BSL/CQU Marine Environmental Monitoring Spillway Creek

July, 2000

R.Johnson, S.Lewis, A.Melzer, M.Walker,
K.McNamara and R.Devine.

Centre for Environmental Management
Centre for Land and Water Resource Management
Faculty of Arts, Health and Sciences
Central Queensland University
Gladstone Q 4680

Central Queensland
UNIVERSITY

BSL/CQU Marine Environmental Monitoring
Spillway Creek

July, 2000

R. Johnson, S. Lewis, A. Melzer, M. Walker, K. McNamara, and R. Devine.

Centre for Environmental Management
Centre for Land and Water Resource Management
Faculty of Arts, Health and Sciences
Central Queensland University
Gladstone Q 4680

TABLE OF CONTENTS

EXECUTIVE SUMMARY 1

1.0 INTRODUCTION 3

1.1 BACKGROUND 3
1.2 AIMS OF THE PROGRAMME 4

2.0 MATERIALS AND METHODS 5

2.1 THE MONITORING STRATEGY 5
2.2 WATER MONITORING PROGRAMME 5
2.2.1 Physico-chemical water quality and toxicants 5
2.2.2 Metals in water 6
2.3 SEDIMENT PROGRAMME 6
2.3.1 Sediment physical characteristics 6
2.3.2 Fluoride levels in sediment 7
2.3.3 Metals in sediment 8
2.4 MANGROVE MONITORING 8
2.4.1 Permanent plots 8
2.4.2 Fluoride levels in shoots, roots, new and old leaves and bark 9
2.5 MACROBENTHIC FAUNA MONITORING 10
2.5.1 Identification of macrobenthic fauna in sediment 10
2.5.2 Identification and fluoride analysis of macrobenthic fauna species trapped 10

3.0 RESULTS 11

3.1 WATER 11
3.1.1 Physico-chemical water quality and toxicants 11
3.1.2 Metals in water 13
3.2 SEDIMENT 14
3.2.1 Sediment physical characteristics 14
3.2.2 Fluoride levels in sediment 15
3.2.3 Metals in sediment 16
3.3 MANGROVE MONITORING 16
3.3.1 Growth, survival, productivity and shoot production 16
3.3.2 Fluoride levels in shoots, roots, new and old leaves and bark 18
3.4 MACROBENTHIC FAUNA MONITORING 19
3.4.1 Identification of macrobenthic fauna in sediment 19
3.4.2 Identification and fluoride analysis of macrobenthic species trapped 20

4.0 CONCLUSIONS 22

5.0 REFERENCES 24

FIGURE 1. 27

APPENDIX 1 28

APPENDIX 2 33

APPENDIX 3 36

APPENDIX 4 39

APPENDIX 5 41

APPENDIX 6 .... **46**

LIST OF TABLES

Table 1. Comparison of physicochemical water quality parameters.

Table 2. Metals analysis of marine water in Spillway Creek.

Table 3. Particle size and combustible matter of mangrove plot sediment.

Table 4. Particle size and combustible matter of Spillway Creek benthic sediment.

Table 5. Fluoride levels in Spillway Creek sediment.

Table 6. Metals analysis of Spillway Creek sediment.

Table 7. Mangrove monitoring parameters.

Table 8. Total fluoride concentrations in mangrove components.

Table 9. Comparison of fluoride in mangroves and *Eucalyptus* sp.

Table 10. Abundance, richness and diversity for Spillway Creek sites in December 1997.

Table 11. Abundance, richness and diversity for the banks and mid-channel of Spillway Creek in April 1998.

Table 12. Abundance, richness and diversity for Spillway Creek sites in April 1998 with abundance normalized to 10 samples.

Table 13. Fluoride concentrations in macrobenthic species.

Executive Summary

In 1997, the Centre for Environmental Management, Central Queensland University, was invited by Boyne Smelters Limited (BSL) to participate in a co-operative study following a review of BSL's aquatic monitoring programme.

The key factors studied included water quality parameters and toxicants, metals in water and sediment, fluoride in benthos and mangrove vegetation, and a general assessment of the existing mangrove and macrobenthic environment. Sites were established accordingly and monitored for one year.

Physico-chemical water quality parameters and toxicant concentrations within the study area satisfied the ANZECC guideline requirements and conformed to the release quality characteristic limits for BSL discharge.

Metal concentrations in water exceeding the ANZECC water quality criteria were found in Spillway Creek and discharge waters. There were no apparent trends in these data and no relationship to the BSL discharge point was evident.

Metal concentrations in sediments were below ANZECC screening levels with the exception of arsenic at sites 4 and 5. There was no apparent relationship between BSL discharge and the elevated arsenic at these sites.

Mangrove productivity and shoot production declined during the year which was consistent with seasonal data elsewhere. Productivity was similar to other Port Curtis sites and sites in Missionary Bay, Queensland. Basal area of mangroves generally increased.

Fluoride levels in mature mangrove components were consistently higher than in new growth and roots, and concentrations varied little between sampling periods. Fluoride concentrations decreased with distance from BSL in a manner consistent with that seen in the terrestrial vegetation.

Fluoride levels in one crab species were typically higher than those found in mature mangrove leaves and bark but followed the same pattern as vegetation. This probably reflects the decreasing concentration of fluoride with distance from the smelter. Further studies are required to assess the significance of this finding.

Generally, the mangrove communities and benthos of Spillway Creek were healthy. Some variation was shown through the year probably due to season and natural environmental influences.

1.0 Introduction

1.1 Background

Boyne Smelters Limited (BSL), in consultation with the Environmental Protection Agency, developed a scope of work for aquatic monitoring of Spillway Creek. The scope included components of water quality, mangrove productivity, sediment constituents and macrobenthic animals. BSL invited the Centre for Environmental Management (CEM), Central Queensland University, to conduct this programme co-operatively with BSL personnel on a one-year basis.

Aluminium production is a dry process but waste water arises from associated production processes as well as rainfall events and includes storm water runoff, cooling water blow down and wash down water from BSL. Water is collected and held on site in a settling pond prior to discharge into a man-made, densely vegetated channel referred to as Spillway Channel. The channel runs for approximately one kilometre before discharging into an upstream tributary of the extended tidal inlet known as Spillway Creek. Spillway Channel receives a constant low volume flow of process water from BSL together with periodic inputs of stormwater runoff from the smelter site, and from land owned by Queensland Alumina (QAL) including the QAL red mud dam. This water runs into South Trees Inlet where tidal flushing and currents cause mixing in the mouth and lower reaches of the creek.

Air emissions from the smelter include gaseous and particulate fluoride which is also present in waste water. Mangroves in the vicinity of Spillway Creek therefore are likely to be influenced by both air- and water-borne fluoride.

The monitoring programme undertaken by the CEM considered both the mangrove communities and adjacent macrobenthic communities to assess the impact of water and air-borne emissions from the Boyne Island smelter on the surrounding aquatic and intertidal environment.

1.2 Aims of the programme

The aims of this programme were:

- To record the present conditions of the Spillway Creek ecosystem and establish base line data;
- To determine whether the water and sediments in Spillway Creek meet the accepted standards for water and sediment quality, and
- To determine whether there are any trends in the condition of the ecosystem which could be related to BSL operations.

2.0 Materials and methods

2.1 The monitoring strategy

Spillway Creek mangrove plots and macrobenthic stations were sampled in December 1997 and April 1998. Additional mangrove monitoring was undertaken in June and October 1998 to fulfill the requirements of the scope of work.

Five sites, numbered from 1 – 5, were selected to represent the dominant mangrove habitat with decreasing distance from the smelter along Spillway Creek (Figure 1). Site 1 was at the mouth of the inlet and site 5 was one kilometre downstream from the Spillway Channel/Spillway Creek confluence. Sites 2, 3 and 4 were distributed as shown on Figure 1.
At each site, mangrove plots were established in December 1997 and macrobenthic sampling was undertaken adjacent to these plots in the creek. Plots were predominantly *Rhizophora* scrub situated in the low intertidal zone. The plot at site 4 differed with the presence of only two trees, one mature *Rhizophora stylosa* and one mature *Xylocarpus granatum*.

Sites were accessed by boat on a high tide as lower tides limited the accessibility of Spillway Creek due to lack of water.

2.2 Water monitoring programme

2.2.1 Physico-chemical water quality and toxicants

Spillway Creek sites were sampled in-situ for pH, dissolved oxygen concentrations and conductivity using a Grant YSI probe in December 1997. Measurements were taken on consecutive days in the creek's main channel at high slack tide to limit any effects of tidal flow. Due to malfunction of the probe, data were not obtained for sites 1 and 2 at this time.

The Grant YSI probe was unavailable for sampling in April 1998. Dissolved oxygen was measured in-situ at all sites on the same day using a dissolved oxygen probe. Water samples were collected and conductivity and pH determined in the BSL laboratory.

In both December 1997 and April 1998 surface water samples were collected from midstream at each Spillway Creek site using standard protocols (AS/NZS 5667-2:1991) and held in polyethylene bottles. One sample was for fluoride, dissolved oxygen and suspended solids analysis. A separate bottle contained a sample for cyanide analysis to which 3 mls of sodium hydroxide were added. The samples were kept on ice and sent to the National Association of Testing Authorities (NATA) accredited Boyne Smelters Limited laboratory for analysis by BSL Analytical Services.

Water quality monitoring data were collected at five BSL monitoring points on a monthly basis. These points were L06 (site discharge point), L11 (1km down from the site discharge point - Spillway Channel), L13 (corresponding to site 5), L24 (corresponding to site 3) and L25 (corresponding to site 2) (Figure 1).

2.2.2 Metals in water

One surface water sample was taken from each Spillway Creek site using standard protocols (AS/NZS 5667-2:1991). The samples were kept on ice and sent to the Australian Laboratory Services (ALS) in Brisbane for analysis of metals including arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc. Results of this analysis were forwarded independently to the CEM and BSL.

Total metals in water were also measured monthly by BSL at L06 (discharge point) and L11 (Spillway Channel) and the data forwarded to the CEM.

2.3 Sediment programme

2.3.1 Sediment physical characteristics

2.3.1.1 Moisture content of air dried sediments

Sediment samples were obtained from each Spillway Creek site using a van Veen grab with an effective volume of $0.005m^3$ and sampling area of $0.05m^2$ in December 1997 and April 1998. Sediment samples were also taken from each mangrove plot during the same period. Prior to the analysis of particle size distribution and organic matter content, the moisture content of air dried sediment was determined to correct for the extra mass of water present in dry samples (Bruce and Rayment, 1982). About 100g of air dried sediment (dried at 40°C) from each mangrove site was weighed and placed in an oven at 105°C until constant mass was achieved through subsequent weighing. Moisture content of air dried sediment was taken as the water remaining in the sediment after air drying calculated as a percentage of the oven dry sample mass (AS1289. B1.1, 1977; Bruce and Rayment, 1982).

2.3.1.2 Particle size analysis

Approximately 100 g (for sediment with a range of very coarse to fine particles, at least one kilogram of sediment is needed to establish a more accurate distribution of particle sizes) of air dried sediment was ground with mortar and pestle. The resultant sample was weighed and then sieved through an agitated stack of Endecott test sieves with apertures of 2mm, 1mm, 500μm, 250μm, 125μm and 63μm respectively. After dry sieving, the sediment fractions remaining on the sieves were then wetted with a 0.004% sodium hexametaphosphate dispersing solution and allowed to stand for approximately one day. The resultant slurry was then hand washed through the sieve stack with water until the wash water was clear and the remaining material air dried at 40°C until constant mass was reached. Each fraction's mass was calculated as a percentage of the total mass of the sample after correction for moisture content. The fraction less than 63μm (mud) was calculated as the difference between the sum of the fractions greater than 63μm and the total mass of the sample less moisture (AS 1289. C6.1, 1977).

2.3.1.3 Total combustible matter

Approximately 100 grams of sediment from each site was ground, placed in a crucible with lid, and oven dried at 105°C until constant mass was reached. Mass was recorded and the samples placed in an ashing furnace to be combusted for one hour at a temperature of 850°C (AS 3580. 10.1, 1991). Samples were then placed in the drying oven at 105°C and then a desiccator to cool before further weighing. The difference in mass between initial and final weighing was expressed as a percentage of the initial mass and used as an estimate of the percentage organic matter of the oven dried sample.

2.3.2 Fluoride levels in sediment

A sediment sample was taken from the side and middle (where possible) of Spillway Creek at each site in December 1997 and April 1998 using a van Veen grab with an effective volume of $0.005m^3$ and sampling area of $0.05m^2$. Samples were air dried in an oven at 40°C until constant mass was achieved and then approximately 50g of sediment from each sample was sent to the BSL laboratory for fluoride analysis by BSL Analytical Services. Determination of total fluoride in sediment was carried out using the ion selective electrode method (LAB150).

In April 1998, the Environmental Analysis Laboratory (EAL) in Lismore as requested by BSL undertook an additional method of fluoride analysis. This method was used to determine the bio-available fluoride component of sediment by 10% HCl digestion.

2.3.3 Metals in sediment

A sediment sample was extracted at each Spillway Creek site in December 1997 as for the fluoride sample and immediately placed in an acid washed bottle provided by ALS. Samples were kept on ice and sent to ALS laboratories in Brisbane for analysis of metals including arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. In April 1998, samples were similarly acquired but were dried in BSL laboratories. Samples were then divided using a riffle box, representative samples from each site sent to ALS for total metals analysis and EAL for acid extractable (bio-available) metal analysis as requested by BSL. Results of the analyses were forwarded by EAL independently to the CEM and BSL.

2.4 Mangrove monitoring

2.4.1 Permanent plots

Mangrove plots were established as outlined in English, Wilkinson and Baker (1994).

One 25m^2 permanent mangrove plot was established at each Spillway Creek site. A corner of each plot was marked as the origin co-ordinate (0,0) from which the positions of all plants within the plot were mapped in terms of XY co-ordinates. Plants were identified to species. Stainless steel screws and tags were positioned in tree stems at breast height (~1.2m). These allowed identification of individual plants and served as a reference point for measurements of girth and to estimate sedimentation/erosion.

Measurements of girth using a tailors tape or Vernier callipers were taken at breast height. The sum of live tree girth measurements divided by the plot area gave an estimate of the area covered by mangrove stems or basal area (m^2/hectare). Sedimentation/erosion was recorded by taking the vertical distance from the screw to the sediment surface with a measuring pole (1cm graduations). Numbers of seedlings and propagules present were recorded.

Rates of leaf fall were measured at successive sampling events in December 1997, March, June and October 1998, using 2 litter traps in each plot – each was a $1m^2$ frame of tubular PVC to which tapering bags of shade cloth were attached (Duke *et al.*, 1981). These were suspended in the canopy (above the high water mark) within close proximity to the plot for periods of three months. Litter collected in these traps was separated into components (leaves, stipules and reproductive parts). Components were counted and oven dried at 70°C for 72 hours and weighed. The frequency of attack on leaves was calculated for each site as the percentage of leaves showing herbivory. Productivity was calculated as dry weight of litter per square metre per day (g/m^2/day). Shoot production was assessed by counting the number of stipules (the shoot emerges within a stipule pair that protects the new growth) found in the leaf litter and halving the result (shoots/m^2/day). A visual estimate of percentage canopy cover was taken for October 1998.

2.4.2 Fluoride levels in shoots, roots, new and old leaves and bark

Whole mature leaf samples were taken in December 1997 and April 1998 from each mangrove species adjacent to the plots (*Rhizophora stylosa, Avicennia marina* and *Xylocarpus granatum.).* Samples of shoots, whole new leaves, bark and prop root (at or below the level of the mud) were also taken from *Rhizophora stylosa* trees adjacent to the plots. All components were washed free of excess mangrove mud using distilled water and then oven dried at 70°C until constant mass was reached.

All samples were then sent to BSL laboratory for total fluoride analysis by the LAB-0150 ion selective electrode method. In the second sampling period, total fluoride in mangrove components was analysed using the LAB-0150 and LAB-0032 ion selective electrode methods. The LAB-0150 method was used in this and other work to measure total fluoride in sediments and crabs/fish, and the LAB-0032 method was used in other studies to measure total fluoride in *Eucalyptus* species. Total fluoride data for mangrove components was therefore comparable with other total fluoride data.

2.5 *Macrobenthic fauna monitoring*

2.5.1 Identification of macrobenthic fauna in sediment

Benthic fauna of Spillway Creek was sampled using a van Veen grab with an effective volume of $0.005m^3$ and sampling area of $0.05m^2$. At each site, ten random samples were taken along a cross-section of the creek in December 1997. Due to sampling difficulties, this method was revised and in April 1998, 15 samples were taken from each site - five samples near each bank and five samples from the middle of the creek. Allowance for this was made in the data by normalizing the abundance of the 15 samples to a 10-sample abundance for comparability with the December 1997 data.

Each sample was photographed and then washed through a 1mm sieve within 2 hours of collection and preserved in 5% formalin. After 72 hours, samples were transferred into 70% ethanol for storage until identification. Samples were later sorted in the laboratory using stereo microscopes and macrobenthic fauna were classified to family level. One individual of each taxa collected was sketched and retained as part of a reference collection.

Macrobenthic data were analysed to assess whether there were any spatial differences among sites or temporal trends within sites. The Shannon-Weiner index of diversity was used to represent macrobenthic fauna assemblages at each site and species richness and abundance were also determined for each site.

2.5.2 Identification and fluoride analysis of macrobenthic fauna species trapped

Trapping was undertaken in and around each mangrove plot in December 1997 and April 1998 using 10 small traps and 2 large crab pots. Traps were retrieved after 24 hours and all fauna identified. All animals were measured and weighed. Upon return to the laboratory, crabs were washed free of excess mangrove mud and dried at 100°C until constant mass was obtained. All individuals were then sent to BSL for fluoride analysis by the LAB-0150 ion selective electrode method as originally determined by BSL for sediments and mangrove components.

3.0 Results

3.1 Water

3.1.1 Physico-chemical water quality and toxicants

Table 1. Comparison of physicochemical water quality parameters in Spillway Creek, discharge point (L06) and Spillway Channel (L11) for the December 1997 and April 1998 sampling periods (analysed by BSL Analytical Services). Additional data for L06 are shown in Appendix 1. Dissolved oxygen data were obtained in the field using the YSI probe in December and a portable dissolved oxygen probe in April.

Site	Sampling Date	pH	Conductivity µS/cm	Fluoride mg/L	Susp.Sol. mg/L	Cyanide mg/L	Dissolved O_2 mg/L
1	Dec-97	8.2	50800	1.1	20.0	<0.02	NA
	Apr-98	8.0	50000	1.6	29.2	<0.02	9.2
2	Dec-97	8.2	51000	1.1	24.0	<0.02	NA
	Apr-98	7.9	51300	1.5	12.4	<0.02	7.5
3	Dec-97	8.3	51200	1.1	31.2	<0.02	6.9
	Apr-98	7.7	51300	2.4	24.0	<0.02	7.1
4	Dec-97	8.2	51400	1.2	18.4	<0.02	6.8
	Apr-98	7.6	50900	3.4	38.4	<0.02	7.1
5	Dec-97	8.0	52900	1.2	19.2	<0.02	6.0
	Apr-98	7.6	47700	4.9	14.0	<0.02	7.2
L11	Dec-97	7.3	903	21.4	NA	NA	NA
	Apr-98	7.5	808	22.2	<1	<0.02	NA
L06	Dec-97	7.5	569	24.1	13.2	<0.02	10.66
	Max	8.0	666	38.9	29.0		
	Min	7.1	429	12.6	4.0		
L06	Apr-98	7.8	625	17.3	10.1	<0.02	NA
	Max	8.4	826	27.0	18		
	Min	7.0	433	6.0	4		
ANZECC	Fresh	6.5-9.0	<1500			0.005	>6
	Marine	<0.2*				0.005	>6
BSL License*	Spillway Creek	6.5-9.0		≤30	≤30	≤0.1	

* <0.2 pH unit change; NA= not available. *Source: Queensland Environmental Protection Agency – BSL Environmental Authority.

Physico-chemical characteristics of Spillway Creek (1-5), BSL discharge point (L06) and Spillway Channel (L11) are shown in Table 1. Monthly water quality data for BSL sites L06, L11, L13, L24 and L25 are shown in Appendix 1.

3.1.1.1 pH

At all locations, pH levels were within the alkaline range as expected. The pH levels at the discharge point and in the discharge channel were within ANZECC guidelines for fresh water (ANZECC, 1992) and all levels conformed to the quality characteristics of release to waters required of BSL under its environmental authority.

3.1.1.2 Conductivity

Conductivity readings were similar for all sites and times within Spillway Creek and values reflect the tidal nature of the inlet. Spillway Channel (site L11) and the discharge point (site L06) recorded lower conductivity values, typical of freshwater (Table 1), and were within the ANZECC guidelines for protection of aquatic systems.

3.1.1.3 Suspended solids

Suspended solids were variable with no trends apparent in the data. This was expected given the daily tidal variation within Spillway Creek and the effects of storm events in the catchment. Concentrations at the discharge point and Spillway Channel were below the maximum limit required by BSL under its Environmental Authority.

3.1.1.4 Dissolved Oxygen

All concentrations of dissolved oxygen (Table 1) were at or above the ANZECC recommendations of 6mg/L minimum for aquatic systems (ANZECC, 1992).

3.1.1.5 Fluoride

BSL's Environmental Authority permits a maximum fluoride release of 30mg/L in discharge. Average levels were all below this. The licensed limit was exceeded on 4 December 1997 with 38.9 mg/L of fluoride recorded at the discharge point (Table 1). Fluoride data for Spillway Creek (sites 1-5) was consistent with past data obtained in South Trees Inlet, Spillway Creek, Sandy Creek and Boyne River (Yezdani, 1996) (Appendix 5 – Table A).

3.1.1.6 Cyanide

The ANZECC water quality guidelines recommend cyanide levels not exceed 0.005mg/L in both fresh and marine ecosystems. Values obtained from analysis by BSL indicated that the detection limits required were not achievable at this time. The cyanide levels in Spillway Creek and the discharge point and channel were well below the maximum of 0.1 mg/L allowed in BSL's license limits.

3.1.2 Metals in water

Table 2. Metals analysis of marine water conducted by Australian Laboratory Services Pty Ltd for 5 Spillway Creek sampling sites in December 1997 and April 1998 (mg/L). BSL sites L06 and L11 for December 1997 and March 1998 (April not available) are included, as are the ANZECC (1992) guidelines for marine waters. * represents concentrations above ANZECC screening levels. IS denotes insufficient sample.

Site	Period	Arsenic	Cadmium	Chromium	Copper	Nickel	Lead	Zinc	Mercury
1	Dec-97	<0.05	<0.002	<0.05	0.02*	<0.005	<0.005	<0.05	<0.0001
	Apr-98	<0.05	<0.002	<0.05	0.025*	<0.005	<0.005	0.05	<0.0001
2	Dec-97	<0.05	<0.002	<0.05	0.02*	0.02*	<0.005	<0.05	0.0012*
	Apr-98	<0.05	<0.002	<0.05	0.025*	<0.005	<0.005	<0.05	<0.0001
3	Dec-97	<0.05	<0.002	<0.05	0.02*	0.015	0.005	<0.05	0.0002*
	Apr-98	<0.05	<0.002	0.05	0.03*	<0.005	<0.005	<0.05	<0.0001
4	Dec-97	<0.05	<0.002	<0.05	0.02*	0.01	0.01*	<0.05	<0.0001
	Apr-98	<0.05	<0.002	0.05	0.03*	<0.005	<0.005	<0.05	<0.0001
5	Dec-97	<0.05	<0.002	<0.05	0.02*	0.005	<0.005	<0.05	IS
	Apr-98	<0.05	<0.002	0.10*	0.02*	<0.005	<0.005	<0.05	<0.0001
L11	Dec-97	<0.5	<0.005	<0.01	<0.01	<0.01	<0.01	0.06*	NA
	March-98	0.012	0.002	0.003	0.005	0.005	0.033*	3.34*	NA
L06	Dec-97	<0.5	<0.005	<0.01	0.02*	0.01	0.01*	0.36*	NA
	March-98	0.008	0.001	0.004	0.03*	0.004	0.003	0.124*	NA
ANZECC 1992		0.05	0.002	0.05	0.005	0.015	0.005	0.05	0.0001

Metals analysed included arsenic, cadmium, chromium, copper, nickel, lead, zinc and mercury. Arsenic and cadmium levels in Spillway Creek were below levels for marine water quality criteria presented by ANZECC (Table 2).

Zinc was within the ANZECC specifications of 0.05mg/L in Spillway Creek sites, however BSL data for sites L06 at the discharge point and L11 in the discharge channel (Table 2) show zinc concentrations to be higher than ANZECC specified levels for marine and fresh waters in December 1997 and March 1998. Study of the available data sets for L06 and L11 in 1997 and 1998 (Appendix 2) shows the high levels in December and March were not typical for Spillway Channel (site L11). Zinc concentrations at the discharge point (site L06) were generally higher than in Spillway Channel and more frequently exceeded ANZECC levels.

Within Spillway Creek, nickel exceeded the ANZECC water quality criteria at site 2, lead at site 4 and mercury at sites 2 and 3 in December 1997, and chromium exceeded the quality criteria in site 5 in April 1998. Lead concentrations exceeded ANZECC criteria in sites L06 in December and L11 in March (Table 2).

Copper levels exceeded the ANZECC guideline levels (0.005mg/L) in all Spillway Creek sites and the discharge point (L06) by four to six times (Table 2). ANZECC guidelines were also exceeded in Spillway Channel (L11) in June and August 1997. The ALS limits of reporting (LOR) for copper and other metals were not low enough to compare with ANZECC criteria prior to March 1998. It was not possible to determine copper concentrations below 0.01mg/L before this period (Appendix 6). However, improved analytical sensitivity at ALS lowered limits of reporting for March sampling (Appendix 6). These results indicated that copper levels in Spillway Channel (L11) were at the specified guideline level in March 1998. There was little evidence in the data to suggest BSL was the source of the high copper levels in Spillway Creek.

3.2 Sediment

3.2.1 Sediment physical characteristics

Table 3. Particle size fractions (%) and combustible matter (%) of sediment taken from within mangrove plots at Spillway Creek. December 1997 and April 1998 values have been averaged.

Site	Particle size fractions (%)according to sieve aperture size							% Combustible Matter
	<63µm	63µm	125µm	250µm	500µm	1mm	2mm	
1	56.05	30.44	7.44	1.81	1.07	0.33	1.43	7.73
2	55.84	9.9	11.18	12.28	4.14	1.49	3.38	7.17
3	49.23	19.34	20.77	7.41	0.39	0.45	0.76	7.4
4	90.38	5.34	0.94	0.41	0.11	0.07	0.51	8.24
5	69.75	9.46	7.07	10.34	1.79	0.27	0.32	6.64

Table 4. Particle size fractions (%) and combustible matter (%) of sediment taken from Spillway Creek adjacent to Mangrove plots in April, 1998.

Site	Location	Particle size fractions (%)according to sieve aperture size							% Combustible Matter
		<63µm	63µm	125µm	250µm	500µm	1mm	2mm	
1	Bank	46.84	31.9	10.65	4.91	1.3	0.85	1.69	5.74
	Middle	0.31	0.74	34.2	63	1.11	0.2	0.01	1.51
2	Bank	43.42	34.97	15.65	2.31	0.41	0.36	0.8	5.43
3	Bank	23.54	40.23	27.75	3.19	0.46	0.28	3.41	4.04
4	Bank	55.57	31.46	9.6	0.61	0.01	0.02	0	7.05
	Middle	0.2	0.37	5.61	54.56	35.15	3.21	0.5	2.42
5	Bank	17.37	11.32	7.17	11.74	3.21	0.62	46.78	5.66
	Middle	0.13	0.26	4.83	66.9	25.54	1.43	0.48	1.64

Samples taken from within the Spillway Creek mangrove plots were muddy sediments with sites 1 and 3 containing higher percentages of sand. Organic matter content was estimated to range between 6% and 8% (Table 3).

The sides of Spillway Creek at sites 1 to 4 (Table 4) were muddy (clay/silt) with some fine sand. Site 5 was found to be coarse sand.

Sediments in the middle of Spillway Creek were sandy (Table 4). Sediment samples were not obtained for sites 2 and 3 due to the presence of large pebbles and cobbles but were classified as granulose and pebbled based on observations.

As expected, mid stream samples were characteristically low in organic matter while samples from the side ranged between 4% and 7% estimated organic matter (Table 4).

3.2.2 Fluoride levels in sediment

Table 5. Fluoride levels in sediment (mg/kg) at sites in Spillway Creek as measured by BSL using the ion specific electrode method (total fluoride) in December 1997 and April 1998, and EAL using the acid extraction method (bio-available fluoride) in April 1998.

Site	Date	Total fluoride Bank	Total fluoride Middle	Bio-available fluoride
1	Dec-97	197.2	NA	NA
	Apr-98	84.08	48.92	20
2	Dec-97	86.63	NA	NA
	Apr-98	93.2	NA	22
3	Dec-97	131.95	NA	NA
	Apr-98	119.98	NA	16
4	Dec-97	210.16	69.41	NA
	Apr-98	108.78	40.36	26
5	Dec-97	215.25	118.89	NA
	Apr-98	112.51	43.82	19

Fluoride concentrations determined in April using the ion specific electrode method (total fluoride) and acid extraction method (bio-available) showed very little variation between sites in Spillway Creek (Table 5). The proportion of fluoride available to biota was considerably less than the total fluoride concentration of sediment in April. Comparison of these data with HCL extractable fluoride data from sediments in South Trees Inlet using one-way ANOVA showed bio-available fluoride to be significantly higher ($P < 0.05$) in Spillway Creek sediments than in South Trees Inlet (McConchie *et al.*, 1996) (Appendix 5 – Table B).

3.2.3 Metals in sediment

Table 6. Metals in sediment (mg/kg) analysed by Australian Laboratory Services Pty Ltd (total metals) in December 1997 and April 1998, and Environmental Analysis Laboratory (bio-available metals) in April 1998 for 5 Spillway Creek sampling sites. ANZECC preliminary screening levels for sediments (ANZECC, 1996; Moss and Costanzo, 1998) are also given for comparison.

Site	Period	Method	Arsenic	Cadmium	Chromium	Copper	Nickel	Lead	Zinc	Mercury
1	Dec-97	Total metals	17	<1	20	7	7	10	25	<0.1
	Apr-98	Total metals	10	<1	17	12	7	3	26	<0.1
	Apr-98	Bio-available	2.88	<0.01	6.57	3.89	3.79	3.83	13.8	0.04
2	Dec-97	Total metals	15	<1	14	5	5	4	25	<0.1
	Apr-98	Total metals	14	<1	17	10	7	4	27	<0.1
	Apr-98	Bio-available	5.53	0.07	7.91	4.98	4.49	5.13	16.9	0.03
3	Dec-97	Total metals	14	<1	17	6	6	5	26	<0.1
	Apr-98	Total metals	8	<1	13	6	5	3	21	<0.1
	Apr-98	Bio-available	4.07	0.16	7.1	4.44	4.45	4.32	15.4	0.03
4	Dec-97	Total metals	20*	<1	21	12	8	7	39	<0.1
	Apr-98	Total metals	17	<1	23	12	9	5	36	<0.1
	Apr-98	Bio-available	5.74	0.17	7.86	6.45	4.64	6.27	19.3	<0.01
5	Dec-97	Total metals	21*	<1	24	14	12	12	62	<0.1
	Apr-98	Total metals	13	<1	15	8	7	2	25	<0.1
	Apr-98	Bio-available	3.08	0.12	5.91	3.72	3.59	4.03	14.3	<0.01
ANZECC			20	1.5	80	65	21	75	200	0.15

* Represents concentrations at or above ANZECC screening levels.

All recorded levels of metals in sediments were below ANZECC screening levels (Table 6), except for arsenic at Sites 4 and 5 in December 1997. The negligible levels of arsenic in discharge waters (Table 2) indicate that BSL was not a source of elevated arsenic concentrations in Spillway Creek sediment at that time. Elevated arsenic levels have been reported previously in Port Curtis marine sediments (range 6.6 – 32mg/kg) and along the east coast of Australia suggesting that the marine sediments have naturally high arsenic levels (QDEH, 1994; ANZECC 1998). The bio-available proportions of metals determined in April using the HCL extractable method, were all below ANZECC levels (Table 6). Spillway Creek data were similar to acid extractable data obtained in South Trees Inlet and Wild Cattle Creek (McConchie *et al.*, 1996) (Appendix 5 – Table B).

3.3 Mangrove Monitoring

3.3.1 Growth, survival, productivity and shoot production

The mean dry weights and counts for the components of mangrove litter found in traps at each site are tabulated (Appendix 2). Productivity has been calculated for total litter in grams of litter produced per m^2 per day (Table 7). Other measurements taken in mangrove plots have been summarised (Table 7).

Productivity and shoot production were generally lower at upstream sites and decreased over the year as expected, with reduced leaf and reproductive components consistent with seasonal data elsewhere (Hutchings and Saenger, 1987; Lovelock, 1993). The productivity of Spillway Creek mangrove plots was closely comparable to *Rhizophora* scrub sites elsewhere in Port Curtis (Johnson *et al.*, 1999) and to *Rhizophora* sp. dominant mangroves of Missionary Bay, Hinchinbrook Island (Duke *et al.*, 1981) (Appendix 5 – Table C). Spillway Creek site 4 differed due to the presence of *Xylocarpus granatum*, a deciduous mangrove species.

Herbivory, the frequency of insect attack expressed as a percentage (Appendix 3), was variable spatially and temporally in Spillway Creek.

Screw heights showed variable sediment deposition and erosion throughout the year. Basal area generally increased within plots. Canopy cover was generally similar across sites with the exception of Site 4. All sites were observed to be healthy. Seedling and propagule numbers were relatively low and variable.

Table 7. The average screw height, basal area (m^2/ha), percentage canopy cover, number of seedlings and propagules, shoot production and productivity at five sites in Spillway Creek.

Site	Period	Screw Height (cm)	Basal Area (m^2/ha)	Canopy Cover (%)	Seedlings	Propagules	Shoot Prod (N/m^2/day)	Productivity (g/m^2/day)
1	Nov-97	81.0	19.95	NA	0	0	NA	NA
	Apr-98	80.7	21.52	NA	0	0	2.8	3.03
	Jun-98	78.7	NA	NA	0	0	1.5	1.48
	Oct-98	77.9	22.47	85	1	0	1	0.91
2	Nov-97	62.0	22.67	NA	0	0	NA	NA
	Apr-98	63.7	29.50	NA	0	5	2.7	2.83
	Jun-98	63.9	NA	NA	0	0	2.2	2.09
	Oct-98	71.7	29.01	70	1	0	1.8	1.59
3	Nov-97	84.7	20.18	NA	0	0	NA	NA
	Apr-98	85.6	23.25	NA	0	4	3.1	2.00
	Jun-98	84.0	NA	NA	0	0	2	1.62
	Oct-98	84.1	20.90	85	0	0	2	1.42
4	Nov-97	116.9	51.39	NA	0	0	NA	NA
	Apr-98	115.8	57.16	NA	0	0	0.5	0.61
	Jun-98	115.5	NA	NA	0	0	0.1	0.08
	Oct-98	117.1	60.26	45	0	0	1.1	0.70
5	Nov-97	62.2	21.73	NA	0	0	NA	NA
	Apr-98	64.3	23.08	NA	2	0	1.9	1.80
	Jun-98	63.2	NA	NA	0	0	1.1	0.75
	Oct-98	63.6	23.94	70	2	0	1.3	0.85

NA = Not analysed.

3.3.2 Fluoride levels in shoots, roots, new and old leaves and bark

Table 8. Total fluoride concentrations (mg/kg) in fresh mangrove components for each site in Spillway Creek in December 1997 and April 1998. Tested as per LAB-0150

Species	Sample	Site 1		Site 2		Site 3		Site 4		Site 5	
		Dec-97	Apr-98	Dec-97	Apr-98	Dec-97	Apr-98	Dec-97	Apr-98	Dec-97	Apr-98
Rhizophora	Shoot	16.74	4.79	16.06	17.37	22.25	37.30	56.88	19.92	2.54	14.75
	New Leaf	31.15	26.70	25.12	70.02	17.38	30.09	51.27	17.94	9.31	28.53
	Mature Leaf	63.51	95.61	106.40	110.34	127.59	98.64	133.29	156.53	175.64	211.72
	Bark	62.61	106.07	97.36	133.93	267.08	231.52	117.89	197.89	120.81	285.89
	Root	26.34	6.77	39.31	19.78	42.08	26.49	67.17	4.19	29.50	10.40
Avicennia	Mature Leaf			14.07	30.14			9.50	90.22		
Xylocarpus	Mature Leaf							23.46	32.48		

Table 9. Fluoride concentrations (mg/kg) in *Rhizophora stylosa* and *Eucalyptus* sp. components for Spillway Creek sites and BSL terrestrial sites in April, 1998 determined by the LAB-0032 method. BSL terrestrial sites correspond with Spillway Creek sites 2 and 4 and Spillway Channel monitoring point L11. BSL site 8 is a background terrestrial site (Figure 1 – inset).

Species	Sample	Site 1	Site 2	Site 3	Site 4	Site 5	L11 Spillway Channel	BSL Background Site 8
Rhizophora	Root	<LOR	<LOR	<LOR	<LOR	2.57		
	Bark	33.78	35.86	77.82	49.17	78.45		
	Mature leaf	29.58	51.18	58.18	77.64	105.74		
	New leaf	3.87	8.15	0.3	14.4	8.77		
	Shoot	<LOR	<LOR	0.49	1.89	43.77		
Eucalyptus	Leaf		29		130		78	6

LOR = Limit of reporting

Fluoride concentrations in *Rhizophora stylosa, Avicennia marina* and *Xylocarpus granatum* vegetative components are shown in Table 8 and a comparison between *Rhizophora stylosa* and *Eucalyptus* sp. fluoride concentrations is shown in Table 9.

Fluoride levels in shoots, new leaves and roots were consistently lower than in mature leaves and bark and varied between sampling periods. Mature leaves accumulate higher fluoride levels due to facilitation of diffusion through increased surface area and concentration gradients, and greater exposure time (Doley, 1986). Fluoride in mature leaves and bark decreased with distance from fluoride sources, the smelter exhaust points or stacks (air-borne fluoride) and the discharge point (water-borne fluoride). Fluoride levels in *Rhizophora stylosa* mature leaves and *Eucalyptus* sp leaves were similar for April (Table 9) also declining with distance from the source.

3.4 Macrobenthic fauna monitoring

3.4.1 Identification of macrobenthic fauna in sediment

In December 1997, 34 species and 451 individuals of macrobenthic fauna were identified from Spillway Creek macrobenthic sampling. In April 1998, the number of species was 45 and the number of individuals decreased to 446. Of these species, bivalves (shellfish) were most common with 24 species recorded, followed by crustaceans (crabs, prawns, etc) with 10 species, polychaetes (marine worms) with 8 species and 3 species from other assorted taxa. Abundance, species richness and Shannon-Weiner diversity (log to base e) for each site in December and April have been calculated and tabulated (Table 10 and 11).

Table 10. The total number of individuals (abundance) and species (richness) and the Shannon-Weiner diversity index for Spillway Creek sites 1 – 5 in December 1997.

		Site 1	Site 2	Site 3	Site 4	Site 5	Total
All species	Abundance	33	29	41	204	144	451
	Richness	13	13	13	18	12	34
	Diversity	2.07	2.34	2.27	1.11	0.58	
Bivalvia	Abundance	21	9	13	178	128	349
	Richness	9	6	4	8	3	15
Crustacea	Abundance	4	12	11	3	7	37
	Richness	3	3	4	2	4	8
Misc.	Abundance	0	0	9	6	2	17
	Richness	0	0	1	2	1	3
Polychaeta	Abundance	8	8	8	17	7	48
	Richness	1	4	4	6	4	8

Table 11. Total number of individuals (abundance) and species (richness) and the Shannon-Weiner diversity index for samples taken from banks and mid channel at Spillway Creek sites 1 – 5 in April, 1998.

		Site 1			Site 2			Site 3			Site 4			Site5		
		Bank	Mid	Bank	Bank	Mid	Bank	Bank	Mid	Bank	Bank	Mid	Bank	Bank	Mid	Bank
All species	Abundance	13	9	6	10	4	5	3	0	14	43	119	17	8	130	65
	Richness	6	5	5	6	2	2	3	0	5	10	3	6	4	3	10
	Diversity	1.61	1.52	1.61	1.61	0.00	1.00	1.10	0.00	1.40	1.66	0.20	1.49	1.07	0.18	1.11
Bivalvia	Abundance	11	3	1	1	0	0	1	0	2	5	114	2	5	125	50
	Richness	4	1	1	1	0	0	1	0	2	1	1	1	1	1	2
Crustacea	Abundance	2	3	2	6	0	3	1	0	3	7	1	6	0	0	6
	Richness	2	2	1	2	0	1	1	0	1	4	1	1	0	0	3
Misc.	Abundance	0	1	0	1	0	0	0	0	6	1	4	0	2	4	2
	Richness	0	1	0	1	0	0	0	0	1	1	1	0	2	1	2
Polychaeta	Abundance	0	2	3	2	4	2	1	0	3	30	0	9	1	1	7
	Richness	0	1	3	2	2	1	1	0	1	4	0	4	1	1	3

Table 12. The total number of individuals and species and the Shannon-Weiner diversity index for Spillway Creek sites 1 – 5 in April 1998. Bank and mid channel data for abundance have been pooled and normalized from 15 samples to 10 samples for comparison with December 1997 data.

		Site 1		Site 2		Site 3		Site 4		Site 5		Total	
	N° of samples	15	10	15	10	15	10	15	10	15	10	15	10
All species	Abundance	28	18.71	19	12.73	17	11.39	179	119.93	203	136.01	446	298.77
	Richness	10	10	8	8	8	8	15	15	10	10	45	
	Diversity	2.39	2.39	1.81	1.81	1.81	1.81	1.41	1.41	0.62	0.62		
Bivalvia	Abundance	15	10.05	1	0.67	3	2.01	121	81.07	180	120.6	320	214.4
	Richness	5	5	1	1	3	3	3	3	2	2	24	
Crustacea	Abundance	7	4.69	9	6.03	4	2.68	14	9.38	6	4.02	40	26.8
	Richness	3	3	2	2	2	2	5	5	3	3	10	
Misc.	Abundance	1	0.67	1	0.67	6	4.02	5	3.35	8	5.36	21	14.07
	Richness	1	1	1	1	1	1	1	1	2	2	3	
Polychaeta	Abundance	5	3.35	8	5.36	4	2.68	39	26.13	9	6.03	65	43.55
	Richness	1	1	4	4	2	2	6	6	3	3	8	

Sites 4 and 5 had consistently high abundance. Many species found in low abundance in Sites 4 and 5 were not present at other sites.

April 1998 sampling involved systematic sampling from the two banks and the middle of the creek. This allowed comparison of faunal composition between the bank and the centre of the creek (Table 11). Samples taken in the centre of the creek had consistently lower diversity than samples taken in the bank regions. Abundance, species richness and diversity of macrobenthic fauna within Spillway Creek were consistent with macrobenthic data from Boat Creek, a similar estuarine site (Melzer *et al.*, 1999; Appendix 5 – Table D). In contrast, independent-samples t tests showed abundance ($P<0.05$), richness ($P<0.001$) and Shannon-Weiner diversity ($P<0.05$) to be significantly lower in Spillway Creek and Boat Creek than in open water sites elsewhere in Port Curtis (Lewis *et al.*, 1999; Appendix 5 – Table D) due to inherent differences between estuarine and open water environments.

3.4.2 Identification and fluoride analysis of macrobenthic species trapped

Species trapped in the mangrove areas included four species of crabs (*Sesarma messa*, *Metapograpsus* sp., *Thalamita* sp., and *Scylla serrata*) one prawn species and two species of fish (Bream and Estuary Cod).

Number of species trapped, their weight and width are tabulated (Appendix 4). Generally, *Scylla serrata* were the largest species found along with two estuary cod. In December 1997, *Sesarma* *messa* were the most abundant crustacean trapped, while in April 1998, prawns were most abundant.

Table 13. Fluoride concentrations (mg/kg) in crabs (*Sesarma messa, Metapograpsus frontalis, Thalamita* sp., *Scylla serrata*) and in species of prawn, bream and estuary cod trapped at sites in Spillway Creek in December 1997 and April 1998.

Site	Period	*S. messa*	*M. frontalis*	*Thalamita* sp.	*S. serrata*	Prawn	Bream	Estuary Cod
1	Dec-97	114.40	93.47	84.40	72.48			
	Apr-98			58.61	131.88	32.78	146.20	
2	Dec-97	120.20						
	Apr-98	61.09	40.20	54.75	211.20	61.00		
3	Dec-97	147.70	50.70		172.70			
	Apr-98	37.23	42.38		98.20	18.10		117.03
4	Dec-97	238.70	654.70		193.70			
	Apr-98		23.80		178.99	52.73		
5	Dec-97	245.70	102.70		257.7			
	Apr-98	101.21	18.50			59.2		112.08

Due to the low numbers of *Metapograpsus* sp, *Thalamita* sp, *Scylla serrata, Sesarma messa,* Bream, Estuary Cod and prawns trapped and analysed, the fluoride concentration data for these species is interpreted cautiously. The fluoride concentration in whole *Sesarma messa* and *Scylla serrata* appeared to decrease with distance from the discharge point in December 1997 (Table 13) following the trend expressed in the mangrove component data (Table 8) during the same period. Fluoride concentrations in *S. messa* appeared to be lower in April than December and there was a reduction in crabs trapped (Appendix 4). Generally, crabs are more active during summer months than winter months in temperate mangroves (Yates, 1978) and the lower numbers of captures in April may reflect this pattern in Port Curtis.

Fluoride concentration varied in different species. Prawns were found to have lower levels than crabs, with fluoride concentration ranging from 18 to 61mg/kg (Table 13).

Sesarma messa recorded levels of fluoride typically in excess of those found both in mangrove components (Table 8) and in previous mangrove epifauna studies (Yezdani, 1996). Similarly, fluoride concentrations in *Metapograpsus frontalis* and *Scylla serrata* exceeded those in mangrove components at some sites though the low numbers caught precluded definite interpretation of these data.

Metapograpsus frontalis had fluoride concentrations generally less than 100mg/kg, with one high recording of 654.7 mg/kg in this study. *M. frontalis* numbers were insufficient to validate this data. Similar levels averaging 96.0 mg/kg were found previously in the same species (Yezdani, 1993).

4.0 Conclusions

Physico-chemical water quality parameters and toxicant concentrations within Spillway Creek and the BSL Spillway Channel satisfied the ANZECC guideline requirements and conformed to the release quality characteristic limits for BSL discharge.

Metal concentrations in water exceeding the ANZECC water quality criteria were found in Spillway Creek and discharge waters. There were no apparent trends in these data and little relationship to the BSL discharge point was evident.

Metal concentrations in sediments were below ANZECC screening levels with the exception of arsenic at sites 4 and 5. There is no apparent relationship between BSL discharge and the elevated arsenic at these sites.

Metal and fluoride concentrations in Spillway Creek water and sediment were comparable to concentrations found in South Trees Inlet and other sites in southern Port Curtis.

Mangrove productivity and shoot production were lower in December and are consistent with seasonal data elsewhere. Productivity was similar to other Port Curtis sites and sites in Missionary Bay, Queensland. Basal area of mangroves generally increased. The Spillway Creek mangrove communities were healthy.

Fluoride levels in mature mangrove components were consistently higher than in new growth and roots, and concentrations varied little between sampling periods. Fluoride concentrations decreased with distance from BSL, consistent with patterns seen in the terrestrial vegetation.

Fluoride levels in one crab species were typically higher than those found in mature mangrove components and followed the same pattern as vegetation, decreasing further from the source. These trends probably reflect the gradient of fluoride concentration with distance from the smelter. Further study is required to assess the significance of this finding.

Abundance, species richness and diversity of macrobenthic fauna within Spillway Creek were consistent with macrobenthic data from other Port Curtis estuarine sites but differed significantly from open water sites.

Generally, the mangrove communities and benthos of Spillway Creek were healthy. Some variation occurred through the year probably with season and natural environmental influences.

5.0 References

Australian and New Zealand Environment and Conservation Council (1992) *Australian Water Quality Guidelines for Fresh and Marine Water.* ANZECC, Canberra.

Australian and New Zealand Environment and Conservation Council (1996) *Environmental assessment of the sea disposal of dredged and excavated material. Draft guidelines.* ANZECC, Canberra.

Australian and New Zealand Environment and Conservation Council (1998) *Interim – Ocean Disposal Guidelines,* ANZECC Secretariat, Canberra.

Australian/New Zealand Standard AS/NZS 5667-2 (1991) *Water quality – Sampling – Part 2: Guidance on sampling techniques.* Standards Australia and Standards New Zealand.

Australian Standard AS 1289.B1.1 (1977) *Methods of testing soil for engineering purposes: Determination of the moisture content of a soil - oven drying method (standard method)* Standards Association Australia.

Australian Standard AS 1289.C6.1 (1977) *Methods of testing soil for engineering purposes: Determination of the particle size distribution of a soil - standard method of analysis by sieving.* Standards Association Australia.

Australian Standard AS 3580.10.1 (1991) *Methods for sampling and analysis of ambient air: Method 10.1 Determination of particulates - deposited matter - gravimetric method.* Standards Association Australia.

Bruce, R.C. and Rayment, G.E. (1982) *Analytical methods and interpretations used by the Agricultural Chemistry Branch for soil and land use surveys.* Queensland Department of Primary Industries Bulletin QB820004.

Doley, D. (1986) *Plant fluoride relationships; an analysis with particular reference to Australian vegetation.* Inkata Press, Melbourne.

Duke, N.C., Bunt, J.S. and Williams, W.T. (1981) Mangrove leaf litter in north-eastern Australia I. Annual totals by components in selected species. *Aust. J. Bot.* **29**: 547-553.

English, S., Wilkinson, C and Barker, V. (1994) *Survey manual for tropical marine resources.* Australian Institute of Marine Science, Townsville.

Hill, B.J. (1980) Effects of temperature on feeding and activity in the crab *Scylla serrata. Mar. Biol.* **59**, 189-192.

Hutchings, P. and Saenger, P. (1987) *Ecology of Mangroves.* University of Queensland Press, St Lucia.

Johnson, R., Shearer, D., Melzer, A., Wild, D. and Houston, W. (1999) *Port Curtis Mangrove Monitoring Programme.* Report for the Gladstone Port Authority (Centre for Environmental Management, Centre for Land and Water Resource Management, Central Queensland University, Gladstone).

Lewis, S., McNamara, K., McKillup, S., Coates, M., Campbell, P., Melzer, A., Johnson, R., Walker, M., Campbell, J., Shearer, D. and Dobbie, R. (1999) *Port Curtis Macrobenthic Monitoring Programme.* Report for the Gladstone Port Authority (Centre for Environmental Management, Centre for Land and Water Resource Management, Central Queensland University, Gladstone).

Lovelock, C. (1993) *Field Guide to the Mangroves of Queensland.* Australian Institute of Marine Science, Queensland.

McConchie, D., Saenger, P. and Holmes, N. (1996) An environmental assessment of the Boyne River estuary. In *Proceedings of the Boyne River Estuary Workshop -Gladstone 1996.* Centre for Coastal Management, Southern Cross University, Lismore, NSW.

Melzer, A., Walker, M., Elliot, B., Roberts, D., Tucker, G., Aspland, S., Houston, W., Heinrich, B., Augusteyn, J., Price, M., Hendry, R., Knight, R. and Radic, P. (1999) *Terrestrial and Aquatic Flora and Fauna Studies – Stuart Oil Shale Project Stage 2.* Report for Southern Pacific

Petroleum Development (Industrial Land Management Programme, Centre for Land and Water Resource Management, Central Queensland University, Rockhampton, Qld).

Moss, A and Costanzo, S. (1998) *Levels of heavy metals in the sediments of Queensland rivers, estuaries and coastal waters.* Environment technical report No. 20. Department of Environment.

QDEH (1994) *Curtis Coast Study Resource Report.* Queensland Dept. of Environ. and Heritage, Rockhampton.

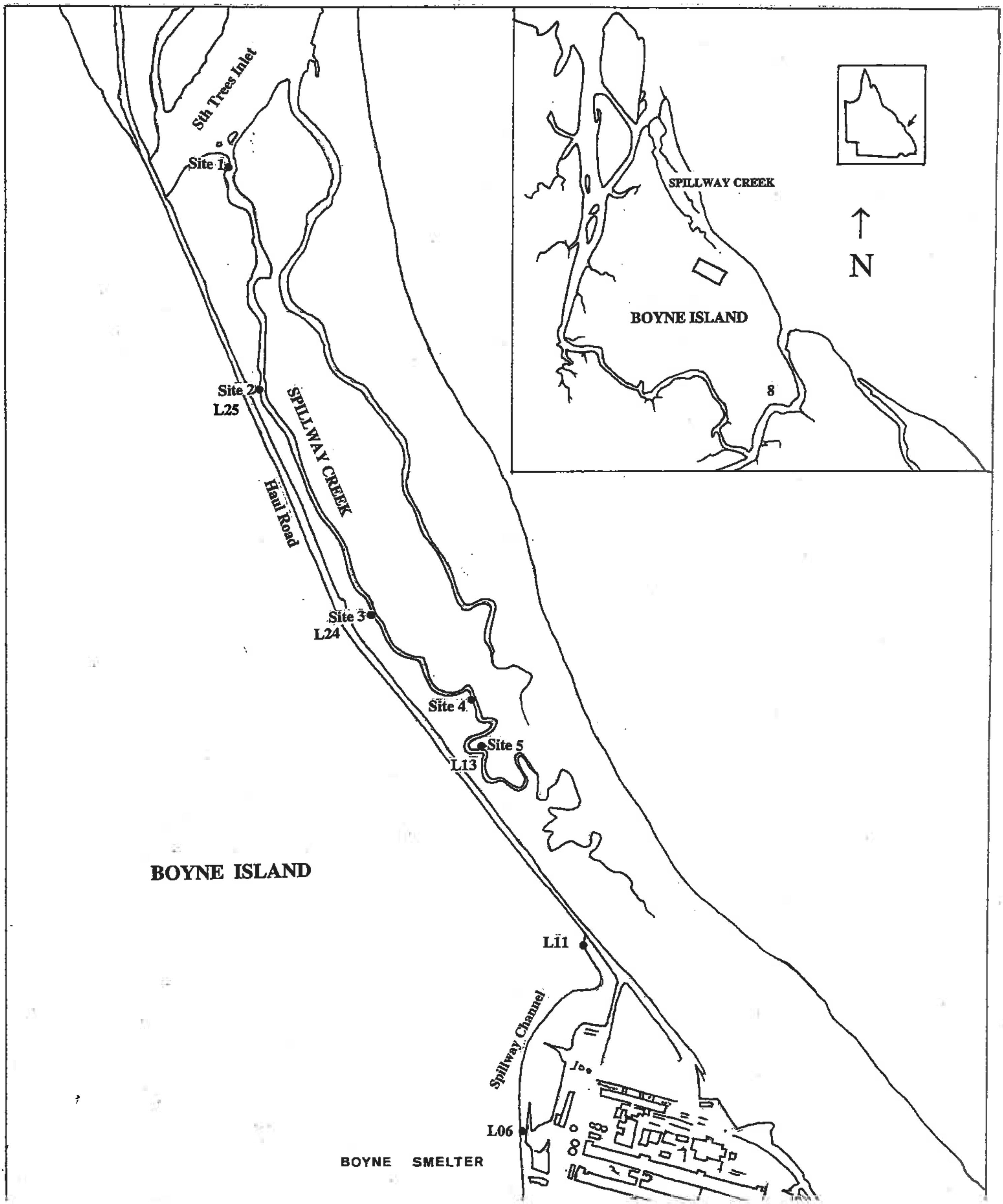
Yates, R.W. (1978) Aspects of the ecology and reproductive biology of crabs in a mangrove swamp at Patonga Creek, NSW. *M.Sc. thesis*, Univ. Sydney.

Yezdani, G.H. (1996) Aquatic environment monitoring in the Boyne River and Port Curtis. In *Proceedings of the Boyne River Estuary Workshop -Gladstone 1996* Centre for Land and Water Resources, Central Queensland University, Rockhampton.

Yezdani, G.H. (1993) Biological and Baseline Monitoring Project Report 1989-1992. Technical Report to Boyne Smelters Ltd, Gladstone.

Figure 1.

BSL/CQU Aquatic Monitoring Sites – Spillway Creek



Appendix 1

BSL water quality data (Spillway Creek and site discharge).

		WATER QUALITY CHARACTERSITICS - SITE DISCHARGE												
Monthly data L06	L06													
	Jan '97	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Jan '98	Feb
pH pH units (median)	8.3	8.6	8.4	8.8	8.3	8.1	7.6	8.5	8.4	8.1	7.5	7.3	7.85	7.8
Conductivity uS/cm (mean)	485	466	404	724	525	610	600	625	679	692	664	602	652	659
Suspended Solids mg/L (mean)	7.4	9.7	13.87	17.5	10.5	6.8	12.6	17.8	19.1	16	4	23.2	14.5	11.5
Fluoride mg/L (mean)	12.1	11.45	10.9	13.5	14.1	10.1	11.68	13.66	17.33	10.78	17.2	28.15	14.54	12.05
Cyanide mg/L (mean)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

	March '98	April
pH pH units (median)	7.9	8.1
Conductivity uS/cm (mean)	700	625
Suspended Solids mg/L (mean)	8.25	11.5
Fluoride mg/L (mean)	12.3	16.64
Cyanide mg/L (mean)	<0.02	0.016

WATER QUALITY DATA - SPILLWAY CREEK

Monthly data L11

	Jan '97	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Jan '98
pH pH units	8		7.8	7.7	7.7	7.8	7.7	7.7	7.6	7.5	7.4	7.3	7.6
Conductivity uS/cm	756		742	660	824	747	810	1092	955	862	1160	903	824
Suspended Solids mg/L	<1		13	<1	10	3	<1	2	2	8	2		2
Fluoride mg/L	15		8.82	10.8	15.6	17.4	13.7	11.8	16.7	15.1	23	21.4	19.7
Cyanide mg/L	<0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02		<0.02

Monthly data L13

	Jan '97	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Jan '98
pH pH units	7.1		8	7.5	7.4	7.6	7.6	7.6	7.6	7.7	7.9		7.8
Conductivity uS/cm	27600		49700	26400	43600	39300	42400	43700	44500	53300	50500		51600
Suspended Solids mg/L	16		17	33	29	6	24	10	12		26		52
Fluoride mg/L	9.83		1.46	7.35	4.74	5.3	4.8	4.6	5.21	1.98	2.48		2.34
Cyanide mg/L	<0.02		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02		<0.02

Monthly data L24

	Jan '97	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Jan '98
pH pH units			7.8	7.7	7.6	7.8	7.8	7.7					
Conductivity uS/cm			48400	38700	47600	46500	48700	47000					
Suspended Solids mg/L			15	32	64	<1	13	9					
Fluoride mg/L			1.73	3.95	2.57	2.73	2.49	3.37					
Cyanide mg/L			<0.02	<0.02	<0.02	<0.02	<0.02	<0.02					

Monthly data L25

	Jan '97	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Jan '98
pH pH units			8.1	7.8	7.9	8	8	7.7					
Conductivity uS/cm			50900	47200	49500	50300	50200	48600					
Suspended Solids mg/L			54	20	23	10	<1	8					
Fluoride mg/L			1.33	1.92	1.47	1.39	1.45	2.62					
Cyanide mg/L			<0.02	<0.02	<0.02	<0.02	<0.02	<0.02					

Monthly data L11			
	Feb'98	March	April
pH pH units	7.7	7.5	7.5
Conductivity uS/cm	810	880	808
Suspended Solids mg/L	<1	4	<1
Fluoride mg/L	19.4	18	22.2
Cyanide mg/L	<0.02	<0.02	<0.02
Monthly data L13			
	Feb'98	March	April
pH pH units	7.7	8.1	7.7
Conductivity uS/cm	41700	5220	50500
Suspended Solids mg/L	10	14	88
Fluoride mg/L	5.78	1.47	4.52
Cyanide mg/L	0.02	<0.02	<0.02
Monthly data L24			
	Feb'98	March	April
pH pH units			
Conductivity uS/cm			
Suspended Solids mg/L			
Fluoride mg/L			
Cyanide mg/L			
Monthly data L25			
	Feb'98	March	April
pH pH units			
Conductivity uS/cm			
Suspended Solids mg/L			
Fluoride mg/L			
Cyanide mg/L			

	2-Dec-97	4-Dec-97	11-Dec-97	17-Dec-97	19-Dec-97	23-Dec-97	30-Dec-97	2-Apr-98	7-Apr-98	9-Apr-98
L06										
pH pH units	7.9	7.1	7.3	7.3	*	8	7.6	8.4	8.2	8.2
Conductivity uS/cm	627	666	576	429	*	648	467	703	726	826
Suspended Solids mg/L	4	29	*	17	*	12	4	10	5	9
Fluoride mg/L	14.1	38.9	24.5	25.5	*	12.6	29	21.1	6	6.15
Cyanide mg/L	*	<0.02	*	*	<0.02	*	*	<0.02	<0.02	*

* = No sample taken

	2-Dec-97	4-Dec-97	11-Dec-97	17-Dec-97	19-Dec-97	23-Dec-97	30-Dec-97	2-Apr-98	7-Apr-98	9-Apr-98
L11										
pH pH units			7.3						7.5	
Conductivity uS/cm			903						808	
Suspended Solids mg/L			*						<1	
Fluoride mg/L			21.4						22.2	
Cyanide mg/L			*						<0.02	

* = No sample taken

Appendix 2

Total metal concentrations in discharge water (L06) and Spillway Channel (L11).

TOTAL METAL CONCENTRATIONS IN DISCHARGE WATER												
TOTAL METALS	L06											
Sample Date	02/06/97	18/06/97	18/07/97	18/08/97	17/09/97	17/10/97	20/11/97	12/12/97	27/01/98		18/03/98	Average
Compound mg/L												
Ca	29	40	33	35	36	42	44	29	49		43	38.00
Mg	7	15	11	12	13	14	14	9	16		17	12.80
Na	56	83	70	61	63	71	89	64	78		85	72.00
K	5	11	6	6	7	7	8	5	8		10	7.30
Al (total)	1	1.3	3	0.7	0.8	1.3	2	3.2	0.9		1	1.52
As	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		0.008	0.01
B	<0.2	<0.02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2		0.2	0.20
Ba	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		0.026	0.03
Cd	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		0.001	0.00
Co	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		<0.001	0.01
Cr	<0.01	<0.01	<0.01	0.03	<0.01	0.13	<0.01	<0.01	<0.01		0.004	0.05
Cu	0.1	<0.01	0.04	0.02	<0.01	<0.01	<0.01	0.02	<0.01		0.03	0.04
Fe	<1	<1	<1	<1	<1	<1	<1	<1	<1		<0.1	<1
Mn	0.04	0.05	0.06	0.04	0.03	0.02	0.04	0.04	0.02		0.038	0.04
Mo	0.07	0.08	0.08	0.06	0.07	0.15	0.07	0.06	0.09		0.043	0.08
Ni	0.03	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.01	<0.01		0.004	0.02
P	<1	1	<1	<1	<1	<1	<1	<1	<1		<1	1.00
Pb	<0.01	<0.01	<0.01	0.03	0.01	<0.01	0.02	0.01	<0.01		0.003	0.01
S	11	73	20	14	25	21	24	13	19		22	24.20
Si	4.4	7.8	6.2	5.8	6.9	7.3	8.2	4.6	7.8		8.7	6.77
Sr	0.11	0.24	0.11	0.18	0.2	0.22	0.26	0.13	0.26		0.26	0.20
V	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		0.005	0.01
Zn	0.11	0.05	0.26	0.05	0.08	0.05	0.07	0.36	0.05		0.124	0.12
Al (dissolved)	0.5	0.7	0.8	0.5	0.6	1.1	1	2	0.8		0.8	0.88
ANZECC guideline Al	0.1											
ANZECC guideline Zn	0.05											
ANZECC guideline Cd	0.002											
ANZECC guideline Cu	0.005											
ANZECC guideline Fe	1											
ANZECC guideline Ni	0.15											
ANZECC guideline Pb	0.005											

TOTAL METAL CONCENTRATIONS IN WATER - SPILLWAY CREEK												
TOTAL METALS	L11											
Sample Date	02/06/97	18/06/97	18/07/97	18/08/97	17/09/97	17/10/97	20/11/97	12/12/97	27/01/98		18/03/98	AVERAGE
Compound mg/L												
Ca	31	41	41	28	39	46	33	51	39		45	39.40
Mg	14	17	19	10	16	21	9	21	14		17	15.80
Na	154	111	113	61	83	102	58	111	91		98	98.20
K	4	8	7	4	6	8	3	8	5		7	6.00
Al (total)	0.5	0.6	1.9	0.8	0.4	0.2	1.1	0.4	0.5		1.9	0.83
As	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		0.012	0.01
B	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2		<0.2	0.20
Ba	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	0.1	<0.1		0.464	0.33
Cd	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		0.002	0.00
Co	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		<0.001	0.01
Cr	<0.01	<0.01	<0.01	0.02	0.02	0.11	<0.01	<0.01	<0.01		0.003	0.04
Cu	0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01		0.005	0.01
Fe	<1	<1	<1	<1	<1	<1	<1	<1	<1		<1	<1
Mn	0.01	0.04	0.24	0.03	0.1	0.06	0.1	0.31	0.13		0.227	0.12
Mo	0.04	0.17	0.03	0.03	0.05	0.07	0.03	0.04	0.03		0.485	0.10
Ni	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		0.005	0.01
P	<1	<1	<1	<1	<1	<1	<1	<1	<1		<1	<1
Pb	0.02	<0.01	<0.01	0.01	<0.01	<0.01	0.04	<0.01	<0.01		0.033	0.03
S	11	65	12	14	21	23	10	20	13		18	20.70
Si	2.4	3.4	3.9	3.7	3.7	4.6	4.6	5.9	4.6		6.2	4.30
Sr	0.11	0.21	0.14	0.12	0.2	0.25	0.12	0.25	0.16		0.221	0.18
V	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		<0.005	<0.01
Zn	0.11	0.04	0.05	0.03	0.02	<0.01	0.03	0.06	0.03		3.34	0.41
Al (dissolved)	0.2	0.4	0.2	0.5	0.5	<0.1	0.8	0.3	0.4		0.6	0.41
ANZECC guideline Al	0.1											
ANZECC guideline Zn	0.05											
ANZECC guideline Cd	0.002											
ANZECC guideline Cu	0.005											
ANZECC guideline Fe	1											
ANZECC guideline Ni	0.15											
ANZECC guideline Pb	0.005											

Appendix 3

Mean dry weights (g), productivity (g/day), shoot production (shoots/day) and counts of mangrove litter components at sites in Spillway Creek

	Site 1			Site 2			Site 3			Site 4			Site 5		
	Apr-98	Jun-98	Sep-98	Apr-98	Jun-98	Sep-98	Apr-98	Jun-98	Sep-98	Apr-98	Jun-98	Sep-98	Apr-98	Jun-98	Sep-98
NO HERBIVORY	241.25	56.38	39.35	159.91	106.21	127.55	112.45	66.53	86.12	39.27	1.23	44.15	148.17	32.81	58.39
HERBIVORY	35.23	25.6	8.35	44.7	19.2	11.33	47.25	31.65	27.61	17.28	7.65	16.52	19.16	7.66	11.87
% FREQUENCY OF ATTACK	12.71	31.13	17.11	21.79	15.28	8.08	29.42	32.21	23.68	30.53	86.15	27.15	11.44	18.86	16.8
APICAL LEAVES	0.61	0.25	0.57	0.56	0.26	0.88	0.93	0.10	2.32	0.06		0.10	0.19	0.16	0.33
BROKEN LEAVES	0.02		0.53	0.01		0.39	0.01		0.55			0.07	0.01		0.07
TOTAL LEAVES	277.10	82.23	48.79	205.16	125.66	140.15	160.62	98.27	116.58	56.61	8.88	60.84	167.52	40.62	70.66
STIPULES	45.32	17.25	14.69	37.05	22.47	21.15	46.42	18.25	24.72	26.68	1.73	12.79	33.52	12.33	14.90
FRASS	3.51	1.60	1.27	5.74	2.23	2.33	2.24	2.23	2.60	2.85	0.11	1.03	3.66	1.04	0.81
FLOWERS	3.97	0.33		10.77	7.73	2.51	5.98	4.50	0.04	3.81	1.43	1.28	12.18	2.23	0.76
FRUIT	4.75	1.00	0.31	16.11	3.09	0.89	3.01	1.71	0.97	2.69		2.23		0.45	1.02
PROPAGULES	34.82			43.89	10.49		8.50	5.50							
TOTAL	43.54	1.33	0.31	70.77	21.30	3.40	17.48	11.70	1.00	6.50	1.43	3.51	12.18	2.68	1.78
STEMS	1.78	0.31	0.32	5.11	4.14	0.71	3.10	1.84	0.12	1.29	0.59	0.67	4.47	1.27	0.24
WOOD	7.44	7.96	39.15	5.10	1.36	5.03	4.15		12.56	0.01		1.53	0.52		9.80
TOTAL	9.21	8.27	39.47	10.21	5.50	5.74	7.25	1.84	12.68	1.30	0.59	2.20	4.99	1.27	10.04
LICHEN									0.55						
MISTLETOE LEAF	0.01		0.22	5.21	0.70	5.80	1.45	0.37	5.69	0.01			0.01		
MISTLETOE FLOWER				0.36	0.01	0.01	0.13	0.13	0.01					0.01	
MISTLETOE SEED															
MISTLETOE WOOD															
TOTAL PARASITES	0.01			5.57	0.71	5.81	1.58	0.50	6.24	0.01			0.01	0.01	
TOTAL LITTER	378.68	110.66	104.74	334.48	177.85	178.56	235.57	132.77	163.81	93.95	12.74	80.37	221.86	57.93	98.17
PRODUCTIVITY	3.03	1.48	0.91	2.83	2.09	1.59	2.00	1.62	1.42	0.61	0.08	0.70	1.80	0.75	0.85

	MEAN COUNT														
	Site 1			Site 2			Site 3			Site 4			Site 5		
	Apr-98	Jun-98	Sep-98	Apr-98	Jun-98	Sep-98	Apr-98	Jun-98	Sep-98	Apr-98	Jun-98	Sep-98	Apr-98	Jun-98	Sep-98
NO HERBIVORY	324.5	80.5	62.5	240.5	152.5	168	182.5	99.5	120	32.0	1.5	66	229.0	47.5	87
HERBIVORY	69.5	39.0	18.5	70	30	15	79	51.5	42.5	13	2.5	30	37.5	11	18.5
% FREQUENCY OF ATTACK	17.4	32.2	21.6	21.8	16.2	7.4	28.9	33.9	22.9	28.3	62.5	30.6	14	18.5	16.7
APICAL LEAVES	6.0	1.5	4.5	11.0	2.5	5.5	11.5	1.0	21.5	1.0		1	1.5	1.0	5
BROKEN LEAVES						11.5			2			1			0.5
TOTAL LEAVES	400.0	121.0	85.5	321.5	185.0	202.5	273.0	152.0	186	46.0	4.0	98	268.0	59.5	111
STIPULES	351.0	110.0	116	316.0	189.0	198.5	371.5	165.0	235.5	67.5	8.0	125	233.5	86.0	149.5
CUP MOTH CUPS	0.5														
FLOWERS	30.5	2.0		77.5	52.0	12	49.0	38.0	0.5	15.5	5.0	6	99.0	18.0	3
FRUIT	1.5	1.5	0.5	4.5	1.0	1	1.0	0.5	2	0.5		5		1.0	2
PROPAGULES	2.5			2.5	0.5		1.5	0.5		0.5			0.5		
LICHEN															
MISTLETOE LEAF	0.5			51.5	6.5	27.5	8.0	2.0	27.5	0.5			0.5		
MISTLETOE FLOWER				14.5	1.5	0.5	4.5	3.0	0.5					0.5	
MISTLETOE SEED															
MISTLETOE WOOD															
SHOOT PRODUCTION	2.8	1.5	1.0	2.7	2.2	1.8	3.1	2.0	2.0	0.5	0.1	1.1	1.9	1.1	1.3

Appendix 4

Numbers, width (mm), weight (g) and fluoride content (mg/kg) of fauna trapped in Spillway Creek in December 1997 and April 1998

		Sesarma messa (Inter-tidal crab)						*Metapograpsus* sp. (Inter-tidal crab)						*Thalamata* sp. (Inter-tidal crab)			
		Fluoride	No.	Width (mm)		Weight (g)		Fluoride	No.	Width (mm)		Weight (g)		Fluoride	No.	Width	Weight
Site	Period	mg/kg		Mean	SD	Mean	SD	mg/kg		Mean	SD	Mean	SD	mg/kg		(mm)	(g)
1	Dec'97	114.40	16	20.06	3.04	5.00	2.88	93.47	4	26.00	2.71	6.76	2.42	84.40	1	60.00	47.21
	Apr'98		0						0					58.61	1	60.00	58.92
2	Dec'97	120.20	10	21.40	3.86	6.27	3.44		0						0		
	Apr'98	61.09	2	23.50	2.12	6.38	1.61	40.20	4	27.00	2.58	6.11	2.27	54.75	1	74.00	117.01
3	Dec'97	147.70	2	22.50	2.12	6.95	1.23	50.70	5	27.40	1.82	7.318	2.22		0		
	Apr'98	37.23	3	20.67	3.51	4.45	2.88	42.38	8	27.50	3.16	7.06	2.99		0		
4	Dec'97	238.70	15	24.00	1.60	7.84	2.43	654.70	1	28.00		6.38			0		
	Apr'98		0					23.80	2	23.50	2.12	3.89	1.07		0		
5	Dec'97	245.70	23	21.26	3.53	5.51	2.65	102.70	3	27.00	2.00	6.64	2.07		0		
	Apr'98	101.21	5	23.60	3.36	6.51	2.77	18.50	1	39.00		7.34			0		

		Scylla serrata (Mud crab)						Prawn						Bream				Estuary Cod			
		Fluoride	No.	Width (mm)		Weight (g)		Fluoride	No.	Width (mm)		Weight (g)		Fluoride	No.	Width	Weight	Fluoride	No.	Width	Weight
Site	Period	mg/kg		Mean	SD	Mean	SD	mg/kg		Mean	SD	Mean	SD	mg/kg		(mm)	(g)	mg/kg		(mm)	(g)
1	Dec'97	72.48	1	134.00		516.68			0										0		
	Apr'98	131.88	1	151.00		1120.00		32.78	11	44.64	7.31	1.26	0.49	146.20	1	190.00	260.61		0		
2	Dec'97		0						0						0				0		
	Apr'98	211.20	1	135.00		547.46		61.00	24	43.46	15.77	1.25	1.04		0				0		
3	Dec'97	172.70	1	133.00		370.10			0						0				0		
	Apr'98	98.20	1	160.00		864.39		18.10	19	47.53	10.46	1.67	0.87		0			117.03	1	325.00	768.27
4	Dec'97	193.70	4	136.25	26.25	589.24	303.84		0						0				0		
	Apr'98	178.99	3	142.33	11.24	721.84	161.31	52.73	21	54.14	8.84	2.26	0.91		0				0		
5	Dec'97	257.7	4	139.75	14.17	723.84	344.74		0						0				0		
	Apr'98		0					59.2	21	38.48	9.47	0.96	0.72		0			112.08	1	335.00	836.50

Appendix 5

Comparative data tables for fluoride in water and sediment; metals in water and sediment; mangrove productivity; and macrobenthic faunal abundance, richness and diversity.

Table A: Fluoride (mg/L) and metals concentrations (µg/L) for water in South Trees Inlet, Boyne River Estuary, Wild Cattle Creek and Spillway Creek.

Site	Fluoride	Arsenic	Cadmium	Chromium	Copper	Nickel	Lead	Zinc	Mercury
South Trees Inlet									
1	0.80	3	0.05	<20	0.2	0.21	0.13	0.41	0.036
2	0.90	2.5	0.06	<20	0.23	0.20	0.13	0.43	0.036
3	1.00	4	0.06	<20	0.25	0.24	0.12	0.43	0.040
4	1.00	5	0.05	<20	0.21	0.24	0.2	0.42	0.033
5	0.90	7	0.05	<20	0.23	0.24	0.21	0.42	0.042
6	1.00	6.5	0.06	<20	0.25	0.22	0.2	0.45	0.033
Mean	0.90	4.7	0.055		0.23	0.225	0.165	0.43	0.037
SD	0.082	1.835	0.006		0.020	0.018	0.042	0.014	0.004
Boyne River Estuary									
7	0.90	5.5	0.05	<20	0.21	0.21	0.19	0.4	0.036
8	1.00	3.5	0.05	<20	0.26	0.23	0.15	0.39	0.043
Mean	0.95	4.5	0.05		0.235	0.22	0.17	0.395	0.0395
SD	0.071	1.414			0.035	0.014	0.028	0.007	0.005
Wild Cattle Creek									
9	0.90	3	0.05	<20	0.23	0.22	0.14	0.46	0.037
10	0.90	2	0.05	<20	0.23	0.19	0.15	0.43	0.031
11	0.90	3	0.05	<20	0.26	0.20	0.12	0.43	0.038
Mean	0.90	2.7	0.05		0.24	0.20	0.137	0.44	0.035
SD		0.58			0.02	0.015	0.015	0.017	0.004
Spillway Creek									
Site 1 Dec-97	1.1	<50	<2	<50	20*	<5	<5	<50	<0.1
Apr-98	1.6	<50	<2	<50	25*	<5	<5	50	<0.1
Site 2 Dec-97	1.1	<50	<2	<50	20*	20*	<5	<50	1.2*
Apr-98	1.5	<50	<2	<50	25*	<5	<5	<50	<0.1
Site 3 Dec-97	1.1	<50	<2	<50	20*	15	5	<50	0.2*
Apr-98	2.4	<50	<2	50	30*	<5	<5	<50	<0.1
Site 4 Dec-97	1.2	<50	<2	<50	20*	10	10*	<50	<0.1
Apr-98	3.4	<50	<2	50	30*	<5	<5	<50	<0.1
Site 5 Dec-97	1.2	<50	<2	<50	20*	5	<5	<50	IS
Apr-98	4.9	<50	<2	100*	20*	<5	<5	<50	<0.1
Mean Dec-97	1.14(0.05)				20*				
Apr-98	2.76(1.42)				26*(4.18)				
ANZECC		50	2	50	5	15	5	50	0.1

IS denotes insufficient sample *Exceeds ANZECC guidelines ( ) standard deviations

Table B: HCl extractable fluoride and metals concentrations (mg/kg) in whole sediment samples from the top 10cm in South Trees Inlet, Boyne River Estuary, Wild Cattle Creek and Spillway Creek.

Site	Fluoride	Arsenic	Cadmium	Chromium	Copper	Nickel	Lead	Zinc	Mercury
South Trees Inlet									
1	NA	6.1	<0.05	17.0	5.0	9.5	4.5	28.2	0.51
2	6	6.2	<0.05	20.5	9.0	14.2	7.5	33.4	0.51
3	9	5.9	<0.05	30.6	19.4	19.4	9.7	50.5	0.51
4	11	7.5	<0.05	30.9	22.0	20.0	11.2	53.6	0.51
5	17	8.8	<0.05	28.6	16.2	17.6	7.4	45.4	0.45
6	19	8.4	<0.05	31.6	20.1	23.3	9.0	52.4	0.46
Mean	12.4	7.2		26.5	15.3	17.3	8.2	43.9	0.49
SD	5.46	1.2		5.7	6.2	4.4	2.1	9.7	0.0
Boyne River Estuary									
7	17	4.0	<0.05	19.5	5.0	11.2	4.2	26.1	0.27
8	NA	6.0	<0.05	15.5	3.8	9.5	3.2	20.6	0.30
Mean		5.0		17.5	4.4	10.4	3.7	23.4	0.3
SD		1.4		2.8	0.8	1.2	0.7	3.9	0.0
Wild Cattle Creek									
9	12	2.8	<0.05	9.5	1.8	8.0	2.9	11.5	0.23
10	11	2.0	<0.05	13.3	2.8	10.0	3.4	16.0	0.22
11	4	1.8	<0.05	14.0	1.7	7.9	2.6	16.5	0.15
Mean	9	2.2		12.27	2.10	8.63	2.97	14.67	0.20
SD	4.36	0.53		2.42	0.61	1.18	0.40	2.75	0.04
Spillway Creek									
1	20	2.9	<0.01	6.6	3.9	3.8	3.8	13.8	0.04
2	22	5.5	0.07	7.9	5.0	4.5	5.1	16.9	0.03
3	16	4.1	0.16	7.1	4.4	4.5	4.3	15.4	0.03
4	26	5.7	0.17	7.9	6.5	4.6	6.3	19.3	<0.01
5	19	3.1	0.12	5.9	3.7	3.6	4.0	14.3	<0.01
Mean	20.6	4.3		7.1	4.7	4.2	4.7	15.9	
SD	3.71	1.34		0.86	1.10	0.47	1.00	2.22	
ANZECC		20	1.5	80	65	21	75	200	0.15

Table C: Mangrove productivity means (g/m^2/day) for all sampling periods in Port Curtis and Spillway Creek, and all sites and seasons in Missionary Bay, North Queensland.

Site	Mean	SD
Port Curtis		
C1	1.31	0.51
C2	1.34	0.64
C3	1.82	1.31
C4	1.53	0.88
C5	0.86	0.59
C6	0.95	0.47
C7	0.70	0.33
C8	1.62	1.20
G1	1.18	0.57
G2	1.85	0.47
G3	1.30	0.44
G4	1.40	0.80
B1	1.77	0.66
B2	1.61	0.61
B3	1.21	0.49
B5	1.34	0.79
B8	1.31	1.44
B9	1.33	0.67
B10	2.68	2.28
B11	1.67	0.71
B12	1.04	0.32
B13	1.43	0.75
Mean & SD	**1.42**	**0.41**
Spillway Creek		
Site 1	1.81	1.10
Site 2	2.17	0.62
Site 3	1.68	0.29
Site 4*	0.46	0.33
Site 5	1.14	0.58
Mean & SD	**1.45**	**0.32**
Missionary Bay	1.61	0.29

**Xylocarpus granatum* present

Table D: Mean abundance, species richness and Shannon-Weiner diversity for sites in Boat Creek, Port Curtis and Spillway Creek.

Site	Mean Abundance	SD	Mean species richness	SD	Mean diversity	SD
Boat Creek						
B0	30.67	10.69	12.67	0.58	2.35	0.06
B1	74.67	41.00	22.00	4.00	2.57	0.24
B2	19.33	8.39	7.33	3.06	1.59	0.53
B3	19.67	4.62	8.67	2.08	1.82	0.18
B4	19.00	7.55	11.00	3.00	2.17	0.31
B5	23.00	6.56	6.67	3.51	1.22	0.68
Mean & SD	31.06	21.81	11.39	5.67	1.95	0.50
Port Curtis						
Site 1	343	124.45	58	16.35	2.89	0.17
Site 2	211	21.21	53	16.09	3.34	0.01
Site 3	856	106.07	93.5	26.96	2.92	0.26
Site 4	621	241.83	73	25.78	2.90	0.51
Site 5	841.5	218.50	49	18.70	2.22	0.03
Site 6	262.5	183.14	43	15.06	2.93	0.07
Mean & SD	130.9	72.02	61.58	18.65	2.87	0.36
Spillway Creek						
Site 1	26	9.90	11.5	2.12	2.23	0.23
Site 2	21	11.50	10.5	3.54	2.07	0.37
Site 3	26	20.94	10.5	3.54	2.04	0.32
Site 4	162	59.45	16.5	2.12	1.26	0.21
Site 5	140	5.65	11	1.41	0.60	0.03
Mean & SD	75	70	12	2.55	1.64	0.69

APPENDIX 6

Changes to the Australian Laboratory Services limits of reporting (LOR) for various analytes between January 1998 and March 1998.

Australian Laboratory Services - Change in limits of reporting for various analytes

Analyte	Units	Limit of Reporting (LOR) Jan-98	Limit of Reporting (LOR) Mar-98
Calcium - total	mg/L	1	1
Magnesium - total	mg/L	1	1
Sodium - total	mg/L	1	1
Potassium - total	mg/L	1	1
Aluminium - filtered	mg/L	0.1	0.1
Aluminium - Total	mg/L	0.1	0.05
Arsenic - total	mg/L	0.5	0.001
Boron - total	mg/L	0.2	0.2
Barium - total	mg/L	0.1	0.001
Cadmium - total	mg/L	0.005	0.001
Cobalt - total	mg/L	0.01	0.001
Chromium - total	mg/L	0.01	0.001
Copper - total	mg/L	0.01	0.001
Iron - total	mg/L	1	0.1
Manganese - total	mg/L	0.01	0.001
Molybdenum - total	mg/L	0.01	0.001
Nickel - total	mg/L	0.01	0.001
Phosphorus - total	mg/L	1	1
Lead - total	mg/L	0.01	0.001
Sulphur - total	mg/L	1	1
Silicon - total	mg/L	0.1	0.1
Strontium - total	mg/L	0.01	0.001
Vanadium - total	mg/L	0.01	0.005
Zinc - total	mg/L	0.01	0.001