays. Trace element distributions decline in concentration in residential-free areas and reach background levels in deeper sediment cores.

Keywords: Surface sediments; trace elements; risk assessments; sediment quality; Georges River, GIS.

1. Introduction

Coastal and estuarine ecosystems can play a significant role as reservoirs for many persistent organic and inorganic contaminants, such as nutrients and trace elements, through adsorption onto suspended matter and subsequent sedimentation [1, 2]. The main sources of contamination in estuaries are derived from catchment area runoff and include mining, industries, urban development, sewage discharge, agricultural and irrigation runoff, and atmospheric deposition [3-5]. In addition, contamination may come from boat moorings and boatyards within bays. These contaminants are rapidly transported and adsorbed onto sediments, especially fine particles such as clay minerals and organic matter, via chemical, physical and biological processes. When changes in environmental conditions occur, the resultant chemical (pH and Eh), physical (temperature and turbidity) and biological processes can release contaminants back into the water column. This secondary contamination can have a significant effect on marine ecosystems [5, 6]. Accumulation of trace element pollution occurs in the upper layer of sediments in aquatic environments through geochemical and biological processes and may become toxic to sediment-dwelling organisms and fish [7, 8]. As a consequence, trace element pollution is one of the largest problems in coastal marine ecosystems causing potential bio-accumulation and bio-magnification, resulting in long-term implications since it can enter the human body via the food chain. The objectives of this study were to determine the spatial distribution of trace elements, identify pollution sources and assess potential risks from sediments in the Georges River system, NSW, Australia.

Coastal environments (estuaries and embayments) are important because they act as a sink for sediments and trap large quantities of fine particles. These sediments are related to

pollution because the fine particles have charged surfaces and occur in a protected environment, sheltered from fast currents, waves, tides and wind activities [9]. Both the sediment particles and pollutants may be derived from the adjacent land and transported by runoff, stormwater outlets, tidal activity and waves. The entrapment is due to estuarine environments having a circulatory current activity, which can inhibit the sediment particles from escaping the estuary. Depositional processes for sediments within the estuaries are controlled by flocculation and transportation by tidal current activity and non-tidal waves. Sediment size has an important role in the depositional processes since fine particles can be moved in suspension [10, 11].

The deposition of fine sediment particles can be inhibited by strong tidal activities and large river flow discharges, which occur at the mouth and head of the bay, respectively. Away from the mouth of the bay, the strength of tidal currents and waves declines into the side embayments. As a consequence, the deposition of sediment particles occurs gradually in the inner parts of bays mainly as a result of flocculation. Originally, the coarse sediment fractions comprising pebbles and coarse sands are deposited close to river and stormwater discharge points. In other words, the deposition of coarse to fine sand occurs near the shoreline where the sediment is reworked by wave action. Fine to very fine sediment particles ($< 63\mu\text{m}$) are concentrated in the inner and upper reaches of the estuary and bays, which also contain organic matter [11, 12].

2. Study area

The Georges River system is located approximately 15 km south of the central business district of Sydney ($33^{\circ} 55' \text{ S}$, $151^{\circ} 11' \text{ E}$; Fig. 1) and is classified as a drowned river valley estuary, discharging into a broad bay (Botany Bay) with an unrestricted entrance to the ocean [13]. The smaller Cooks River also drains into Botany Bay to the north of the Georges River. The whole system of the two river estuaries and Botany Bay form an area of approximately

49 km² with a mouth, approximately 1.1 km wide [14]. The system is partly protected from the oceanic tides and waves by headlands. Both main rivers entering the bay have catchment areas that extend into Sydney; thus they have large discharges of urban and industrial stormwater, feeding Botany Bay with an annual water runoff of approximately 520*10⁶ m³ [14]. This study investigates selected sub-environments in the Georges River estuary comprising Woollooware Bay, Kogarah Bay, Oyster Bay, Oatley Bay, Woronora River, Salt Pan Creek and the main arm of the upper Georges River estuary (Fig. 1).

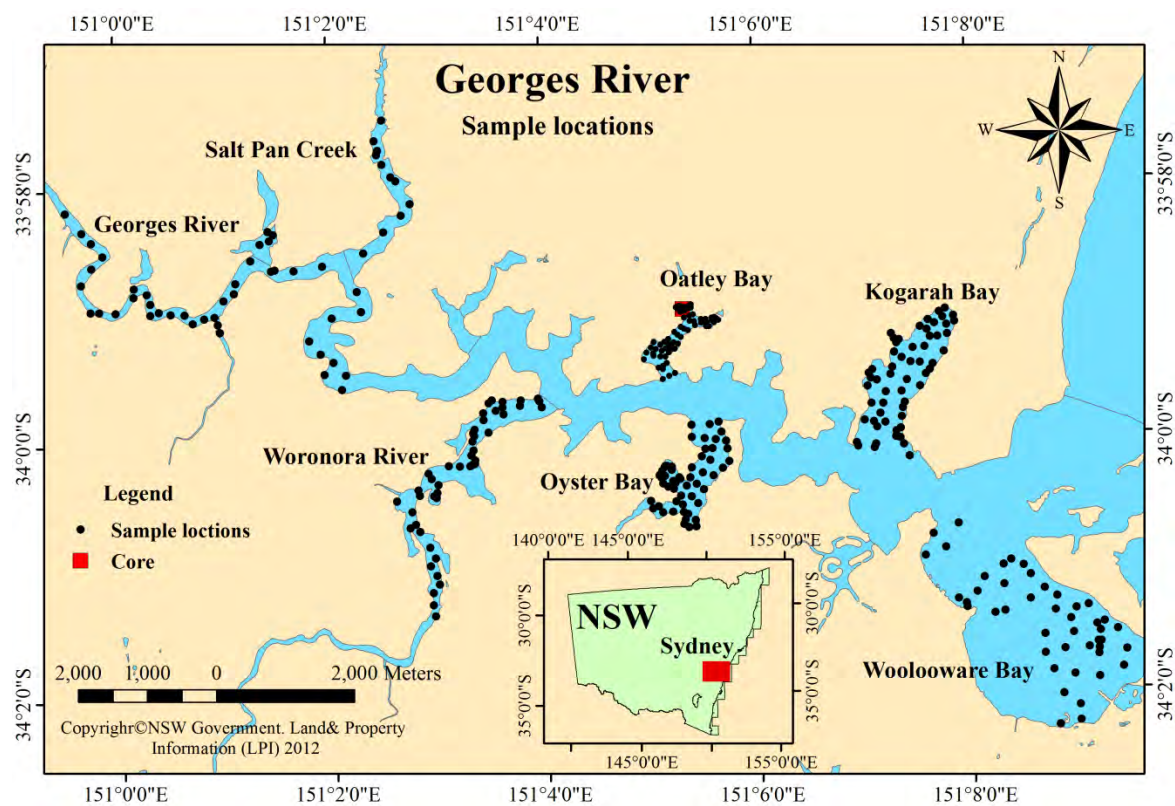


Fig.1. Sample locations from the Georges River system, NSW, Australia.

3. Materials and methods

3.1 Sample collection and analyses

A total of 146 surface sediment samples were collected using a grab sampler during summer 2013, and they were combined with 179 samples from previous work [Fig.1; 15, 16, 17]. The surface 5 cm of sediment was reserved for analysis. Water depth and sample locations were

recorded at each site using echo-sounding (sonar) and a Geographical Position System (GPS). Grain size analyses were conducted using a Malvern Mastersizer 2000, and classified according to [18]. Trace elements were measured using an XRF Spectro-Xepos energy dispersive spectrometer fitted with a Si-docile detector, following an established standard procedure [19]. While a full spectrum of trace elements was determined by the XRF analyses, only chromium (Cr), nickel (Ni), arsenic (As), copper (Cu), zinc (Zn), lead (Pb), rubidium (Rb) and bromine (Br) are presented in this paper because of limited space. The other elements exhibited similar spatial distributions. Subsurface sediment samples from deeper cores (>2.5 m below the sediment surface) were used to assess the more stable pre-European background subsurface trace element concentrations [15]. These background concentrations were used to determine the amount of trace element contamination in the samples.

3.2 Sediment risk assessments

Assessment factors used to evaluate sediment quality in this study include the modified degree of contamination (mC_d), potential load index (PLI) and potential ecological risk index (RI). Abraham and Parker [20] introduced a modified and generalised formula based on Hakanson's [21] original formula to calculate the modified degree of contamination for trace element pollution in estuarine sediments.

$$CF^i = C_{\text{sample}} / C_{\text{background}} \quad (1)$$

$$mC_d = \frac{\sum_{i=1}^{i=n} CF^i}{n} \quad (2)$$

Where: CF^i is the contamination factor, C_{sample} is the measured concentration of each trace element; $C_{\text{background}}$ is the concentration of the trace elements in a core at 2.5 m depth, mC_d is the modified degree of contamination, and n is number of trace elements analysed.

The potential load index (PLI) was proposed by Sheppard [22] to calculate contamination as it allows comparison of contaminant concentrations between locations at different times. The PLI was calculated by using the following formula, and the PLI values were classified.

$$PLI = (CF_1^i \times CF_2^i \times CF_3^i \dots CF_n^i)^{1/n} \quad (3)$$

The potential ecological risk index (RI) was used to assess the effects of the trace element pollution in the study area. The RI was originally defined by Hakanson [21], and was calculated using Reboredo's [23] modification:

$$E_r^i = T_r^i \times CF^i \quad (4)$$

$$RI = \sum_i^n E_r^i \quad (5)$$

where, CF^i is the contamination factor; E_r^i is the monomial potential ecological risk factor; T_r^i is the response coefficient for the toxicity of a single trace element, which was adopted as the evaluation criterion, i.e. Cr=2, Ni=Cu=Pb=5, Zn=1 and As=10, [21, 24]; and RI is the sum of all risk factors for trace elements in the sediments. According to Hakanson [21], the RI values are rated in four classes from low to very high risk.

3.3 Geographic Information System

ArcGIS desktop software, version 10.2, was used to create contour maps for the variables measured for the sediment samples from each bay. For each of the variables analysed (e.g. water depth, mud particles and trace elements), values between the sampled sites were interpolated using the 'Spline with Barriers' method from the ArcGIS Spatial Analyst Toolbox. Raster layers were created for each variable for analysis and mapping purposes. The final maps are presented as contour plots of relevant variables.

4. Results and discussion

4.1. Grain size analysis

The results of the grain size analyses provide information to classify the sedimentary environments and to assist in the evaluation of depositional processes [18]. The grain size ternary diagram for the Georges River system is based on Folk's 1974 classification and shows a continuum of sizes from sandy silt to clean sand with a few samples in the clay and silty clay zone (Fig. 2). The textural distributions in the estuary samples are related to the source rocks in the catchment which are predominantly sedimentary.

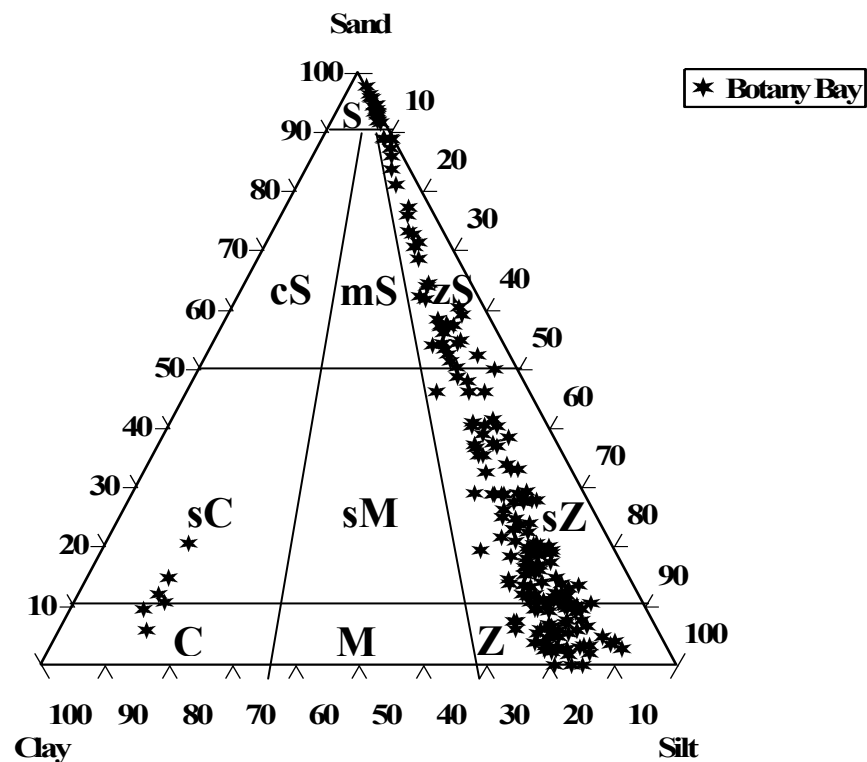


Fig. 2. Classification of surface sediments in the Georges River system after Folk [18]

Where: S: sand, s: sandy, Z: silt, z: silty, M: mud, m: muddy, C: clay and c: clayey.

The spatial distribution of the textural classifications is made using a classification presented by [25] and is illustrated in Fig. 3a. Muddy particles dominate the central parts of the tributary bays where grain size ranges between mud and very fine sand. Fine and medium sands become dominant close to the shallow margins. The sand content ranges from 0% to

100% (Fig. 3b). The highest percentages of sand have accumulated in shallow water, especially at the mouth and along the edges and shoreline of each bay, where wave activity is highest, causing transport of fine particles and leaving medium and coarse particles close to the shoreline. High percentages of sand were also found in the Woronora River and the previously dredged main channel of Georges River below Salt Pan Creek (Fig. 3b).

In general, the deepest water areas have the lowest percentages of sand. This is related to low current activity at depth within the bays where waves do not disturb the bottom sediments. Fine particles such as silt and clay can be transported by the currents and tides into the deeper water, and then gradually settle and concentrate in these deeper areas (Fig. 3c).

The percentages of mud particles in the Georges River system also range between 0% and 100% (Fig. 3c). The clay particle percentages are low compared with those of silt and sand (Fig. 2). The highest percentages of mud accumulate in the inner and middle sites of the bays, such as Kogarah Bay, Oyster Bay, Oatley Bay and Woollooware Bay, because the wave and current activity is less compared with the main channel. Mud content is low in the main channel of the Woronora River, as well as around the edges and mouths of the bays, where local wind waves prevent deposition of fine particles or re-suspended them; these sites are dominated by sand [16].

The percentage of mud declines as depth becomes shallower along the shoreline (Fig. 3c). Fine organic matter can also stay undisturbed in deeper water areas because current velocities and waves are less effective. Exceptions to this pattern included Salt Pan Creek and Oyster Bay which had shallow water depths (<1.5m) but also low percentages of sand. Their sediment consisted of high percentages (approximately 80%) of fine to very fine particles, which may have been because of the low wave and current activity in their sheltered

environments. Consequently, the fine particles do not escape from Salt Pan Creek and Oyster Bay.

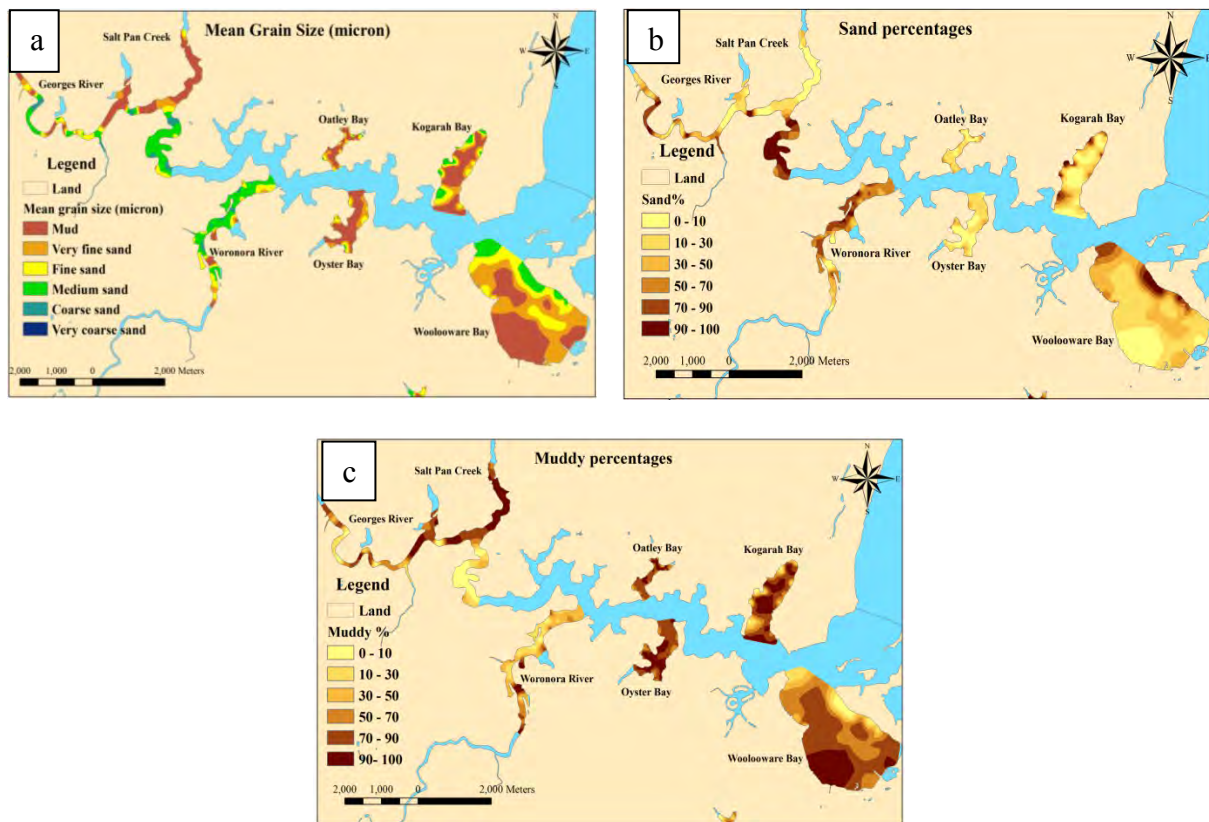


Fig. 3. (a) Mean grain size (b) Sand percentages and (c) mud percentages within the Georges River system.

4.2. Spatial distribution of trace elements

The trace element concentrations Cr, Ni, As, Cu, Zn, Pb, Rb and Br in the surface sediments within the inner parts of the Georges River system are illustrated in (Table 3). Generally, it was found that concentrations of trace elements had similar patterns in most embayments in the Georges River system with the highest concentrations at the head and in the middle of the bays (Fig. 4a-h). Trace elements such as Cu, Zn and Pb are concentrated within the deeper inner portions of the bays. In addition, trace elements were concentrated around harbours and marinas where many boats are moored.

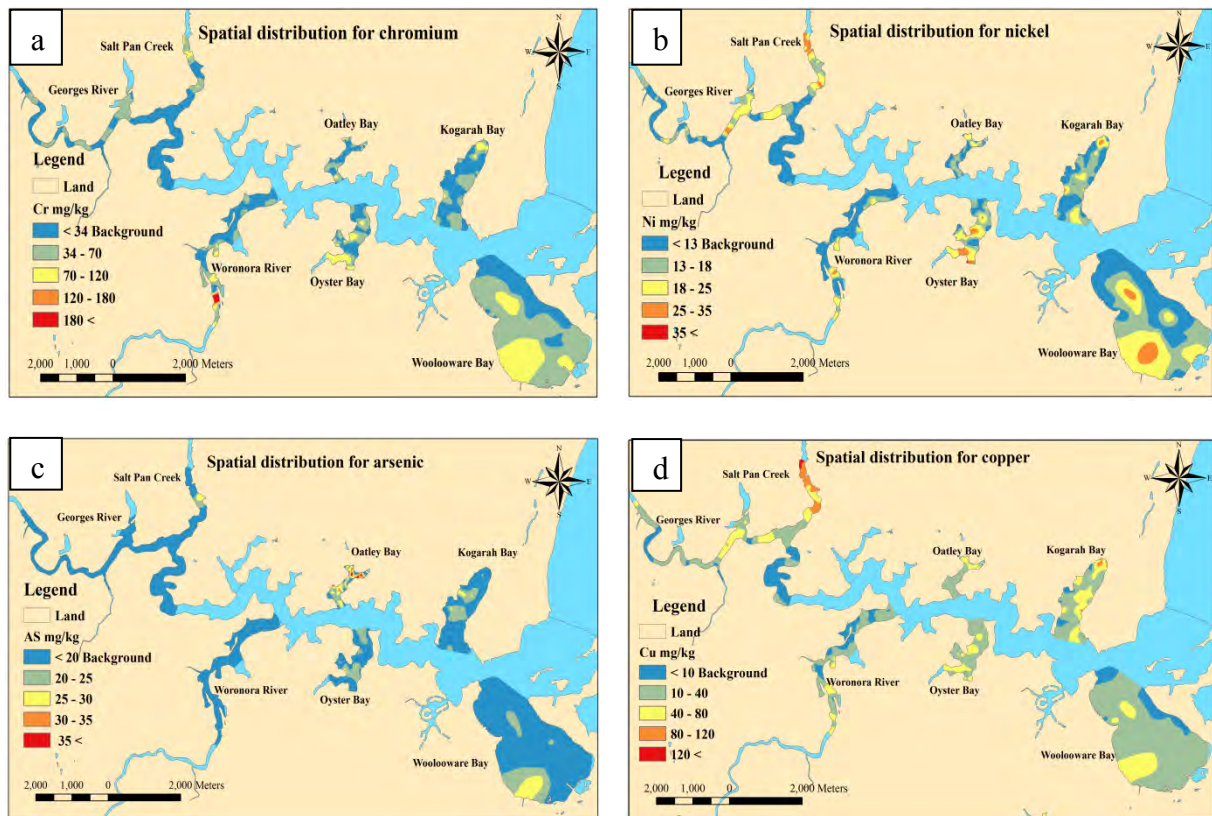
Table 3
Comprise of trace elements in the Georges River system.

Study area	Cr mg/kg	Ni mg/kg	Cu mg/kg	Zn mg/kg	As mg/kg	Pb mg/kg	Rb mg/kg	Br mg/kg
Georges River								
Range	3-126	0.7-38	2-138	7-788	0.8-27	3-267	3-92	10-566
Mean± SD.	39±27	13±8	30±23	157±127	11±7	67±56	45±27	127±89

The concentrations of trace elements declined markedly towards the edges and mouths of the bays as well as in the main Georges River channel and Woronora River where the sandy sediments had the lowest concentrations of trace elements. These oxidising environments had a high sand content and low percentages of mud particles and organic matter (Fig. 3b). Most of the bays had their highest concentrations of trace elements located around drains and discharge points and within the inner parts of the bays. There are several reasons for this pattern. Firstly, surface sample sites close to discharge points and stormwater drains from roadways and residential areas have sediment particles combining with trace elements, flocculating and settling close to the discharge points due to the mixing of fresh and salt water. Secondly, samples that are close to boatyards where boats are painted to prevent fouling have high contaminant concentrations. There are also large numbers of moored watercraft with potential contaminant spills. Thirdly, the high percentages of mud (Fig. 3c), including clay minerals such as illite, kaolinite and chlorite, at the surface sample sites can accumulate and trap trace elements through absorption, ion exchange and metal substitution with muddy particles [5, 17, 26, 27]. The high clay content is shown by the high concentrations of Rb between 50 mg/kg and 90 mg/kg in the inner parts of the bays (Fig. 4g) that are typically associated with the aluminosilicate mud particles. Finally, percentages of organic matter (total carbon) were also higher at these deeper muddy sites [28]. The concentration of Br, which has a positive relationship with organic matter, ranged from 100 mg/kg to 500 mg/kg in the inner parts of the bays, and it exceeded 300 mg/kg in some bays such as Kogarah Bay and Woollooware Bay (Fig. 4h). These sites represent anoxic conditions,

allowing trace elements to be captured by the minerals and organic matter [29]. According to previous studies [28, 29], organic matter has an affect on chemical speciation transformation and the absorption of trace elements in sediments and can affect the toxicity and bioavailability of trace elements. Finally, increased percentages of organic matter (total carbon) may be correlated with anoxic environments in which trace elements can be captured [28, 30].

Salt Pan Creek is considered to be a very highly polluted creek, and has the highest concentrations of trace elements in the analysed samples from the Georges River. Concentrations ranged between 24-86 mg/kg for Cr; 17-30 mg/kg for Ni; 74-138 mg/kg for Cu; 349-788 mg/kg for Zn; 11-26 mg/kg for As; and 138-268 mg/kg for Pb.



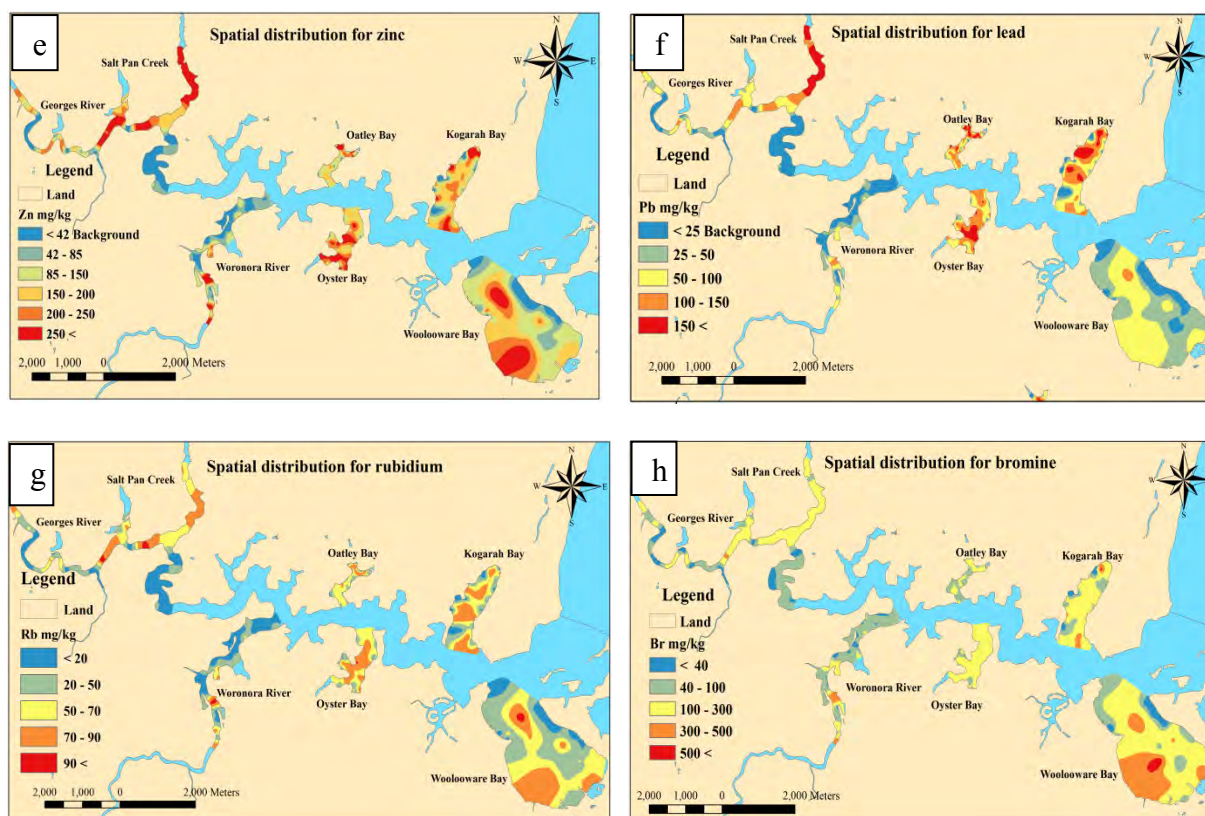


Fig. 4. Spatial distribution of (a) Cr, (b) Ni, (c) As, (d) Cu, (e) Zn (f) Pb (g) Rb and (h) Br (mg/kg) in surface sediments within embayments of the Georges River system.

Historical location of industries using or generating various chemicals in the catchment of Salt Pan Creek had previously produced and discharged large amounts of trace elements into both the creek and the Georges River, as well as discharges from stormwater and wastewater that are thought to be an important ongoing contributor to the general pollution of these waterways. Secondly, Salt Pan Creek contains high percentages of mud particles, ranging from 70% to 96%. Finally, the high percentages of pyrite (1.6-3.6%) and the high Br contents (organic matter) represent anoxic conditions in which trace elements tend to be concentrated [30, 31].

4.3 Correlation between sediment particle size and trace elements

A correlation matrix was constructed in order to search the relationship between sediment particle size and trace elements. Table 4 summarizes the correlation matrix results for the Georges River samples. There is a strongly significant correlation between Cr, Ni, Cu, Zn, As and Pb, muddy particles (clay and silt) and organic matter, as shown by the regression values.

The correlation coefficients also support the previously described relationship between trace elements and mud particles, indicated by Rb and organic matter, indicated by Br. It is apparent that the concentrations of trace elements increase with increasing percentages of mud particles and organic matter (Table 4). This represents an anoxic environment, which can absorb and accumulate trace elements. Trace elements have a negative relationship with increased sand fraction (Table 4). This is because sand is left as a residual deposit where local waves become more active in shallow marginal areas, re-working finer sediments and trace elements which will then deposit in calmer and/or deeper sections of the creeks and bays.

Table 4
Correlation coefficients for sediment particles and trace elements of sediment samples in the Georges River system.

	Sand	Silt	Clay	Cr	Ni	Cu	Zn	As	Br	Rb	Pb
Sand	1.00*										
Silt	-0.99	1.00									
Clay	-0.87	0.82	1.00								
Cr	-0.36	0.36	0.33	1.00							
Ni	-0.76	0.76	0.67	0.61	1.00						
Cu	-0.63	0.65	0.47	0.42	0.79	1.00					
Zn	-0.69	0.70	0.55	0.45	0.85	0.93	1.00				
As	-0.80	0.83	0.56	0.14	0.59	0.53	0.55	1.00			
Br	-0.61	0.62	0.52	0.42	0.66	0.55	0.61	0.41	1.00		
Rb	-0.89	0.89	0.76	0.30	0.82	0.71	0.77	0.82	0.66	1.00	
Pb	-0.76	0.78	0.57	0.13	0.64	0.74	0.76	0.83	0.41	0.84	1.00

*P=0.05

4.4. Assessment of sediment contamination

As outlined previously, three parameters, the potential load index (PLI), modified degree of contamination (mCd) and potential ecological risk index (RI) were applied to evaluate sediment contamination by trace elements [21, 32]. The potential ecological risk index (RI) is the most popular method used in order to evaluate the hazards of trace elements for both human and environmental ecosystems. It indicates the concentration of trace elements that may cause adverse effects in biological toxicology, environmental chemistry and ecology [Fig.7c; 33, 34].

The values of the three contamination factors were found to vary between samples in the same bay, and from one bay to another in the surface sediments. The values vary from very low risk and/or unpolluted to a high degree of contamination or pollution (Fig. 5a-c) and are controlled by variables, such as distance from source of pollution, sediment grain size and the type and amount of various minerals. Higher degrees of contamination indicated by highly polluted and very high risk values (exceeding and/or slightly less than 120 RI) indicate that some sites in Kogarah Bay, Oyster Bay and Salt Pan Creek are highly polluted. This is because these sites are close to discharge points, stormwater outlets, watercraft or boatyards as well as having sediment types that are dominated by muddy particles in the inner parts of the bays where they are unaffected by active waves and currents. In contrast, other nearby sites in the study areas have low degrees of contamination, are unpolluted and have low risk values. These were found along the shorelines, edges and in the mouths of bays, such as in Oyster Bay, Georges River and Woronora River that are dominated by coarse particles (sand and/or coarse silt). At these sites currents and waves are more active leading to transportation of fine particles and trace elements toward deeper areas. The highest values PLI, mC_d and RI for Cu, Zn and Pb, respectively, all occur in the very highly contaminated Salt Pan Creek, which includes contamination from previous manufacturing and a waste dump [14].

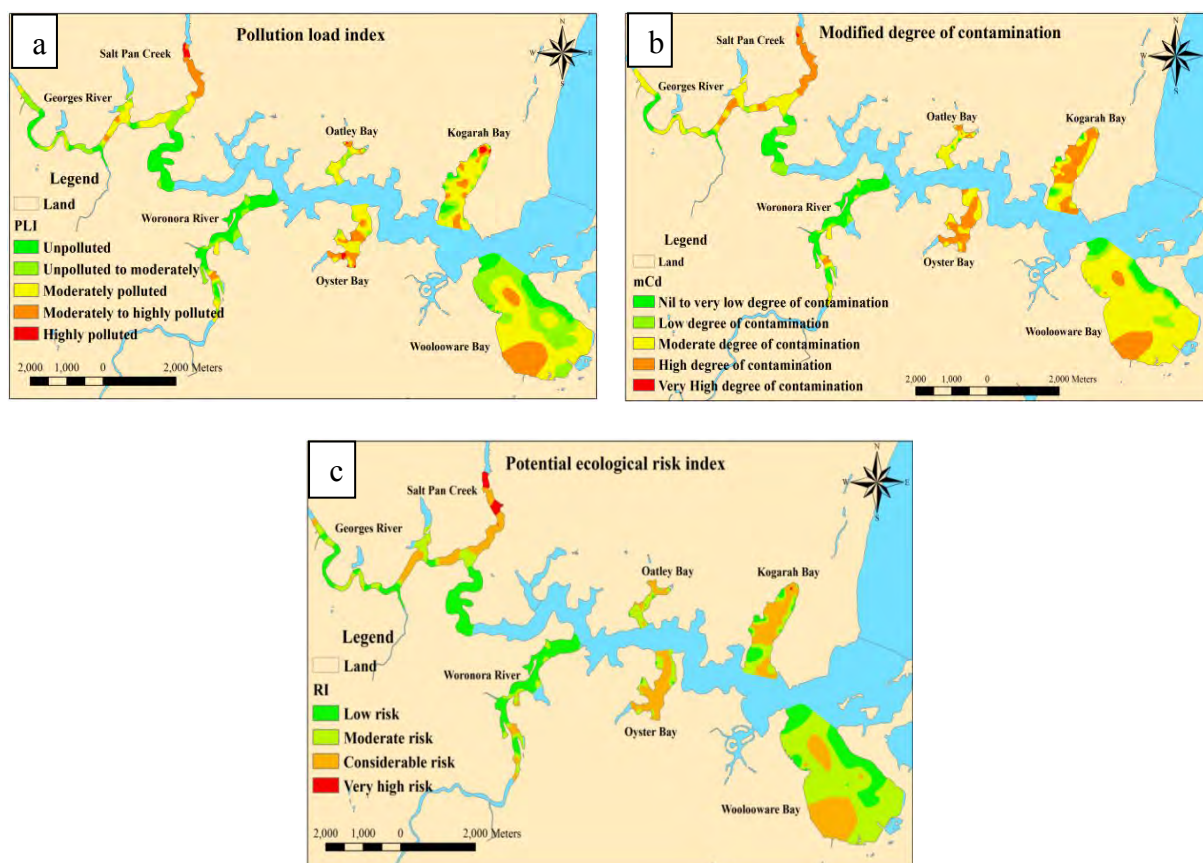


Fig.5. (a) Potential load index, (b) modified degree of contamination and (c) potential ecological risk for marine sediments in the Georges River system.

4.5. Comparison with Australian estuaries and sediment quality guidelines

In this study the range and mean values of the trace element concentrations in marine sediment samples were compared with the ANZECC and NHMRC [35] sediment and water quality guidelines (Table 5). Some additional elements are included in this table for illustration. This comparison determined whether the trace elements were within acceptable ranges (low risk), between low and high triggers values, or exceeded the high trigger values that require further investigation according to the national guidelines. Adverse biological effects of trace elements are occasionally detected between the low and high values in the ANZECC and NHMRC [35] guidelines.

According to ANZECC and NHMRC [35] protocols, the anthropogenic pollution of trace elements such as Cr, Ni, Cu, Zn, As and Pb within the sediments of the study sites were generally below the interim sediment quality guideline values (ISQG-low) except for

elements like Pb in Kogarah Bay, Oyster Bay and Salt Pan Creek; Cu and Ni in Salt Pan Creek; and Zn in Oyster Bay and Salt Pan Creek (Table 5). Table 5 is divided into sections: the study sites in the Georges River system and, for comparison, other estuaries where comprehensive trace element studies have been completed.

Table 5

Comparison of sedimentary trace element concentrations in the study areas with previous studies in Australian estuaries and Interim Sediment Quality Guideline values.

Trace elements Sites	Cr mg/kg	Ni mg/kg	Cu mg/kg	Zn mg/kg	As mg/kg	Pb mg/kg	References
Woolloomare Bay							
Range	6-99	1.1-26	9-58	8-314	1.2-22	3.3-104	Present study
Mean \pm SD	43 \pm 24	12 \pm 7	21 \pm 2	116 \pm 74	11 \pm 6	37 \pm 24	
Woronora River							
Range	4-84	0.7-24	3-55	9-329	1-19	4-105	Present study
Mean \pm SD	33 \pm 25	10 \pm 7	19 \pm 16	92 \pm 87	6 \pm 5	30 \pm 28	
Georges River							
Range	4-68	1.3-27	3-60	11-431	2-20	4-154	Present study
Mean \pm SD	27 \pm 19	10 \pm 7	23 \pm 17	132 \pm 113	8 \pm 6	48 \pm 54	
Salt Pan Creek							
Range	24-86	17-30	74-138	349-789	11-26	138-268	Present study
Mean \pm SD	57 \pm 23	23 \pm 5	102 \pm 21	556 \pm 144	16 \pm 4	188 \pm 38	
Kogarah Bay							
Range	7-91	1-28	5-100	11-433	2-28	5.4-235	[17]
Mean \pm SD	33 \pm 24	12 \pm 7	37 \pm 24	158 \pm 99	12 \pm 8	87 \pm 60	
Oyster Bay							
Range	9-127	7-39	10-63	43-386	1.9-26	14-198	[16]
Mean \pm SD	51 \pm 32	19 \pm 7	35 \pm 13	204 \pm 84	15 \pm 6	98 \pm 48	
Oatley Bay							
Range	7.9-130	6.6-30	7-156.6	38-915	6-42	14-582.2	[15]
Mean \pm SD	40 \pm 22	14.5 \pm 5	40 \pm 25	196 \pm 134	23 \pm 8	117 \pm 81	
Botany Bay							
Range	NA	NA	<50->200	<200->1500	NA	<100->400	[36]
Sydney Harbour							
Range	7-698	17-86	13-1078	46-2246	NA	44-1319	[37]
Mean	118	38	124	548		268	
Derwent estuary							
Range	<5-183	<2-35	<2-1182	<2-22593	1-657	4-3866	[38]
Mean \pm SD	63 \pm 33	16 \pm 1	106 \pm 184	2103 \pm 3897	51 \pm 97	580 \pm 763	
Huon River							
Range	50-80	<2-28	7-32	<2-66	4-25	<2-48	[38]
Mean \pm SD	71 \pm 8	20 \pm 6	17 \pm 6	40 \pm 18	16 \pm 6	25 \pm 12	
Burrill Lake							
Range	NA	3-20	5-80	3-82	2.9-22	0-32	[39]
Mean \pm SD		11 \pm 4	32 \pm 24	29 \pm 23	11 \pm 6	13 \pm 9	
Port Hunter	21-167	44-156	19-283	32-5161	NA	25-843	[40]
ISQG / Low	80	21	65	200	20	50	[35]
ISQG / High	370	52	270	410	70	220	[35]

NA is not available.

For the Georges River system the trace element concentrations were noted to be between the ISQG-low ANZECC and NHMRC [35] and high values at some sites in all bays. These concentrations depend on the sources and discharge points as well as boatyards and watercraft. Salt Pan Creek is the most highly polluted by trace elements in the study area. The

levels can be correlated with both water depth and muddy particles, but show the highest concentrations in the study areas. This can be attributed to historical dumping of waste into the creek and chemical industry (e.g. oil refinery) discharged waste within it. The mean values of trace element pollution for Cu, Zn and Pb in the surface sediments of the study areas generally had higher concentrations compared with the more pristine environments in both Burrill Lake and the Huon estuary [38, 39]. The surface sediments in both the Huon estuary and Burrill Lake are dominated by clean sand fractions and low percentages of organic matter, and their catchment areas are non-industrialised and lightly developed [38, 39]. The results for the current study are slightly higher than for a previous study in Botany Bay [36]. Trace element concentrations for Cr, Ni and As in surface sediments from the Huon River were similar to all the present study areas, except for Ni in Salt Pan Creek and As in Oatley Bay (Table 5). This is because of the large amount of dolerite in the source rock in the Huon River releasing trace metals as it weathers. Thus it is important to understand the natural contributions from the catchment geology when assessing the amount of pollution in any area. This factor has been overcome for the Georges River sites by using local background trace element concentrations from a time prior to significant anthropogenic pollution.

Surface sediments in Salt Pan Creek were more concentrated in trace elements compared with the Huon estuary and Burrill Lake (e.g. 3x times for Cu, 14x times for Zn and 7x times for Pb). This was caused by dumping waste from an oil refinery and other waste disposal sites, and for this reason Salt Pan Creek is markedly more polluted compared to other parts of the study areas. However, the values of trace elements in surface sediments from the current study area had low concentrations in comparison to previous studies in Port Hunter, Sydney Harbour, Port Kembla, Griffins Bay and the Derwent River, except for Zn and Pb in Salt Pan Creek. Surface sediments in Sydney Harbour [37] and the Derwent River [38] have been

subject to large amounts of contamination from urban, industrial and commercial activities, such as a zinc refinery, stormwater runoff, mine discharges, vehicles exhausts, sewage effluent and watercraft, as well as leaching from reclamation areas. 4.6. Comparison with estuaries worldwide

Most estuaries and embayments located near population concentrations around the world are typically polluted by trace elements derived largely from human activity. Selected examples of trace element concentrations in other locations are summarized in Table 6.

There is considerable variation between trace element concentrations in the study areas and trace elements in the estuaries around the world. This is because of several reasons: the sediment types; chemical, physical and hydrological characteristics of the water; the sources and amounts of pollution discharged into the bays (e.g. industrial activities, farming, fishing and transportation as well as residential, commercial and agricultural runoff); background concentrations of trace elements; and possibly the use of different analytical methods to estimate the concentrations of trace elements. As a result, the behaviour of trace elements is varied in many estuaries and bays around the world. The different concentrations of trace elements in the various countries in Table 6 reflect differing industrial and other use concentrations in source areas with varying concentrations of development, as well as pollutant control measures. These average figures do not provide information on the distribution of trace elements with these systems. Detailed mapping of pollutant distribution within bays and estuaries is required before any management or remediation action can be considered. Limited comparison could be made if distributions are linked to morphological or hydrodynamic properties as a system example but detailed spatial mapping is far more effective.

Table 6

Comparison of trace elements (mg/kg) in sediments with various other coastal regions around the world.

Locations	Country	Cr	Ni	Cu	Zn	Pb	References
Bremen Bay	Germany	131	60	87	790	122	[41]
Gulf of Naples	Italy	NA	6.93	27.2	602	221	[42]
Bengal Bay	India	194.8	38.6	506.2	126.8	32.3	[43]
Masan Bay	Korea	67.1	28.8	43.3	206.3	44	[44]
Estero Salado, Ecuador	South America	94.5	82.2	253.8	678.3	81.3	[45]
Izmit Bay	Turkey	74.3	NA	67.6	930	102	[46]
Georges River Range Mean±SD.	Australia	3-126 39±27	0.7-38 13±8	2-138 30±23	7-788 157±12	3-267 67±56	Present study

NA is not available.

4.7. Summary of the differences between bays

The distribution pattern of sediment particles and trace elements in the different bays in this study appears to be related to different bay morphologies and their interactions with catchment and tidal flows. In wide bays with wide-open mouths (Kogarah Bay and Oyster Bay) deposition of trace elements generally follows the current and tide trajectories, with secondary concentrations in boatyards and under moored boats where leaching, anti-fouling and fuel spillages add to the pollutant sources. Linear and elongated bays usually have a single major point source for water and thus pollutant flows show trace element distributions that are constrained by the narrow bay form. Trace element pollution is concentrated in Salt Pan Creek, which has the highest concentrations of trace elements around the Georges River, with the concentrations significantly declining when the creek joins with the main Georges River channel. The current velocities are faster in this creek compared to other bays largely, because the creek has a narrow, elongated channel form, aiding distribution of trace elements well away from initial discharge points.

5. Conclusions

Chemical composition of sediments can be used as a sensitive indicator for both spatial and temporal trend monitoring of contaminants in the coastal marine environment. Marginal marine sediment contamination is considered to be one of the main environmental concerns for marine ecosystems. A combined total of 325 surface sediments were analyzed from the Georges River system, NSW, Australia. Highly polluted and high risk sites were in Salt Pan Creek, and some locations within other bays. However, low polluted and low risk sites were found in Woronora River and close to shoreline areas in bays. Toxic pollutants, such as trace elements, and organic matter originating from human activities like transport, industry, stormwater runoff drains, boatyards and watercraft, are continuing to be introduced to aquatic environments through rivers, waste dumping and emission processes. They are then deposited in marine sediments, which act as both a sink and source of pollution in the aquatic environment. This study provides useful baseline information to contribute to future management and water quality planning. It is necessary to investigate the distribution and degree of trace element pollution in order to protect environmental ecosystems from accumulating pollution and to provide basic information for coast utilization and management.

Acknowledgements

This paper is a part of the first author's PhD. thesis undertaken at School of Earth and Environmental Sciences, University of Wollongong. It was financially supported by the Ministry of Higher Education and Scientific Research in the Iraqi Government, and by the GeoQuEST Research Centre, University of Wollongong, Australia.

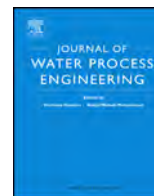
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Removal of volatile organic compounds (VOCs) from groundwater by reverse osmosis and nanofiltration



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ARTICLE INFO

Article history:

Received 19 September 2015

Received in revised form

23 November 2015

Accepted 29 November 2015

Keywords:

Volatile organic compounds (VOCs)

Reverse osmosis (RO)

Nanofiltration (NF)

Botany Bay

ABSTRACT

A comprehensive study was conducted to examine the removal of volatile organic compounds (VOCs) which exist in groundwater at Southlands-Botany Bay (Sydney region). The ability of nanofiltration (NF) and reverse osmosis (RO) as advanced treatments was investigated using two commercially available NF or RO membranes. Laboratory-scale tests were used with cross-flow; tests were conducted with 16 ubiquitous compounds that represented the significant volatile organic compounds found in the contaminated groundwater.

The results reported in this study indicate that the removal efficiency of reverse osmosis (RO) was better than NF in rejecting the VOCs detected in groundwater. This study revealed that the performance of NF and RO membranes in rejecting hydrophilic volatile organic compounds was higher than that for hydrophobic compounds and the highest rejection achieved by NF and RO membranes amounted 98.4% and 100%, respectively. Hydrophilic compounds can be effectively rejected by NF/RO membranes using the size exclusion mechanism (steric hindrance), whereas hydrophobic compounds can be adsorbed into NF/RO membranes and then diffuse through the dense polymeric matrix, resulting in the lower removal for these compounds compared to hydrophilic compounds.

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Altalyan, H, Jones, B, Bradd, J, Nghiem, L, & Alyazichi, Y 2016, 'Removal of volatile organic compounds (VOCs) from groundwater by reverse osmosis and nanofiltration', *Journal of Water Process Engineering*, vol. 9, pp. 9-21.

Available from: [10.1016/j.jwpe.2015.11.010](https://doi.org/10.1016/j.jwpe.2015.11.010)

Final manuscript can be accessed from Research Online

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