AMBIENT WATER QUALITY of the Port River Estuary

1995-2000

South Australia

WATER

Government
of South Australia

Water monitoring report

Ambient water quality
of the
Port River estuary

September 1995–August 2000

Ambient Water Quality Monitoring:
Port River Estuary, September 1995–August 2000

Author: Sam Wade

For further information please contact:
Information Officer
Environment Protection Agency
Department for Environment and Heritage
GPO Box 2607
Adelaide SA 5001

Telephone:	(08) 8204 2004
Facsimile:	(08) 8204 9393
Free call (country):	1800 623 445

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SUMMARY

This report summarises the water quality of the Port River estuary between September 1995 and August 2000. In an on-going monitoring program water samples are collected monthly from nine sites in the Port River, Barker Inlet, the inner harbour and Outer Harbor. These are analysed for a range of physical, chemical and biological parameters including salinity, turbidity, metals, nutrients, algae and bacteria.

This is the second report the Environment Protection Authority has published on the ambient water quality of the Port River. The first report summarised data from September 1995 to December 1996 (EPA, 1997a).

The report sets criteria for each water quality parameter, allowing us to describe water quality as good, moderate or poor. As reported in 1997, the water quality status of the Port River is mainly poor to moderate. Key conclusions from this report are as follows:

- Compared to the 1995–96 report, turbidity, copper and total phosphorus have improved; iron, zinc and faecal coliforms have not changed; and TKN, chlorophyll *a*, faecal streptococci and enterococci are worse. Comparisons cannot be made for aluminium, cadmium, lead, mercury and ammonia because analytical methodology has changed, and oxidised nitrogen and *Escherichia coli* were not discussed in the previous report.
- On-going environment improvement programs by industry and the continuing development of wetlands to treat stormwater should further improve turbidity over time.
- Aluminium, cadmium, iron, lead and mercury are classified as good at all sites.
- Copper is moderate at five sites and poor at four. Given the toxic nature of copper this is a concern but recent trends suggest copper concentrations are decreasing.
- Zinc is moderate at all sites.
- Ammonia is poor at seven sites and moderate at two. The high ammonia concentrations, high pH and high temperature of the Penrice outfall are concerns. This combination of factors indicates that ammonia concentrations may be high enough to be toxic near the Penrice outfall.
- The high ammonia and oxidised nitrogen concentrations are a significant issue for algae in the Port River, as these forms of nitrogen are highly bioavailable. It is likely that these nitrogen concentrations are promoting greater algal growth, and therefore higher chlorophyll concentrations in the Port River. However, environment improvement programs by industry and on-going development of wetlands to treat stormwater are expected to lead to improvements in the nutrient status of the Port River.
- Chlorophyll *a*, an indicator of algae, is poor or moderate at all sites, not surprising given the high nutrient loading to the Port River.
- Microbiological ratings are poor at six sites and moderate at three because of faecal streptococci and enterococci. The results suggest occasional events that reduce microbiological quality for short periods, rather than a consistently high concentration of bacteria.

A number of positive developments should contribute to improved water quality in the Port River over time:

- environment improvement programs by industry, reducing nutrient concentrations and turbidity
- the Environment Protection (Water Quality) Policy, promoting reductions in diffuse source pollution

- on-going development of wetlands to treat stormwater, reducing the amount of nutrients, metals, bacteria and suspended solids entering the Port River.

Reductions in nutrient concentrations should be followed by a decrease in algal growth.

Expectations of improvements in the water quality of the Port River should be tempered by an understanding that we have been polluting the Port River for many years. Even if we could prevent all pollution from entering the Port River, water quality may take years to recover; some parameters may improve rapidly in response to environmental improvements but in most cases we should expect to see gradual improvement rather than sudden changes.

This report will be updated every five years.

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The Port Adelaide wastewater treatment plant discharges treated effluent into the southern end of the Port River, by the West Lakes tidal outlet gate.

A trash rack and a newly designed wetland system are designed to improve the quality of stormwater before it is discharged into the Port River.

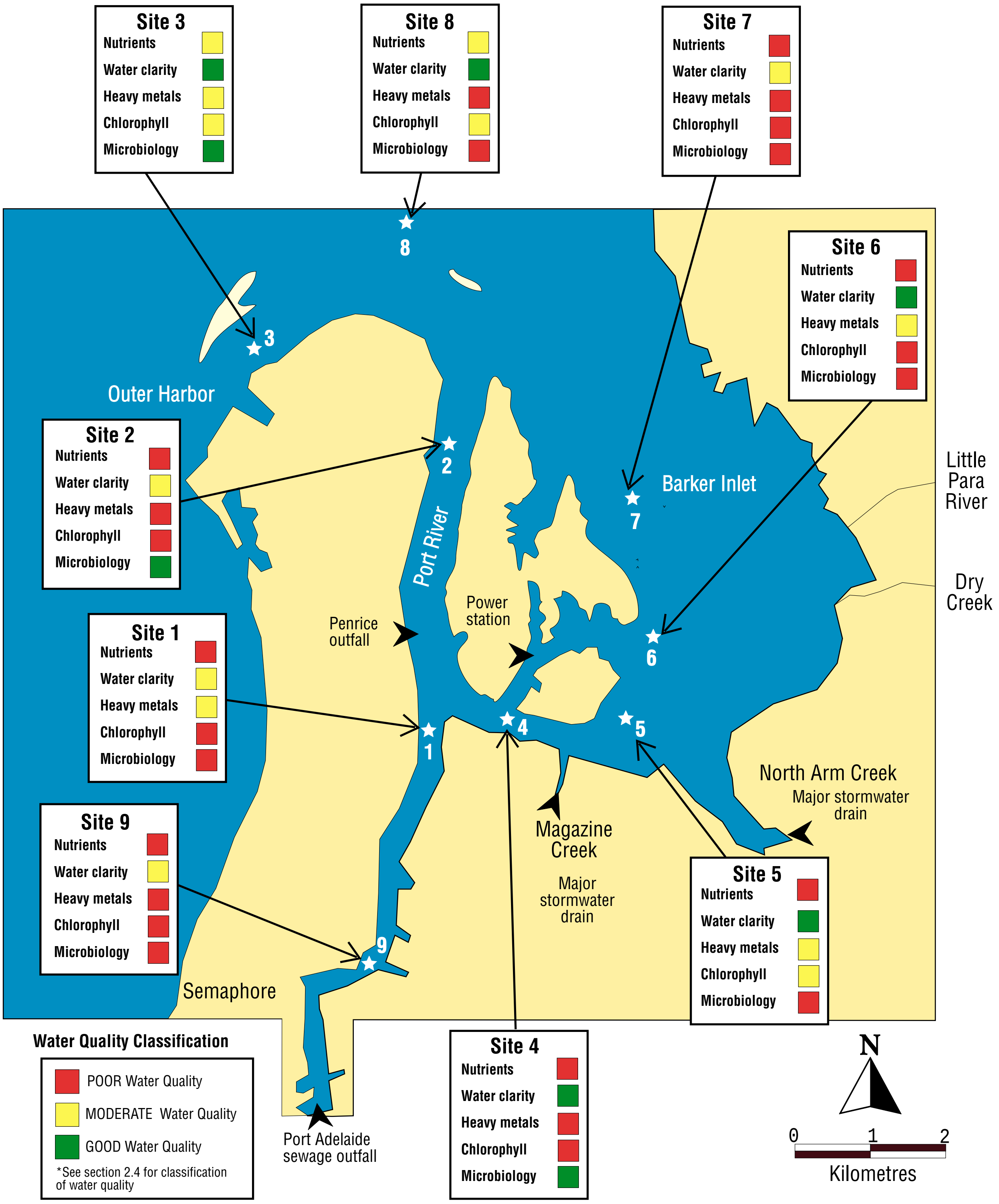

Figure 1 Port River ambient water quality monitoring sites and water quality classification from September 1995 to August 2000

1 INTRODUCTION

In September 1995 the Environment Protection Authority began an on-going ambient water quality monitoring program designed to provide a long-term assessment of water quality in the Port River estuary. Water samples are collected monthly from nine sites (Figure 1[1]) and analysed for a range of physical, chemical and biological parameters including salinity, turbidity, metals, nutrients, algae and bacteria. In total, results from 21 water quality parameters are reported here. The selection of parameters was based on the major environmental issues and threats in the Port River area.

The nine sites are spread around the estuary, so spatial patterns in water quality can be examined. Monthly sampling allows us to examine seasonal patterns, annual variability and long-term trends. An initial report by the Environment Protection Authority, released in November 1997 (EPA, 1997a), covered the results from September 1995 to December 1996. This report summarises the first five years of the survey, from September 1995 until August 2000.

1.1 The Port River estuary

The Port River estuary consists of West Lakes, the Port River, North Arm, Outer Harbor, and the Angas and Barker inlets. The physical habitat of the estuary ranges from deep channels that are dredged to allow shipping movements through to extensive shallow mud flats and sandy areas. Many of the shallow areas are intertidal and tidal currents can be quite strong in the channels. Biologically the estuary is very rich; it supports extensive mangrove and seagrass beds and is an important feeding and nursery ground for fish, crustaceans, molluscs and migratory birds. Three nature reserves overlap parts of the estuary: the Torrens Island Conservation Park, the St Kilda–Chapman Creek aquatic reserve, and the Barker Inlet–St Kilda aquatic reserve.

The water quality status of the Port River should be examined within the context of historical changes to the estuary. The development and urbanisation of Adelaide have changed the volume and timing of fresh and marine water inputs into the Port River. Before Breakout Creek was constructed in the early 1900s, fresh water from the Torrens River flowed north through swampy areas behind the coastal sand dunes and entered the Port River. Holmes and Iversen (1976) estimated that in a typical year this flow would probably have continued from May to November. Since the Breakout Creek construction diverted the Torrens River, less fresh water has entered the Port River.

Subsequent urbanisation has increased the area of impervious surfaces, such as paved roads and roofing, in the catchment area of the Port River. This has reduced the volume of water that infiltrates into the ground and has probably increased the total discharge of water to the Port River. Although more water may be now entering the Port River, that stormwater quality is poorer and the duration of flows is shorter. The flow-through system constructed in the 1970s, which draws seawater into West Lakes and discharges it through the Port River, has probably changed the flow and salinity environment of the Port River. The average flow of water from West Lakes to the Port River is about 500 ML a day. The exact impact of these hydrological changes is unclear but it is certain that they have lowered the quality of water entering the Port River. It is also likely that the seasonal variability in the salinity of some parts of the Port River is different today from that before the development of Adelaide.

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[1] Note that in Figure 1 the colour coded water quality classifications of each site were determined on the basis of the worst performing water quality parameter in each group. For example, of the seven metals classified at site 9 five received good rankings, zinc was moderate and copper was poor. The poor ranking of metals at site 9 was therefore based on the copper rating only. For a summary of each parameter within a group see the summary tables at the end of the metals (Table 16), nutrient (Table 21) and microbiology (Table 27) chapters. Water clarity and chlorophyll *a* ratings are based on a single parameter each.

Physical changes to the structure of the Port River may also influence water quality. Dredging has changed the river's channel structure, and removal of vegetation such as mangroves and seagrass in the upper reaches of the river may have changed the stability of the sediments. Both will influence factors such as nutrient uptake and turbidity.

The numerous uses of the estuary include recreational activities such as boating, fishing and swimming. Industrial uses are many and include the loading and unloading of ships with manufactured goods, agricultural produce, livestock, petrochemicals, fertilisers and other chemicals, and slipway maintenance and construction of ships. Recreational, fishing and Navy vessels are moored there, and the movement of international ships within the port means the estuary is at risk of invasion by exotic marine organisms.

There are a number of significant industrial effluent discharges into the Port River. The Torrens Island, Osborne and Pelican Point power stations use estuary water for cooling purposes, which in turn adds thermal pollution to the estuary. Sources of major chemical discharges to water include the SA Water wastewater treatment plants at Bolivar and Port Adelaide, along with wastewater from the Penrice Soda Products plant at Osborne.

There are a number of landfill sites close to the Port River estuary, including the Garden Island landfill and the Adelaide City Council site at Wingfield. Landfills can leach pollutants into groundwater, which may then enter the marine environment through groundwater flow.

The highly urbanised catchment feeding stormwater to the Port River contains many industries. Much of this industry discharges pollutants to the air that can be deposited to the ground during rainfall or by dry deposition. Road runoff is a major source of pollutants including lead, copper, zinc and oil. Leaf litter, other organic debris, litter, and rubber from motor vehicles are also deposited in catchments, especially along roads; these pollutants can then be washed into the Port River estuary. On-going development of artificial wetlands on the creeks and drains that discharge into the Port River should improve the quality of stormwater entering it over time.

The Port River estuary is an important natural asset to the State of South Australia. It is a highly productive and biologically diverse aquatic ecosystem. Not only should it be protected for its intrinsic ecological value, it also has economic value as a nursery for commercial and recreational fish species such as King George whiting. Other human uses of the estuary, such as recreation, transport and industry, bring economic benefit to the State but may also threaten the health of the estuary. The environmental values for the estuary are therefore protection of water quality:

- to support the aquatic ecosystem
- for recreational and aesthetic uses
- for industrial uses of the water.

1.2 Aims of this ambient water quality monitoring program

Ambient water quality is a representative measure of the overall water quality of a waterbody. It indicates the quality of water when all the effects that may influence a waterbody are considered as a whole rather than focusing on the effects of particular discharges. The results in this report are indicative of water quality in the Port River estuary from September 1995 to August 2000.

In this monitoring program we aimed to:

- determine the water quality of the Port River estuary
- categorise water quality as good, moderate or poor, using a classification system based on the national guidelines for the protection of aquatic ecosystems by the Australian and New Zealand Environment and Conservation Council (ANZECC, 1992) and, for the recreational use of water, by the National Health and Medical Research Council (NHMRC, 1990)
- examine spatial differences in water quality within the estuary and discuss what factors might

cause variability between sites

- provide data to assess any changes in water quality over time to ensure that the development of the Port River estuary is ecologically sustainable in the long term.

2 SURVEY METHODOLOGY AND DATA ANALYSIS

2.1 What is monitored?

The parameters monitored in the program can be classified as physical, chemical or biological. The choice of water quality parameters was based on those required to support the designated environmental values listed in Section 1.1. Guidelines for these water quality parameters are contained in the *Australian guidelines for fresh and marine waters* (ANZECC, 1992) and the *Australian guidelines for the recreational use of water* (NHMRC, 1990).

Physical parameters measured include turbidity, conductivity (salinity) and temperature. Chemical parameters can be divided into metals (soluble and total aluminium, total cadmium, total copper, total iron, total lead, total mercury, soluble and total zinc) and nutrients (ammonia, oxidised nitrogen, total Kjeldahl nitrogen (TKN) and total phosphorus). Biological parameters include an estimate of algal biomass (chlorophyll *a*) and microbiological parameters (faecal coliforms, *Escherichia coli*, faecal streptococci and enterococci).

2.2 Survey design

In this monitoring program, we assess the continuing water quality of the Port River estuary by taking occasional, small and representative samples. We cannot sample, and therefore know, the water quality of all points in the Port River estuary at all times. The samples we collect are only a small subset of all possible samples that could be taken, and we use this set of samples to estimate the water quality of the river as a whole. Clearly, this process involves a degree of uncertainty as environmental measurements often show much variability. To interpret data of this nature effectively we must use a number of simple statistical techniques.

Water samples are collected from a boat using a Van Dorn sampler. The water in estuaries is often poorly mixed and is vertically layered because of temperature and salinity differences. Consequently, water quality in estuaries often varies at different depths. To overcome this problem we collect three sub-samples at each location, one each from the surface, bottom and mid point of the water column, and combine them to give a sample representative of the whole water column. Temperature is measured at the surface only. Water samples are collected and analysed at a NATA (National Association of Testing Authorities) registered laboratory

2.3 Statistical methods

Descriptive statistics

Water quality measurements from most natural environments are highly variable, so descriptive statistics are used to summarise the data. Detailed descriptions of the statistics we have used are beyond the scope of this report; for further explanation and examples of calculations see the statistical text *Biometry* (Sokal & Rohlf, 1995).

Mean (or average)

The mean, often called the average, is the most common measure of central tendency. The sample mean is a good estimate of central tendency when the distribution of a sample is symmetrical, but if the distribution is skewed the mean should be used with caution. Most of the samples in this study are strongly skewed to the right, with some very large measurements substantially increasing the mean.

95% confidence interval of the mean

The 95% confidence interval of the mean (95% CIM) allows us to determine the certainty of the sample estimate of the population mean. For example, the 95% CIM for turbidity at site 1 is 2.1–8.5 nephelometric turbidity units (NTU) and the sample mean is 5.3 NTU. It would be tempting to assume that the population mean is 5.3 but, in reality, there is only a 95% chance that the population mean falls between 2.1 and 8.5.

Standard deviation

The standard deviation is a measurement of the dispersion or variability of all the measurements in a sample. Generally speaking, it is the average distance of sample points from the sample mean.

Median

Another common estimate of central tendency is the median or 50th percentile. The median is the middle point of a distribution and an equal number of measurements fall below and above it. The median is a more robust estimate of central tendency than the mean as it is not influenced so strongly by skewed distributions or outliers.

90th and 10th percentiles

The 90th and 10th percentiles are used instead of a maximum and minimum to indicate the range of a sample; 80% of all points in a distribution fall between the two.

Geometric mean and the 95% confidence interval for the geometric mean

Microbiological data sets are often highly skewed, with a few high readings combined with many lower values. In distributions such as this, the mean and median are substantially different. To overcome this problem, geometric means have traditionally been used when assessing microbiological data as they are more robust estimates of central tendency for skewed data sets.

Unlike the normal 95% CIM, the 95% confidence interval for the geometric mean (95% CIGM) is not symmetrical around the mean, providing a better estimate of the 95% confidence interval of distributions that are skewed. See Sokal and Rohlf (1995) for information on calculating the geometric mean and confidence intervals for the geometric mean.

Differences between sites

Descriptive statistics allow us to summarise the data from each site; inferential statistics allow us to determine differences between sites. The inferential statistical methods used here allow us to determine if there are statistically significant differences between sites at the p=0.05 level.

The parametric tests of analysis of variance, together with a pairwise comparison such as a Tukey's test, are traditionally used to determine differences between samples. However, our data sets are not normally distributed and do not meet many of the assumptions of parametric tests, therefore non-parametric alternatives were used.

Friedman's test was used to determine whether there were any differences between sites for each parameter. If this test showed that there were statistically significant differences between sites at the p=0.05 level, then a Wilcoxon signed ranks test was used to discover exactly which sites were different from each other[2]. These results are contained in the 'statistical site comparisons' column of the data table for each characteristic.

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[2] When making multiple pairwise comparisons the chances of committing a type 1 error (concluding that two samples are different when they are really the same) are increased substantially. The Dunn-Sidak method was used to correct the critical α for pairwise comparisons to maintain an experimentwise type 1 error rate of 0.05 for each characteristic tested. Practically, this means for each group of site comparisons for each character there is a probability of only 1 in 20 that any difference in means has arisen by chance.

2.4 Water quality classification

It is useful to broadly classify the water quality at each site as good, moderate or poor, but there are no formal national standards for such classifications. The following criteria have been developed based on the percentage of time that water quality conditions exceed Australian water quality guidelines for the protection of aquatic ecosystems (ANZECC, 1992), and Australian guidelines for the recreational use of water (NHMRC, 1990). These classifications are somewhat arbitrary but they do provide a useful and relatively simple means of broadly classifying water quality.

Metals

The criteria for metals have been based on two factors: the position of the median and 90th percentile relative to the Australian water quality guidelines for the protection of aquatic ecosystems (ANZECC, 1992); and any single exceedence likely to cause toxic effects.

GOOD:	90th percentile is less than or equal to the ANZECC guideline (water quality less than the ANZECC guideline most of the time)
MODERATE:	90th percentile is above the ANZECC guideline but median is below the ANZECC guideline
POOR:	The median is greater than or equal to the ANZECC guideline OR any single measurement is more than 10 times the ANZECC guideline (water quality exceeds the ANZECC guideline more than 50% of the time or a single measurement is at the concentration when acute toxic effects may be observed in some organisms)

Microbiology

The criteria for microbiology are based on the position of the median and 90th percentile relative to the Australian guidelines for the recreational use of water (NHMRC, 1990).

GOOD:	90th percentile is less than or equal to the NHMRC primary contact guidelines (water quality is good provided the NHMRC primary contact guidelines are not exceeded or are only exceeded on the odd occasion)
MODERATE:	90th percentile is greater than the NHMRC primary contact guideline but the median is less than the guideline
POOR:	The median is greater than the NHMRC primary contact guideline OR a specific number of measurements exceed an upper limit (water quality is poor if numbers of microbiological indicator organisms exceed NHMRC guidelines more than 50% of the time or a designated number of samples exceed the upper limits listed in Table 1)

Table 1 Microbiological guidelines for primary contact

	Primary contact guideline	Upper limit	Conditions of upper limit
Faecal coliforms	150 organisms/100 mL	600 organisms/100 mL	4/5 samples must contain less than 600 organisms/100 mL
Escherichia coli	150 organisms/100 mL	600 organisms/100 mL	4/5 samples must contain less than 600 organisms/100 mL
Enterococci	33 organisms/100 mL	60 organisms/100 mL	60 is maximum allowed in any one sample
Faecal streptococci	no guideline	no guideline	no guideline

Nutrients, turbidity and chlorophyll *a*

There are no specific ANZECC guidelines for nutrients, turbidity or chlorophyll *a* in estuaries, only indicative range concentrations for estuaries and coastal waters. Table 2 describes a classification system for nutrients, turbidity and chlorophyll *a* in the Port River estuary based on range criteria for marine and estuarine waters (ANZECC 1992), and on background concentrations observed at Port Hughes, South Australia and in the Southern Metropolitan Coastal Waters Study conducted by the Western Australian Department of Environment Protection (DEP, 1996). Classification is determined by the relative position of the 90th percentile to the upper and lower guidelines.

Table 2 Guidelines for comparison of the 90th percentile to classify water quality for nutrients, turbidity and chlorophyll.

	TKN–N (mg/L)	**Oxidised nitrogen** (mg/L)	**Total phosphorus** (mg/L)	**Ammonia (as N)** (mg/L)	**Turbidity** (NTU)	**Chlorophyll *a*** (µg/L)
Good	<1.0	<0.1	<0.1	<0.05	<5	<1
Moderate	1.0–10.0	0.1–1.0	0.1–1.0	0.05–0.5	5–25	1–10
Poor	>10.0	>1.0	>1.0	>0.5	>25	>10

2.5 Sites

Descriptions of the nine sites in this program are summarised in Table 3. Eastings and northings are provided in GDA 94 datum and we have used medians to summarise depths. There was some variability in depths within sites, mainly due to tidal movements. Site 9 was added to the program in July 1996, 10 months after monitoring began. This will have negligible impact on guideline classification for this report, but the few data for site 9 in the first report may have not given an accurate classification of water quality. Changes in the water quality classification of this site between the two reports may not reflect true changes in water quality.

Table 3 Descriptions, median depths and locations of the nine Port River sampling sites

Site	**Description**	**Median depth** (metres)	**Location** (GDA 94 datum)
1	Hindmarsh Reach, adjacent Snowdens Beach	10.5	272612–6145423
2	Lipson Reach adjacent quarantine station	0.8	272707–6148989
3	Outer Harbor	13.7	269915–6149863
4	North Arm adjacent causeway bridge	5.1	273589–6145067
5	North Arm adjacent Magazine Creek	1.8	275021–6145217
6	Torrens Reach adjacent mouth of Angas Inlet	3.1	275689–6146193
7	Torrens Reach	2.4	275207–6147926
8	Barker Inlet north of Section Bank	1.1	271598–6152175
9	Inner harbour	10.6	271729–6141704

3 WATER QUALITY PARAMETERS

3.1 Physical parameters

Turbidity

Generally speaking, turbidity is a measure of the transmission of light through water. Specifically, it relates to the amount of scattering of light by particulate and dissolved material in water. Particulate matter such as clay, silt, organic matter and living organisms can all scatter light, as can large dissolved molecules. Turbidity is measured in nephelometric turbidity units (NTU) and is approximately related to visibility as follows:

Turbidity	Depth (m)
2 NTU	10
5 NTU	4
10 NTU	2
25 NTU	0.9
100 NTU	0.2

While turbidity generally increases when the amount of suspended solids in water increases, the correlation between turbidity and suspended matter is often poor because the size, shape and composition of different particles influence the amount of light they scatter. Dissolved substances, which are not part of the suspended solid load, can also affect turbidity

Sources

Stormwater runoff contains particulate and dissolved matter from soil erosion, decaying organic matter and other pollutants, such as rubber particles from tyre wear. Industry can also discharge particulate matter. For example, in 1999 Penrice Soda Products discharged about 70 ML of wastewater per day with more than 3700 mg/L of suspended solids—mainly calcium carbonate, with some lime and small amounts of other contaminants. This equates to about 259 tonnes a day of suspended solids, enough to increase turbidity substantially. The new wastewater treatment procedures Penrice implemented in April 2001 should reduce the load of suspended solids as well as turbidity in the Port River.

Discharges from wastewater treatment plants can increase turbidity directly by increasing suspended loads. In 1999–2000, the Port Adelaide wastewater treatment plant discharged 297 tonnes of suspended solids. Turbidity can also be increased indirectly—nutrients from wastewater treatment plants and other sources can increase the abundance of planktonic algae and zooplankton, which are small plants and animals that live suspended in the water column.

Dredging and storms can resuspend sediments that have been deposited in the estuary, causing increases in turbidity. Dredging has been carried out to remove solids discharged by Penrice and to maintain channels for shipping.

Impacts

Turbidity is a measure of light penetration that is related to the amount of suspended sediment in waters and therefore has two areas of impact: reduced light penetration, and suspended particles.

Plants and algae require light to carry out photosynthesis, and turbidity reduces the distance light penetrates into water. A reduction in light penetration can limit the depth at which plants can grow, restricting them to shallower areas than they may otherwise occupy. This in turn can reduce the amount of habitat and food for fish and other marine organisms. Loss of plants such as seagrass will reduce the stability of sediments and lead to erosion, which can increase turbidity further.

Suspended particles can affect the environment in a number of ways. The deposition of fine particles can change the makeup of sediments, increasing the proportion of fine particles and clogging interstitial spaces. These fine particles can smother organisms that live on the bottom, such as anemones and corals. Filter-feeding organisms are particularly vulnerable to increases in the amount of suspended inorganic material, and turbidity will disadvantage animals that search or hunt for food by sight. Poor water clarity can also affect the recreational values of the waterbody by making swimming unsafe and degrading its aesthetic value.

Results

Four sites (1, 2, 7 and 9) had moderate turbidity, while five sites were classified as good (Table 4). Of the 472 measurements taken, only three exceeded the poor guideline, and 47 (10%) fell into the moderate category, leaving a substantial 89% in the good category. At all four sites where the 5 NTU guideline was exceeded, the 90th percentile was still at the low end of the moderate scale, and all median values except site 2 were less than half the 5 NTU guideline (Figure 2). When compared to the 1995–96 results, sites 4, 6 and 8 improved from moderate to good but site 9 declined from good to moderate.

Conclusions

Overall, these results suggest that the turbidity values in the Port River have slightly improved or, at worst, remained static since 1995–96. There are a number of possible causes of the variation in turbidity between sites. Sites 1 and 2 bracket the Penrice discharge and site 9 is the closest site to the Port Adelaide wastewater treatment plant outfall. Site 7 is close to the mouth of Dry Creek and the Little Para River, possible sources of highly turbid water. On-going environment improvement programs by Penrice and SA Water, along with extensive wetland development for the treatment of stormwater, should improve turbidity readings in the Port River in the long term.

Table 4 Statistical summary of turbidity at nine sites in the Port River estuary 1995–2000

	Mean (NTU)	**95% confidence interval** (NTU)	**Standard deviation** (NTU)	**Median** (NTU)	**10th percentile** (NTU)	**90th percentile** (NTU)	**Number of samples**	**Water quality classification** (a)	**Statistical site comparisons** (b)
Site 1	5.3	2.1—8.5	11.6	2.4	1.0	9.8	54	moderate	Site 1>3,5
Site 2	3.6	2.8—4.5	3.2	2.9	0.9	6.9	53	moderate	Site 2>3,4,5,8
Site 3	1.8	1.5—2.2	1.4	1.5	0.6	3.5	52	good	n.s.
Site 4	2.1	1.7—2.5	1.5	1.6	0.9	3.6	53	good	n.s.
Site 5	1.9	1.5—2.3	1.6	1.3	0.6	3.6	54	good	n.s.
Site 6	2.5	1.7—3.2	2.7	1.8	0.7	4.5	54	good	n.s.
Site 7	3.3	2.1—4.6	4.6	2.1	0.9	6.9	53	moderate	Site 7>5
Site 8	1.8	1.4—2.2	1.4	1.4	0.5	3.5	53	good	n.s.
Site 9	3.2	2.3—4.1	3.0	2.0	1.1	7.9	46	moderate	Site 9>3,5

(a) Water quality classification is based on 90th percentile as follows-good: <5 NTU; moderate: 5–25 NTU; poor: >25 NTU

(b) Friedman probability: P <0.001-statistically significant differences between sites. For pairwise site comparisons n.s. signifies the site is not significantly greater than any other site. The > symbol indicates which sites the specified location is significantly greater than.

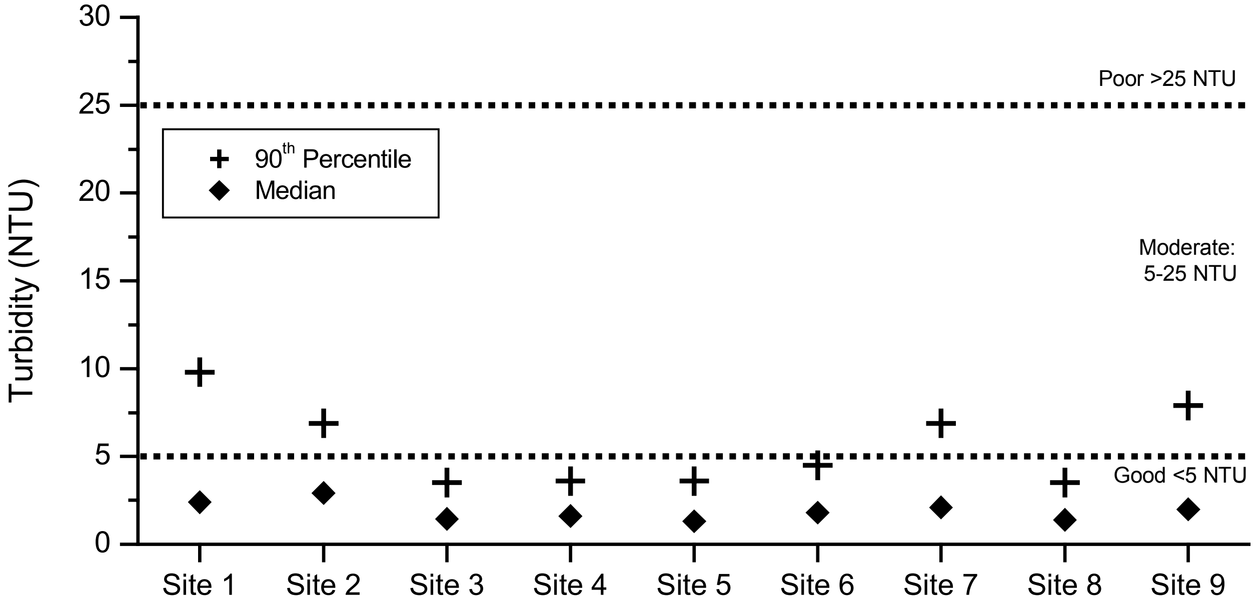


Figure 2 Median and 90th percentile turbidity at nine sites in the Port River estuary 1995–2000

Conductivity (salinity)

Electrical conductivity it is a reliable way to estimate salinity in estuaries and marine waters. Salinity is the concentration of all dissolved salts, predominantly sodium chloride in marine systems. Electrical conductivity is expressed in micro-Siemens per cm (µS/cm); one µS is equivalent to one electrical conductivity (EC) unit. The exact relationship between salinity and electrical conductivity varies with temperature; our conductivity results are standardised to 25°C.

Sources

The Port River is a marine-dominated estuarine system that is naturally saline, but salinity in estuaries does vary. Low salinity is caused by freshwater inputs from land, and tidal movements introduce seawater with salinity levels around 35 g/L. Salinity levels higher than this may occur naturally with evaporation in sheltered areas with little tidal exchange. Human activity can alter salinity—some industries, such as salt fields, are potential sources of brine solutions, and freshwater inputs can come from industries and drainage systems.

Historically, three factors may have altered the salinity regime of the Port River:

- the construction of Breakout Creek, channelling River Torrens water directly to the sea
- the urbanisation of Adelaide, changing the volume and timing of freshwater runoff entering the river each year
- the flow-through system that draws seawater into West Lakes and discharges it through the Port River (see Section 1.1).

Impacts

According to the ANZECC guidelines (ANZECC, 1992), changes in salinity in coastal and estuarine systems should not exceed 5% of natural background levels. However, as salinity varies naturally in estuaries it is difficult to determine what background levels are. Many organisms are adapted to particular salinity ranges, and both increases and decreases can have adverse impacts. Changes in salinity result in changes in osmotic potential, which can be detrimental to animals and plants. Salinity can also affect organisms indirectly—any increase in salinity decreases the solubility of oxygen in water, and lower oxygen concentrations will stress many aquatic organisms. However, it is fair to assume that many organisms living in an estuarine environment would have evolved a degree of tolerance to variable salinity.

Results

Our monitoring results showed a small amount of variability in conductivity between sites (Figure 3), and the estimated median salinity ranged from 37.3 g/L at site 1 to 38.1 g/L at site 7. While there were statistically significant differences between sites (Table 5), these differences were small and were probably not environmentally important.

Salinity levels at individual sites varied substantially over time, as shown in the conductivity time series plots in Appendix 1 (Figure 24). In the most striking reading, in July 1996, a conductivity of 970 µS/cm (0.66 g/L) was recorded at site 6. During 1996 in Adelaide, over 100 mm of rainfall fell each month during June, July and August; presumably, the influx of freshwater from Dry Creek, Little Para River and stormwater drains, combined with a low tide at the time of sampling, caused this low reading. Less dramatic drops in salinity were recorded at a number of other sites.

Conclusions

Overall, the data does not suggest any major problems with salinity changes in the Port River.

Table 5 Statistical summary of conductivity at nine sites in the Port River estuary 1995–2000

	Mean (µS)	**95% confidence interval** (µS)	**Standard deviation** (µS)	**Median** (µS)	**10th percentile** (µS)	**90th percentile** (µS)	**Number of samples**	**Water quality classification** (a)	**Statistical site comparisons** (b)
Site 1	55,258	54,057–56,460	4,358	54,800	51,720	61,640	53	n.a.	n.s.
Site 2	55,244	53,634–56,855	5,900	55,400	52,190	61,520	54	n.a.	n.s.
Site 3	55,080	53,494–56,666	5,810	55,300	51,510	60,570	54	n.a.	n.s.
Site 4	55,970	54,809–57,132	4,255	55,650	52,090	62,060	54	n.a.	Site 4>1
Site 5	56,320	55,127–57,514	4,372	55,700	51,890	62,740	54	n.a.	Site 5>1,2,9
Site 6	54,692	52,064–57,320	9,629	55,950	51,720	63,660	54	n.a.	Site 6>9
Site 7	56,456	54,922–57,989	5,618	56,000	52,600	63,670	54	n.a.	Site 7>1,2,3,6,9
Site 8	56,023	54,838–57,207	4,298	55,300	52,120	62,300	53	n.a.	n.s.
Site 9	54,907	53,705–56,109	4,001	54,900	50,540	60,400	45	n.a.	n.s.

(a) No water quality classification for conductivity in marine or estuarine waters

(b) Friedman probability: P <0.001-statistically significant differences between sites. For pairwise site comparisons n.s. signifies the site is not significantly greater than any other site. The > symbol indicates which sites the specified location is significantly greater than.

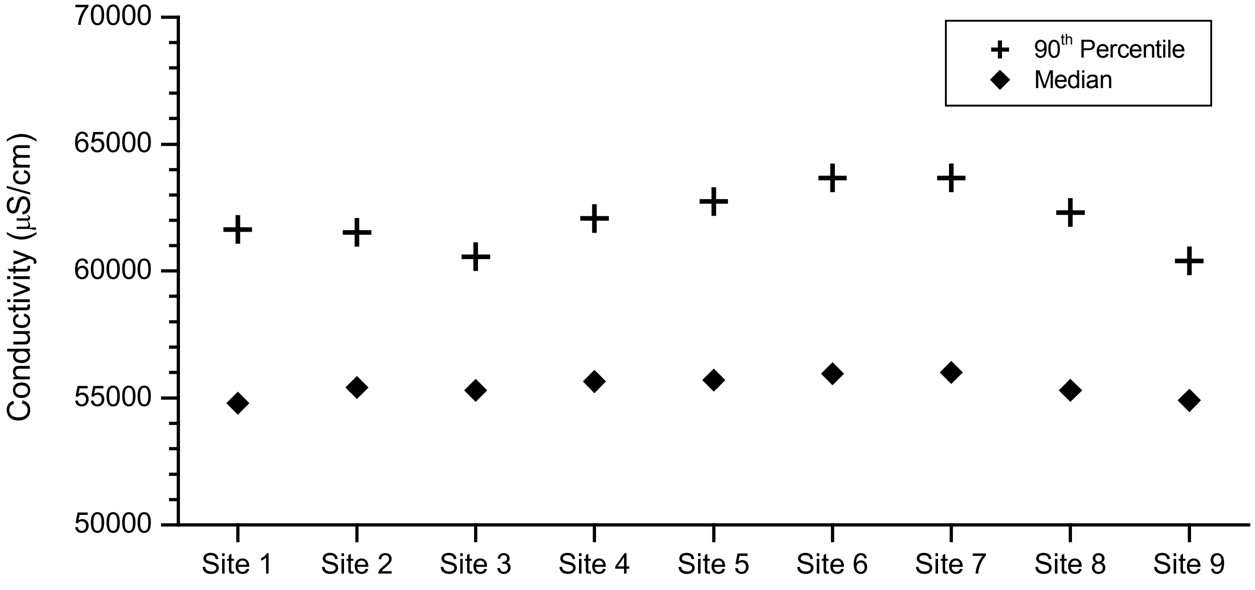


Figure 3 Median and 90th percentile conductivity at nine sites in the Port River estuary 1995–2000

Temperature

Sources

In aquatic systems, temperature varies seasonally, from day to night, and at different depths in the water column. Human activity should not increase temperature by more than 2°C over natural background levels (ANZECC, 1992). Thermal pollution from industry can alter temperature patterns in estuaries, and there are a number of thermal outfalls in the Port River.

Three power stations take cooling water from the Port River; this water is heated and then discharged back to the estuary. The Torrens Island power station run by TXU has two cooling water outlets. In the year 2000–01, 'A' section discharged 157,000 ML of water with a median temperature increase of 1.5°C and a maximum increase of 3.8°C between inlet and outlet temperatures, while 'B' section discharged 503,000 ML of water with a median temperature increase of 5.0°C and a maximum increase of 8.0°C.

Between November 1999 and October 2000 the Osborne Co-generation power station discharged approximately 12,400 ML of water. The use of cooling towers and dilution kept the median temperature increase above background to less than 1°C. National Power's Pelican Point power station has only recently been commissioned so the thermal discharge from this source is not considered in this report.

Manufacturing industries also release thermal pollution. From January to December 2000 Penrice Soda Products at Osborne discharged approximately 70 ML of wastewater a day. Weekly average temperature of this discharge ranged from 36.6°C in June to 47.4°C in February. In comparison, median monthly temperatures at site 2 range from 12°C in July to 25.5°C in February.

Impacts

Increased temperature can have a range of impacts. The speed of many chemical reactions and biological processes varies with temperature. Growth rates and development times of organisms can be changed by increases in temperature, and increased rates of primary production can lead to nuisance algal growth or even algal blooms. The restricted temperature tolerances of some organisms can be due to the reduced solubility of oxygen in water as temperatures increase. Areas of higher temperature can increase the chance and success of colonisation by exotic aquatic organisms from warmer climates. Finally, prolonged exposure to temperatures above 35°C can lead to hyperthermia, rendering some areas affected by thermal discharges unsafe for swimming.

Results

Median seasonal patterns in temperature for all sites combined reached a low of 12°C in July and a peak of 25.5°C in February (Figure 4). July was consistently the coldest month, and February the warmest at all sites. Median temperatures varied across the sites by 2°C, and site 5 at North Arm, Magazine Creek, was significantly warmer than site 3 at Outer Harbor (Table 6, Figure 5), which was the deepest sampling point and the nearest to open water.

Conclusions

Our sampling program has not detected any changes in temperature due to thermal discharges but this does not mean there were not thermal impacts. The combination of the discharges detailed above place a substantial thermal load on the Port River estuary, but buffering by the large volume of water in the Port River appears to keep the impacts of thermal discharges localised.

Table 6 Statistical summary of temperature at nine sites in the Port River estuary 1997–2000

	Mean (°C)	95% confidence interval (°C)	Standard deviation (°C)	Median (°C)	10th percentile (°C)	90th percentile (°C)	Number of samples	Water quality classification (a)	Statistical site comparisons (b)
Site 1	18.5	16.6–20.4	4.6	17.0	12.8	24.0	25	n.a.	n.s.
Site 2	18.1	16.2–20.0	4.6	17.0	12.4	24.0	25	n.a.	n.s.
Site 3	18.0	16.1–19.9	4.4	17.0	13.0	24.0	24	n.a.	n.s.
Site 4	19.3	17.4–21.2	4.5	18.5	14.0	24.7	24	n.a.	n.s.
Site 5	19.1	17.2–21.1	4.7	19.0	12.8	25.2	25	n.a.	Site 5>3
Site 6	18.5	16.6–20.4	4.6	18.0	12.8	24.0	25	n.a.	n.s.
Site 7	18.7	16.7–20.7	4.6	18.0	13.2	24.0	23	n.a.	n.s.
Site 8	18.0	16.0–19.9	4.7	17.0	12.0	24.0	25	n.a.	n.s.
Site 9	18.2	16.3–20.1	4.5	17.0	12.8	24.0	25	n.a.	n.s.

(a) No water quality classification for temperature in marine or estuarine waters

(b) Friedman probability: P =0.001-statistically significant differences between sites. For pairwise site comparisons n.s. signifies the site is not significantly greater than any other site. The > symbol indicates which sites the specified location is significantly greater than

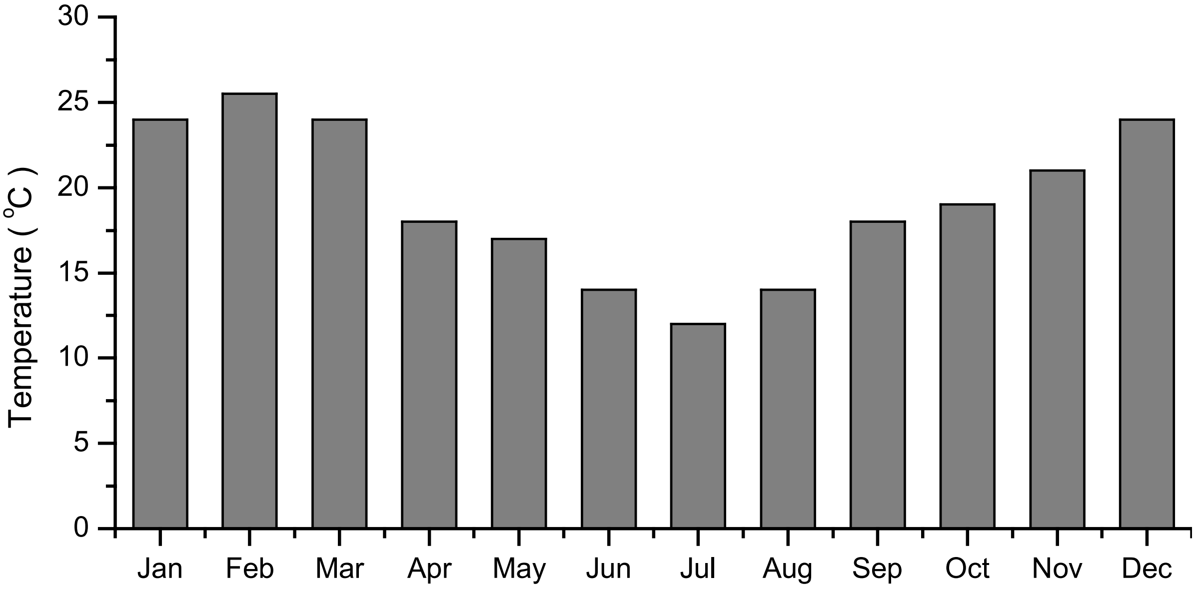


Figure 4 Median monthly temperatures at nine sites in the Port River estuary 1997–2000

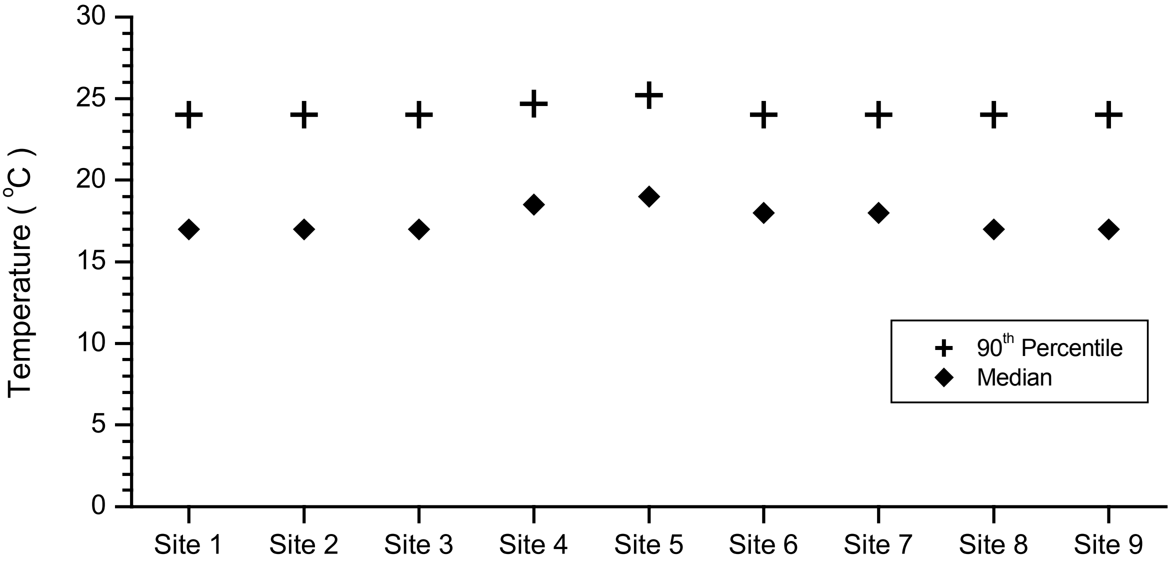


Figure 5 Median and 90th percentile temperatures at nine sites in the Port River estuary 1997–2000

Summary of physical parameters

Salinity varied over time at a number of sites, and in some cases this variability was substantial. This is consistent with the natural patterns expected in an estuarine system with freshwater inputs.

There was spatial and seasonal variability in temperature. This sampling program was designed to examine ambient conditions and could not determine the extent of the temperature changes caused by hot water discharged from power stations and industry. These temperature changes were probably localised.

Turbidity was good at five sites, but moderate at four sites, three of which are in the main arm of the Port River. Discharges from Port Adelaide wastewater treatment plant and Penrice Soda Products may have contributed to increased turbidity at these sites. It is also possible that algae contributed to turbidity and, if so, nutrients from the Penrice and Port Adelaide wastewater treatment plant may have been increasing turbidity indirectly. There were slight improvements in turbidity since the 1995–96 report, and the SA Water and Penrice environment improvement programs should lead to further improvements over time.

3.2 Metals

Metals occur in mineral deposits and can enter the environment naturally through weathering of rocks and ores. Human activities, such as ore refining and many industrial processes, release metals into the environment at a rate far higher than natural processes. Metal contamination in the Port River can be directly linked to both industrial sources and urban runoff. The wearing of vehicle parts such as tyres, brake pads and brake linings is a major source of metal contamination. Other sources include vehicle and aircraft exhaust, leaking lubricating oil, smelters, power stations, port facilities, wastewater treatment plants, chemical producers and manufacturing plants.

Compared to the more open waters of Gulf St Vincent, the Port River estuary is sheltered—an environment in which metals are likely to be deposited and accumulate in the sediments. Metals can be present in dissolved forms but they are often associated with particles. Metals in the water column may have either recently entered the Port River or been resuspended from sediment by tidal movement, storms and human activities such as dredging.

Metals such as iron, copper, zinc and magnesium have biological functions and are essential components for many forms of life, but they can be toxic at higher concentrations. Some other metals, including cadmium, lead and mercury, have no known biological functions and can be toxic at very low concentrations. Dissolved forms of metals, which have greater bioavailability, are generally more toxic than particulate forms.

The fate and consequences of metals in the environment depend largely on physical and chemical conditions, including pH and salinity. Metals are generally more toxic at lower salinity levels, and pH affects the solubility of metals in water. Metals in water adsorb onto particles including clay and organic matter; turbid waters may have higher metal concentrations but the metals may not be bioavailable. However, changes in chemistry, such as lowered pH, can increase the bioavailability of metals in sediments.

Metals can affect biota in a number of ways; they can be acutely or chronically toxic, cause reproductive problems including deformities, or bioaccumulate and move up the food chain. Bioaccumulation occurs when a toxin is taken up at a faster rate than it is excreted or broken down. It may be harmful to the organism that accumulates the metal as well as consumers of that organism. This can make some animals such as shellfish, collected from polluted areas, unsafe for human consumption. If a number of metals are present at one time the overall toxicity may be greater than we would expect from the sum of the individual toxicity of each metal. This synergistic effect is not taken into account in current water quality guidelines (ANZECC, 1992).

Metal accumulation in the fauna and sediments of the Port River is an important issue not covered in this report. (See the Environment Protection Authority publications *Special survey of the Port River: Heavy metals and PCBs in dolphins, sediments and fish* (EPA, 2000) and *Sediment quality monitoring of the Port River estuary* (EPA, 1997b).)

It can be difficult to measure metals at lower concentrations in saline waters as the salts present may interfere with the analytical equipment. Also, because low concentrations of some metals can harm the environment, the ANZECC guidelines for metal concentrations for the protection of aquatic ecosystems are very low. The ANZECC guideline for cadmium is therefore equal to the analytical detection limit, the guidelines for copper and lead are half the analytical detection limit and the guideline for mercury is three times the analytical detection limit. In these cases it is unreasonable to use the relevant ANZECC guidelines to classify the data as all sites would be classified as poor simply because of limitations in analytical technique. Instead, to determine whether sites are good, moderate or poor, based on the location of the median and 90th percentile, we use the analytical detection limit as the guideline for the metal concerned.

Total cadmium

Sources

Cadmium is produced commercially as a by-product of zinc and lead mining. Cadmium is commonly used in electroplating, as an anticorrosive agent in metal alloys, and in the manufacture of nickel–cadmium batteries. It is also used in solders, as a pigment in dyes, and as a stabiliser in plastics. Photographic chemicals contain cadmium and it occurs as an impurity in superphosphate fertilisers.

Wastewater from industry and wastewater and sludges from wastewater treatment plants can also contribute cadmium to the environment, and it enters the aquatic environment from air emissions that are deposited in catchments and transported in stormwater. According to the National Pollutant Inventory (NPI), approximately 720 kg of cadmium was released to the Adelaide airshed in the 1998–99 year, mostly from industry (9%), aircraft emissions (12%) and dust emissions from paved roads (78%).

Impacts

Cadmium is a highly toxic metal that is readily bioaccumulated in organisms, particularly shellfish. Plants can take up cadmium from the soil, and animals concentrate it in the liver and kidneys. In mammals, it can cause skeletal deformities, kidney failure and cancer. Once accumulated in the body cadmium is only excreted very slowly. Cadmium does not appear to be an essential element for life.

Results

The analytical detection limit for cadmium is 0.002 mg/L, which is equal to the ANZECC guideline for the protection of marine aquatic ecosystems. Only a small number of data points, 14 out of 477, exceeded the guideline. The 90th percentile at all sites was equal to the guideline (Figure 6), giving a classification of good for all sites (Table 7). There were no statistically significant differences between sites. The median and 90th percentile scores from 1995–96 were all 0.1 mg/L, half the levels reported here. This was due not to an increase in cadmium concentrations in the Port River but to a change in the analytical reporting limit.

Conclusions

Cadmium concentrations were classified as good at all sites in the Port River estuary. We know that cadmium concentrations did not exceed the ANZECC water quality guideline very often but, unfortunately, we do not know how close concentrations were to the guideline. A reduction in the detection limit for cadmium to a value below the ANZECC guideline will allow us to gain a better understanding of cadmium in the Port River estuary.

Previous work by the EPA on sediments provides further information about the status of cadmium in the Port River. Eight sites were sampled as part of the EPA sediment quality monitoring program in the river. Cadmium was classified as good at seven sites and moderate at one site, at the southern end of the Port River near the Port Adelaide wastewater treatment plant (EPA, 1997b). Sediments were also sampled as part of the EPA special survey of dolphins, sediment and fish. All nine estuarine sites sampled had low cadmium concentrations; however, moderate concentrations of cadmium were found in two stormwater drains entering the Port River (EPA, 2000). These results suggest that sediment cadmium concentrations in the Port River are generally low but there is some recent but low-level input of cadmium into the river.

Table 7 Statistical summary of cadmium at nine sites in the Port River estuary 1995–2000

	Mean (mg/L)	95% confidence interval (mg/L)	Standard deviation (mg/L)	Median (mg/L)	10th percentile (mg/L)	90th percentile (mg/L)	Number of samples	Water quality classification (a)	Statistical site comparisons (b)
Site 1	0.0020	0.0020–0.0021	0.0003	0.0020	0.0020	0.0020	54	good	n.s.
Site 2	0.0020	0.0020–0.0021	0.0002	0.0020	0.0020	0.0020	54	good	n.s.
Site 3	0.0021	0.0020–0.0021	0.0002	0.0020	0.0020	0.0020	54	good	n.s.
Site 4	0.0021	0.0020–0.0022	0.0005	0.0020	0.0020	0.0020	54	good	n.s.
Site 5	0.0020	0.0020–0.0020	0.0001	0.0020	0.0020	0.0020	54	good	n.s.
Site 6	0.0020	0.0020–0.0021	0.0003	0.0020	0.0020	0.0020	54	good	n.s.
Site 7	0.0020	0.0020–0.0021	0.0002	0.0020	0.0020	0.0020	54	good	n.s.
Site 8	0.0020	0.0020–0.0021	0.0002	0.0020	0.0020	0.0020	53	good	n.s.
Site 9	0.0020	0.0020–0.0021	0.0002	0.0020	0.0020	0.0020	46	good	n.s.

(a) Water quality classification is based on 90th percentile as follows-good: 90th percentile ≤0.002 mg/L; moderate: 90th percentile >0.002mg/L but median <0.002 mg/L; poor: median ≥0.002 mg/L. Note that the ANZECC guideline for cadmium is equal to the analytical detection limit.

(b) Friedman probability: P =1.0-no statistically significant differences between sites. n.s. signifies site not significantly greater than any other site.

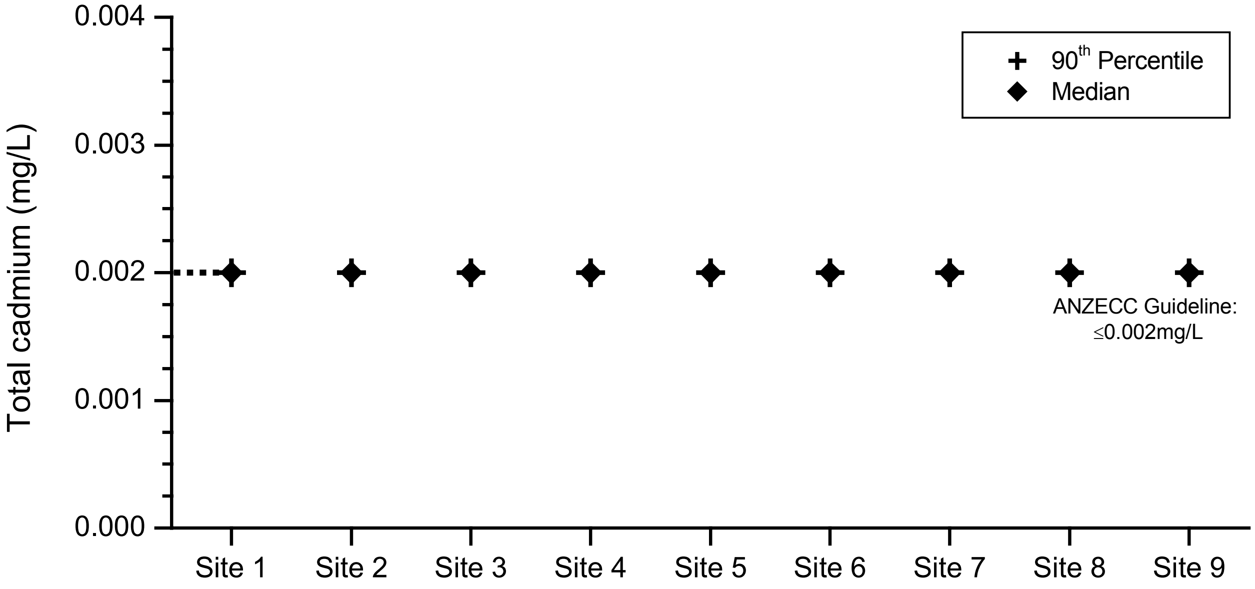


Figure 6 Median and 90th percentile cadmium at nine sites in the Port River estuary 1995–2000 (Note that the analytical detection limit for cadmium is 0.002 mg/L, which the 90th percentile and the median equal at all sites.)

Total copper

Sources

Stormwater and wastewater are two major contributors of copper to aquatic environments. Copper in wastewater probably comes from corrosion of domestic copper piping and water heater components. Copper can also enter the marine environment directly from antifouling paints.

Vehicle brake pad dust has been identified as a major source of copper; in fact, it is the main source of copper entering San Francisco Bay in the USA. According to the Swedish Environmental Protection Agency, copper used in car brake linings is responsible for one-third of copper pollution found in Stockholm. Ironically, copper replaced asbestos in brake pads because of health concerns about asbestos. Overhead power lines also release significant amounts of copper to the environment. According to the NPI, about 4800 tonnes of copper are released to the Adelaide airshed each year and 99% of this is dust emissions from roads. Copper deposited in the Port River catchment from these sources can be transported to the estuary in stormwater.

Impacts

Copper is an essential element for both plants and animals. It is a key component of some enzymes and an essential part of haemocyanin, a respiratory pigment in the blood of many invertebrates; however, it is only required in small amounts and is toxic in high concentrations. It is readily bioaccumulated in plants and animals and is toxic to many organisms including algae, invertebrates, amphibians and fish.

Results

The detection limit for copper is 0.01 mg/L, double the ANZECC guideline value of 0.005 mg/L for the protection of marine aquatic ecosystems. Out of 476 measurements, 116 (24%) exceeded the analytical detection limit and 12% exceeded it by a factor of two. At all sites the median was equal to, and the 90th percentile exceeded, the detection limit of 0.01 mg/L (Figure 7). Based on percentiles alone all sites were classified as moderate; however, four of these sites were classified as poor because they showed copper concentrations over 10 times the ANZECC guideline. There were no statistically significant differences between sites.

Median and 90th percentile scores at every site had dropped considerably since the 1995–96 report. The time series charts (Figure 30) show consistently higher readings at all sites before June 1997, but since then very few readings have exceeded the detection limit. Analytical methods were improved at this time so this apparent reduction in copper concentration may be due to methodological changes, rather than a real decrease in the amount of copper in the Port River.

Conclusions

Given the toxic nature of copper, the poor and moderate classifications of all sites are a concern. However, most of the higher readings were taken before July 1997 and, if current trends in the data continue, the water quality ratings are likely to improve.

Unfortunately, copper concentrations could be exceeding the ANZECC guidelines without our knowledge, as the analytical detection limit for copper is twice the guideline. This could have serious consequences for the natural environment. A reduction in the detection limit for copper to a value equal to or below the ANZECC guideline will allow us to gain a better understanding of copper in the Port River estuary.

Sediment analysis provides further information about the status of copper in the river. Eight sites were sampled as part of the EPA sediment quality monitoring program in the Port River: copper was classified as good at six sites and moderate and poor at one site each (EPA, 1997b). The EPA special survey (EPA, 2000) found four estuarine sites and one stormwater drain had high copper concentrations. These results suggest that copper concentrations in sediments in the Port River are generally low but that there are some locations where they are high. There is also evidence of continuing inputs of copper through the stormwater system.

Table 8 Statistical summary of copper at nine sites in the Port River estuary 1995–2000

	Mean (mg/L)	95% Confidence interval (mg/L)	Standard deviation (mg/L)	Median (mg/L)	10th Percentile (mg/L)	90th Percentile (mg/L)	Number of Samples	Water quality classification (a)	Statistical site comparisons (b)
Site 1	0.012	0.011–0.014	0.006	0.010	0.010	0.018	54	moderate	n.s.
Site 2	0.015	0.011–0.019	0.016	0.010	0.010	0.022	54	poor*	n.s.
Site 3	0.013	0.011–0.015	0.008	0.010	0.010	0.020	53	moderate	n.s.
Site 4	0.014	0.011–0.017	0.012	0.010	0.010	0.022	54	poor*	n.s.
Site 5	0.013	0.011–0.014	0.006	0.010	0.010	0.021	54	moderate	n.s.
Site 6	0.013	0.011–0.015	0.008	0.010	0.010	0.021	54	moderate	n.s.
Site 7	0.013	0.011–0.015	0.007	0.010	0.010	0.023	54	moderate	n.s.
Site 8	0.013	0.010–0.015	0.008	0.010	0.010	0.016	53	poor*	n.s.
Site 9	0.014	0.008–0.019	0.018	0.010	0.010	0.013	46	poor*	n.s.

(a) Water quality classification is based on 90th percentile as follows-good: 90th percentile ≤0.01 mg/L; moderate: 90th percentile >0.01 mg/L but median <0.01 mg/L; poor: median ≥0.01 mg/L. Note the guideline here is higher than the ANZECC recommendation because the analytical detection limit for copper is 0.01 mg/L, two times the ANZECC guideline of 0.005 mg/L. *Poor classification based on single samples exceeding ANZECC guideline by a factor of 10.

(b) Friedman probability: P =0.951-no statistically significant differences between sites. n.s. signifies the site is not significantly greater than any other site.

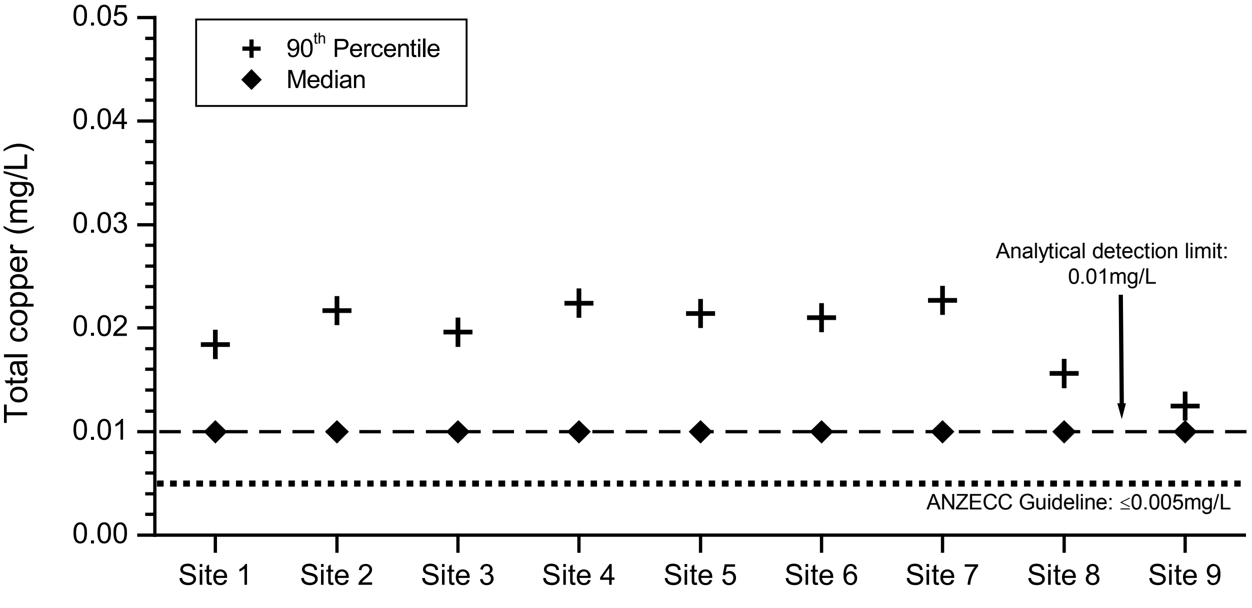


Figure 7 Median and 90th percentile copper at nine sites in the Port River estuary 1995–2000

Total lead

Sources

The primary source of lead in the environment is from leaded fuel. Nearly 10% of all lead produced is used to manufacture tetra-ethyl lead, an additive in leaded fuel. The NPI estimates 65,000 kg of lead were released to the Adelaide airshed in 1998–99, with motor vehicle emissions responsible for 54% and dust from paved roads contributing 43%. Particles released from brake pads are also a major source of lead. The emission of lead to air is decreasing due to the 1985 introduction of unleaded fuel for vehicles, and the substitution for leaded fuel with lead replacement fuel in late 2000. This should reduce the amount of lead entering aquatic environments.

Lead is used in solder, plumbing and ammunition, and some insecticides contain lead. Metallic lead and lead dioxide are used in batteries, and historically lead was used extensively in paints, although this is no longer the case in Australia. Lead reaches the Port River estuary through stormwater runoff, fall-out of lead dust, and wastewater treatment plant and industrial wastewater discharges. Lead adsorbs onto particles and can build up in sediments; under low pH conditions it can be remobilised from sediments.

Impacts

Lead causes acute and chronic toxicity in marine and freshwater organisms including fish, algae and invertebrates. Lead is also bioaccumulated in animals and plants, leading to its transfer up the food chain. Consumption of shellfish in areas polluted by lead is a concern as lead is toxic to humans, and children are particularly sensitive. Once lead enters the body, it is deposited in bone from which it is slowly released. It can cause behavioural and neurological problems in children; it increases the rate of miscarriage and impairs the production of red blood cells.

Results

The analytical detection limit for lead is 0.01 mg/L, which is double the ANZECC guideline value of 0.005 mg/L for the protection of marine aquatic ecosystems. Only nine of 476 measurements exceeded the detection limit and the highest reading was 0.03 mg/L at site 5, six times the ANZECC guideline. At all sites the median and 90th percentile were equal to the analytical detection limit (Figure 8). Consequently, all sites were classified as good (Table 9). There were no statistically significant differences between sites.

In the 1995–96 report, median lead concentrations were lower than in this report, but the difference from the current report should be disregarded as it is due to the revision of the analytical detection limit for lead.

Conclusions

The good classification for all sites is tentative because we are unable to measure lead concentrations below 0.01 mg/L, which is double the ANZECC guideline, and lead concentrations could be exceeding the guideline without our knowledge. A reduction in the detection limit to a value equal to or below the ANZECC guideline will allow us to gain a better understanding of lead in the Port River estuary.

Sediment analysis provides further information about the status of lead in the Port River. The EPA sediment quality monitoring program in the Port River classified lead as good at seven sites and moderate at one site (EPA, 1997b). The EPA special survey of the Port River (EPA, 2000) found that four estuarine sites and eight stormwater drains had high lead concentrations. These results suggest that lead concentrations in sediments in the river are high in some places. There appear to be continuing inputs of lead into the Port River through the stormwater system, probably from road runoff.

Table 9 Statistical summary of lead at nine sites in the Port River estuary 1995–2000

	Mean (mg/L)	95% Confidence interval (mg/L)	Standard deviation (mg/L)	Median (mg/L)	10th Percentile (mg/L)	90th Percentile (mg/L)	Number of Samples	Water quality classification (a)	Statistical site comparisons (b)
Site 1	0.010	0.010–0.010	0.001	0.010	0.010	0.010	54	good	n.s.
Site 2	0.010	0.010–0.010	0.001	0.010	0.010	0.010	54	good	n.s.
Site 3	0.010	0.010–0.010	0.000	0.010	0.010	0.010	53	good	n.s.
Site 4	0.010	0.010–0.010	0.000	0.010	0.010	0.010	54	good	n.s.
Site 5	0.010	0.010–0.011	0.003	0.010	0.010	0.010	54	good	n.s.
Site 6	0.010	0.010–0.010	0.001	0.010	0.010	0.010	54	good	n.s.
Site 7	0.010	0.010–0.010	0.001	0.010	0.010	0.010	54	good	n.s.
Site 8	0.010	0.010–0.010	0.000	0.010	0.010	0.010	53	good	n.s.
Site 9	0.010	0.010–0.010	0.000	0.010	0.010	0.010	46	good	n.s.

(a) Water quality classification is based on 90th percentile as follows-good: 90th percentile ≤0.01 mg/L; moderate: 90th percentile >0.01 mg/L but median <0.005 mg/L; poor: median ≥0.01 mg/L. Note the guideline here is higher than the ANZECC recommendation because the analytical detection limit for lead is 0.01 mg/L, two times the ANZECC guideline of 0.005 mg/L.

(b) Friedman probability: P =0.999-no statistically significant differences between sites. n.s. signifies the site is not significantly greater than any other site.

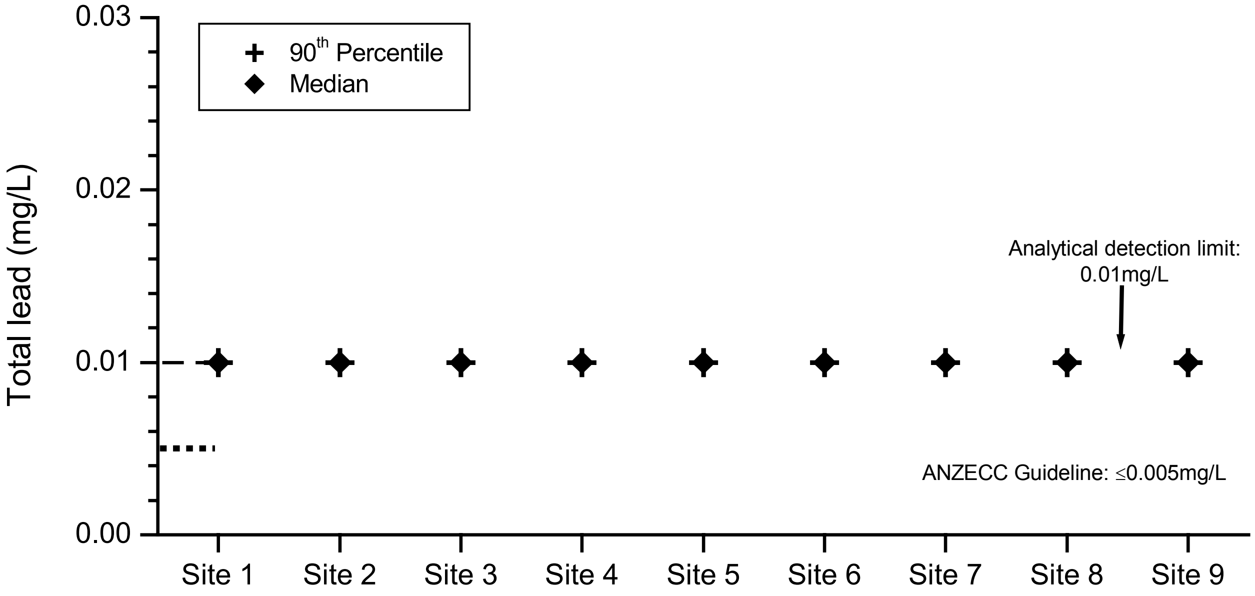


Figure 8 Median and 90th percentile lead at nine sites in the Port River estuary 1995–2000 (Note the median and 90th percentiles are equal)

Total mercury

Sources

Elemental mercury is a liquid at room temperature and vaporises easily; it can also be found as mercury salts and organic mercury compounds. Although it is released to the environment naturally from weathering of minerals, artificial inputs are far more significant. Historically mercurous chloride, or calomel, has been widely used in medicine, and some pesticides contained mercury compounds. Mercury readily forms alloys, or amalgams, with other metals. This property allows its use in the production of gold from ore. Mercury fulminate is used in explosive detonators, and mercuric sulphide is a vermilion-coloured paint pigment. Mercury compounds are also used in mercury vapour lamps, batteries, dental amalgam, thermometers, and as catalysts in industrial processes. Coal fired power stations can be sources of methylmercury as mercury can be a contaminant in coal. Waste incineration and wastewaters can also release mercury to the environment. According to the NPI, in 1998–99 490 kg of mercury were released to the Adelaide airshed, and 96% of this was from re-suspension of road dust. Once mercury reaches the sea it is often adsorbed onto particulate matter and can accumulate in sediments. In sediments, some aquatic micro-organisms can convert various forms of mercury into methylmercury compounds, especially under anoxic conditions.

Impacts

Elemental mercury is particularly toxic, but organic mercury compounds can be from 4 to 31 times as toxic as elemental mercury. Methylmercury is probably the most toxic mercury compound. Mercury can be absorbed directly from seawater by smaller organisms, and is readily bioaccumulated and passed up the food chain. Mercury appears to be toxic to most types of organisms, but selenium reduces the toxic effects of mercury. Many marine animals have high levels of selenium, which enables them to tolerate higher mercury concentrations. Mercury is toxic to humans and does not appear to be a biologically essential element. Poisoning may result from inhalation of the vapour, absorption of mercury through the skin, or ingestion of soluble compounds. Consumption of marine organisms from locations with high concentrations of mercury is unwise.

Results

All sites shared a median of 0.0003 mg/L and 90th percentile of 0.0005 mg/L (Figure 1), and mercury concentrations were classified as good at all sites (Table 10). Only five of 473 measurements exceeded the analytical detection limit and the highest reading was 0.0006 mg/L. There were no statistically significant differences between sites.

At all times the analytical detection limit for mercury was greater than the ANZECC guideline value of 0.0001 mg/L for the protection of marine aquatic ecosystems. The detection limit for mercury was mainly 0.0003 mg/L but it varied between 0.0003 mg/L and 0.001 mg/L. It should be noted that the high value of 0.001 mg/L at all sites on 10 June 1999 (Figure 33) was due to analytical problems. Similarly, mercury concentrations appeared to be higher at all sites from July 1996 to June 1997, but this was due to a change in the analytical detection limit rather than a change in environmental conditions. Median concentrations appeared to have increased since the 1995–96 report, but once again this was an artefact due to changes in analytical detection limits.

Conclusions

The high detection limits prevent us comparing the results with the ANZECC guidelines. The low number of results exceeding the analytical detection limit is a good outcome but mercury concentrations may be exceeding the ANZECC guidelines without our knowledge.

Given the toxic nature of mercury and the problems with the analytical detection limit we considered sediment data to clarify the status of mercury in the Port River. The EPA sediment quality monitoring program in the Port River classified mercury as good at seven sites and poor at one site in North Arm, adjacent to Magazine Creek (EPA, 1997b). The EPA special survey of the Port River (EPA, 2000) found three estuarine sites and two stormwater drains had high mercury concentrations; two other stormwater drains had moderate mercury concentrations. These results suggest that mercury concentrations in sediments in the Port River are generally low but can be high in some places. The mercury in the Port River sediments may be from historical contamination but there appear to be continuing inputs of mercury into the Port River through the stormwater system.

Table 10 Statistical summary of mercury at nine sites in the Port River estuary 1995–2000

	Mean (mg/L)	95% confidence interval (mg/L)	Standard deviation (mg/L)	Median (mg/L)	10th percentile (mg/L)	90th percentile (mg/L)	Number of samples	Water quality classification (a)	Statistical site comparisons (b)
Site 1	0.00037	0.00033–0.00040	0.00013	0.00030	0.00030	0.00050	53	good	n.s.
Site 2	0.00037	0.00033–0.00040	0.00013	0.00030	0.00030	0.00050	53	good	n.s.
Site 3	0.00036	0.00033–0.00040	0.00012	0.00030	0.00030	0.00050	54	good	n.s.
Site 4	0.00036	0.00033–0.00040	0.00012	0.00030	0.00030	0.00050	53	good	n.s.
Site 5	0.00037	0.00033–0.00040	0.00013	0.00030	0.00030	0.00050	54	good	n.s.
Site 6	0.00036	0.00033–0.00039	0.00012	0.00030	0.00030	0.00050	54	good	n.s.
Site 7	0.00036	0.00033–0.00040	0.00012	0.00030	0.00030	0.00050	53	good	n.s.
Site 8	0.00036	0.00033–0.00040	0.00012	0.00030	0.00030	0.00050	53	good	n.s.
Site 9	0.00037	0.00033–0.00041	0.00013	0.00030	0.00030	0.00050	46	good	n.s.

(a) Water quality classification is based on 90th percentile as follows-good: 90th percentile ≤0.0005 mg/L; moderate: 90th percentile >0.0005 mg/L but median <0.0005 mg/L; poor: median ≥0.0005 mg/L. Note the guideline here is higher than the ANZECC recommendation because the analytical detection limit for mercury is 0.0003–0.0005 mg/L, three to five times the ANZECC guideline of 0.0001 mg/L.

(b) Friedman probability: P =1.0-no statistically significant differences between sites. n.s. signifies the site is not significantly greater than any other site.

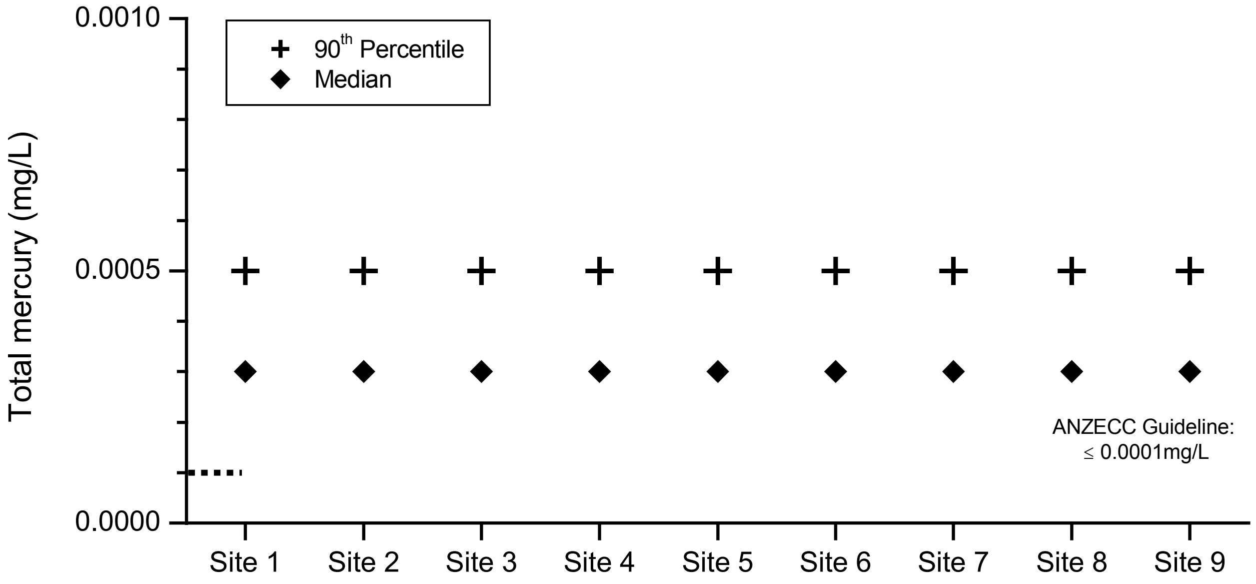


Figure 9 Median and 90th percentile mercury at nine sites in the Port River estuary 1995–2000

Total iron

Sources

Iron is the fourth most abundant element in the earth's crust, and is commonly found in soil and rocks as oxide, sulfide and carbonate minerals. It enters the environment through natural leaching and human activities such as iron mining and smelting. Many things are made from iron or alloys containing iron, and corrosion is a likely source of iron to the environment. Iron was included in the program because of the number of rusting ship hulks in the Port River estuary.

Impacts

Iron is an essential element for life. It is a critical ingredient of haemoglobin, the respiratory pigment that makes blood red, and humans contain about 60 mg of iron per kilogram of body mass. Iron is also essential for plant growth. There has been some suggestion that in oceanic waters it is a major limiting factor of algal growth, and a further suggestion of adding iron salts to oceans to increase algal growth, which would absorb atmospheric carbon dioxide to combat global warming.

However, at higher concentrations iron can be toxic in freshwaters, reducing the reproductive success of some animals and causing poisoning of others. There is insufficient data to develop an ANZECC guideline on the toxicity of iron to marine organisms but the freshwater guideline has been included here as a guide.

Results

Median and 90th percentile iron concentrations in the Port River estuary were significantly below the freshwater guideline (Figure 10). There was high compliance with the ANZECC freshwater guideline; of 475 measurements only three exceeded the guideline. Sites 2 and 7 showed significantly higher results than some other sites (Table 11). Compared to the 1995–96 report, median readings stayed the same or improved at all sites; however, this may not be due to a decrease in the iron concentrations in the river, but rather to a reduction in the analytical detection limit from 0.05 mg/L to 0.025 mg/L in July 1997.

Conclusions

Iron concentrations appear to be well within safe levels, suggesting that iron is not a major concern in the Port River.

Table 11 Statistical summary of iron at nine sites in the Port River estuary 1995–2000

	Mean (mg/L)	**95% confidence interval** (mg/L)	**Standard deviation** (mg/L)	**Median** (mg/L)	**10th percentile** (mg/L)	**90th percentile** (mg/L)	**Number of samples**	**Water quality classification** (a)	**Statistical site comparisons** (b)
Site 1	0.136	0.070–0.200	0.233	0.063	0.036	0.198	54	good	n.s.
Site 2	0.125	0.080–0.170	0.149	0.077	0.036	0.266	54	good	Site 2>3,8
Site 3	0.070	0.050–0.090	0.065	0.050	0.025	0.109	53	good	n.s.
Site 4	0.080	0.060–0.100	0.091	0.050	0.032	0.120	54	good	n.s.
Site 5	0.081	0.060–0.100	0.086	0.050	0.025	0.130	54	good	n.s.
Site 6	0.116	0.060–0.180	0.214	0.057	0.027	0.227	53	good	n.s.
Site 7	0.193	0.080–0.310	0.423	0.080	0.041	0.384	54	good	Site 7>3,4,5,8
Site 8	0.075	0.050–0.100	0.076	0.050	0.026	0.172	53	good	n.s.
Site 9	0.095	0.070–0.120	0.098	0.050	0.025	0.271	46	good	n.s.

(a) Water quality classification is based on 90th percentile as follows-good: 90th percentile ≤1 mg/L; moderate: 90th percentile >1 mg/L but median <1 mg/L; poor: median ≥1 mg/L.

(b) Friedman probability: P <0.001-statistically significant differences between sites. For pairwise site comparisons n.s. signifies the site is not significantly greater than any other site. The > symbol indicates which sites the specified location is significantly greater than.

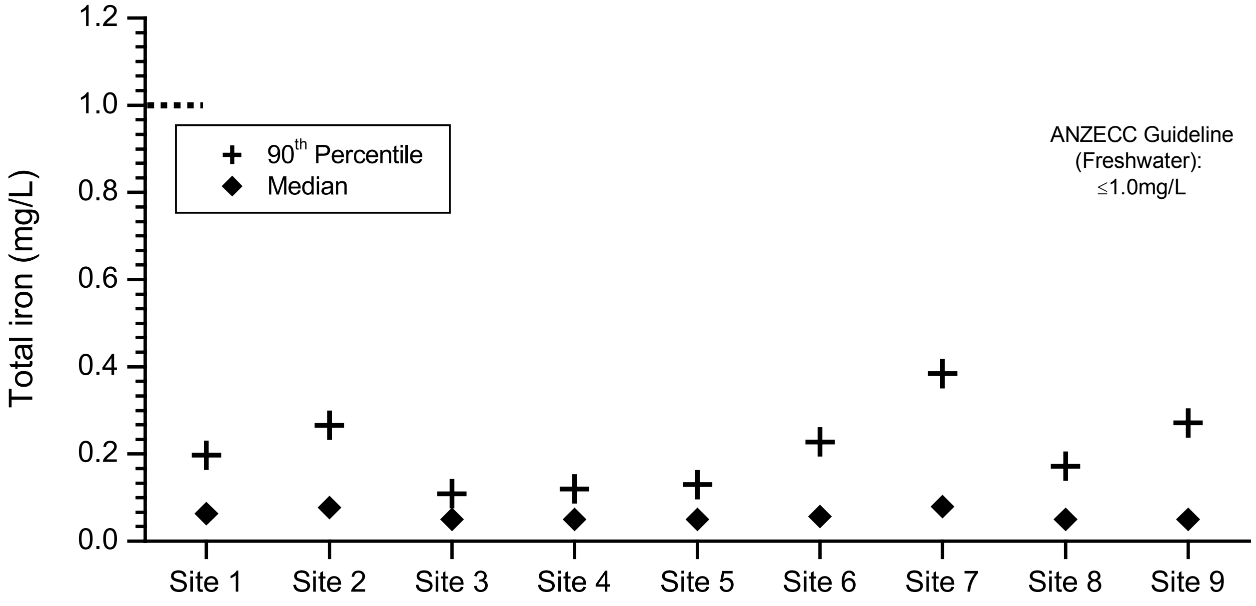


Figure 10 Median and 90th percentile iron at nine sites in the Port River estuary 1995–2000

Total and soluble aluminium

Sources

Aluminium makes up about 8% of the earth's crust and may be present in water owing to natural leaching from rock and soil, or from industrial sources, sewage effluent and water treatment sludges. Low pH water infiltrating through naturally aluminium-rich sediments, or wastes and mining residues containing aluminium, can leach soluble aluminium into the environment. This appears to be an important issue in parts of Europe and North America where acid rain is prevalent, but not in Australia.

Impacts

There are no specific guidelines for aluminium in marine or estuarine waters, but in freshwater systems soluble forms of aluminium are more toxic than particulate forms. Aluminium is also more toxic at lower pH. The mechanism of toxicity is likely to impact on marine species in the same way it impacts on freshwater organisms, so the guideline for freshwater aquatic ecosystems has been used to classify marine waters (0.1 mg/L if pH>6.5). Aluminium appears to be a biologically essential element; it may be an important part of some enzymes that help produce porphyrin, a chemical component of biological molecules such as proteins and chlorophyll.

Soluble aluminium results

Median and 90th percentile concentrations of soluble aluminium were below the guideline of 0.1 mg/L at all sites, and all sites were classified as good (Figure 11, Table 12). Encouragingly, out of 470 measurements only four readings exceeded the guideline of 0.1 mg/L. The median reading at all sites of 0.25 mg/L was equivalent to the minimum reporting limit for this method. There were no statistically significant differences between sites.

Median values in this report were consistently higher than the 1995–96 report, but this was caused by a revision of the laboratory reporting limit for this analytical test since 1995–96, not by an increase in aluminium concentration. The time series graphs (Figure 27) show that before December 1998 most samples were at the detection limit for the test, but at that time all sites showed increases; since then results have been more variable, reflecting the implementation of the more accurate analytical procedure.

Total aluminium results

It is not possible to classify total aluminium, as there are no guidelines for marine or estuarine waters. Total aluminium includes both the dissolved and particulate aluminium present in the water. The total aluminium results (Table 13, Figure 12) were higher and more variable than the soluble aluminium results, suggesting that a significant proportion of aluminium present in the Port River is particulate. Sites 2 and 7 had statistically significantly higher concentrations than some other sites but there was no obvious explanation for this. The slightly higher medians at most sites compared with those from the 1995–96 report were a result of the analytical changes described in the soluble aluminium section above.

Conclusions

Soluble aluminium concentrations were low in the Port River across all sites and, although median concentrations of soluble and total aluminium had increased since the last report, this appears to be due to analytical changes, not to an increase in aluminium in the river. These results suggest that aluminium is currently not a concern for water quality in the Port River.

Table 12 Statistical summary of soluble aluminium at nine sites in the Port River estuary 1995–2000

	Mean (mg/L)	95% confidence interval (mg/L)	Standard deviation (mg/L)	Median (mg/L)	10th percentile (mg/L)	90th percentile (mg/L)	Number of samples	Water quality classification (a)	Statistical site comparisons (b)
Site 1	0.040	0.034–0.046	0.023	0.025	0.025	0.076	53	good	n.s.
Site 2	0.039	0.033–0.045	0.021	0.025	0.025	0.075	53	good	n.s.
Site 3	0.037	0.032–0.042	0.019	0.025	0.025	0.064	53	good	n.s.
Site 4	0.042	0.036–0.049	0.024	0.025	0.025	0.083	53	good	n.s.
Site 5	0.040	0.033–0.046	0.023	0.025	0.025	0.072	53	good	n.s.
Site 6	0.043	0.036–0.05	0.025	0.025	0.025	0.082	53	good	n.s.
Site 7	0.040	0.034–0.047	0.025	0.025	0.025	0.073	53	good	n.s.
Site 8	0.039	0.033–0.046	0.024	0.025	0.025	0.071	52	good	n.s.
Site 9	0.038	0.032–0.044	0.021	0.025	0.025	0.065	46	good	n.s.

(a) Water quality classification is based on 90th percentile as follows-good: 90th percentile ≤0.1 mg/L; moderate: 90th percentile >0.1 mg/L but median <0.1 mg/L; poor: median ≥0.1 mg/L.

(b) Friedman probability: P =0.084-no statistically significant differences between sites. For pairwise site comparisons n.s. signifies the site is not significantly greater than any other site. The > symbol indicates which sites the specified location is significantly greater than.

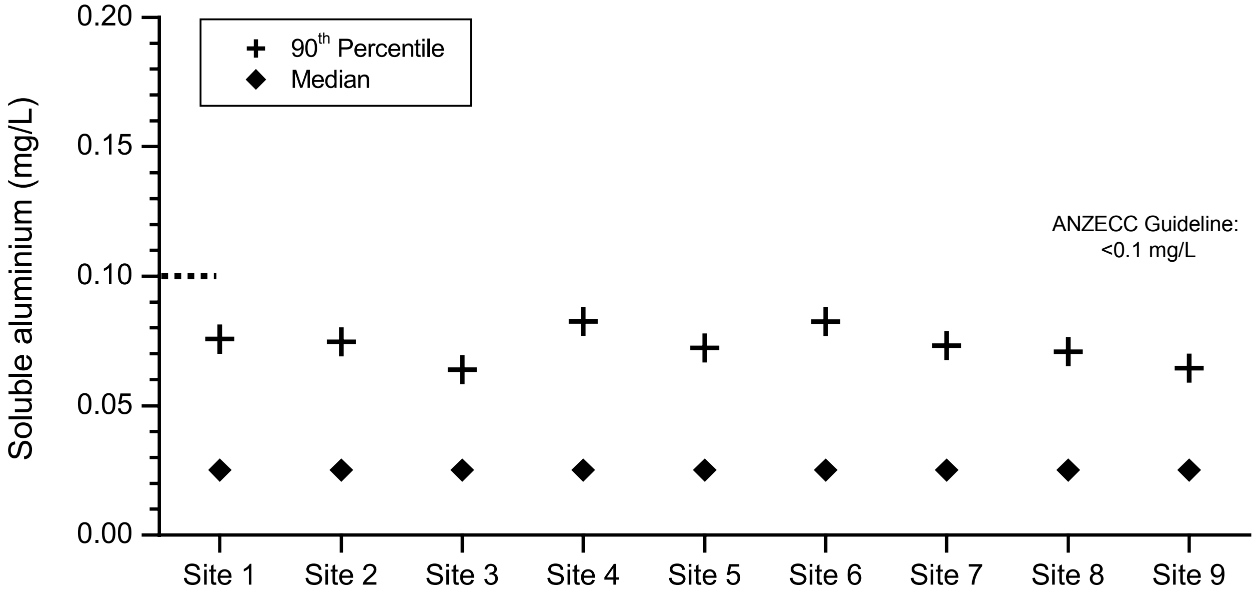


Figure 11 Median and 90th percentile soluble aluminium at nine sites in the Port River estuary 1995–2000

Table 13 Statistical summary of total aluminium at nine sites in the Port River estuary 1995–2000

	Mean (mg/L)	95% confidence interval (mg/L)	Standard deviation (mg/L)	Median (mg/L)	10th percentile (mg/L)	90th percentile (mg/L)	Number of samples	Water quality classification (a)	Statistical site comparisons (b)
Site 1	0.078	0.056–0.099	0.078	0.055	0.025	0.138	53	n.a.	n.s.
Site 2	0.092	0.062–0.122	0.110	0.066	0.025	0.186	53	n.a.	Site 2>4,8
Site 3	0.074	0.040–0.108	0.124	0.046	0.025	0.095	53	n.a.	n.s.
Site 4	0.059	0.039–0.080	0.076	0.035	0.025	0.096	53	n.a.	n.s.
Site 5	0.065	0.041–0.089	0.088	0.036	0.025	0.115	53	n.a.	n.s.
Site 6	0.072	0.050–0.093	0.076	0.052	0.025	0.118	52	n.a.	n.s.
Site 7	0.133	0.037–0.229	0.348	0.058	0.025	0.176	53	n.a.	Site 7>4,5,8
Site 8	0.055	0.044–0.066	0.040	0.037	0.025	0.102	52	n.a.	n.s.
Site 9	0.066	0.052–0.079	0.046	0.057	0.025	0.135	46	n.a.	n.s.

(a) No water quality classification for total aluminium in marine or estuarine waters.

(b) Friedman probability: P <0.001-statistically significant differences between sites. For pairwise site comparisons n.s. signifies the site is not significantly greater than any other site. The > symbol indicates which sites the specified location is significantly greater than.

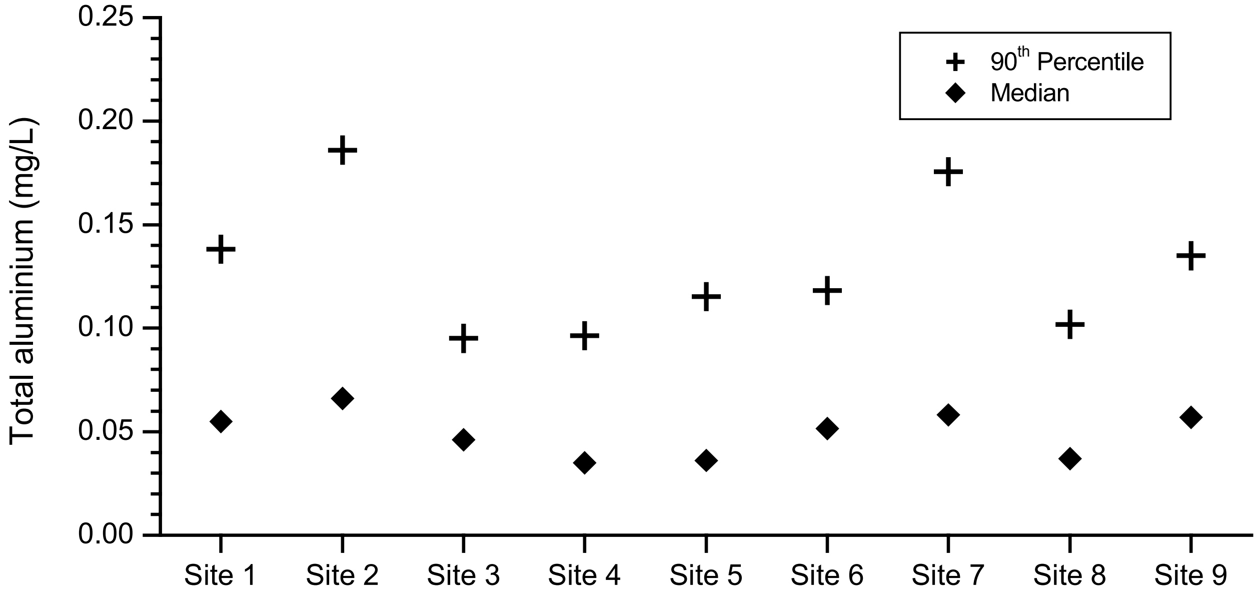


Figure 12 Median and 90th percentile total aluminium at nine sites in the Port River estuary 1995–2000

Total and soluble zinc

Sources

Zinc is widely used in modern society, most commonly to coat or galvanise iron to prevent corrosion. Brass and many other important metal alloys contain zinc. Zinc is used in batteries, and particles released from vehicle tyres and brake linings are a major source of zinc in the environment. Zinc oxide is used in a wide range of products including paint, rubber products, cosmetics and pharmaceuticals. The NPI estimates that 30,000 kg of zinc were released to the Adelaide airshed in 1997–98 and about 94% of that was from resuspended road dust. Most of the remainder was from solid, liquid and gaseous fuel burning.

Impacts

Zinc is an essential element for both plants and animals; it is an important component of many enzymes, and of insulin. However, zinc can be toxic in high concentrations, and its toxicity is influenced by water hardness and pH. It can cause chronic and acute toxicity in fish and invertebrates from both marine and fresh waters. Some organisms bioaccumulate zinc, particularly filter-feeding molluscs. It is likely that soluble forms of zinc are more toxic than particulate forms.

Soluble zinc results

There are no guidelines for soluble zinc in marine waters. Given that it is likely that soluble forms of zinc are more toxic than particulate forms, any exceedences of total zinc guidelines by soluble zinc are a concern. Of 475 soluble zinc measurements, a total of 66, or 14%, exceeded the ANZECC guideline of 0.05 mg/L for total zinc. Seven sites had 90th percentiles exceeding 0.05 mg/L (Figure 13), and using the total zinc guidelines these seven sites would be classified as moderate, with only sites 5 and 8 being good. There were no statistically significant differences between sites (Table 14). Median scores between the 1995–96 and this report were comparable, suggesting little change over time.

Total zinc results

All nine sites were classified as moderate based on total zinc concentrations, with the 90th percentile readings more than double the guideline at sites 1, 2 and 3 (Figure 14). Out of 475 measurements, 129 (27%) exceeded the ANZECC guidelines. There were no statistically significant differences between sites (Table 15). Compared to the 1995–96 report, median readings at seven sites had dropped but the differences were only marginal.

Conclusions

Total zinc concentrations were high enough to be a concern in the Port River estuary, and the failure of the soluble component to meet the total guidelines is an issue given its greater toxicity. The EPA sediment quality monitoring program in the Port River classified zinc as good at seven sites and moderate at one site (EPA, 1997b). The EPA special survey of the Port River (EPA, 2000) found four estuarine sites and 13 stormwater drains had high zinc concentrations, suggesting that zinc continues to enter the Port River, principally from road runoff.

These results are not surprising, given the widespread use of galvanised products in Adelaide, along with the release of zinc from the wear of vehicle tyres and brake linings. The lower toxicity of zinc compared with mercury, cadmium and lead is fortunate, as control of zinc sources will be a difficult long-term problem.

Table 14 Statistical summary of soluble zinc at nine sites in the Port River estuary 1995–2000

	Mean (mg/L)	**95% confidence interval** (mg/L)	**Standard deviation** (mg/L)	**Median** (mg/L)	**10th percentile** (mg/L)	**90th percentile** (mg/L)	**Number of samples**	**Water quality classification** (a)	**Statistical site comparisons** (b)
Site 1	0.032	0.022—0.041	0.035	0.021	0.010	0.071	54	n.a.	n.s.
Site 2	0.032	0.024—0.039	0.028	0.021	0.010	0.069	54	n.a.	n.s.
Site 3	0.031	0.024—0.039	0.026	0.020	0.010	0.074	53	n.a.	n.s.
Site 4	0.026	0.021—0.030	0.018	0.019	0.010	0.052	54	n.a.	n.s.
Site 5	0.023	0.018—0.028	0.019	0.015	0.010	0.049	54	n.a.	n.s.
Site 6	0.026	0.020—0.032	0.020	0.019	0.010	0.053	54	n.a.	n.s.
Site 7	0.025	0.020—0.030	0.018	0.018	0.010	0.051	53	n.a.	n.s.
Site 8	0.027	0.021—0.033	0.021	0.019	0.010	0.050	53	n.a.	n.s.
Site 9	0.025	0.019—0.031	0.020	0.017	0.010	0.053	46	n.a.	n.s.

(a) No water quality classification for soluble zinc in marine or estuarine waters.

(b) Friedman probability: P =0.073-no statistically significant differences between sites. n.s. signifies the site is not significantly greater than any other site.

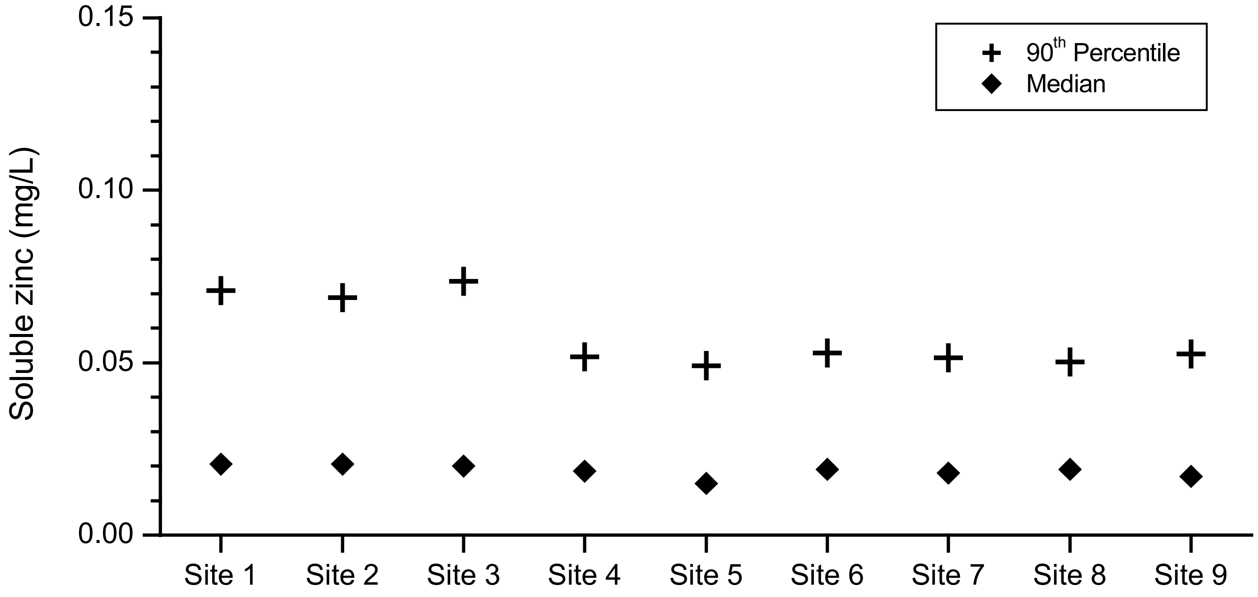


Figure 13 Median and 90th percentile soluble zinc at nine sites in the Port River estuary 1995–2000

Table 15 Statistical summary of total zinc at nine sites in the Port River estuary 1995–2000

	Mean (mg/L)	95% confidence interval (mg/L)	Standard deviation (mg/L)	Median (mg/L)	10th percentile (mg/L)	90th percentile (mg/L)	Number of samples	Water quality classification (a)	Statistical site comparisons (b)
Site 1	0.051	0.038—0.063	0.046	0.037	0.010	0.113	54	moderate	n.s.
Site 2	0.047	0.036—0.059	0.043	0.031	0.010	0.107	54	moderate	n.s.
Site 3	0.051	0.036—0.065	0.054	0.033	0.010	0.112	53	moderate	n.s.
Site 4	0.042	0.033—0.051	0.032	0.032	0.010	0.091	54	moderate	n.s.
Site 5	0.033	0.027—0.040	0.024	0.027	0.010	0.062	54	moderate	n.s.
Site 6	0.039	0.031—0.046	0.028	0.033	0.010	0.062	54	moderate	n.s.
Site 7	0.035	0.029—0.042	0.024	0.029	0.010	0.060	53	moderate	n.s.
Site 8	0.040	0.030—0.049	0.033	0.031	0.010	0.083	53	moderate	n.s.
Site 9	0.040	0.029—0.051	0.038	0.030	0.010	0.069	46	moderate	n.s.

(a) Water quality classification is based on 90th percentile as follows-good: 90th percentile ≤0.05 mg/L; moderate: 90th percentile >0.05 mg/L but median <0.05 mg/L; poor: median ≥0.05 mg/L.

(b) Friedman probability: P =0.173-no statistically significant differences between sites. n.s. signifies the site is not significantly greater than any other site.

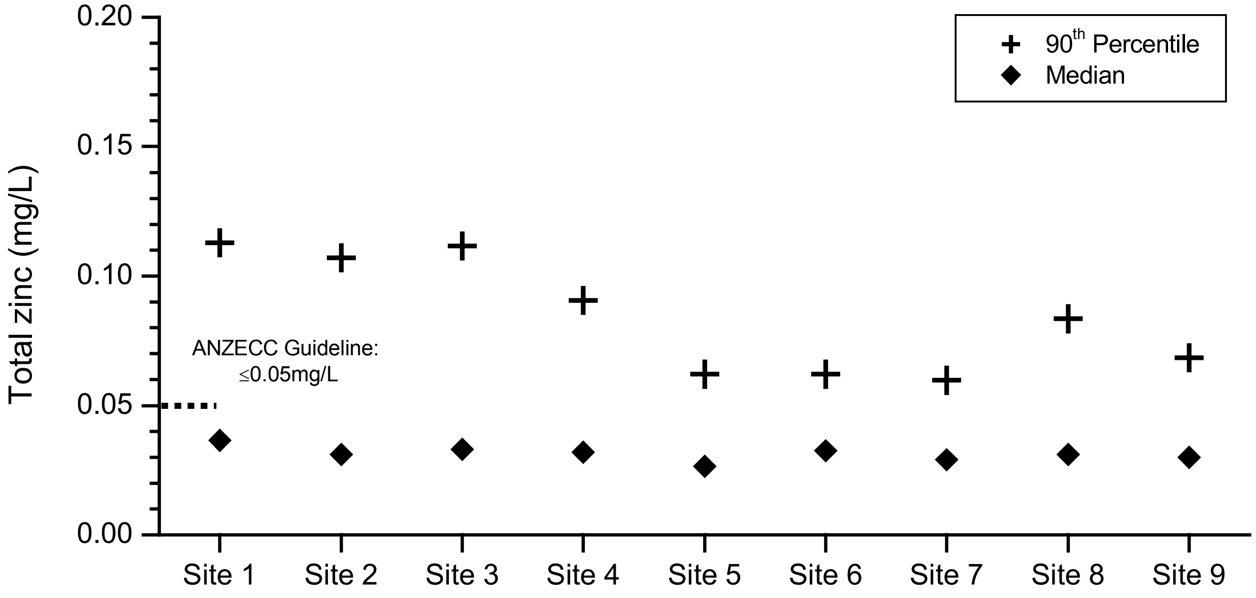


Figure 14 Median and 90th percentile total zinc at nine sites in the Port River estuary 1995–2000

Summary of metals

The water quality classifications for metals showed that 71% of ratings were good, 22% were moderate and 6% were poor. Aluminium, cadmium, iron, lead and mercury were classified as good at all sites. However, zinc was moderate at all sites, and copper was moderate at five sites and poor at four (Table 16). If current trends continue, copper will improve over the next five-year period, but zinc appears to be fairly stable, as does iron. Comparisons with the 1995–96 report are not possible for aluminium, cadmium, lead and mercury because of changes in analytical methodology.

Table 16 Summary of water quality classifications for metals in the Port River 1995–2000

	Soluble aluminium	Total cadmium	Total copper	Total iron	Total lead	Total mercury	Total zinc
Site 1	good	good	moderate	good	good	good	moderate
Site 2	good	good	poor	good	good	good	moderate
Site 3	good	good	moderate	good	good	good	moderate
Site 4	good	good	poor	good	good	good	moderate
Site 5	good	good	moderate	good	good	good	moderate
Site 6	good	good	moderate	good	good	good	moderate
Site 7	good	good	moderate	good	good	good	moderate
Site 8	good	good	poor	good	good	good	moderate
Site 9	good	good	poor	good	good	good	moderate

The high detection limits of mercury, copper and lead, and to a lesser extent cadmium, are of concern as they restrict our ability to understand the status of these metals in the Port River. We are reviewing analytical methods and hope to achieve improvements in detection limits in the future.

Some metals are persistent and cumulative toxins. Over time, even low concentrations may be bioaccumulated by aquatic organisms or stored in sediments. Therefore, the release of metals into catchments from point sources such as industrial discharges, or diffuse sources such as motor vehicles, must be minimised in the future.

3.3 Nutrients

Nutrients are substances that are required for growth and reproduction. Aquatic plants and algae require many resources and conditions to grow and reproduce including carbon dioxide, trace elements, sufficient light, an appropriate temperature range and the right hydraulic conditions. If these basic requirements are met, a lack of nitrogen or phosphorus is the most likely thing to limit algal growth.

Nutrients can be present in soluble, particulate, organic and inorganic forms. The bioavailability of different forms varies; transformation of one form to another depends on the physical and chemical condition of waters and sediments, and is often mediated by biological processes.

Sources

The major sources of nitrogen and phosphorus pollution in the Port River are wastewater treatment plants, industrial discharges and urban stormwater runoff. According to NPI and other monitoring figures, in 1999–2000 the Port Adelaide wastewater treatment plant discharged approximately 68 tonnes of phosphorus and 460 tonnes of nitrogen, with a median ammonia–N concentration of 25 mg/L. Penrice Soda Products at Osborne are major contributors of nitrogen to the Port River owing to the high ammonia concentrations of their wastewater. In 2000 the weekly average concentration of ammonia–N in Penrice's wastewater was 57 mg/L, with a minimum of 22 mg/L and a maximum of 177 mg/L. With a discharge of around 70 ML of wastewater a day, this equates to approximately 4 tonnes a day or over 1454 tonnes a year of nitrogen in the form of ammonia.

Impacts

High concentrations of nutrients (eutrophication) can lead to excessive algal growth. This can deplete oxygen concentrations at night and cause fish deaths; algae can also smother seagrass and other plants, making it difficult for them to survive. Some algal blooms contain toxins, and filter-feeding shellfish can accumulate these toxins in their body tissues. In addition, higher ammonia concentrations are toxic to plants and animals, especially fish.

Ammonia–N

Ammonia is a source of nitrogen to plants and algae but it can have direct toxic effects on marine organisms such as fish, invertebrates, algae and plants; however, it is not a persistent or cumulative toxin. Ammonia (NH_3) is a gas that can be dissolved in water; it occurs in equilibrium with the ionised form, ammonium (NH_4^+), and the equilibrium is dependent on pH, salinity and temperature. Although this section is entitled ammonia, we are really discussing the amount of nitrogen present as ammonia and ammonium, as the analytical test used here does not distinguish between the two forms.

Results

The least sheltered locations, sites 3 and 8, had substantially lower ammonia–N concentrations than other sites (Figure 15). Sites 3 and 8 were classified as moderate, and all other sites were poor (Table 17). Of the 476 samples collected, a substantial 42% exceeded the poor guideline and 54% fell into the moderate category, leaving only 4% of samples classed as good. Sites 1 and 9 had significantly greater concentrations than most other sites. Comparisons with the 1995–96 report are inappropriate, as analytical methodology has changed since that time. Before July 1996 measurements were taken with an ion-specific electrode, while now a far more accurate and sensitive colourimetric method is used.

Conclusions

The high ammonia–N concentrations in the Port River are a concern. Based on these figures there is enough nitrogen to promote substantial algal growth when other conditions are suitable. In much of the Port River the dominant form is probably the non-toxic ammonium ion but, given the high pH and temperature of the Penrice discharge, ammonia toxicity is certain to be an issue in the vicinity of the outfall.

A significant amount of ammonia is discharged from the Port Adelaide wastewater treatment plant and by Penrice Soda Products. Continuing implementation of environment improvement programs should reduce the amount of ammonia entering the Port River and reduce ambient concentrations.

Table 17 Statistical summary of ammonia–N at nine sites in the Port River estuary 1995–2000

	Mean (mg/L)	**95% confidence interval** (mg/L)	**Standard deviation** (mg/L)	**Median** (mg/L)	**10th percentile** (mg/L)	**90th percentile** (mg/L)	**Number of samples**	**Water quality classification** (a)	**Statistical site comparisons** (b)
Site 1	0.78	0.66—0.90	0.44	0.75	0.26	1.39	54	poor	Site 1>2,3,4,5,6,7,8
Site 2	0.47	0.39—0.55	0.30	0.42	0.10	0.79	54	poor	Site 2>3,8
Site 3	0.17	0.13—0.21	0.14	0.13	0.04	0.33	54	moderate	n.s.
Site 4	0.60	0.48—0.72	0.44	0.51	0.18	1.03	54	poor	Site 4>3,5,7,8
Site 5	0.52	0.44—0.59	0.28	0.50	0.11	0.91	54	poor	Site 5>3,7,8
Site 6	0.52	0.44—0.60	0.29	0.47	0.21	0.87	54	poor	Site 6>3,7,8
Site 7	0.38	0.32—0.45	0.25	0.31	0.10	0.72	54	poor	Site 7>3,8
Site 8	0.27	0.14—0.39	0.45	0.12	0.04	0.50	52	moderate	n.s.
Site 9	1.01	0.86—1.16	0.50	0.95	0.47	1.65	46	poor	Site 9>2,3,4,5,6,7,8

(a) Water quality classification is based on 90th percentile as follows-good: <0.05 mg/L; moderate: 0.05–0.5 mg/L; poor: >0.5 mg/L.

(b) Friedman probability: P <0.001-statistically significant differences between sites. For pairwise site comparisons n.s. signifies the site is not significantly greater than any other site. The > symbol indicates which sites the specified location is significantly greater than.

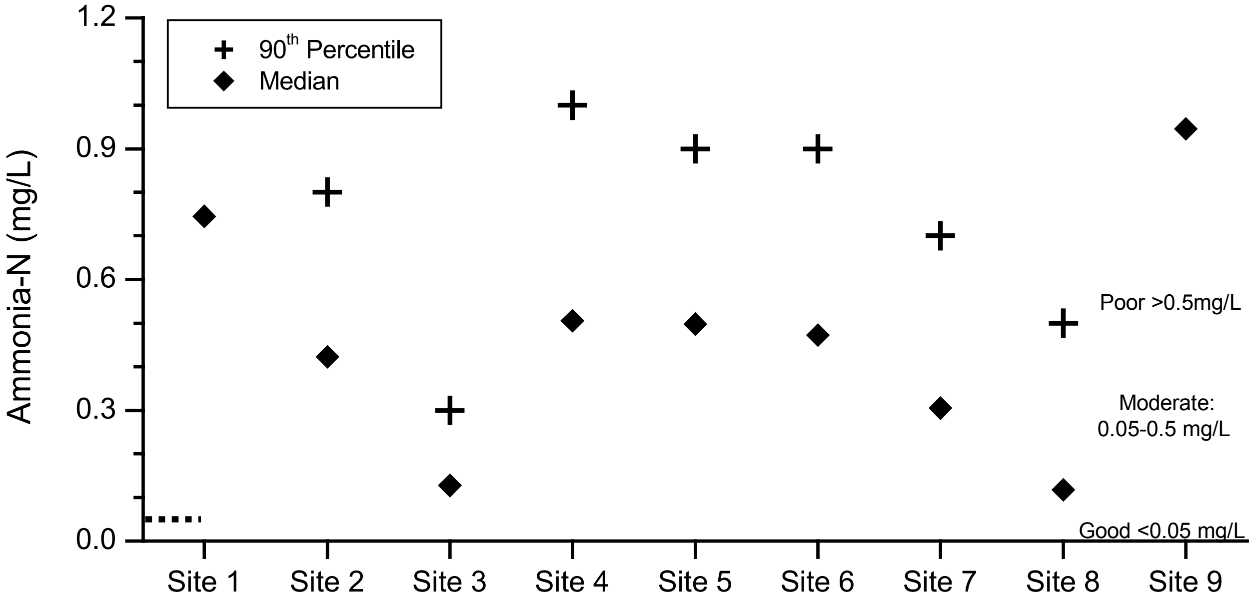


Figure 15 Median and 90th percentile ammonia–N at nine sites in the Port River estuary 1995–2000

Oxidised nitrogen

Oxidised nitrogen consists of the nitrogen present in a sample as nitrate (NO_3^-) and nitrite (NO_2^-). Biologically these two forms have the same consequence as they are both highly bioavailable forms of nitrogen. Nitrate tends to be much more common, as nitrite is readily oxidised to nitrate under aerobic environmental conditions.

Results

The oxidised nitrogen concentrations were lowest at sites 3 and 8, consistent with the ammonia–N data (Figure 16). Oxidised nitrogen concentrations were quite high and, based on the 90th percentile, all sites were classified as moderate (Table 18). From 306 samples, 3% exceeded the poor guideline and 84% fell into the moderate class, leaving only 11% in the good category. The more open sites (2, 3, 7 and 8) had significantly lower concentrations than most other sites, and sites 1, 4, 5, 6 and 9 had higher concentrations. Direct comparisons with the 1995–96 report cannot be made as oxidised nitrogen was not discussed in that report.

Conclusions

The high oxidised nitrogen concentrations in the Port River are a concern and, based on the combined nitrogen and ammonia figures, there is enough bioavailable nitrogen in the Port River to support a large amount of algal growth. Stormwater and the Port Adelaide wastewater treatment plant are probably the major sources of oxidised nitrogen concentrations. Discharge of ammonia will contribute to these high concentrations—in natural waters ammonia is readily transformed into nitrate and nitrite through oxidation.

Table 18 Statistical summary of oxidised nitrogen at nine sites in the Port River estuary 1997–2000

	Mean (mg/L)	**95% confidence interval** (mg/L)	**Standard deviation** (mg/L)	**Median** (mg/L)	**10th percentile** (mg/L)	**90th percentile** (mg/L)	**Number of samples**	**Water quality classification** (a)	**Statistical site comparisons** (b)
Site 1	0.60	0.52—0.67	0.21	0.56	0.36	0.83	34	moderate	Site 1>2,3,7,8
Site 2	0.35	0.29—0.42	0.18	0.32	0.12	0.54	34	moderate	Site 2>3,8
Site 3	0.12	0.08—0.15	0.10	0.09	0.02	0.23	34	moderate	n.s.
Site 4	0.60	0.51—0.70	0.27	0.57	0.27	0.93	34	moderate	Site 4>2,3,7,8
Site 5	0.64	0.55—0.74	0.27	0.65	0.34	0.95	34	moderate	Site 5>2,3,7,8
Site 6	0.59	0.50—0.68	0.26	0.56	0.25	0.85	34	moderate	Site 6>2,3,7,8
Site 7	0.46	0.36—0.56	0.29	0.46	0.10	0.77	34	moderate	Site 7>3,8
Site 8	0.21	0.14—0.28	0.21	0.14	0.01	0.51	34	moderate	n.s.
Site 9	0.55	0.46—0.63	0.24	0.49	0.30	0.81	34	moderate	Site 9>2,3,8

(a) Water quality classification is based on 90th percentile as follows-good: <0.1 mg/L; moderate: 0.1–1.0 mg/L; poor: >1.0 mg/L.

(b) Friedman probability: P <0.001-statistically significant differences between sites. For pairwise site comparisons n.s. signifies the site is not significantly greater than any other site. The > symbol indicates which sites the specified location is significantly greater than.

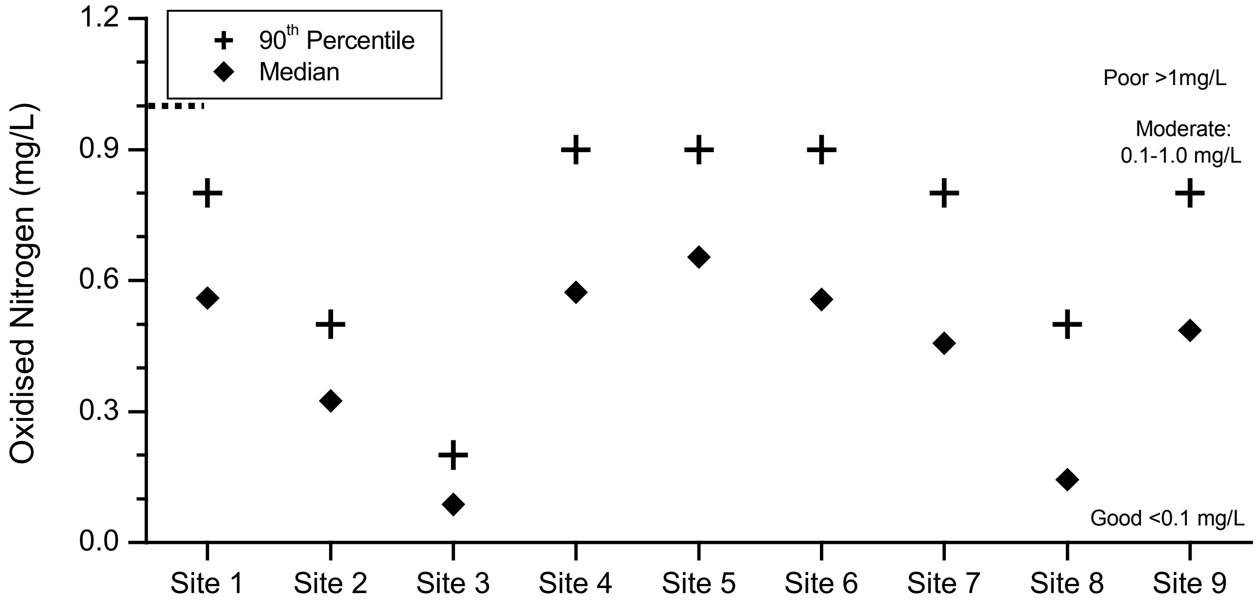


Figure 16 Median and 90th percentile oxidised nitrogen at nine sites in the Port River estuary 1997–2000

Total Kjeldahl nitrogen (TKN)

The total Kjeldahl method determines the amount of soluble and particulate organic nitrogen along with the ammonia nitrogen present in a sample. Total nitrogen can be determined by adding the TKN and oxidised nitrogen concentrations, and organic nitrogen can be determined by subtracting the ammonia nitrogen values from the TKN concentrations. Organic nitrogen is not immediately bioavailable to algae but it provides a store of nitrogen that may be available in the medium to long term. Some chemical and microbiological processes will convert organic nitrogen into ammonium, nitrate or nitrite, rendering it bioavailable to algae. During times of algal blooms high TKN values may be due to nitrogen present in algal cells.

Results

Median TKN concentrations were noticeably lower at sites 3 and 8 than at other sites (Figure 17). Of all sites only site 3 was classified as good and the remainder of sites were considered moderate (Table 19). Site 8 declined from a good reading in 1995–96. Of the 475 samples collected, none exceeded the poor guideline while 32% fell into the moderate category. Sites 1, 4 and 9 had significantly higher TKN readings than many other sites, while sites 3 and 8 had significantly lower readings than most other sites.

Conclusions

Given the considerable nitrogen inputs to the Port River from stormwater and industry, it is not surprising that most sites had moderate TKN concentrations. Further improvements in point source discharges and better control of diffuse pollution in catchments are required to improve this situation.

Table 19 Statistical summary of TKN at nine sites in the Port River estuary 1995–2000

	Mean (mg/L)	**95% confidence interval** (mg/L)	**Standard deviation** (mg/L)	**Median** (mg/L)	**10th percentile** (mg/L)	**90th percentile** (mg/L)	**Number of samples**	**Water quality classification** (a)	**Statistical site comparisons** (b)
Site 1	1.15	1.02—1.29	0.50	1.10	0.69	1.68	53	moderate	Site 1>2,3,4,5,6,7,8,
Site 2	0.79	0.66—0.91	0.46	0.72	0.34	1.25	54	moderate	Site 2>3,8
Site 3	0.55	0.30—0.80	0.92	0.35	0.20	0.79	54	good	n.s.
Site 4	1.02	0.83—1.21	0.69	0.87	0.50	1.47	54	moderate	Site 4>2,3,5,7,8
Site 5	0.86	0.75—0.96	0.38	0.81	0.50	1.27	54	moderate	Site 5>3,8
Site 6	0.87	0.77—0.98	0.39	0.84	0.49	1.37	54	moderate	Site 6>3,7,8
Site 7	0.81	0.70—0.91	0.38	0.71	0.50	1.28	54	moderate	Site 7>3,8
Site 8	0.61	0.47—0.75	0.51	0.42	0.23	1.14	53	moderate	Site 8>3
Site 9	1.48	1.31—1.65	0.57	1.45	0.85	2.06	45	moderate	Site 9>all other sites

(a) Water quality classification is based on 90th percentile as follows-good: <1.0 mg/L; moderate: 1.0–10.0 mg/L; poor: >10.0 mg/L.

(b) Friedman probability: P <0.001-statistically significant differences between sites. For pairwise site comparisons n.s. signifies the site is not significantly greater than any other site. The > symbol indicates which sites the specified location is significantly greater than.

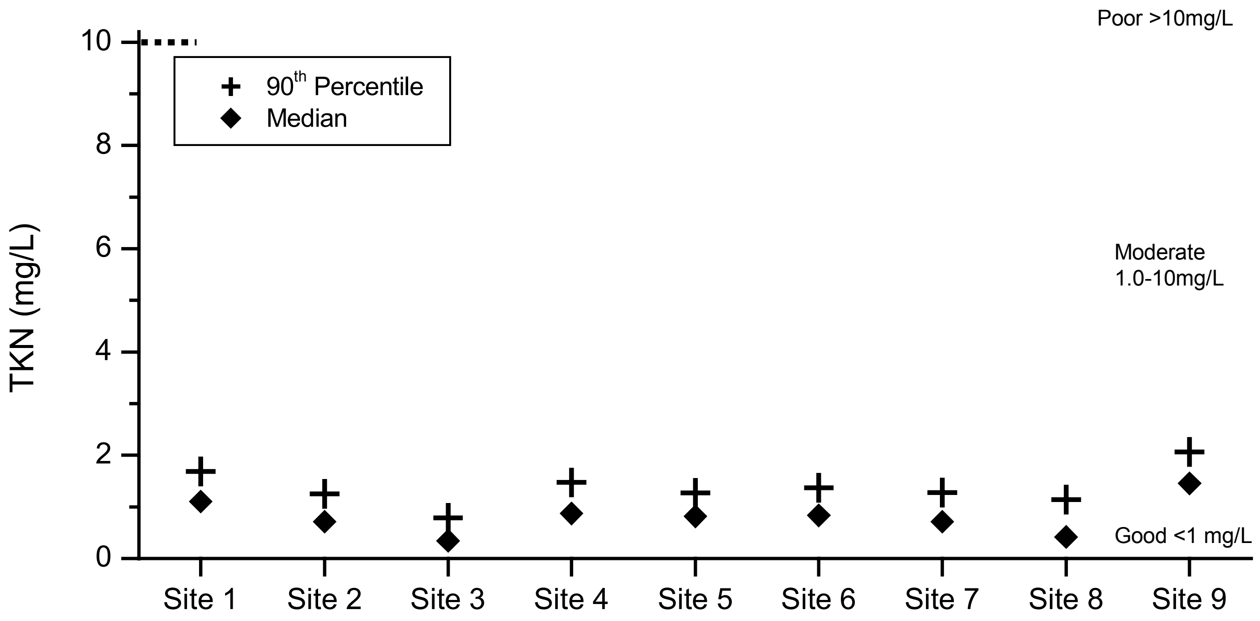


Figure 17 Median and 90th percentile TKN at nine sites in the Port River estuary 1995–2000

Total phosphorus

Phosphorus is an essential element for algal growth although, by mass, algae only require about one-sixth the amount of phosphorus they do of nitrogen. Soluble and particulate forms of organic and inorganic phosphorus are included in this measure. The inorganic phosphate ion (PO_4^{2-}) is the most bioavailable form of phosphorus, although it readily adsorbs onto clay particles and other minerals. Phosphorus can be deposited to the sediments by this process. Many bacteria can break down some organic forms of phosphorus using extra-cellular enzymes, so organic phosphorus may be more bioavailable in the short term than organic nitrogen.

Results

There was significant variability in median total phosphorus concentrations, with site 9 being noticeably higher than other sites (Figure 18). Sites 3 and 5 had good water quality, while the remaining sites were classified as moderate (Table 20). This was an improvement on the 1995–96 data, when all nine sites were moderate. In line with this, medians dropped at all sites except site 9. Of the 477 samples collected, none exceeded the poor guideline of 1.0 mg/L and only 26% fell into the moderate band. There were statistically significant differences between sites, with sites 2, 3 and 8 generally lower than other sites and sites 1 and 9 higher than all other sites.

Conclusions

The high total phosphorus readings of sites 9 and 1 were probably due to their close proximity to the Port Adelaide wastewater treatment plant. Sites 4–7 also had high median concentrations, perhaps due to the numerous stormwater and riverine inputs on the eastern side of the Port River estuary.

Table 20 Statistical summary of total phosphorus at nine sites in the Port River estuary 1995–2000

	Mean (mg/L)	**95% confidence interval** (mg/L)	**Standard deviation** (mg/L)	**Median** (mg/L)	**10th percentile** (mg/L)	**90th percentile** (mg/L)	**Number of samples**	**Water quality classification** (a)	**Statistical site comparisons** (b)
Site 1	0.12	0.10—0.15	0.10	0.09	0.06	0.25	54	moderate	Site 1>2,3,4,5,6,7,8
Site 2	0.06	0.05—0.08	0.06	0.04	0.02	0.10	54	moderate	Site 2>3
Site 3	0.06	0.03—0.08	0.08	0.03	0.02	0.09	54	good	n.s.
Site 4	0.09	0.07—0.12	0.08	0.07	0.05	0.13	54	moderate	Site 4>2,3,8
Site 5	0.09	0.07—0.12	0.10	0.07	0.04	0.10	54	good	Site 5>2,3,8
Site 6	0.10	0.07—0.14	0.13	0.07	0.05	0.12	54	moderate	Site 6>2,3,8
Site 7	0.09	0.07—0.11	0.09	0.07	0.04	0.11	54	moderate	Site 7>2,3,8
Site 8	0.06	0.04—0.08	0.06	0.04	0.02	0.11	53	moderate	n.s.
Site 9	0.17	0.14—0.20	0.10	0.16	0.04	0.30	46	moderate	Site 9>all other sites

(a) Water quality classification is based on 90th percentile as follows-good: <0.1 mg/L; moderate: 0.1–1.0 mg/L; poor: >1.0 mg/L.

(b) Friedman probability: P <0.001-statistically significant differences between sites. For pairwise site comparisons n.s. signifies the site is not significantly greater than any other site. The > symbol indicates which sites the specified location is significantly greater than.

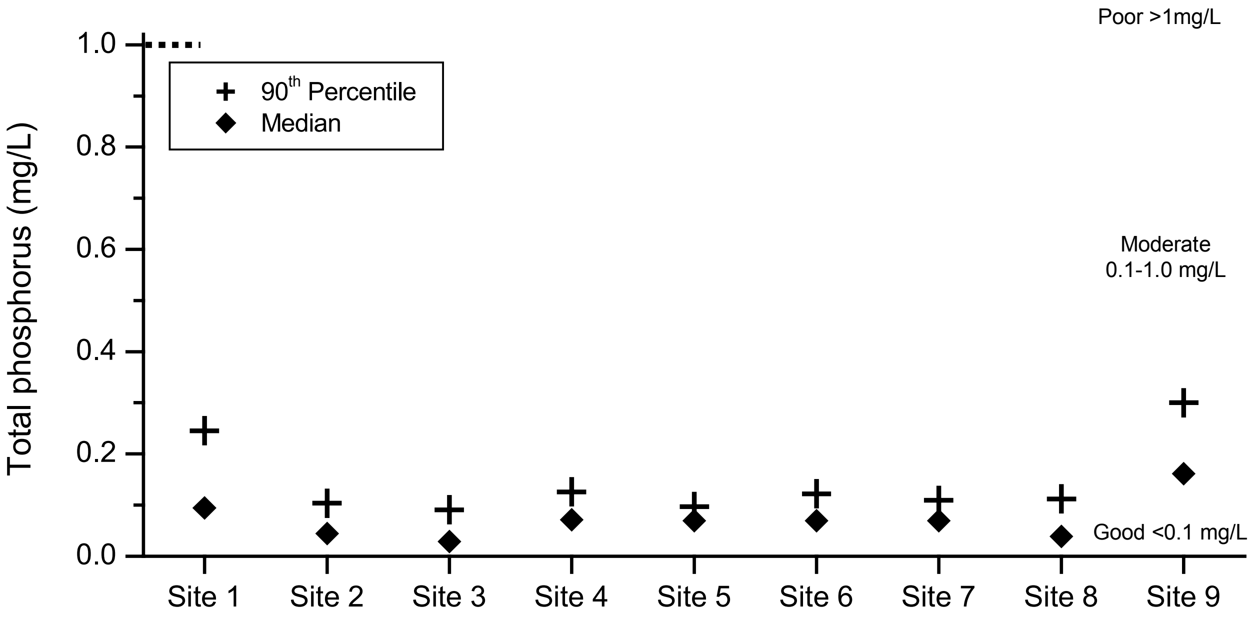


Figure 18 Median and 90th percentile total phosphorus at nine sites in the Port River estuary 1995–2000

Summary of nutrients

The water quality classifications for nutrients show that 8% of ratings were good, 72% moderate and 19% were poor. Ammonia was poor at most sites while the other nutrients were mainly moderate (Table 21).

The nutrient load entering the Port River from the two major point sources, the Port Adelaide wastewater treatment plant and Penrice Soda Products, is substantial and is reflected in the poor and moderate rankings of sites 1, 2 and 9. It is likely that the nutrient contribution from diffuse sources, such as stormwater, is also significant. This may be reflected in the poor and moderate rankings of sites 4, 5, 6 and 7.

Table 21 Summary of water quality classifications for nutrients in the Port River 1995–2000

	Ammonia	Oxidised Nitrogen	TKN	Total phosphorus
Site 1	poor	moderate	moderate	moderate
Site 2	poor	moderate	moderate	moderate
Site 3	moderate	moderate	good	good
Site 4	poor	moderate	moderate	moderate
Site 5	poor	moderate	moderate	good
Site 6	poor	moderate	moderate	moderate
Site 7	poor	moderate	moderate	moderate
Site 8	moderate	moderate	moderate	moderate
Site 9	poor	moderate	moderate	moderate

The absence of oxidised nitrogen from the last report and a change in analytical technique for ammonia mean that comparisons in the performance of these parameters between the current and previous report are not possible. The TKN classification at site 8 declined from good to moderate, while the total phosphorus classification improved from moderate to good at sites 3 and 5.

The high ammonia and oxidised nitrogen concentrations are a significant issue for the Port River as these forms of nitrogen are highly bioavailable and can promote nuisance algal growth. A recent study of the Port River has shown that there is no shortage of phosphorus or nitrogen so these nutrients do not appear to limit algal growth along the main channel (Ault *et al.*, 2000). This is not surprising, given the large loads of these nutrients being discharged into the river.

However, lack of nitrogen was found to limit algal growth in Outer Harbor, a site that is closer to open waters and further from the main nutrient discharge points. This suggests that, historically, lack of nitrogen may have limited algal growth in the river and that the current discharge of large nutrient loads into the river are responsible for the high chlorophyll *a* concentrations reported in the next section (3.4). Therefore, it is likely that a reduction in the amount of nitrogen and phosphorus entering the Port River would reduce the incidence of algal problems, and may lead to an improvement in the chlorophyll *a* concentrations in the river. Environment improvement programs by industry and the development of wetlands to treat stormwater may lead to improvements in the nutrient status of the Port River.

3.4 Algae

Algae are a fundamental part of aquatic systems; they form the base of the food chain that marine ecosystems need to function. Although estimates vary, it is likely that planktonic algae in the upper layers of the ocean carry out over half the primary production on earth. Algae use photosynthesis to produce organic matter from inorganic matter. This requires energy in the form of light, carbon from carbon dioxide, hydrogen from water, and various nutrients. The by-product of this reaction is oxygen.

Despite the importance of algae, they can be a problem if they occur in high numbers and form algal blooms. Their growth can be increased by human impacts such as increases in nutrient loads and thermal pollution. Algae can degrade aesthetic values and recreational safety by reducing water clarity, and some species produce toxins than can bioaccumulate in shellfish, leading to restrictions on the harvesting of these animals.

Algae can impair seagrass survival by shading, competing for resources and physically smothering them. Loss of seagrass reduces seabed stability, promoting erosion and loss of vital habitat for fish and invertebrates.

Blooms of dinoflagellates, a type of planktonic algae, cause the 'red tides' or algal blooms that are frequently observed in the Port River. Optimal conditions for blooms are sufficient nutrients in conjunction with calm, stratified conditions, and optimal water temperature and salinity. A subsurface bloom occurs for six to nine months each year in the river at 3–4 metres depth. When the subsurface bloom rises towards the surface, the water appears red.

Chlorophyll *a*

Algal abundance can be estimated using a number of methods, including cell counts and pigment analysis. The relationship between chlorophyll *a* and algal biomass is not perfect but chlorophyll *a* is the major photosynthetic pigment in algae, and it provides a good indicator of the amount of algae in the water.

Results

Six sites were classified as poor, one more than in the 1995–96 report, while the remaining three were moderate (Table 22). The median and 90th percentile values at sites 9 and 1 were substantially higher than at the remaining sites (Figure 19). Of 477 measurements only 26 (5%) were less than the lower guideline of 0.1 µg/L, while 371 (78%) fell into the moderate band and 80 sites (17%) exceeded the upper guideline of 10 µg/L. From a statistical viewpoint sites 9 and 1 were also significantly higher than all other sites. Median and 90th percentile chlorophyll concentrations had increased at the majority of sites since the 1995–96 report.

Conclusions

Calm, sheltered estuarine conditions, long daylight hours in summer, and median temperatures of 18°C or higher for eight months of the year provide a habitat conducive to algal growth. The chemical requirements of the algae are provided by high nutrient concentrations from wastewater, industrial and stormwater discharges. Given these factors, it is not surprising that chlorophyll concentrations were high in the Port River estuary. The two main nutrient point sources, the Port Adelaide wastewater treatment plant and the Penrice Soda Products plant, encouraged the growth of algae by providing substantial amounts of bioavailable nutrients, particularly nitrogen, to the river.

Table 22 Statistical summary of chlorophyll *a* at nine sites in the Port River estuary 1995–2000

	Mean (µg/L)	95% confidence interval (µg/L)	Standard deviation (µg/L)	Median (µg/L)	10th percentile (µg/L)	90th percentile (µg/L)	Number of samples	Water quality classification (a)	Statistical site comparisons (b)
Site 1	12.6	8.4—16.8	15.4	7.5	1.0	34.7	54	poor	Site 1>2,3,4,5,6,7,8,
Site 2	7.1	3.8—10.4	12.0	3.1	1.0	14.7	54	poor	Site 2>3
Site 3	3.4	2.2—4.5	4.2	2.3	1.0	6.4	54	moderate	n.s.
Site 4	5.4	3.4—7.3	7.1	2.1	0.8	16.1	54	poor	n.s.
Site 5	3.8	2.4—5.1	4.9	1.9	0.8	7.2	54	moderate	n.s.
Site 6	5.2	3.3—7.1	6.9	2.3	1.0	15.8	54	poor	Site 6>5
Site 7	4.3	2.8—5.8	5.5	2.4	1.0	11.7	54	poor	n.s.
Site 8	4.3	2.8—5.8	5.4	2.6	1.0	8.5	53	moderate	n.s.
Site 9	28.6	10.3—47.0	61.8	9.4	1.0	67.0	46	poor	Site 9>2,3,4,5,6,7,8

(a) Water quality classification is based on 90th percentile as follows-good: <1.0 µg/L; moderate: 1.0–10.0 µg/L; poor: >10.0 µg/L.

(b) Friedman probability: P <0.001-statistically significant differences between sites. For pairwise site comparisons n.s. signifies the site is not significantly greater than any other site. The > symbol indicates which sites the specified location is significantly greater than.

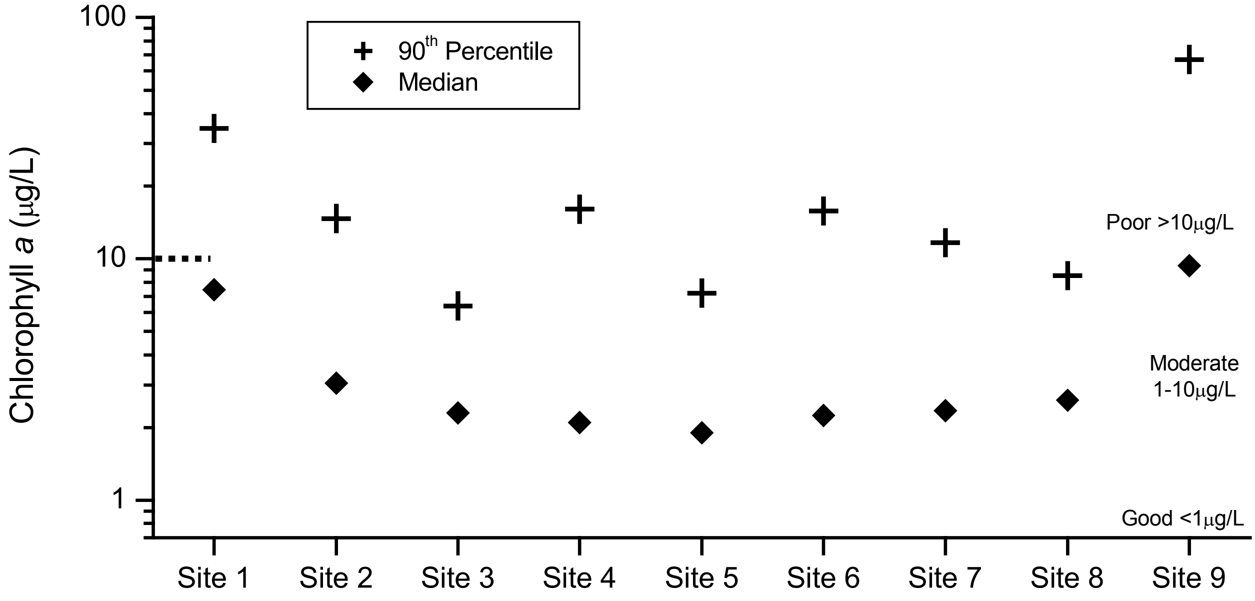


Figure 19 Median and 90th percentile chlorophyll *a* at nine sites in the Port River estuary 1995–2000

3.5 Microbiology

'Environmental' micro-organisms are ubiquitous and occur in very high numbers. Many of these organisms play essential roles in the cycling of nutrients, energy and carbon in aquatic ecosystems. Many higher animals use them as a food source. Micro-organisms are a fundamental component of a healthy aquatic environment.

However, there are also some undesirable micro-organisms. Some bacteria, viruses and protozoans are disease causing, or pathogenic. Unfortunately, it is difficult to isolate, culture and identify many of these pathogens so we use indicator microbes to determine microbiological water quality. Faecal coliforms, *Escherichia coli* (*E. coli*), faecal streptococci and enterococci all occur in the digestive tracts of warm blooded animals and are good indicators of the risk of more dangerous pathogens.

We have assessed the water quality of the Port River against the National Health and Medical Research Council primary contact guidelines (NHMRC, 1990). These are designed to protect people coming into direct contact with water through activities such as swimming, bathing and diving. As discussed in Section 2.3, the skewed distribution of many microbiological data sets means that we use the geometric mean and confidence interval instead of the arithmetic mean and confidence interval.

Sources

The original source of these organisms is faecal contamination, generally from humans or other mammals and birds. Wastewater and sewage outfalls, stormwater from creeks and drains, septic tank leaks and boats can transfer this contamination to natural waters. The discharge from the Port Adelaide wastewater treatment plant is chlorinated but this does not eliminate all bacteria. Monitoring from 1998–2001 showed that the median concentrations of *E. coli* in the discharge were a low 4–5 organisms/100 mL. However, about 10% of all samples collected in this time exceeded 150 organisms/100 mL, with 1300 organisms/100 mL the highest reading recorded.

Impacts

These organisms are indicators of the possible presence of pathogens that commonly cause gastrointestinal, eye, ear, nose and throat infections. Examples of these include viruses, bacteria including *Salmonella* and *Hepatitis,* and protozoa such as *Cryptosporidium* and *Giardia.* These pathogens can be taken up through ingestion, inhalation or breaks in the skin.

Faecal coliforms

Faecal coliforms are found in large numbers in the intestinal tract of humans and other warm-blooded animals. While some faecal coliforms may be of environmental origin, they are a good indicator of recent faecal contamination. They die off more rapidly in marine waters than some other micro-organisms such as viruses and protozoa.

Results

Median and 90th percentile faecal coliform counts were very low compared to the NHMRC guideline (Figure 20). All sites were classified as good on the basis of faecal coliform concentrations, although sites 3, 4, 5 and 6 exceeded the upper limit of 600 organisms/100 mL on one occasion each (Table 23). Out of 465 measurements only 9 exceeded 150 cells/100 mL, showing that cell counts are below the guideline most of the time. The median and 90th percentile scores had increased slightly since the 1995–96 report but were still very low. There were statistically significant differences between sites—site 9 has higher concentrations than four other sites and site 2 is significantly lower than five other sites.

Conclusions

Faecal coliform concentrations were generally low and indicated good water quality at our sampling points.

Table 23 Statistical summary of faecal coliforms at nine sites in the Port River estuary 1995–2000

Site	Geometric mean (organisms/100 mL)	95% Confidence interval GM_L–GM_U (organisms/100 mL)	Median (organisms/100 mL)	10th percentile (organisms/100 mL)	90th percentile (organisms/100 mL)	Number of samples	Samples with ≥60 organisms per 100 mL	Water quality classification (a)	Statistical site comparisons (b)
1	3.1	2.0–4.5	2.0	1.0	10.8	53	0	good	n.s.
2	1.9	1.2–2.7	1.0	0.0	5.9	52	0	good	n.s.
3	4.7	3.2–6.6	5.0	1.0	13.7	52	1	good*	Site 3>2
4	4.2	2.9–6.0	4.0	1.0	13.0	52	1	good*	Site 4>2
5	4.6	3.1–6.5	3.0	1.0	19.8	52	1	good*	Site 5>2
6	5.0	3.5–7.0	5.0	1.0	12.0	53	1	good*	Site 6>2
7	5.4	3.8–7.5	4.5	1.0	21.7	52	0	good	n.s.
8	2.5	1.6–3.7	1.0	0.0	21.6	53	0	good	n.s.
9	9.9	6.9–14.0	11.0	2.0	28.0	46	0	good	Site 9>2,4,6,7

(a) Water quality classification is based on 90th percentile as follows-good: 90th percentile ≤150/100 mL; moderate: 90th percentile >150/100 mL but median ≤150/100 mL; poor: median ≥150/100 mL or more than 1/5 samples exceed 600 organisms/100 mL. *Good, but occasional samples exceed 600 organisms/100 mL.

(b) Friedman probability: P <0.001-statistically significant differences between sites. For pairwise site comparisons n.s. signifies the site is not significantly greater than any other site. The > symbol indicates which sites the specified location is significantly greater than.

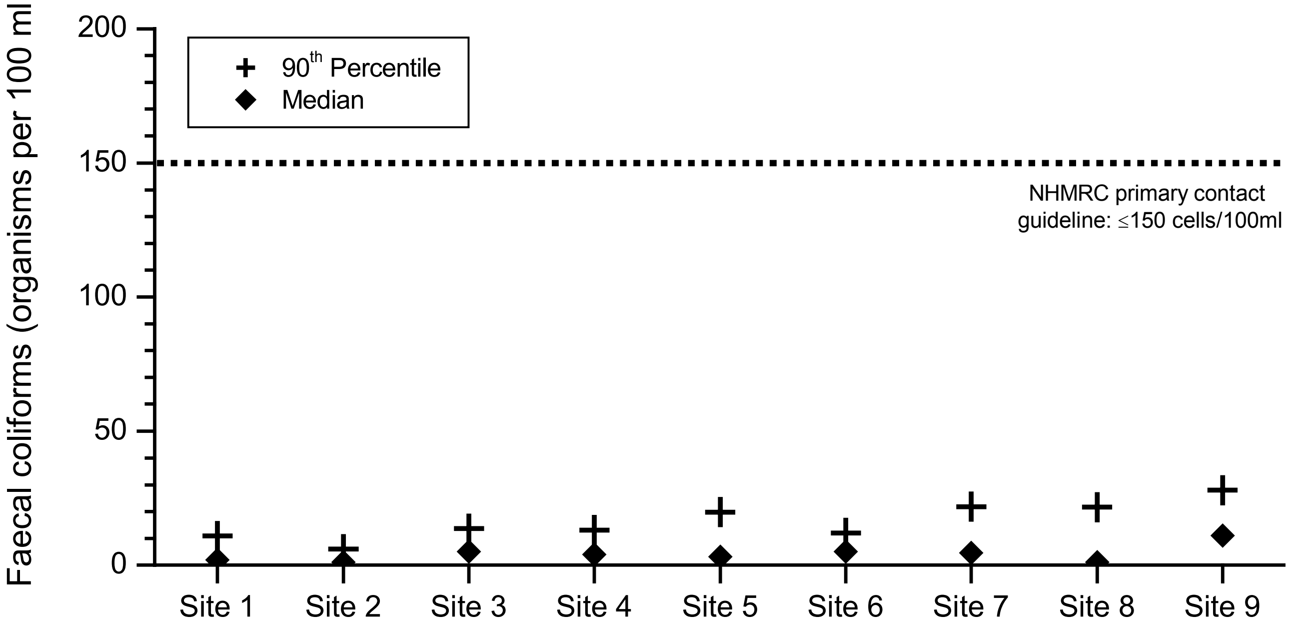


Figure 20 Median and 90th percentile faecal coliforms at nine sites in the Port River estuary 1995–2000

Escherichia coli

E. coli is a major subset of faecal coliforms, making up about 97% of all faecal coliform bacteria in human faecal matter.

Results

E. coli counts were well below the NHMRC guideline at all sites (Figure 21). All sites were classified as good and no samples exceeded the 600 organism/100 mL maximum criterion; in fact, only one sample of a total of 161 exceeded the 150 organism/100 mL guideline (Table 24).

Statistically, sites 4 and 5 were both significantly greater than site 2. As *E. coli* sampling only began in February 1999 we cannot compare these results to the 1995–96 report.

Conclusions

The *E. coli* results indicated good water quality at all sites.

Table 24 Statistical summary of *E. coli* at nine sites in the Port River estuary 1999–2000

Site	**Geometric mean** (organisms/100 mL)	**95% Confidence interval GM_L–GM_U** (organisms/100 mL)	**Median** (organisms/100 mL)	**10th percentile** (organisms/100 mL)	**90th percentile** (organisms/100 mL)	**Number of samples**	**Samples with ≥60 organisms per 100 mL**	**Water quality classification** (a)	**Statistical site comparisons** (b)
1	4.3	2.2—7.7	3.5	1.0	13.8	18	0	good	n.s.
2	1.3	0.7—2.0	1.0	0.0	4.3	18	0	good	n.s.
3	3.9	2.4—6.2	4.5	1.0	9.5	18	0	good	n.s.
4	4.9	3.1—7.4	5.0	1.7	12.7	18	0	good	Site 4>2
5	6.1	4.0—9.0	5.5	2.0	16.0	18	0	good	Site 5>2
6	5.4	3.4—8.3	5.0	2.0	14.4	18	0	good	n.s.
7	6.2	3.0—11.8	5.0	1.6	15.2	17	0	good	n.s.
8	2.3	0.8—4.9	1.0	0.0	18.6	18	0	good	n.s.
9	7.5	4.0—13.6	9.0	1.0	37.5	18	0	good	n.s.

(a) Water quality classification is based on 90th percentile as follows-good: 90th percentile ≤150/100 mL; moderate: 90th percentile >150/100 mL but median ≤150/100 mL; poor: median ≥150/100 mL or more than 1/5 samples exceed 600 organisms/100 mL.

(b) Friedman probability: P <0.001-statistically significant differences between sites. For pairwise site comparisons n.s. signifies the site is not significantly greater than any other site. The > symbol indicates which sites the specified location is significantly greater than.

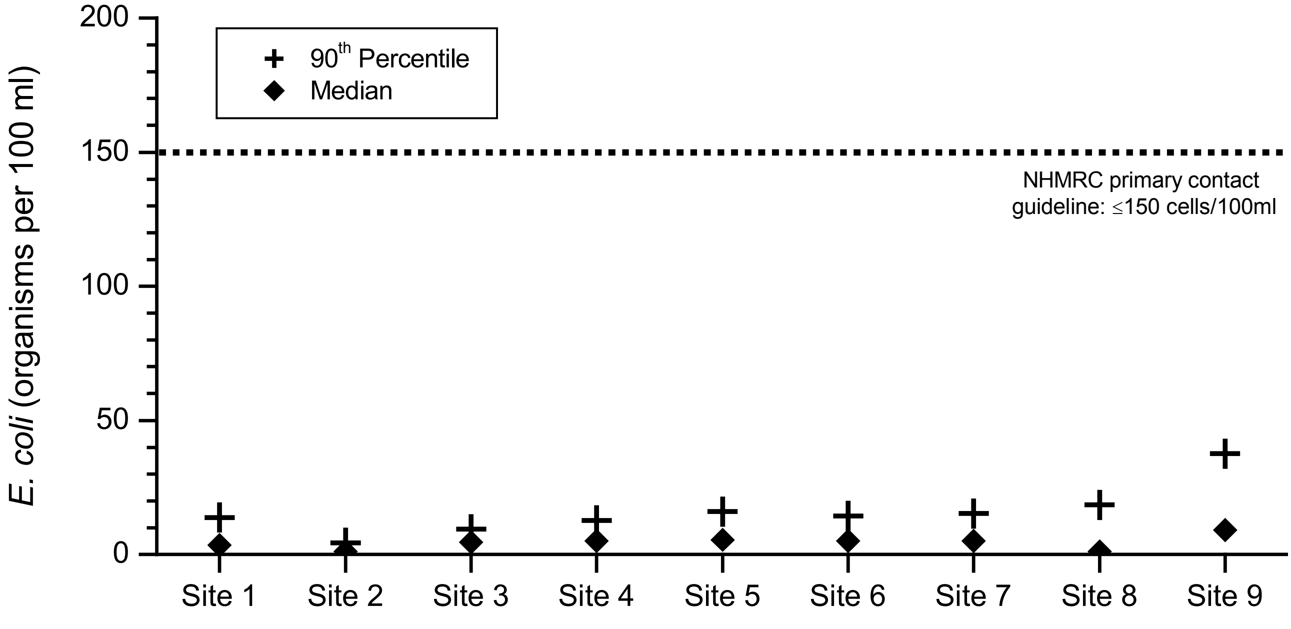


Figure 21 Median and 90th percentile *E. coli* at nine sites in the Port River estuary 1999–2000

Faecal streptococci

Faecal streptococci occur in the faeces of humans and other animals. Faecal streptococci are less abundant than faecal coliforms in humans but in other animals this may be reversed. Not all faecal streptococci can be reliably associated with the gut, so the presence of faecal streptococci suggests faecal contamination but not with the same certainty as faecal coliforms. However, faecal streptococci are more persistent in water than faecal coliforms, so they are a better indicator of the presence of pathogens, such as some viruses, that also die off slowly.

There is no NHMRC guideline for faecal streptococci but the enterococci guideline of 33 organisms per 100 mL has been used to allow comparison. Enterococci are a subset of faecal streptococci and in this monitoring program the majority of faecal streptococci were enterococci. Overall, 97% of the faecal streptococci collected were enterococci and for 91% of the samples collected faecal streptococci were entirely composed of enterococci.

Results

The 90th percentile cell counts varied across sites, with site 9 being noticeably higher than other sites (Figure 22). On the basis of the median and 90th percentile data, site 9 was classified as moderate while all other sites were good. However, sites 1, 5, 6, 7, 8 and 9 had individual samples that exceeded the maximum count of 60 organisms/100 mL, relegating them to a poor status (Table 25). Of a total of 476 readings, 38 samples exceeded the 33 organism/100 mL guideline, and 20 exceeded the 60 organism/100 mL upper limit, three of these by a factor of ten or greater. Compared to the 1995–96 report the median and 90th percentiles had increased, in some cases substantially, and 18 of the 20 exceedences of the 60 organism/100 mL guideline occurred since that time. There were statistically significant differences between sites—site 9 was higher than sites 2, 3 and 8, while site 2 was lower than sites 5, 6, 7 and 9.

Conclusions

These results suggest a worsening of the microbiological water quality in the Port River since 1995–1996. This was not reflected in the faecal coliform results but it may be due to the greater longevity of faecal streptococci in marine waters. Stormwater outlets and rivers discharging into the eastern side of the Port River estuary may have been responsible for the poor classifications of sites 5–8, and it is likely that output from the Port Adelaide wastewater treatment plant contributed to the poor classification of sites 1 and 9.

Table 25 Statistical summary of faecal streptococci at nine sites in the Port River estuary 1995–2000

Site	**Geometric mean** (organisms/100 mL)	**95% Confidence interval GM_L–GM_U** (organisms/100 mL)	**Median** (organisms/100 mL)	**10th percentile** (organisms/100 mL)	**90th percentile** (organisms/100 mL)	**Number of samples**	**Samples with ≥60 organisms per 100 mL**	**Water quality classification** (a)	**Statistical site comparisons** (b)
1	6.5	4.3–9.6	5.0	1.0	20.8	54	4	poor	n.s.
2	3.4	2.4–4.7	3.0	0.2	10.0	53	0	good	n.s.
3	5.8	4.2–7.8	6.0	1.0	21.7	54	0	good	n.s.
4	5.9	4.6–7.6	6.5	1.0	18.0	54	0	good	n.s.
5	7.2	5.2–9.9	7.0	1.0	27.5	54	2	poor	Site 5>2
6	8.7	6.4–11.8	9.0	1.0	25.0	54	3	poor	Site 6>2
7	9.1	6.5–12.6	8.0	1.3	29.7	54	4	poor	Site 7>2
8	3.7	2.5–5.5	3.0	0.2	15.8	53	2	poor	n.s.
9	14.0	9.4–20.6	10.5	3.0	56.5	46	5	poor	Site 9>2,3,8

(a) There is no guideline for faecal streptococci but the enterococci guideline has been used for comparison. Water quality classification is based on 90th percentile as follows-good: 90th percentile ≤33/100 mL; moderate: 90th percentile >33/100 mL but median ≤33/100 mL; poor: median ≥33/ 100 mL or any sample exceeds 60 organisms/100 mL.

(b) Friedman probability: P =<0.000-statistically significant differences between sites. For pairwise site comparisons n.s. signifies the site is not significantly greater than any other site. The > symbol indicates which sites the specified location is significantly greater than.

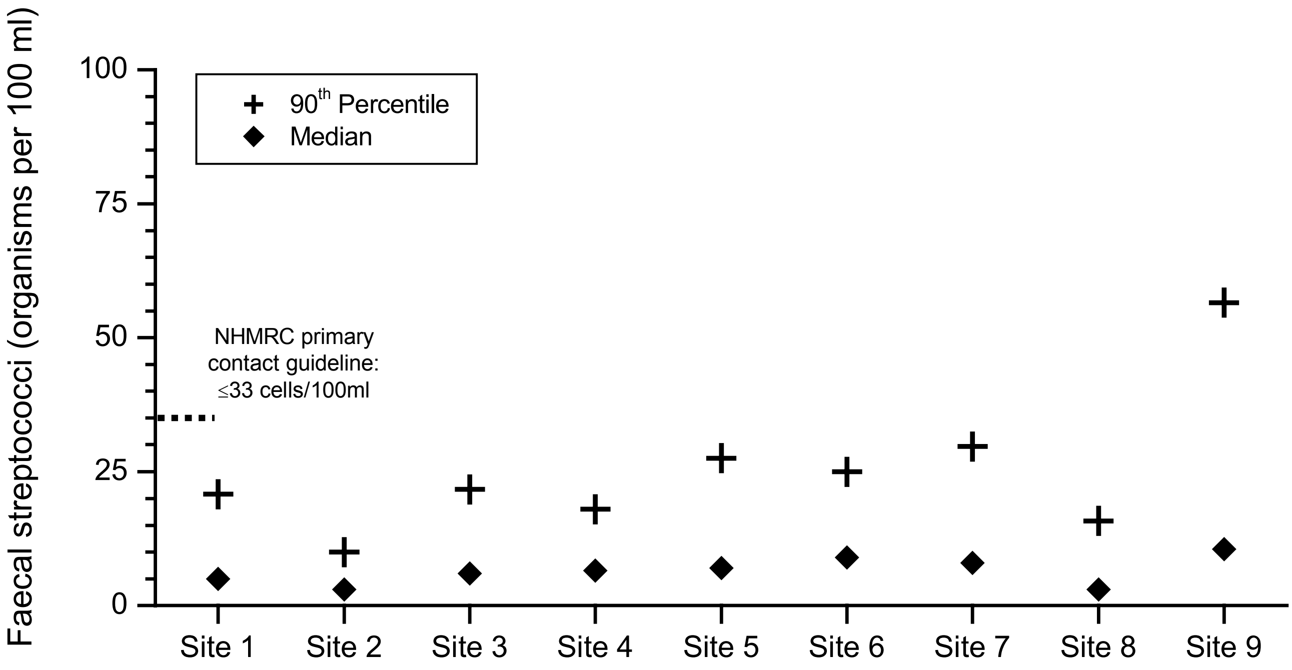


Figure 22 Median and 90th percentile faecal streptococci at nine sites in the Port River estuary 1995–2000

Enterococci

Enterococci are a more specific indicator of faecal contamination than faecal streptococci. They have longer survival times in the environment than faecal coliforms, and are a useful indicator in marine waters where faecal pollution is suspected but faecal coliforms are either absent or present in low numbers.

Results

There was substantial variability in median and 90th percentile enterococci counts, with low values at sites 8 and 2, and higher values at sites 7 and 9 (Figure 23). On the basis of median and 90th percentile values sites 7 and 9 were moderate and the remaining sites were good, but sites 1, 5, 6, 7 and 9 were classified as poor due to exceedences of the 60 organism/100 ml upper limit (Table 26). Of 369 samples collected, 25 exceeded the 33 organism/100 ml guideline and 14 exceeded the 60 organism/100 ml upper limit, two of these by a factor of ten or greater. Median and 90th percentiles had increased at all sites since 1995–96 (site 9 was not sampled until July 1997).

Conclusions

As for faecal streptococci, the enterococci results suggest a decline in microbiological water quality since the last report. As enterococci are specific to the gut, these results suggest this contamination is of animal origin. Stormwater outlets and rivers discharging into the eastern side of the Port River estuary may have been responsible for the poor classifications of sites 5–7, and it is likely that output from the Port Adelaide wastewater treatment plant contributed to the poor classification of sites 1 and 9.

Table 26 Statistical summary of enterococci at nine sites in the Port River estuary 1995–2000

Site	Geometric mean (organisms/100 mL)	95% Confidence interval GM_L–GM_U (organisms/100 mL)	Median (organisms/100 mL)	10th percentile (organisms/100 mL)	90th percentile (organisms/100 mL)	Number of samples	Samples with ≥60 organisms per 100 mL	Water quality classification (a)	Statistical site comparisons (b)
1	7.2	4.4–11.4	5.0	1.0	17.8	42	4	poor	Site 1>2
2	2.9	2.0–3.9	3.0	0.0	8.0	42	0	good	n.s.
3	5.8	4.1–8.1	6.0	1.0	21.9	42	0	good	n.s.
4	6.2	4.7–8.1	6.5	1.1	17.7	42	0	good	Site 4>2
5	6.8	4.7–9.7	6.5	1.0	28.5	42	1	poor	Site 5>2
6	7.4	5.1–10.4	8.0	1.0	21.9	42	2	poor	Site 6>2
7	9.7	6.5–14.1	7.5	2.0	34.4	42	4	poor	Site 7>2,8
8	2.8	1.9–4.2	2.0	0.0	13.0	41	0	good	n.s.
9	11.8	7.8–17.6	9.5	3.0	45.1	34	3	poor	Site 9>2,8

(a) Water quality classification is based on 90th percentile as follows-good: 90th percentile ≤33/100 mL; moderate: 90th percentile >33/100 mL but median ≤33/100 mL; poor: median ≥33/ 100 mL or any sample exceeds 60 organisms/100 mL.

(b) Friedman probability: P =<0.000-statistically significant differences between sites. For pairwise site comparisons n.s. signifies the site is not significantly greater than any other site. The > symbol indicates which sites the specified location is significantly greater than.

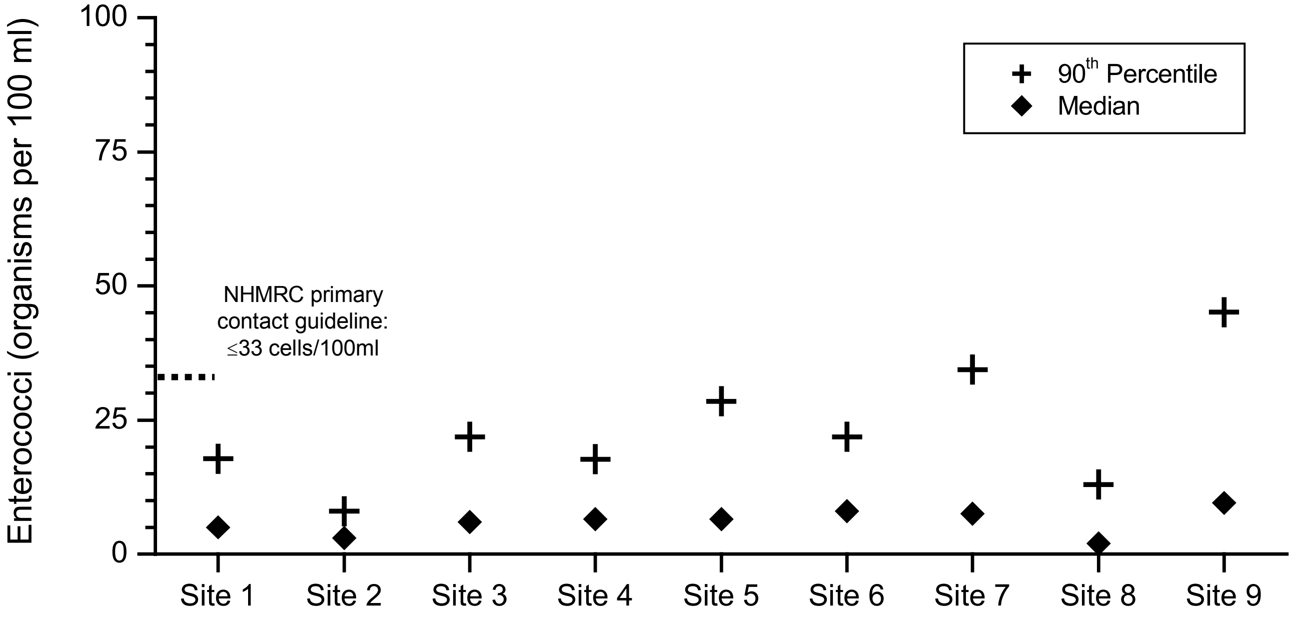


Figure 23 Median and 90th percentile enterococci at nine sites in the Port River estuary 1995–2000

Summary of biological parameters

The classification of biological parameters shows that 45% of ratings are good, 7% are moderate and 38% are poor. Chlorophyll is poor at one-third and moderate at two-thirds of the sites (Table 27), which is one poor site more than the last report. The poor nutrient status of the Port River is likely to be a significant factor in this problem.

Table 27 Summary of water quality classifications for biological parameters in the Port River 1995–2000

Site	Chlorophyll a	Faecal coliforms	*Escherichia coli*	Faecal streptococci	Enterococci
1	poor	good	good	poor	poor
2	poor	good	good	good	good
3	moderate	good	good	good	good
4	poor	good	good	good	good
5	moderate	good	good	poor	poor
6	poor	good	good	poor	poor
7	poor	good	good	poor	poor
8	moderate	good	good	poor	good
9	poor	good	good	poor	poor

Faecal coliform bacteria were good at all sites, as in the previous report, but this is probably due to their poor survival in marine systems, rather than an absence of supply. This reasoning is supported by the numerous poor ratings for faecal streptococci and enterococci, which survive for longer periods in marine waters. Enterococci were poor at five sites in this report, four more than the last report. The poor ratings were all due to samples exceeding the upper limit of 60 organisms per 100 ml, rather than high median values. This suggests that the microbiological status of the Port River was compromised by significant short-term events, rather than on-going inputs of moderate levels of pathogens.

4 CONCLUSIONS

As found in the 1995–96 report, the overall water quality status of the Port River is poor to moderate for a significant amount of the time. Across all sites only 51% of all classifications are good, while 31% are moderate and 18% are poor. Site 3 at Outer Harbor, the best performing site, returned only 71% good ratings, while four sites were good for less than half their classifications (Table 28).

Table 28 Summary of water quality classifications at all Port River sites from 1995–2000

	Site 1 (%)	Site 2 (%)	Site 3 (%)	Site 4 (%)	Site 5 (%)	Site 6 (%)	Site 7 (%)	Site 8 (%)	Site 9 (%)	All sites (%)
good	41	53	71	59	53	47	41	53	41	51
moderate	35	29	29	24	29	29	35	35	29	31
poor	24	18	0	18	18	24	24	12	29	18

Key conclusions from this report are as follows:

- Water clarity, as determined by turbidity, was moderate at four sites. This had improved since the last report where turbidity was moderate at six sites. Environment improvement programs by Penrice and SA Water, along with the on-going development of wetlands to treat stormwater, should deliver further improvement in this parameter.
- Aluminium, cadmium, iron, lead and mercury were classified as good at all sites.
- Comparisons with the 1995–96 report are not possible for aluminium, cadmium, lead and mercury due to changes in analytical methodology.
- Copper was moderate at five sites and poor at four. Given the toxic nature of copper this is a concern, but recent trends suggest copper concentrations are decreasing.
- Zinc was moderate at all sites and concentrations appeared to be fairly stable over time.
- The high detection limits of mercury, copper and lead, and to a lesser extent cadmium, are of concern as they restrict our ability to understand the status of these metals in the Port River.
- Ammonia was poor at seven sites and moderate at two. The high ammonia concentrations, high pH and high temperature of the Penrice outfall are a concern. This combination of factors indicates that ammonia concentrations may be high enough to be toxic in the vicinity of the Penrice outfall.
- The high ammonia and oxidised nitrogen concentrations are a significant issue for algae in the Port River, as these forms of nitrogen are highly bioavailable. It is likely that these nitrogen concentrations are promoting greater algal growth and therefore higher chlorophyll concentrations in the Port River
- Environment improvement programs by industry and development of wetlands to treat stormwater are expected to lead to improvements in the nutrient status of the Port River.
- Chlorophyll was poor or moderate at all sites, which is not surprising given the high nutrient loading to the Port River.
- Coliform bacteria were good at all sites but this was probably due to their poor survival in marine systems, rather than an absence of supply. This was supported by the poor ratings at many sites for faecal streptococci and enterococci, which survive for longer periods in marine waters. Enterococci were poor at five sites, four more than the last report. The results

suggested this was due to occasional events, rather than consistently high concentrations of bacteria.

Future prospects

A number of positive developments should contribute to improved water quality in the Port River over time:

- Environment improvement programs by industry, especially SA Water and Penrice Soda Products, should improve nutrient concentrations and turbidity.
- The Environment Protection (Water Quality) Policy should promote reductions in diffuse source pollution entering the Port River through stormwater and streamflow.
- On-going development of wetlands to treat stormwater should reduce the amount of nutrients, metals, bacteria and suspended solids entering the Port River. However, these wetlands must be managed in a way that allows them to improve water quality in the long term.
- A decrease in algal growth and reductions in chlorophyll concentrations should follow improvements in nutrient concentrations.

Expectations of improvements to the water quality of the Port River should be tempered by an understanding that we have been polluting the river for many years. Even if we could prevent all pollutants from entering the Port River, water quality would take some time to recover. Internal factors, such as the storage of metals and nutrients in the sediments, and the loss of seagrass and mangroves, will have on-going impacts on the water quality of the river. While some parameters may improve rapidly in response to environmental improvements, in most cases we should expect to see gradual improvement rather than sudden changes.

Appendix

APPENDIX: TIME SERIES PLOTS OF WATER QUALITY PARAMETERS

Physical parameters

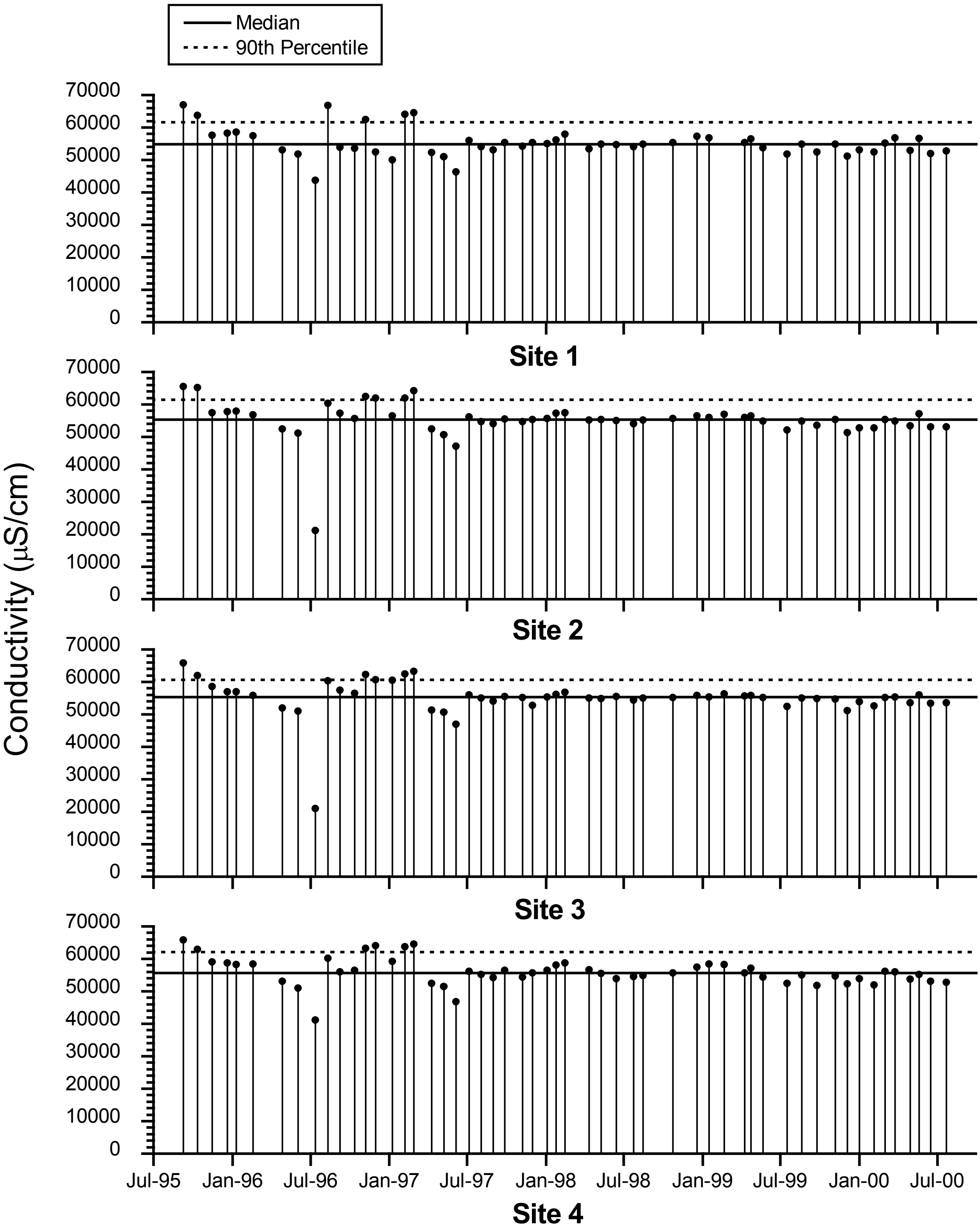
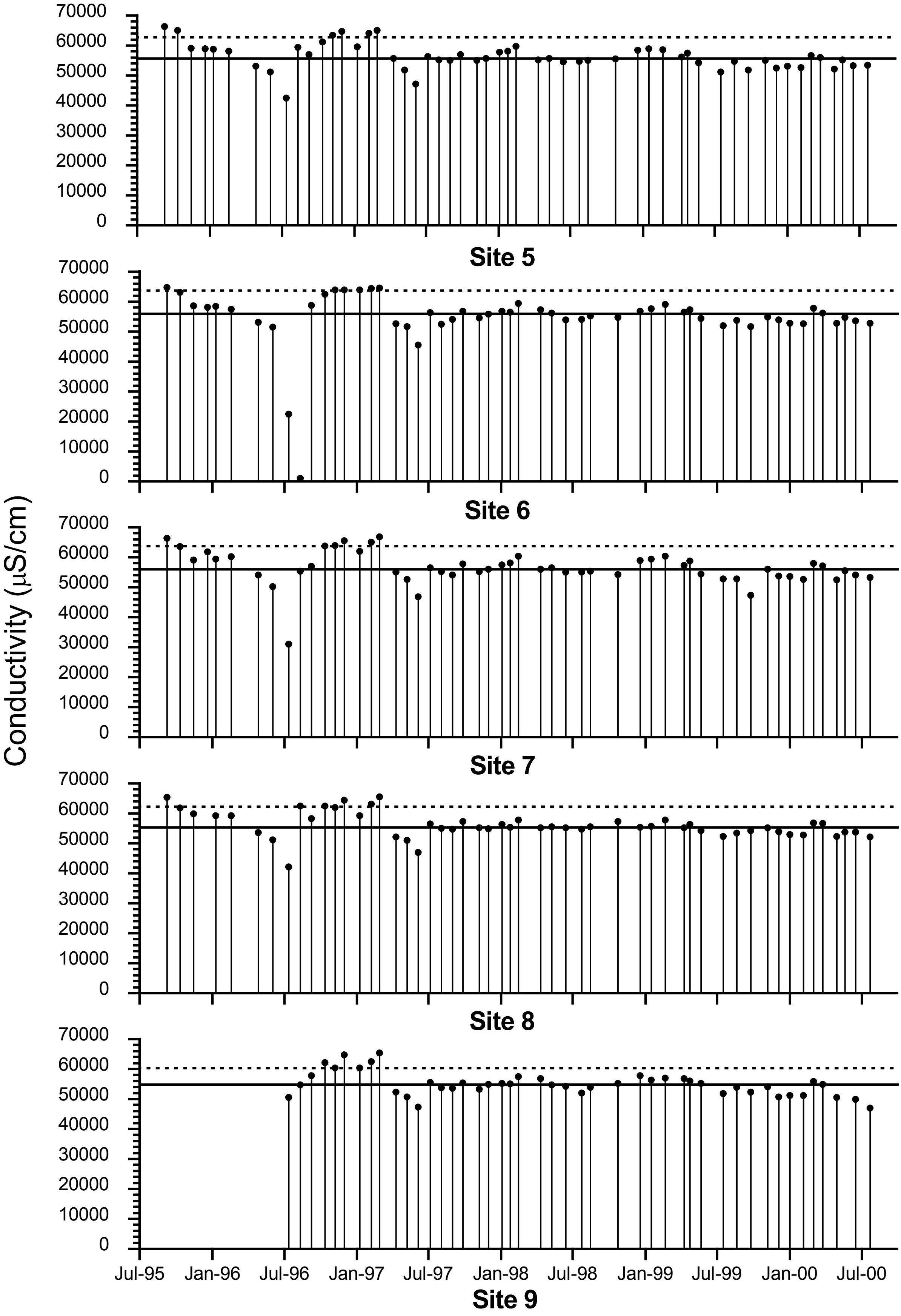


Figure 24 Conductivity at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile.


Conductivity (µS/cm)
70000
60000
50000
40000
30000
20000
10000
0
Site 5
Site 6
Site 7
Site 8
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Site 9

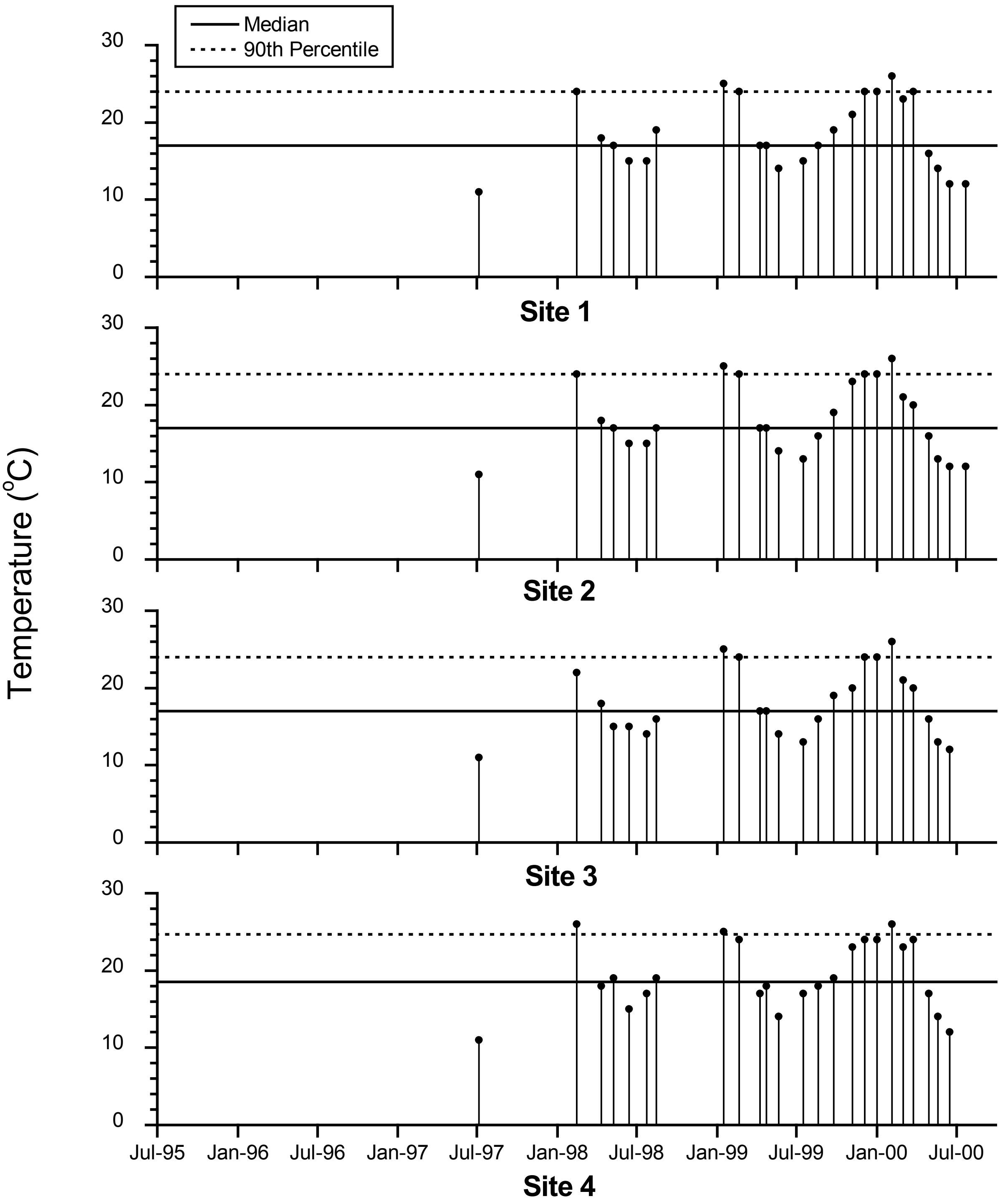
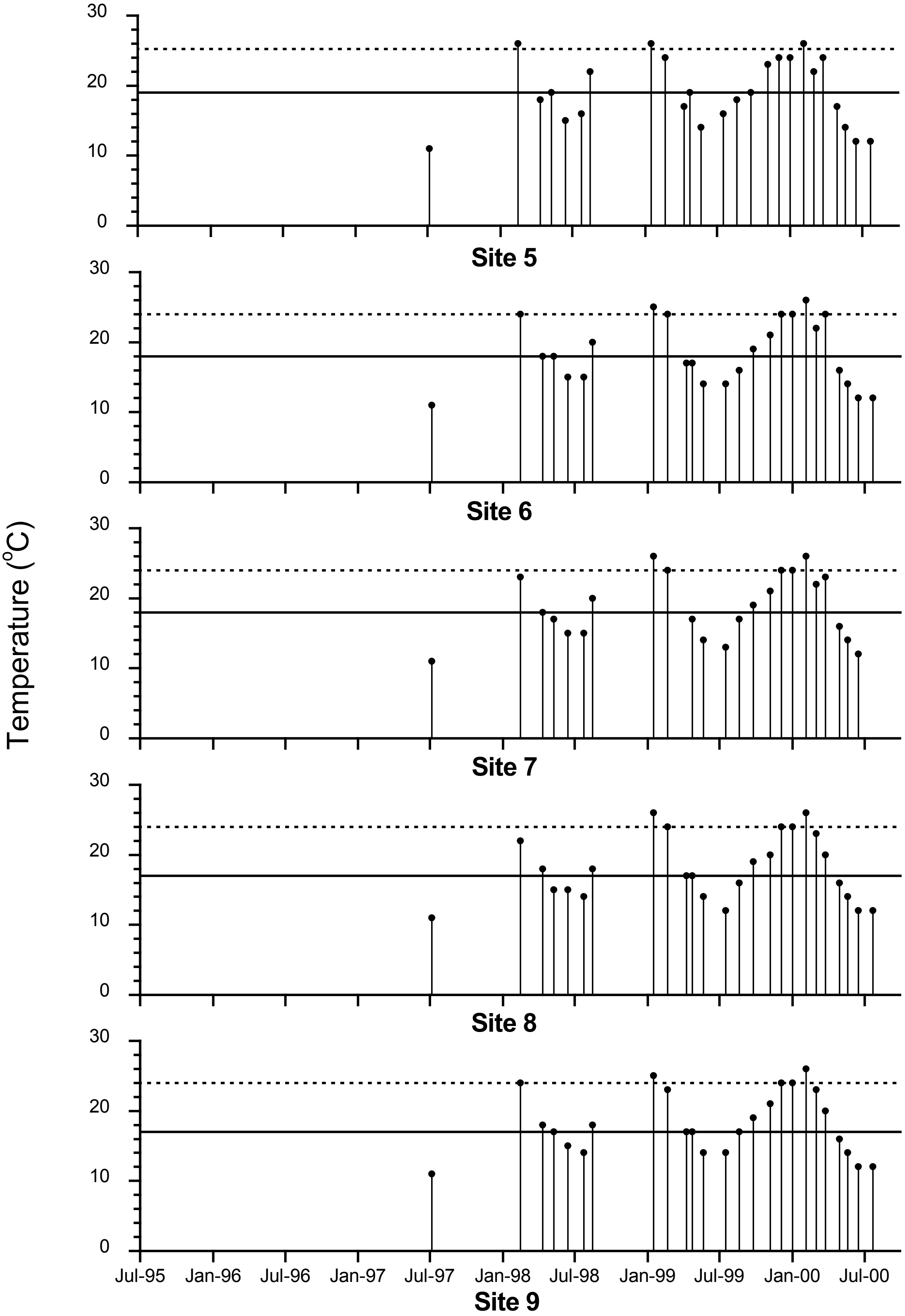


Figure 25 Temperature at nine sites in the Port River estuary, July 1997–August 2000: time series data with median and 90th percentile.


Temperature (°C)
30
20
10
0
Site 5
Site 6
Site 7
Site 8
Site 9
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00

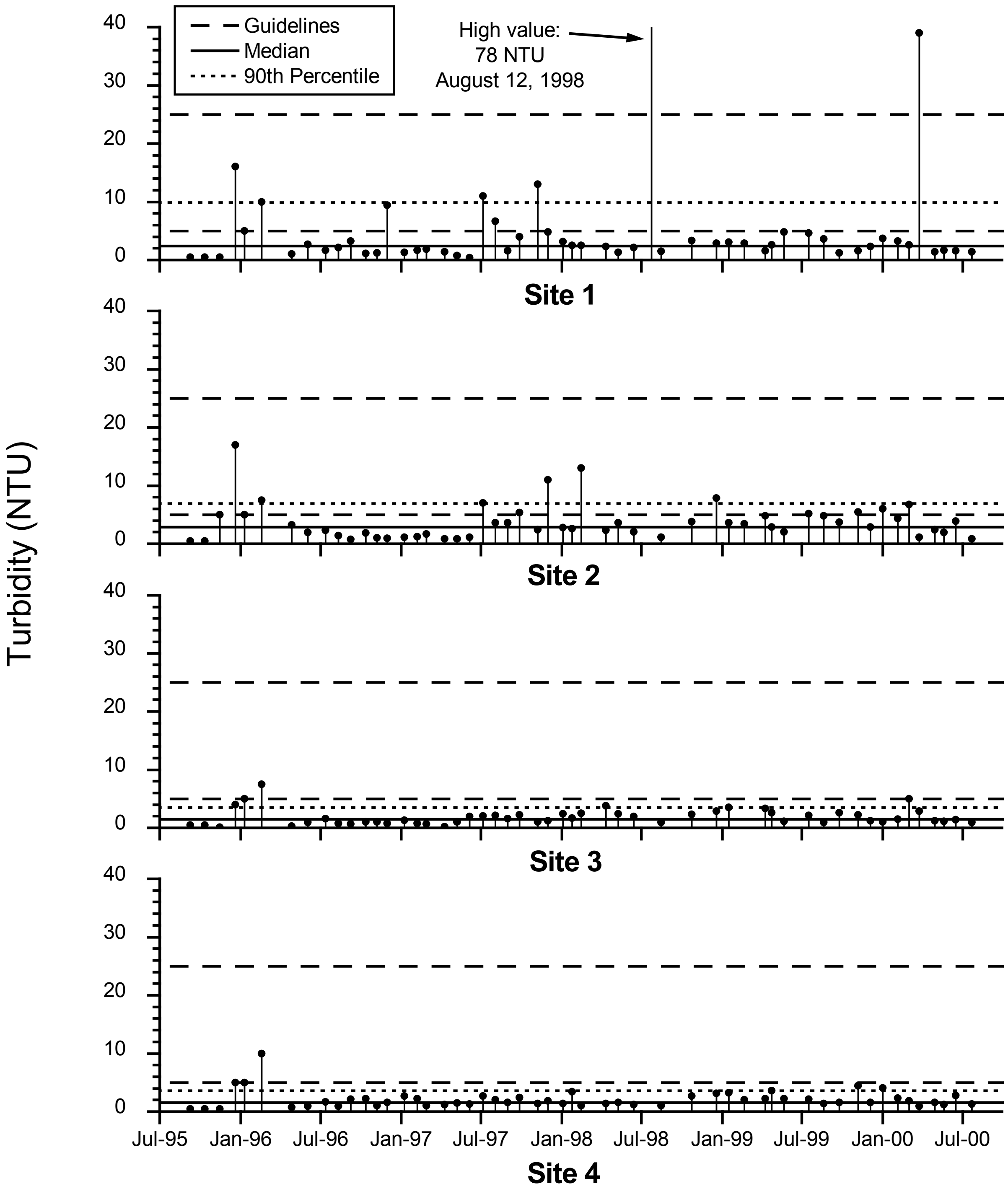
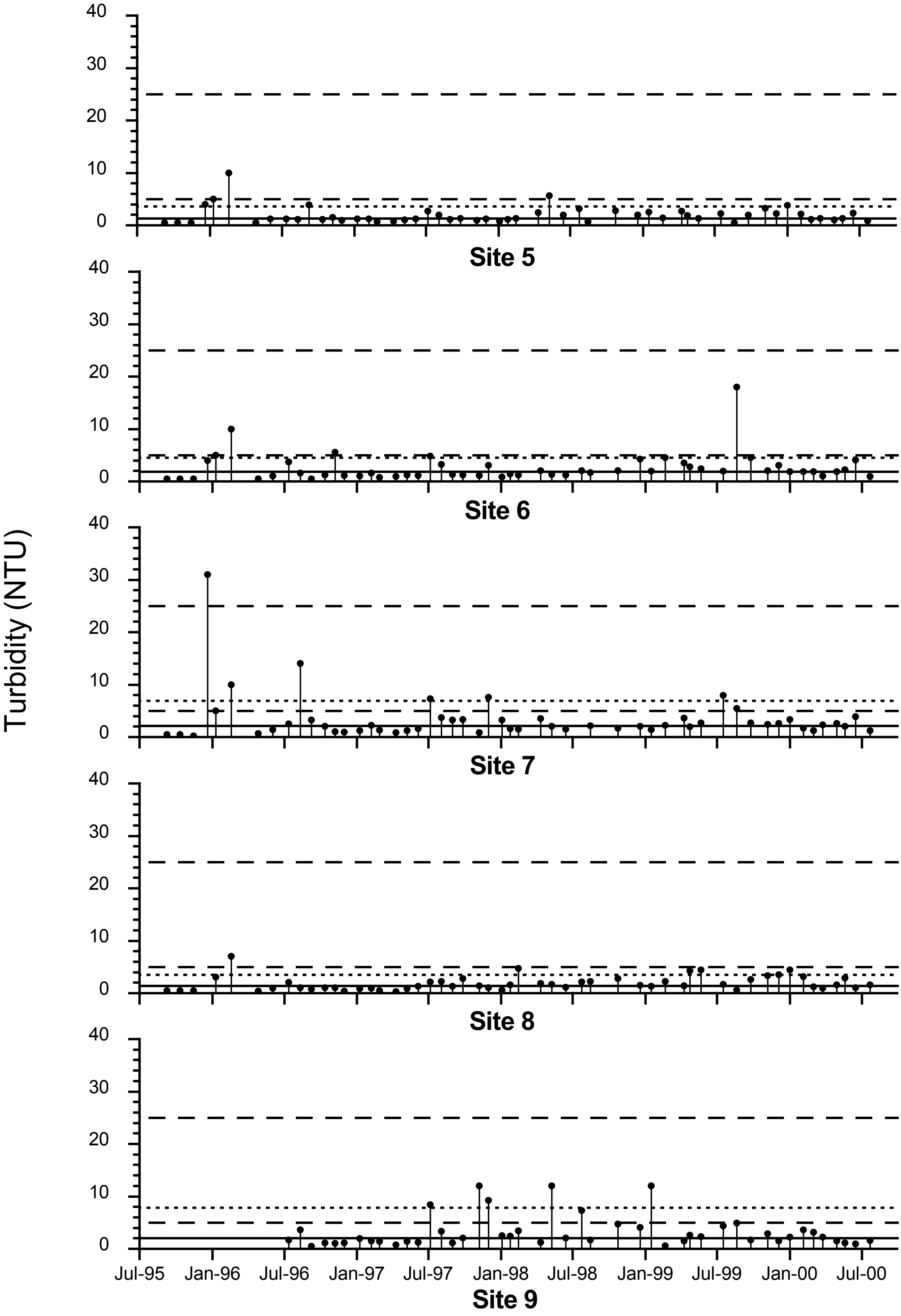


Figure 26 Turbidity concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996). Time series data with median and 90th percentile compared to South Australian EPA guidelines.


Turbidity (NTU)
40
30
20
10
0
Site 5
Site 6
Site 7
Site 8
Site 9
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00

Metals

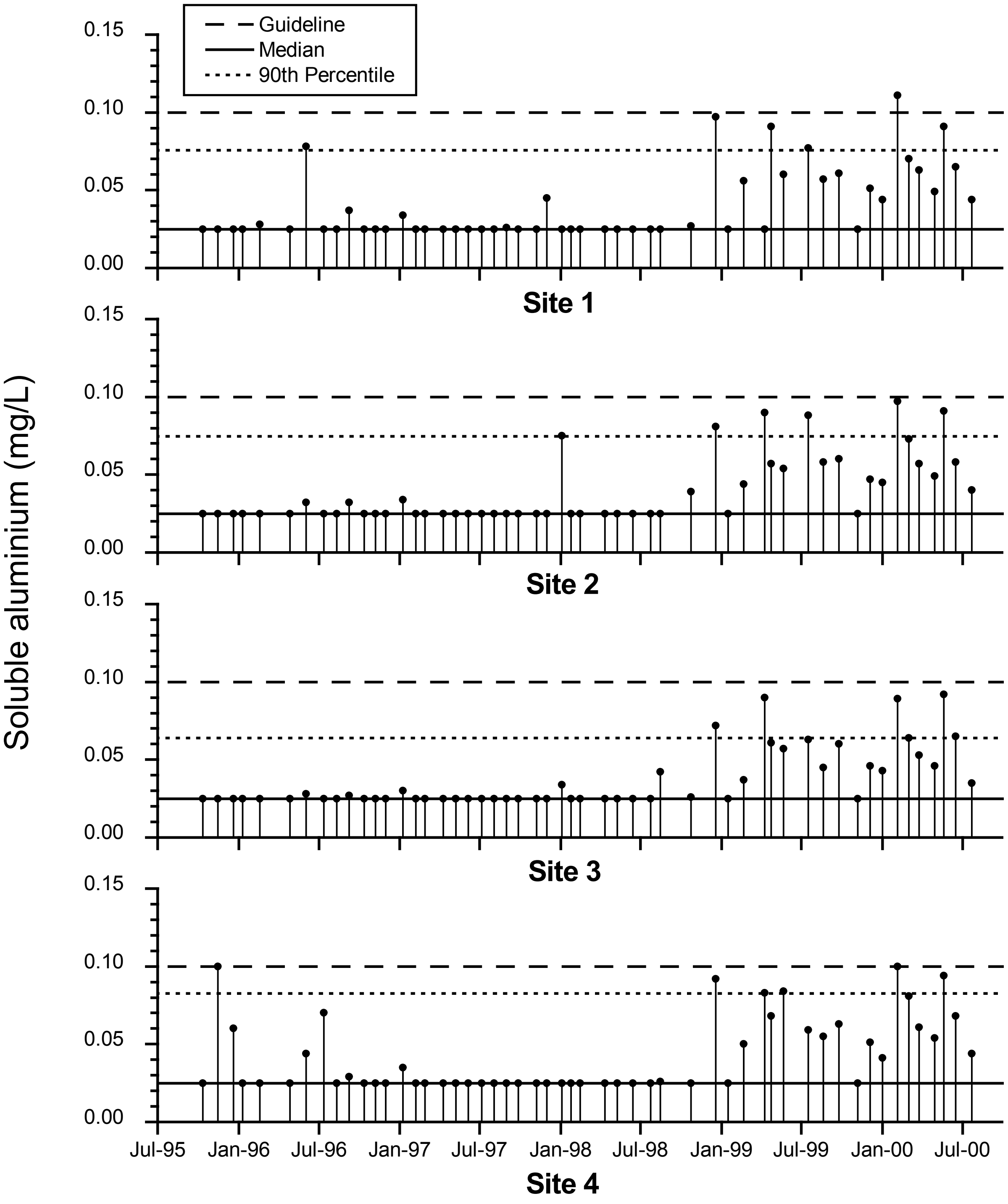
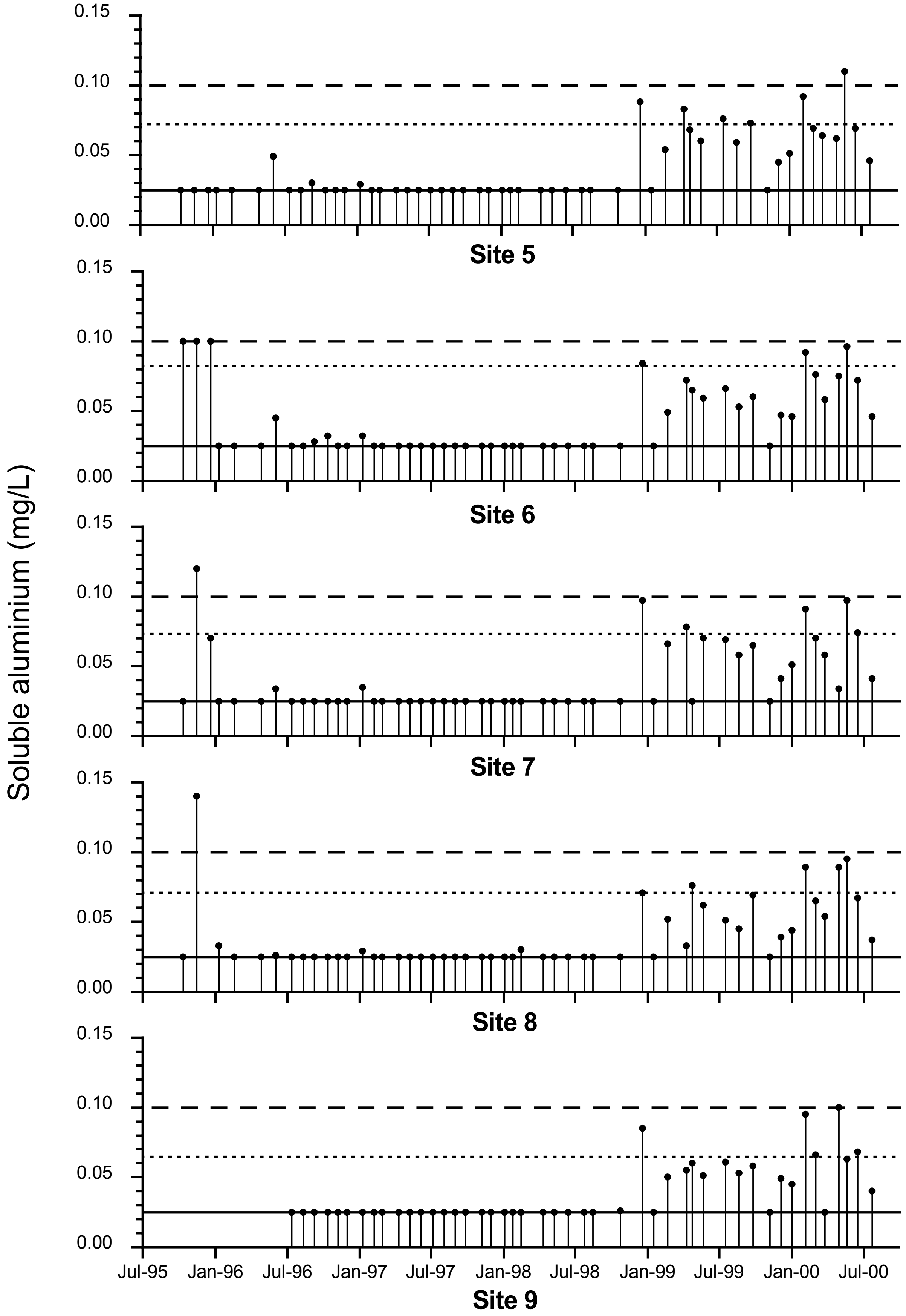


Figure 27 Soluble aluminium concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile compared to South Australian EPA guidelines.


Soluble aluminium (mg/L)
0.15
0.10
0.05
0.00
Site 5
Site 6
Site 7
Site 8
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Site 9

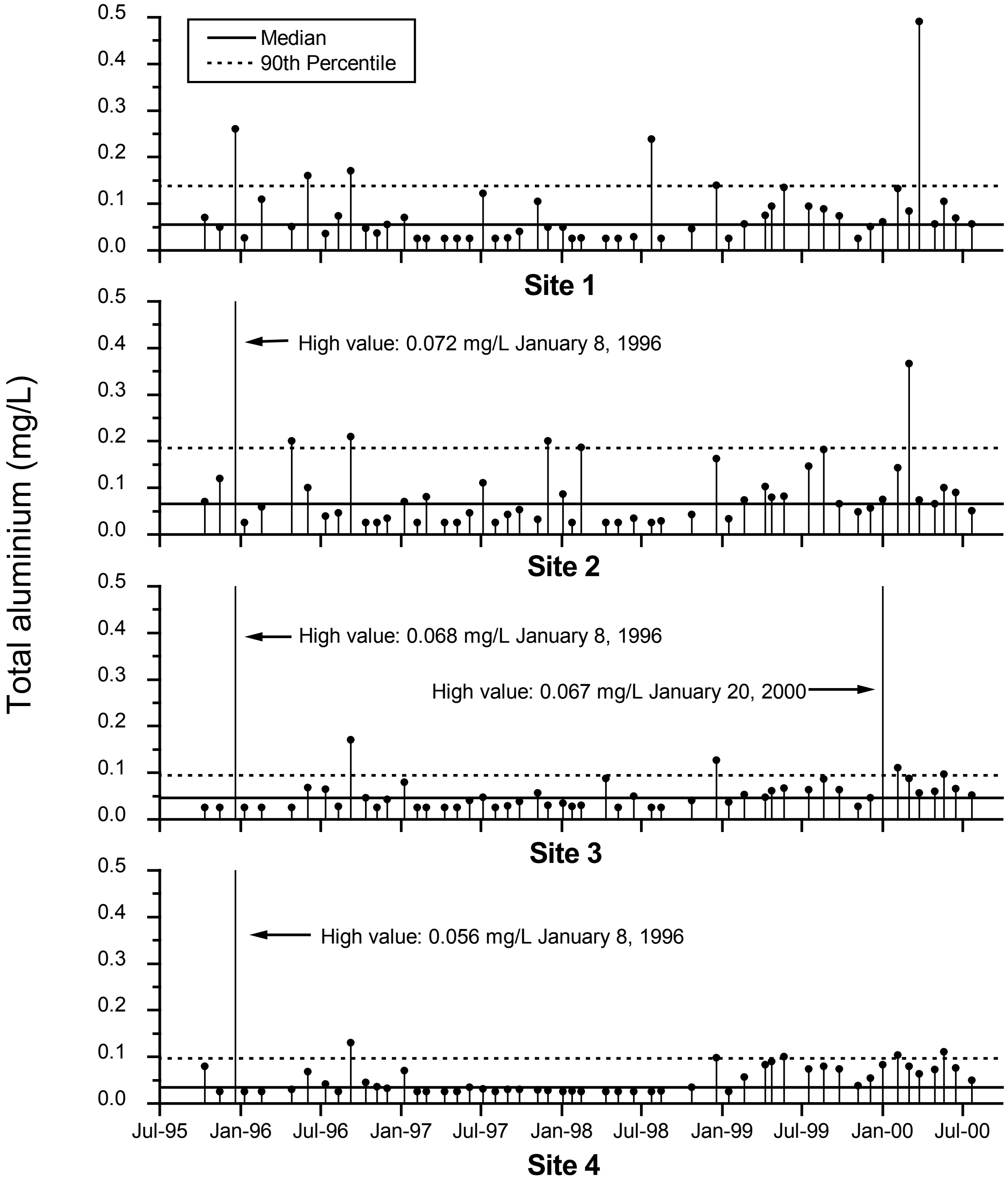
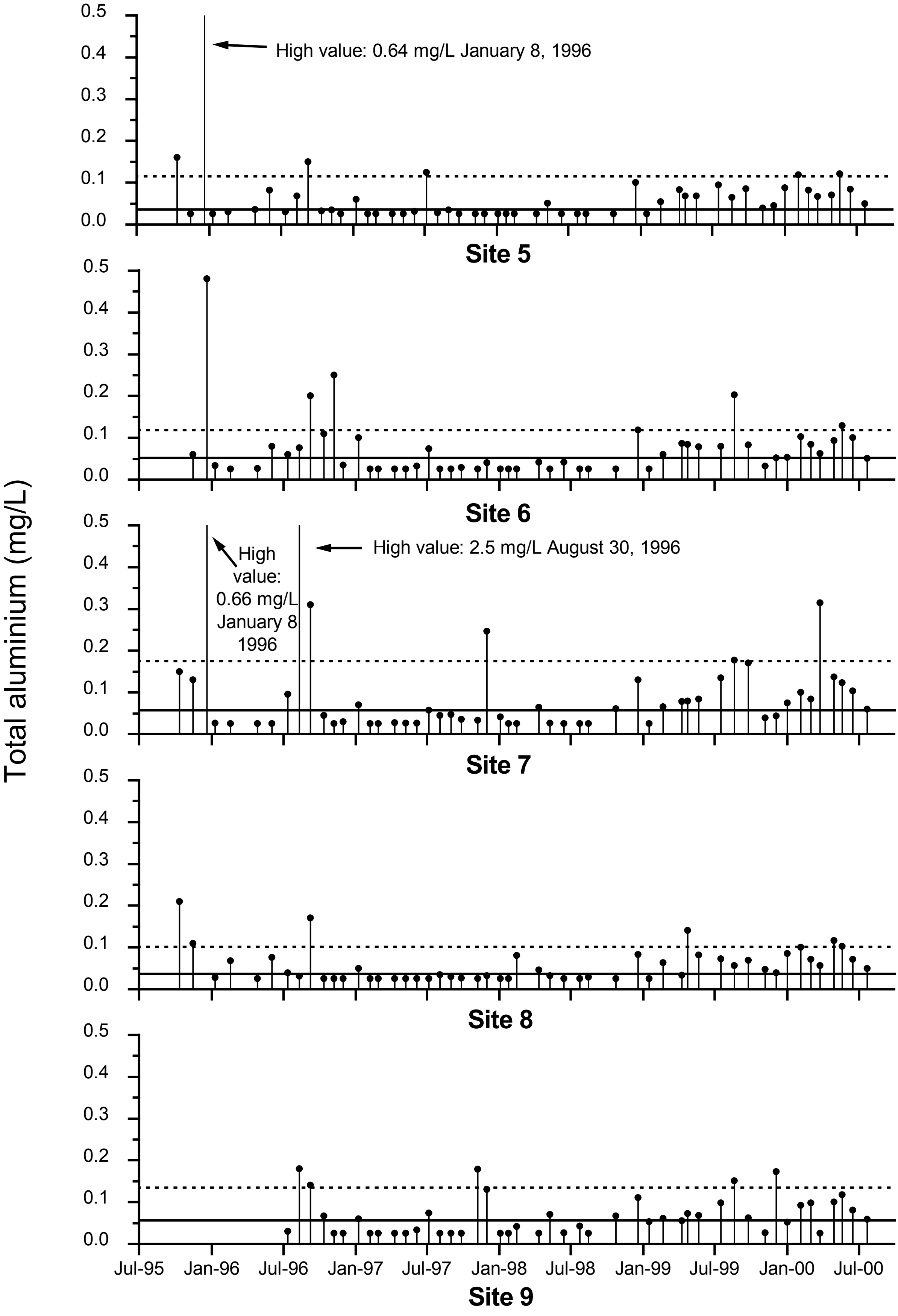


Figure 28 Total aluminium concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile.


Total aluminium (mg/L)
0.5
0.4
0.3
0.2
0.1
0.0
High value: 0.64 mg/L January 8, 1996
Site 5
High value: 2.5 mg/L August 30, 1996
High value: 0.66 mg/L January 8 1996
Site 6
Site 7
Site 8
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Site 9

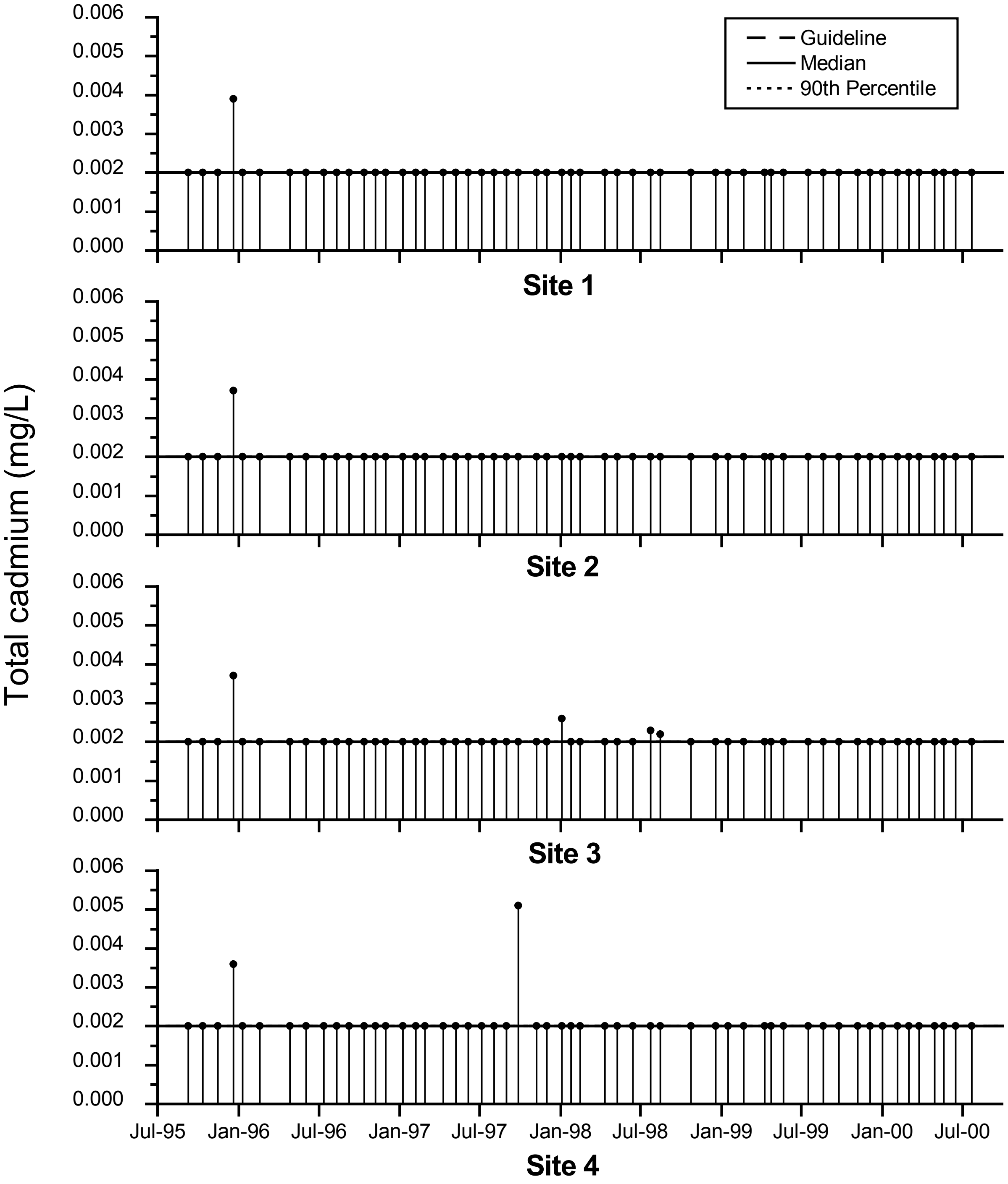
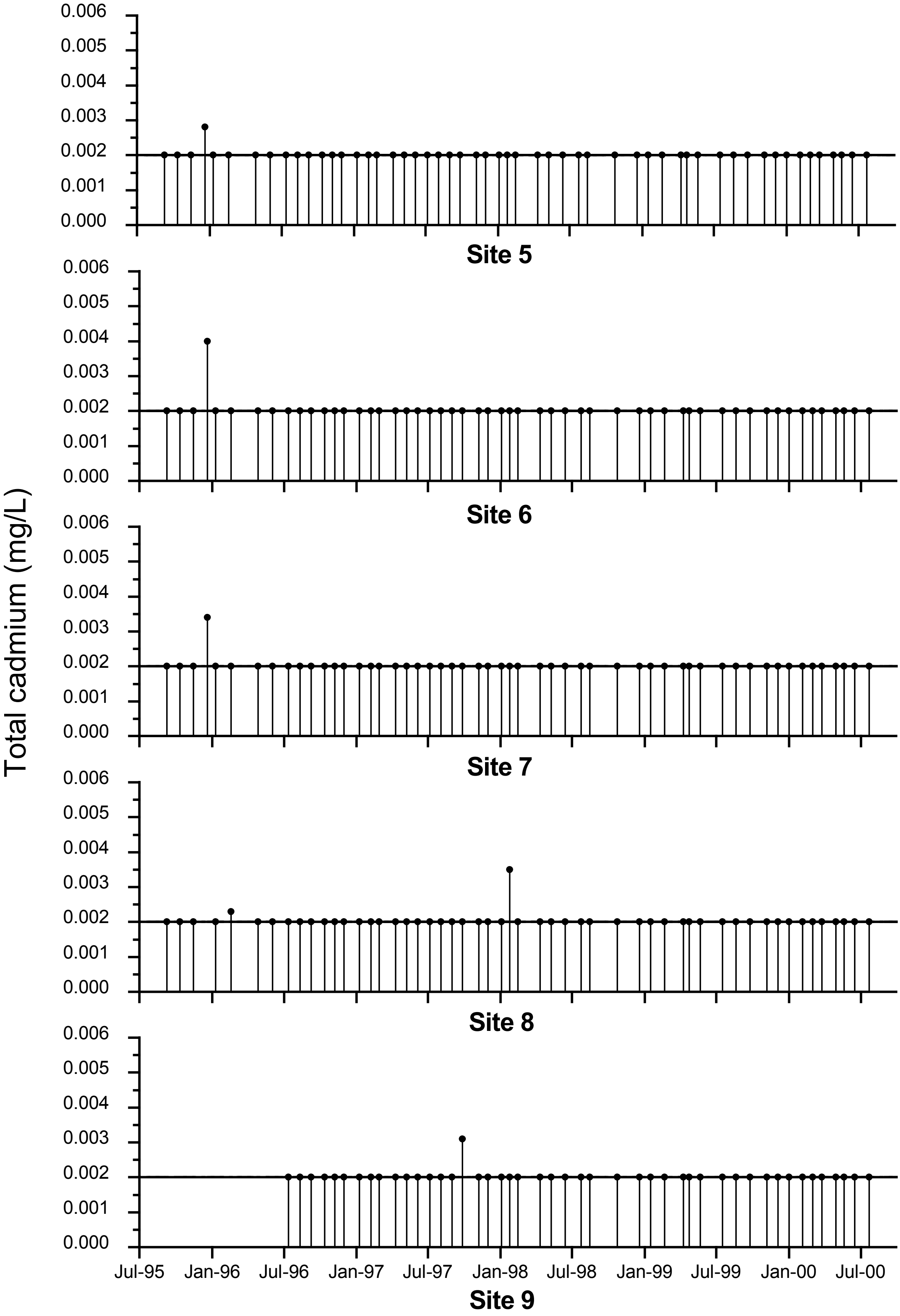


Figure 29 Total cadmium concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile compared to South Australian EPA guidelines. The guideline, median and 90th percentile values are equal at all sites. Note the analytical detection limit equals the guideline.


Total cadmium (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0.000
Site 5
Site 6
Site 7
Site 8
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Site 9

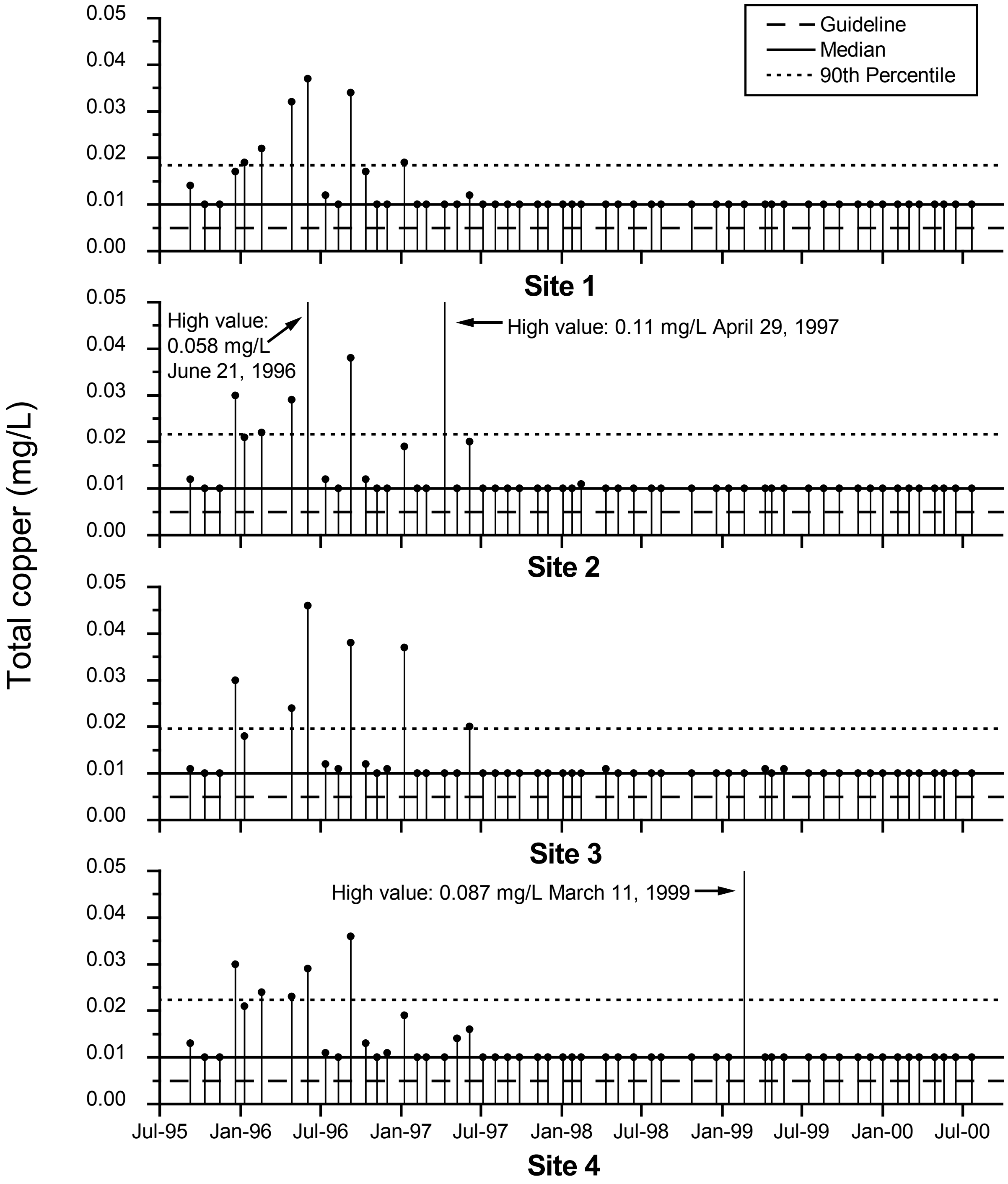
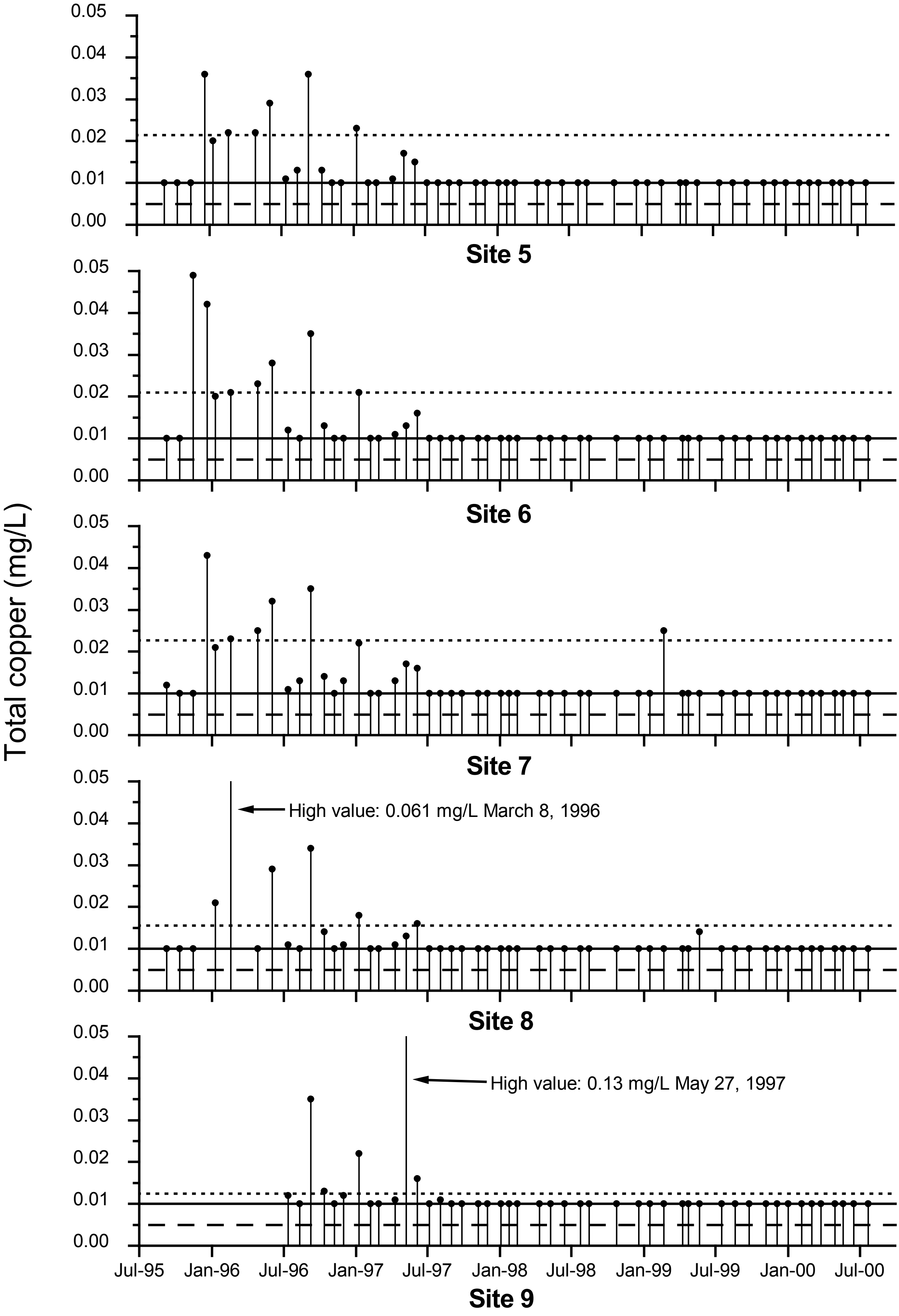


Figure 30 Total copper concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile compared to South Australian EPA guidelines. Note the analytical detection limit is twice the guideline.


Total copper (mg/L)
0.05
0.04
0.03
0.02
0.01
0.00
Site 5
Site 6
Site 7
High value: 0.061 mg/L March 8, 1996
Site 8
High value: 0.13 mg/L May 27, 1997
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Site 9

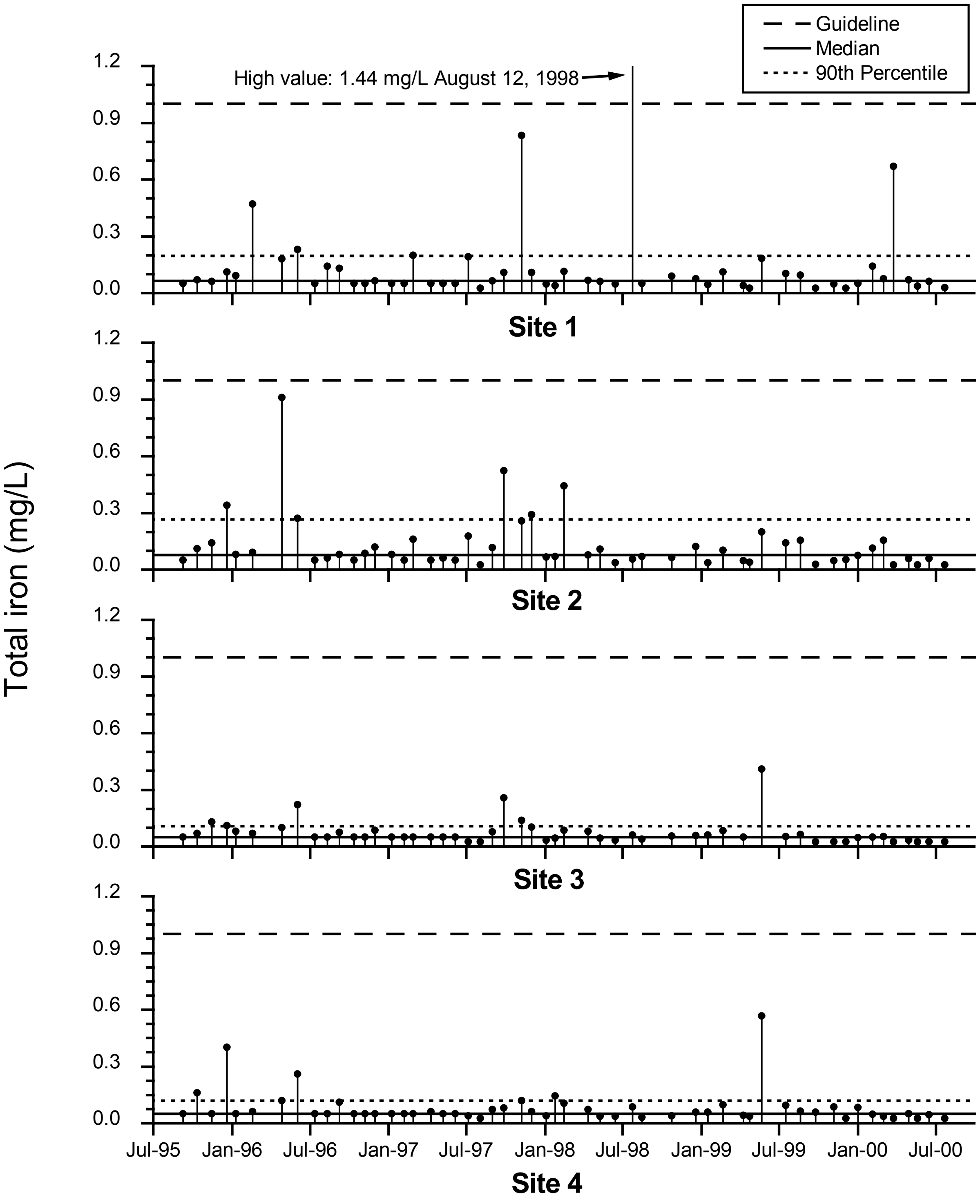
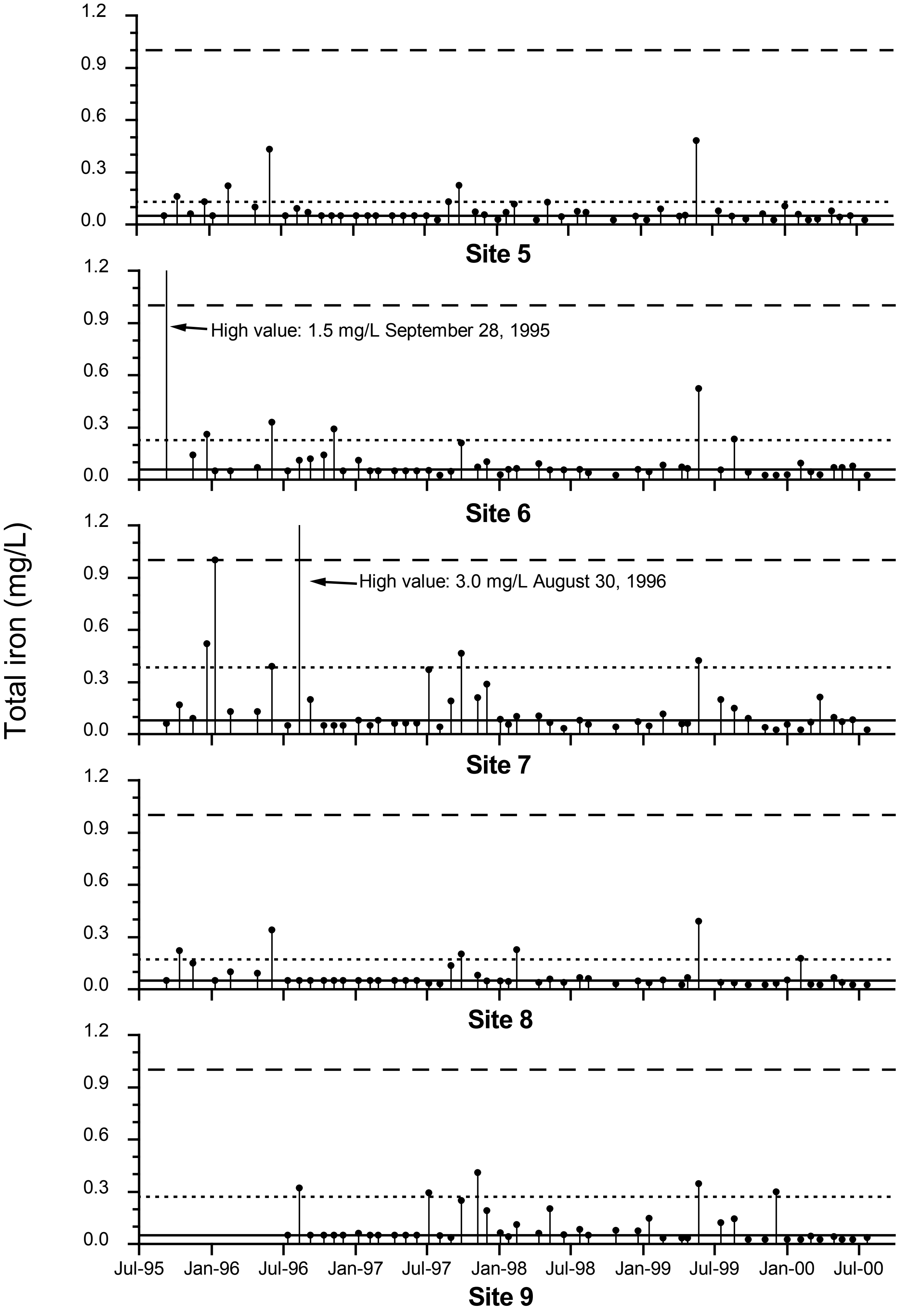


Figure 31 Total iron concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile compared to South Australian EPA guidelines.


Total iron (mg/L)
1.2
0.9
0.6
0.3
0.0
Site 5
High value: 1.5 mg/L September 28, 1995
Site 6
High value: 3.0 mg/L August 30, 1996
Site 7
Site 8
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Site 9

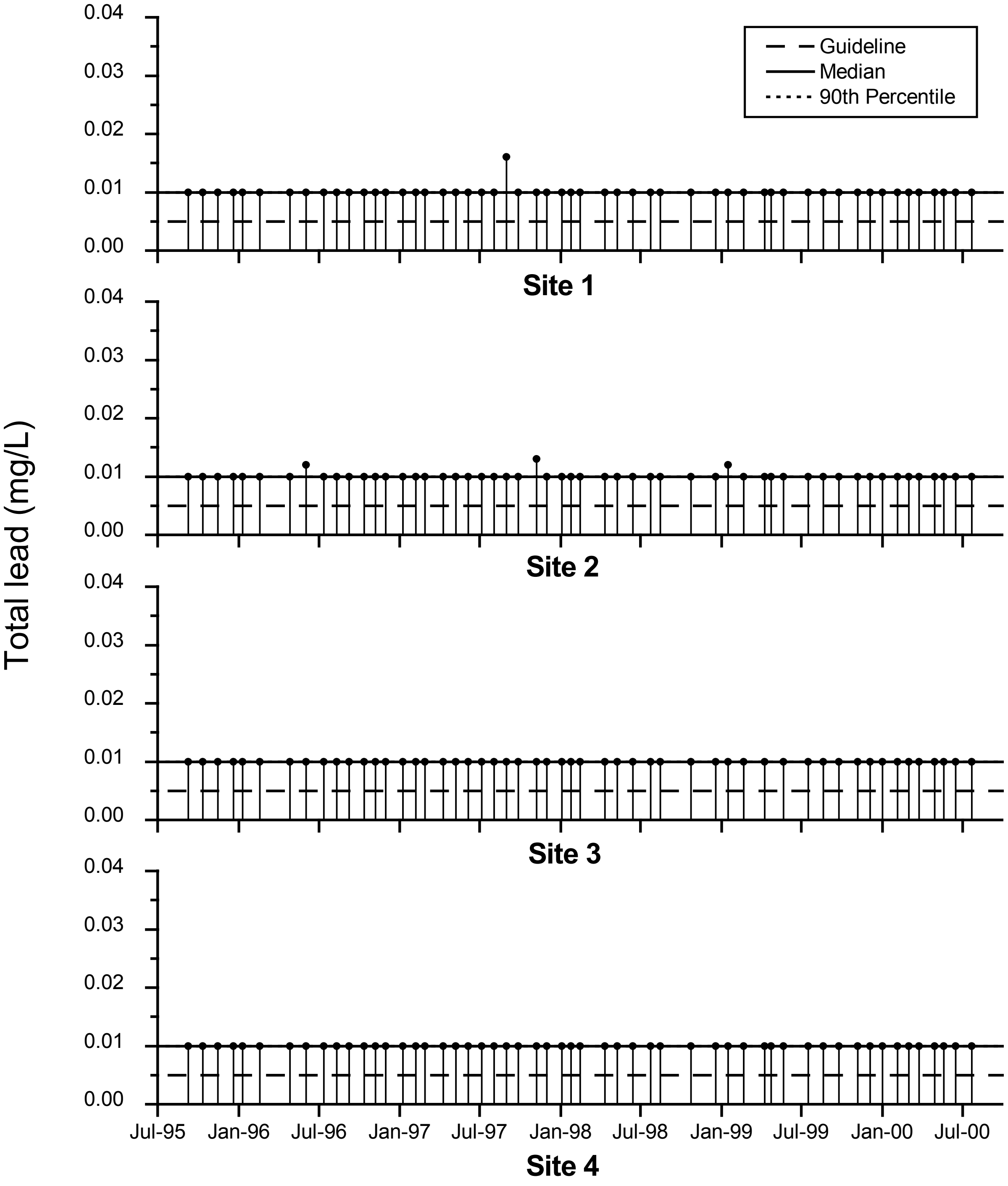
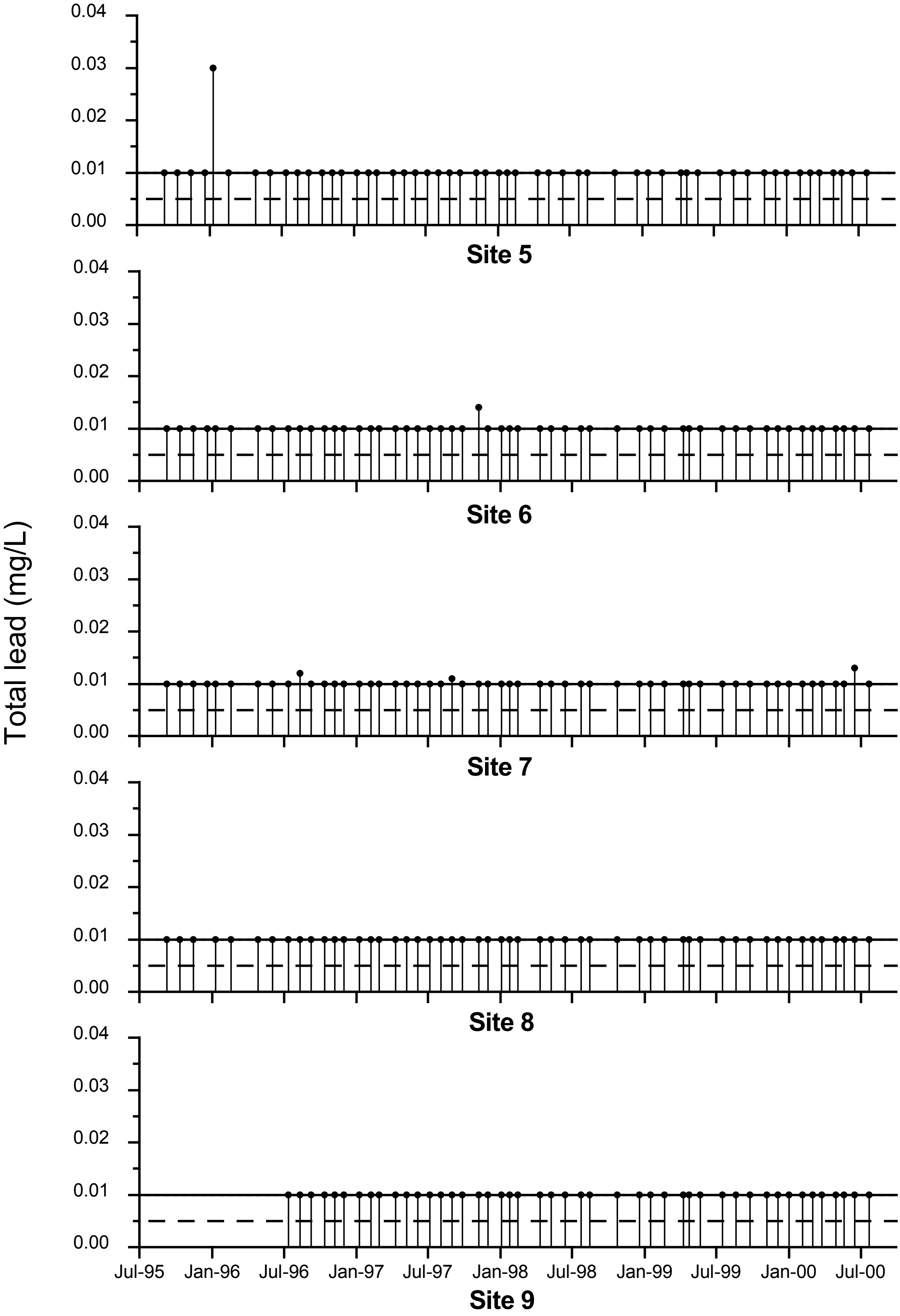


Figure 32 Total lead concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile compared to South Australian EPA guidelines. The median and 90th percentile are equal at all sites. The analytical detection limit for lead is 0.01 mg/L, twice the guideline.


Total lead (mg/L)
0.04
0.03
0.02
0.01
0.00
Site 5
Site 6
Site 7
Site 8
Site 9
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00

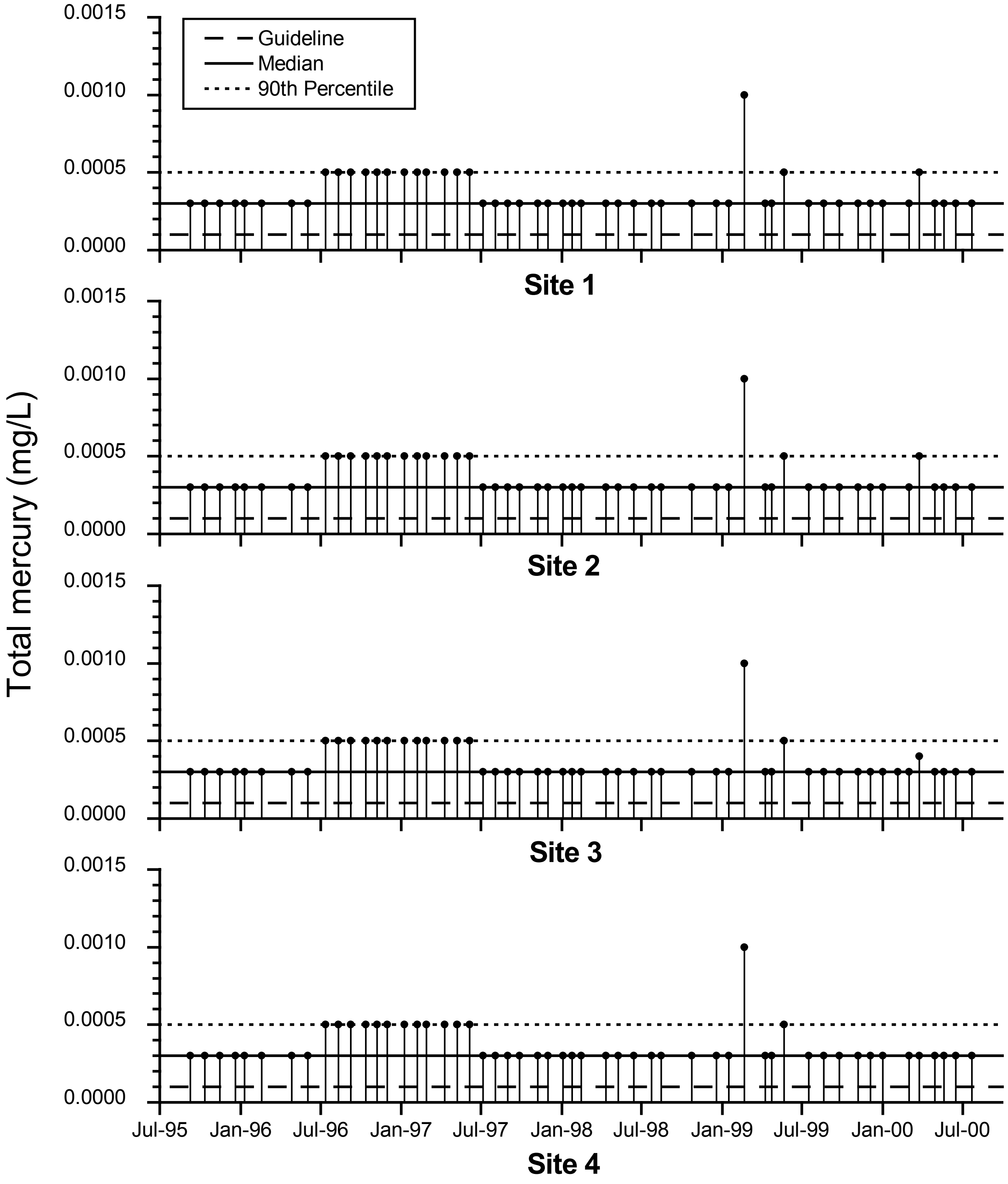
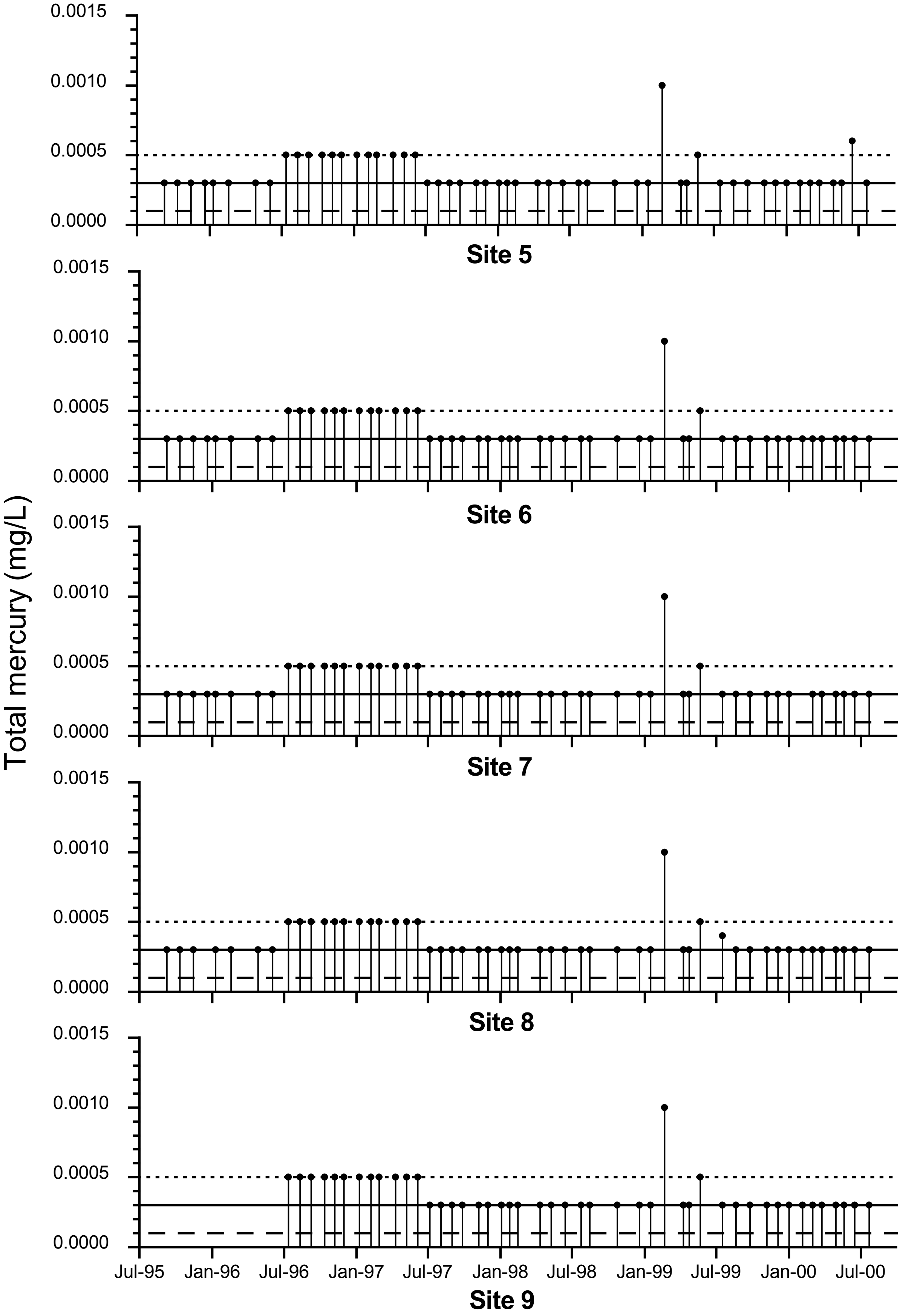


Figure 33 Total mercury concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile compared to South Australian EPA guidelines. The analytical detection limit for mercury has varied but has always exceeded the guideline (see text for discussion).


Total mercury (mg/L)
0.0015
0.0010
0.0005
0.0000
Site 5
Site 6
Site 7
Site 8
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Site 9

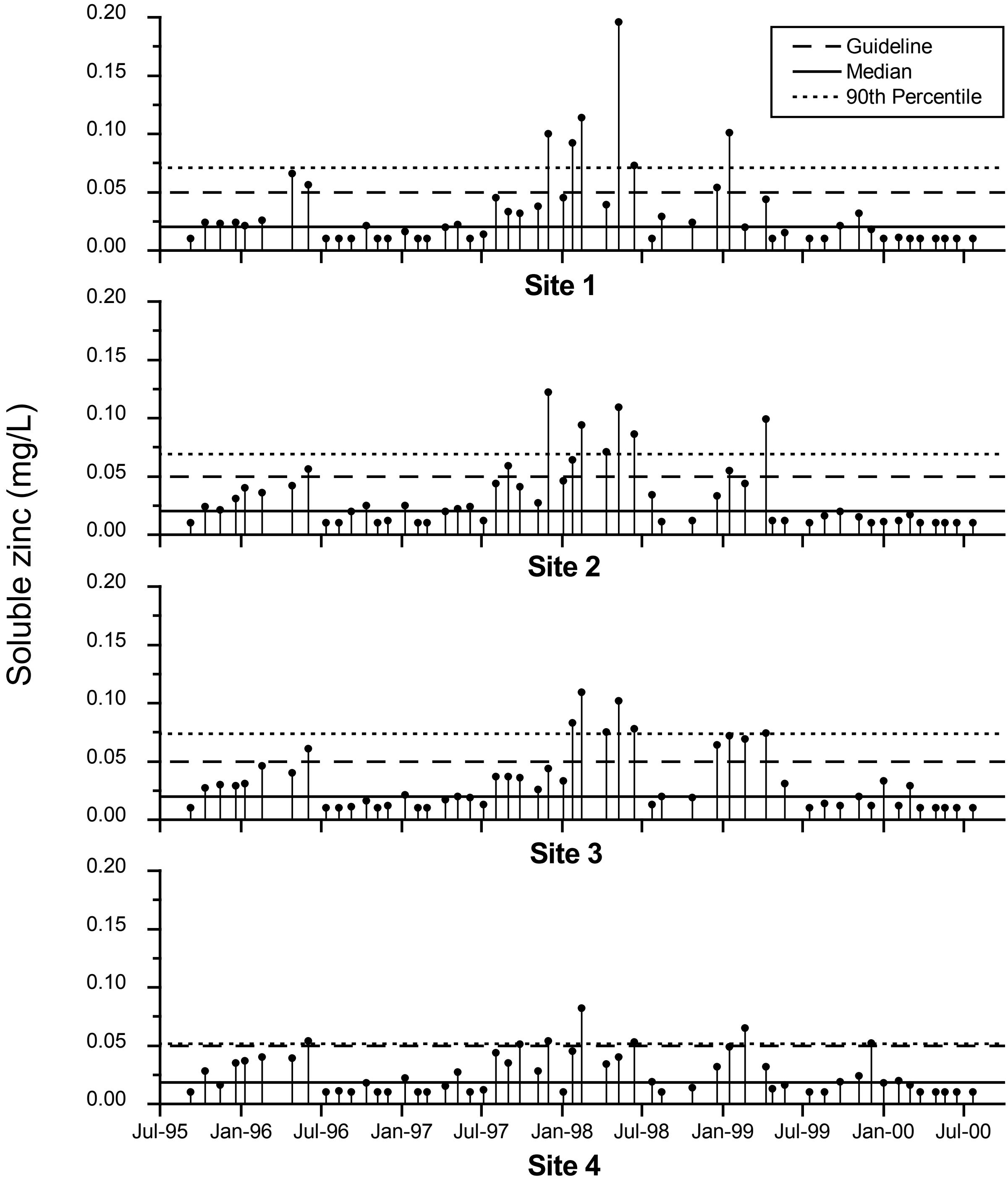
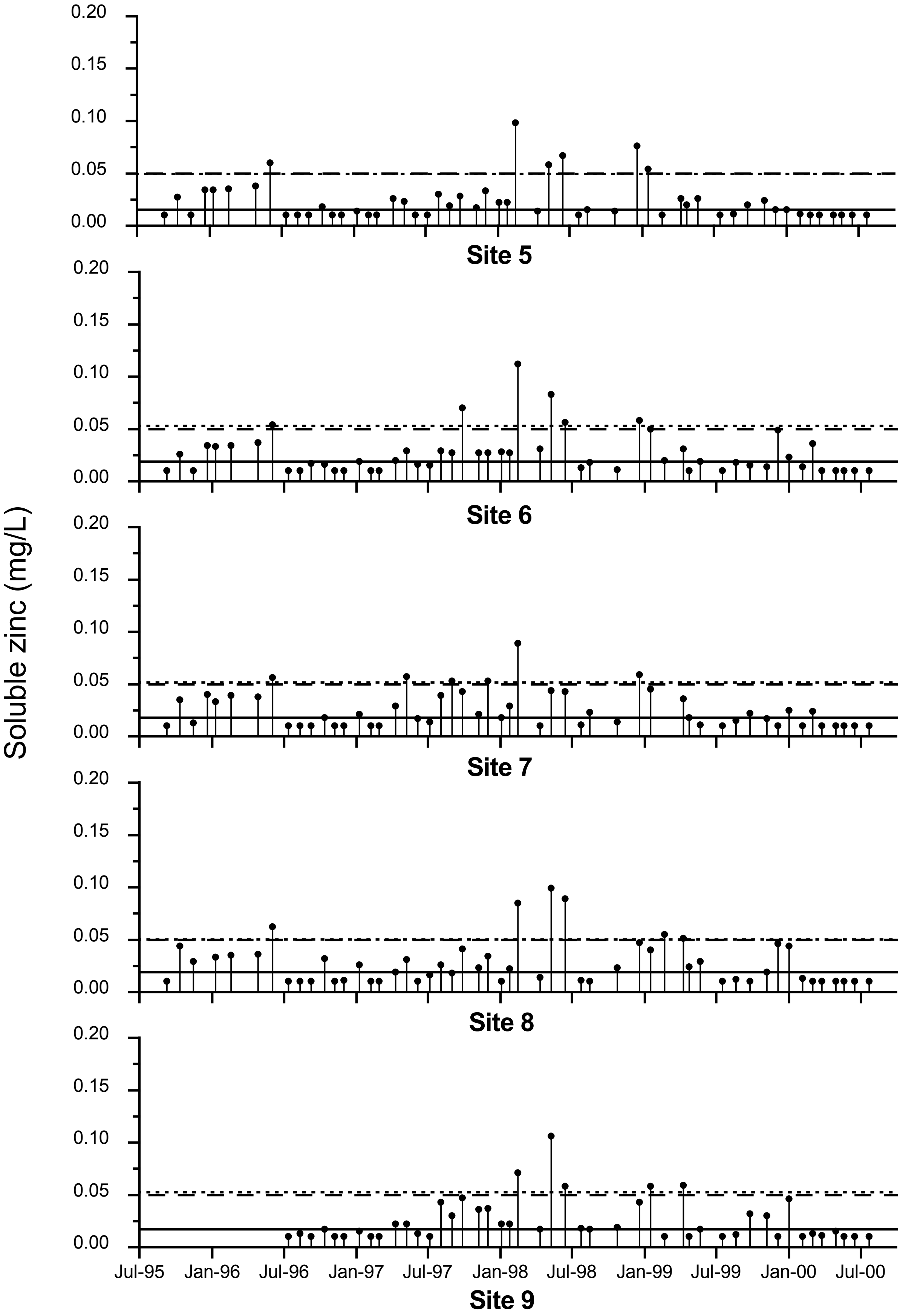


Figure 34 Soluble zinc concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile. There is no guideline for soluble zinc; guideline for total zinc included for comparison.


Soluble zinc (mg/L)
0.20
0.15
0.10
0.05
0.00
Site 5
Site 6
Site 7
Site 8
Site 9
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00

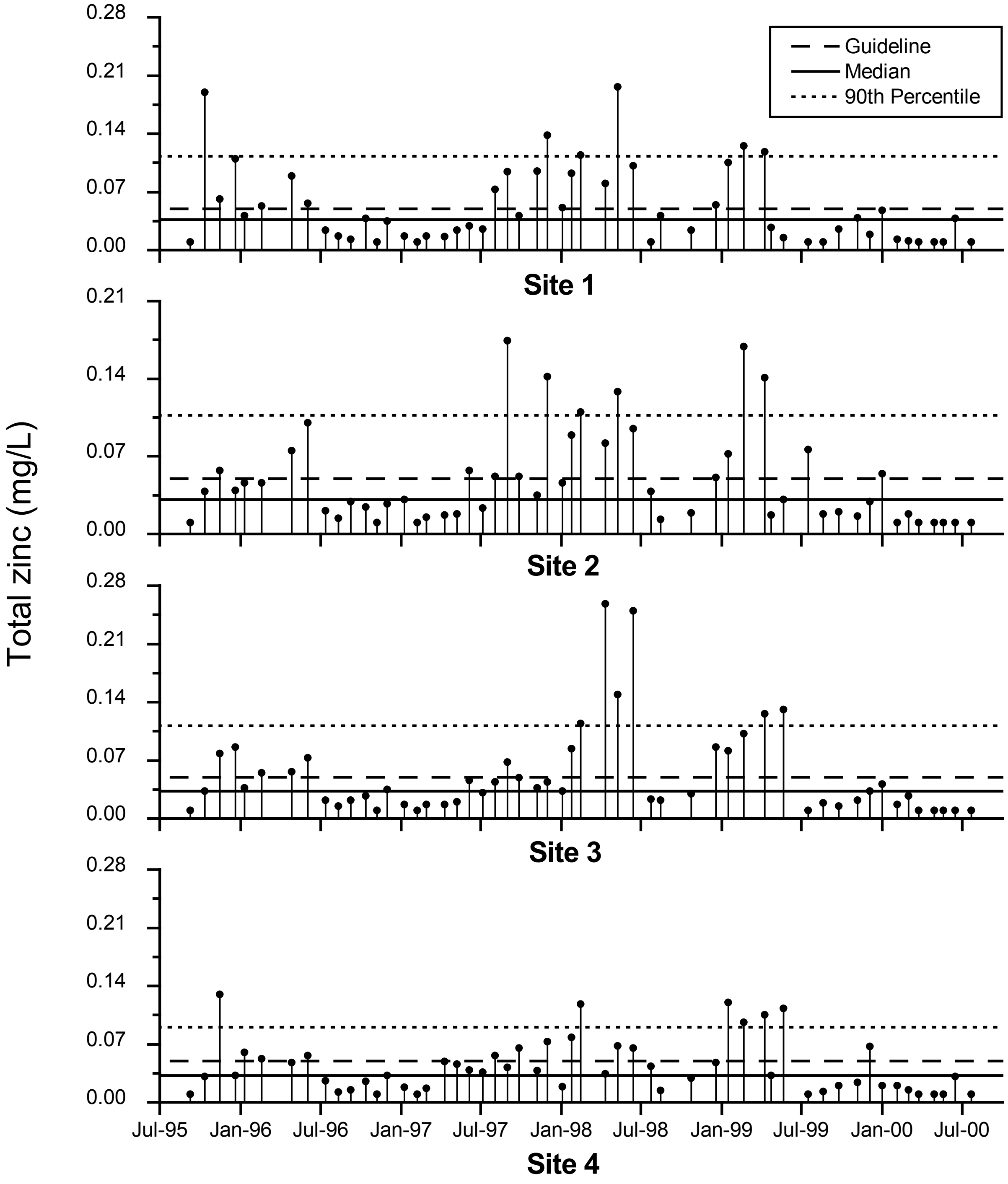
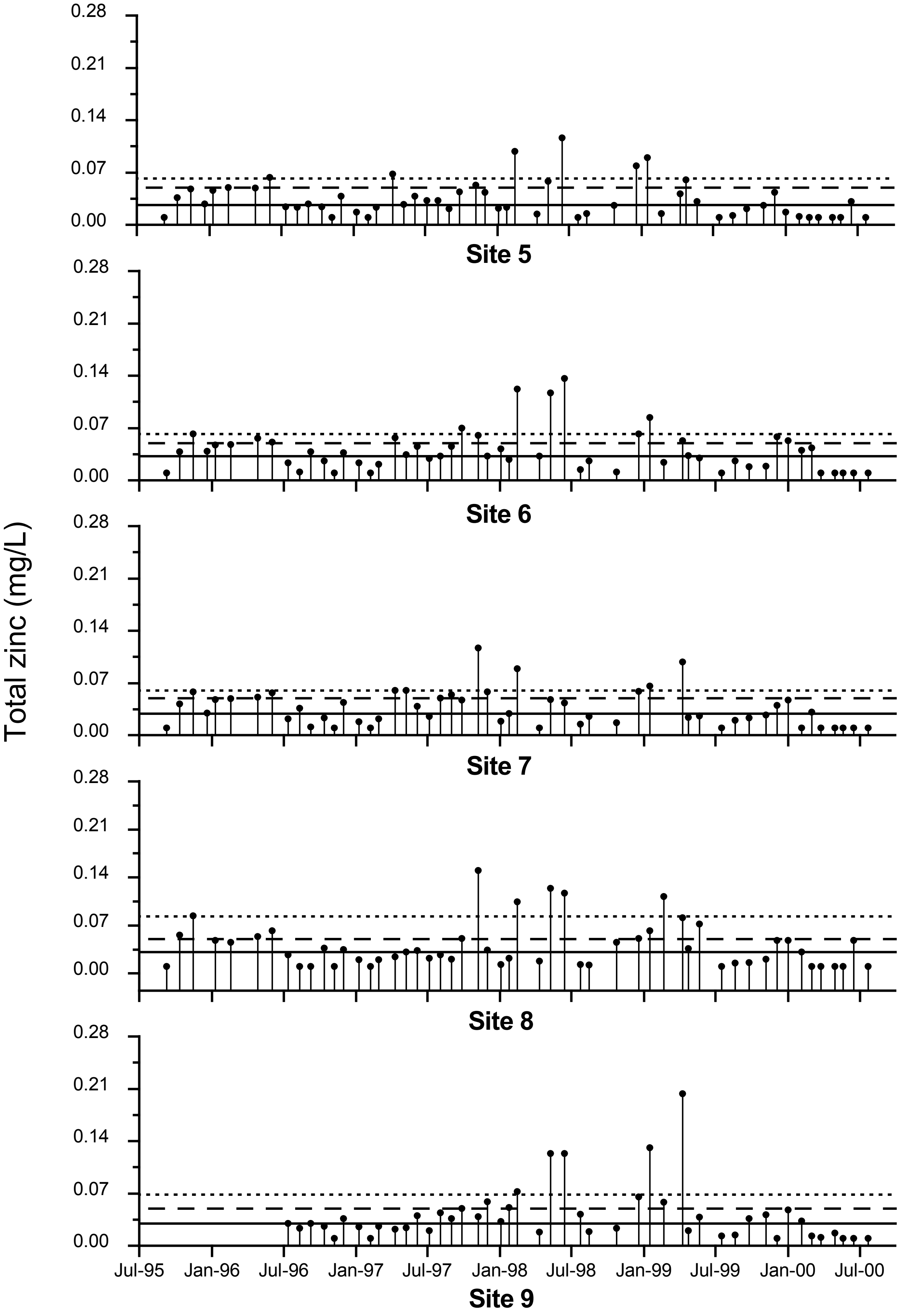


Figure 35 Total zinc concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile compared to South Australian EPA guidelines.


Total zinc (mg/L)
0.28
0.21
0.14
0.07
0.00
Site 5
Site 6
Site 7
Site 8
Site 9
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00

Nutrients

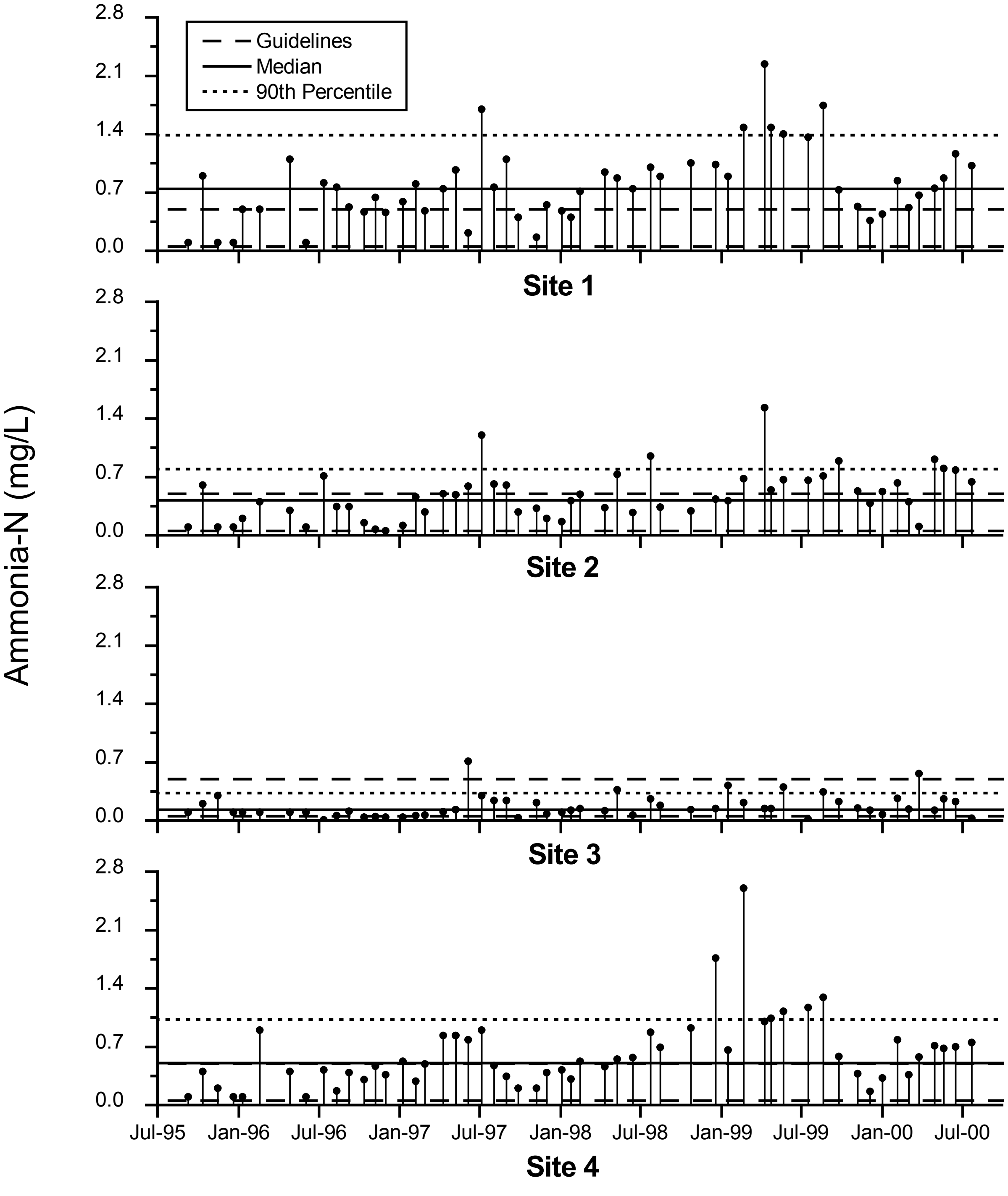
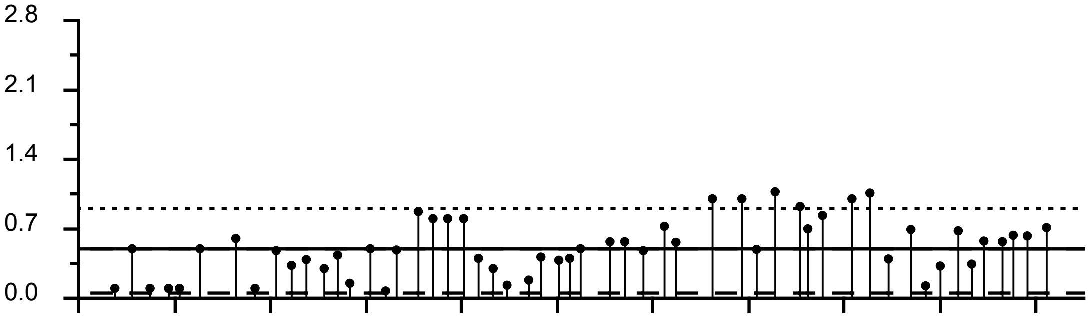
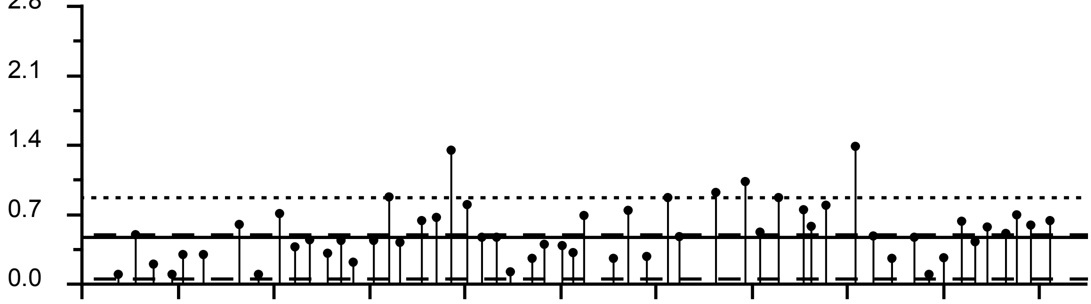


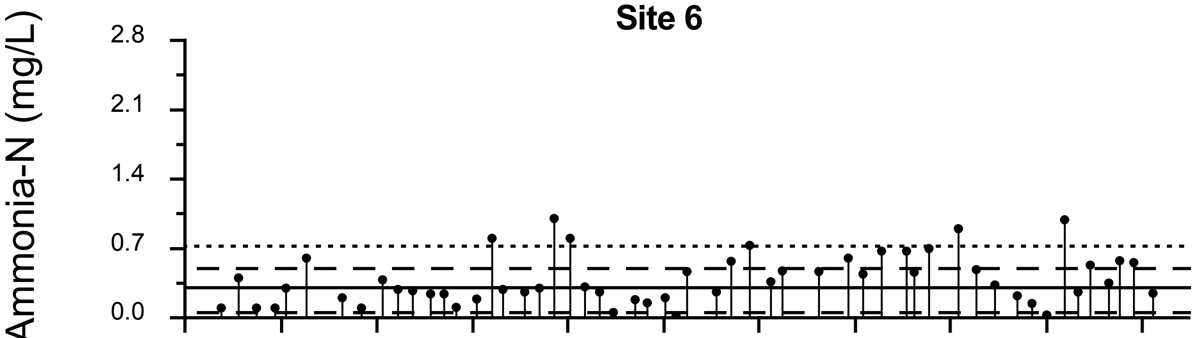
Figure 36 Ammonia concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile compared to South Australian EPA guidelines.



Site 5

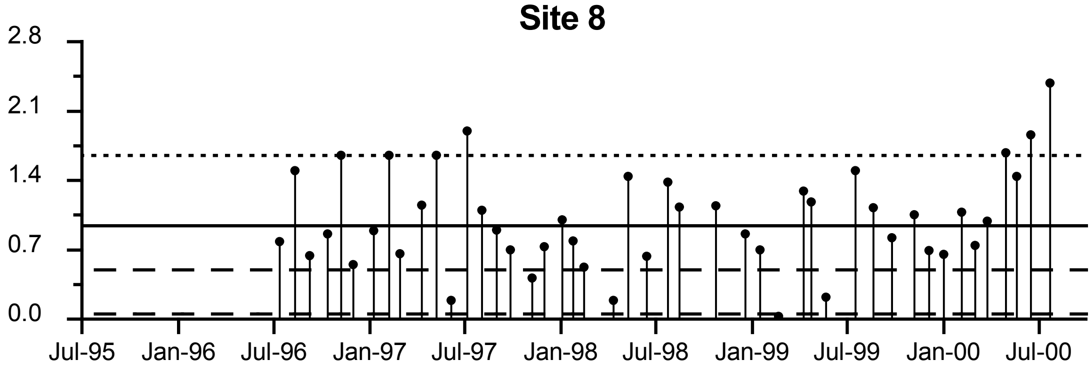


Site 6



Site 7

Site 8



Site 9

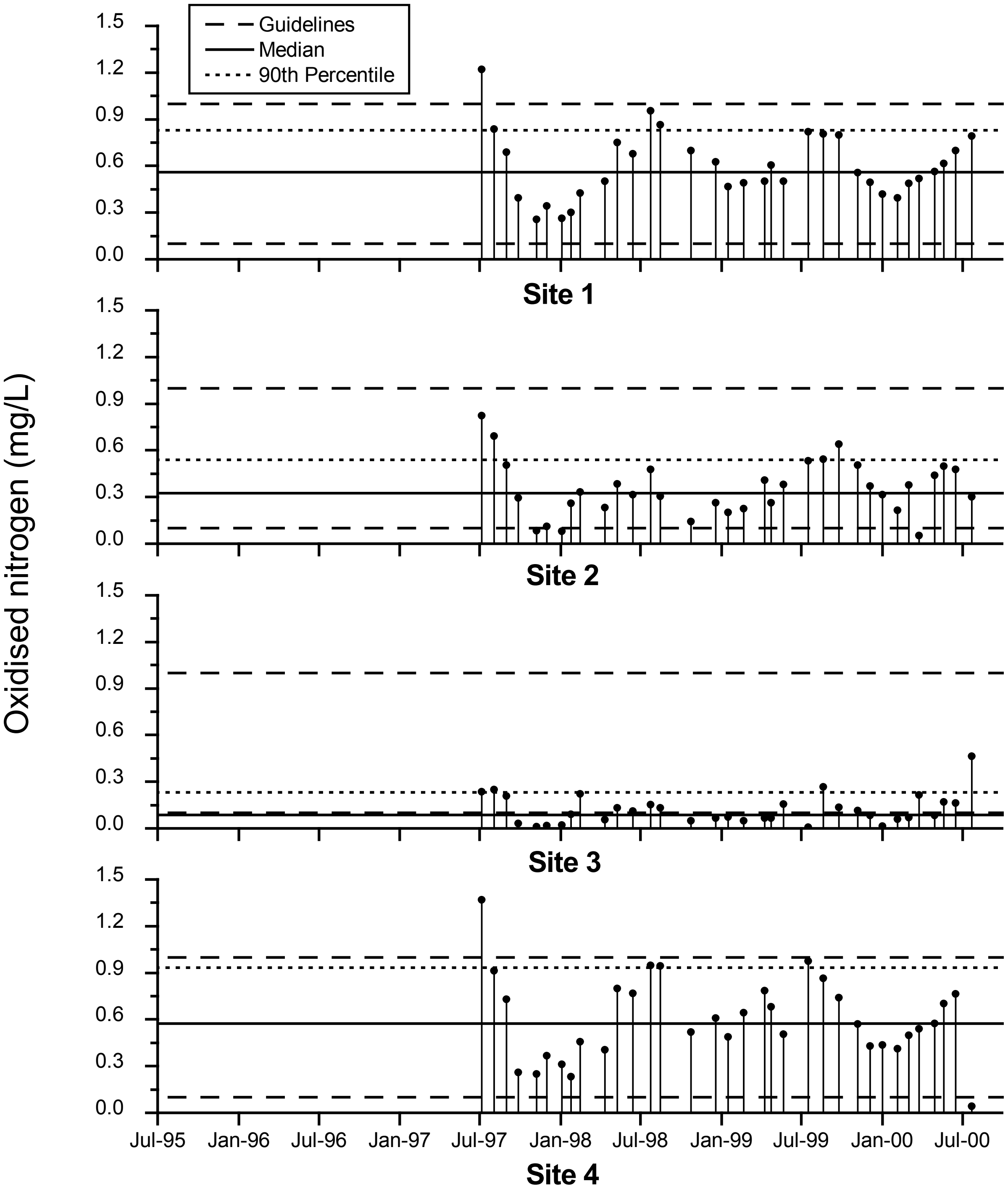
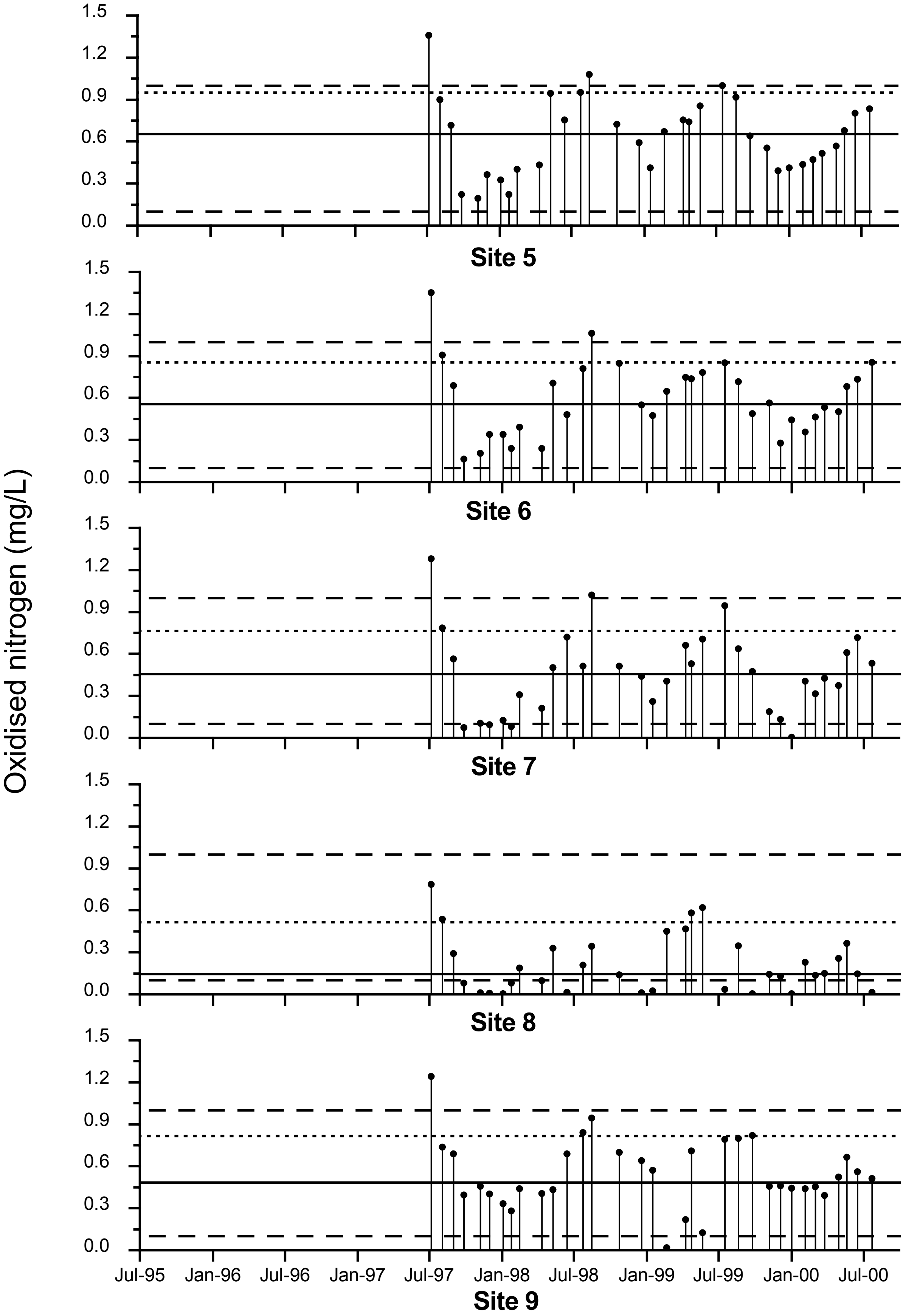


Figure 37 Oxidised nitrogen concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile compared to South Australian EPA guidelines.


Oxidised nitrogen (mg/L)
1.5
1.2
0.9
0.6
0.3
0.0
Site 5
Site 6
Site 7
Site 8
Site 9
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00

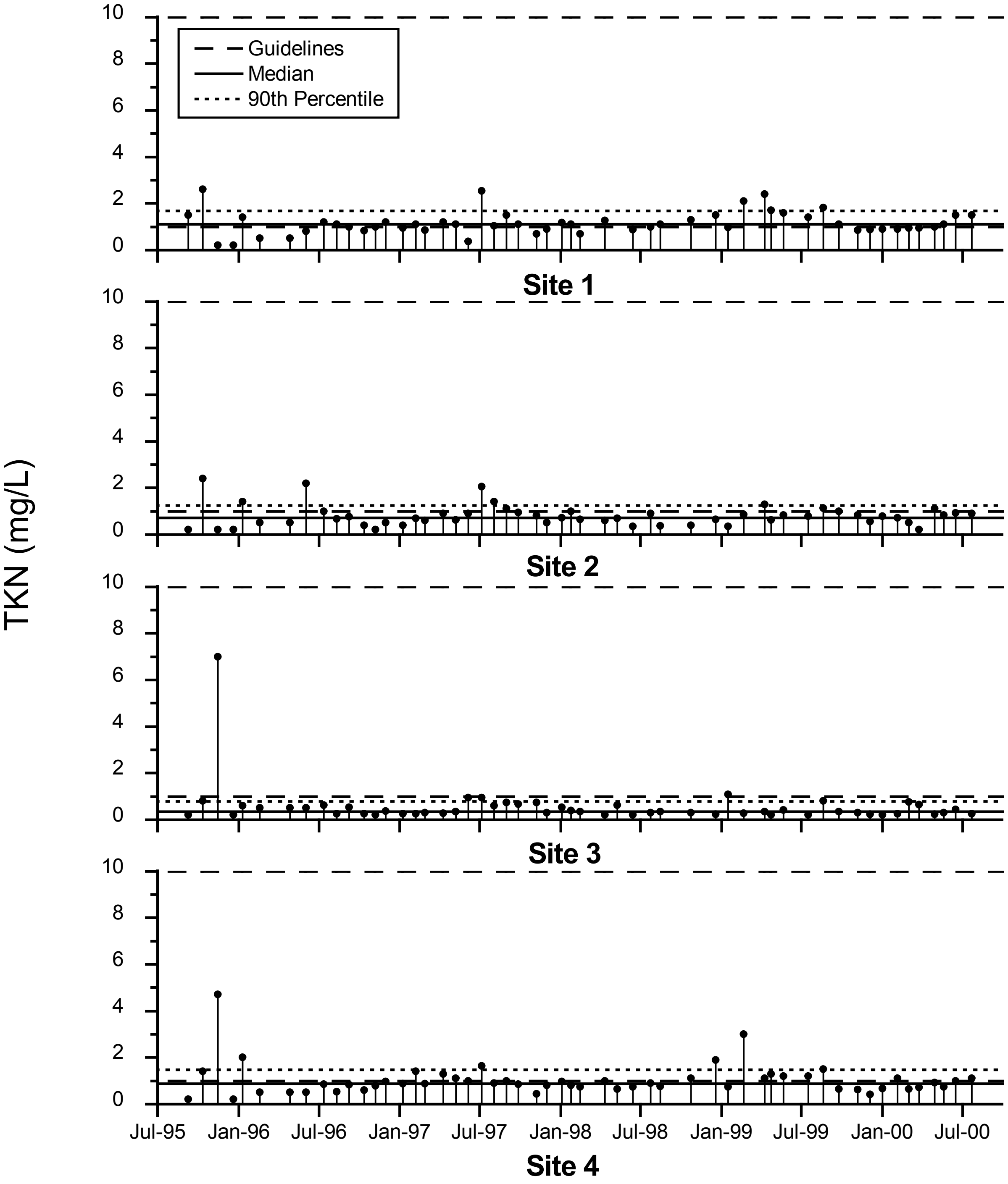
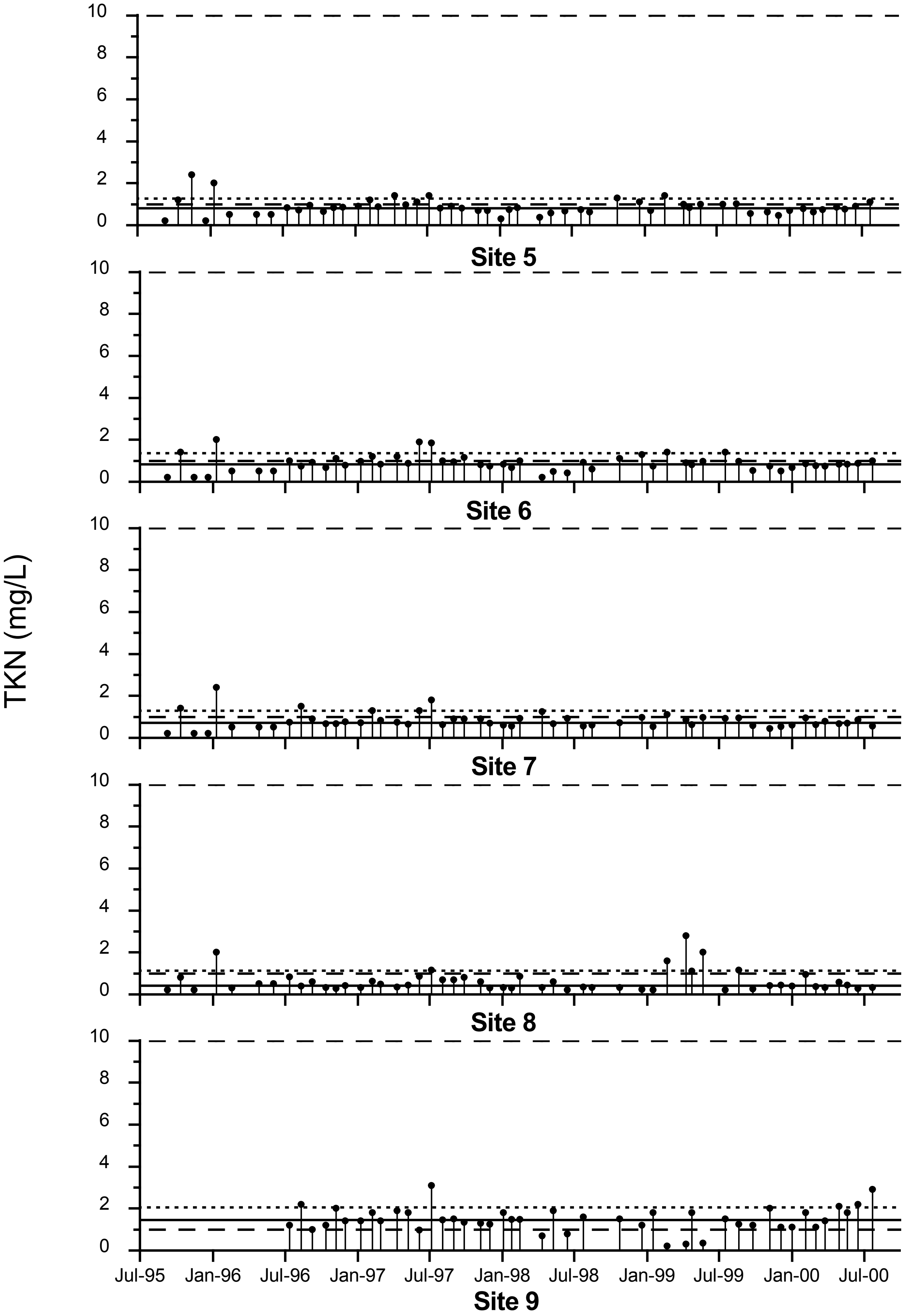


Figure 38 Total Kjeldahl nitrogen (TKN) concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile compared to South Australian EPA guidelines.


TKN (mg/L)
10
8
6
4
2
0
Site 5
Site 6
Site 7
Site 8
Site 9
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00

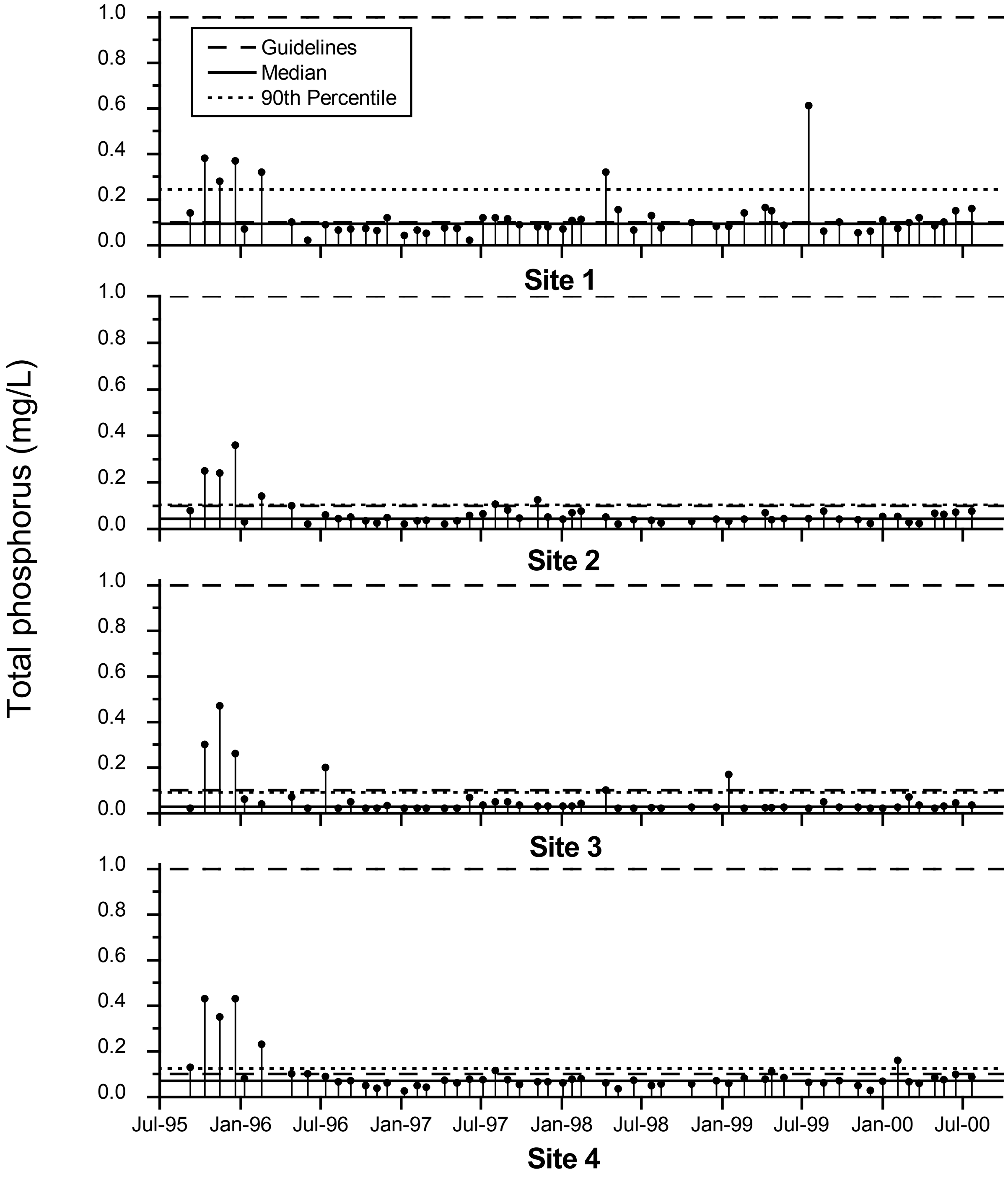
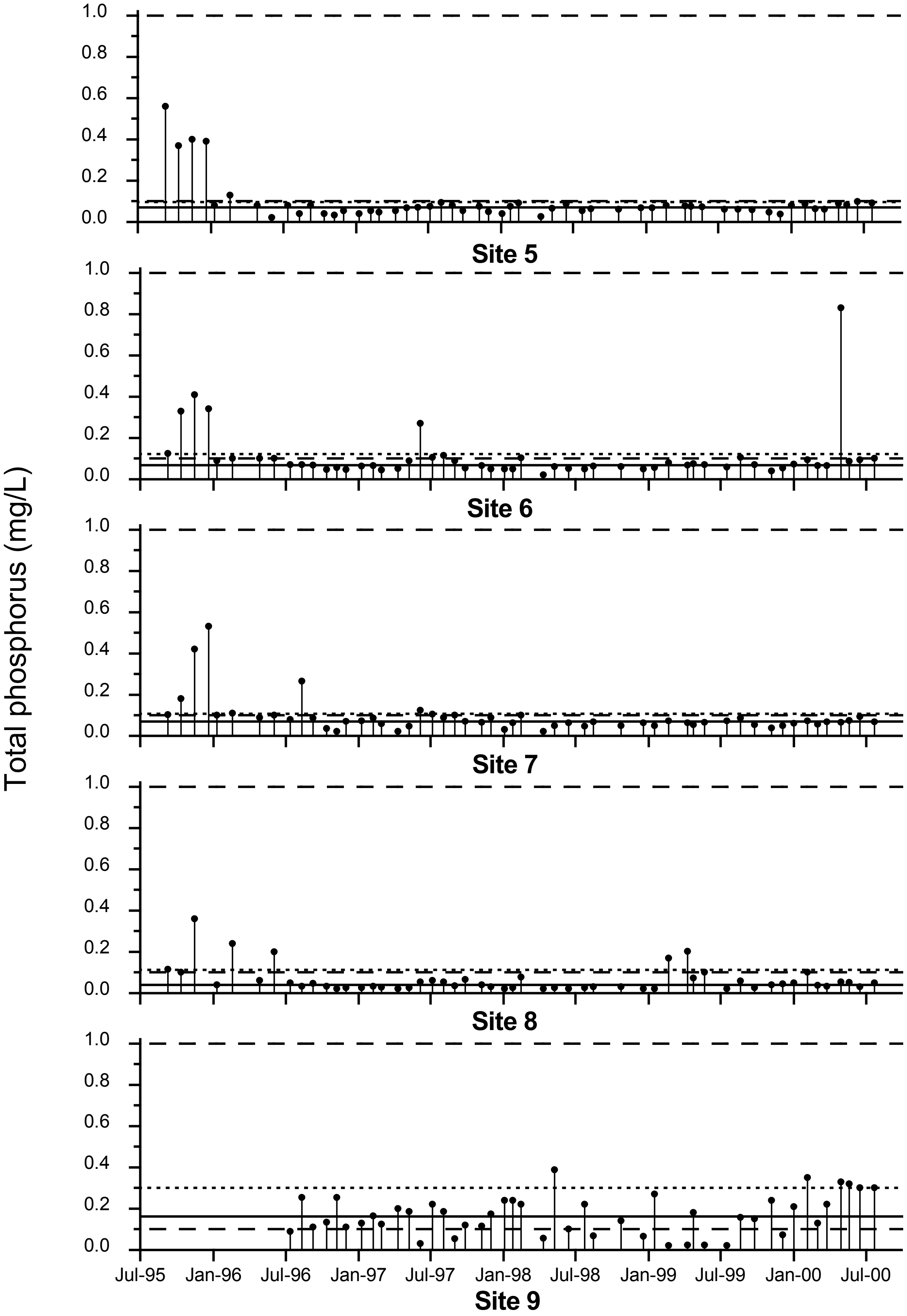


Figure 39 Total phosphorus concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile compared to South Australian EPA guidelines.


Total phosphorus (mg/L)
1.0
0.8
0.6
0.4
0.2
0.0
Site 5
Site 6
Site 7
Site 8
Site 9
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00

Algae

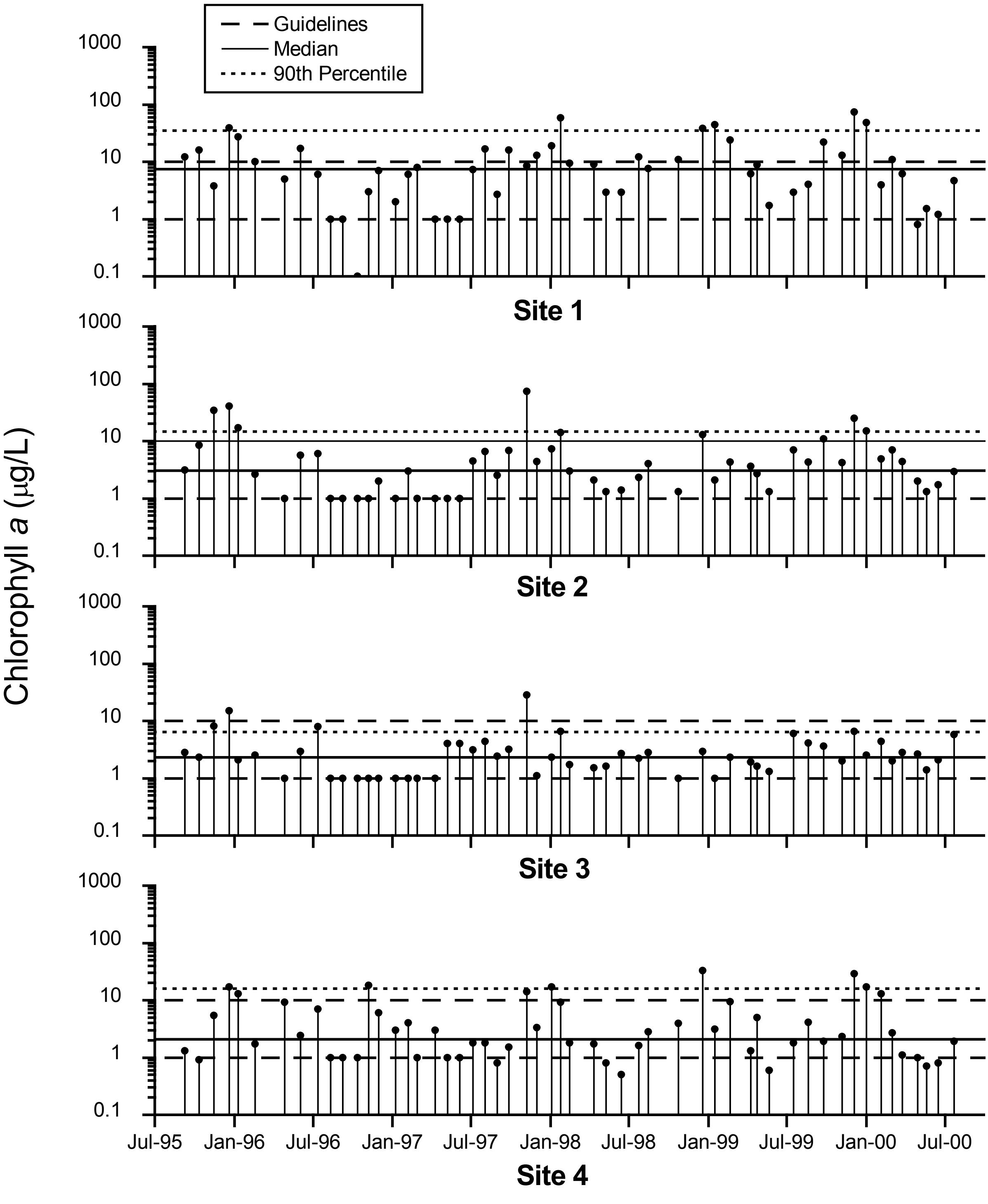
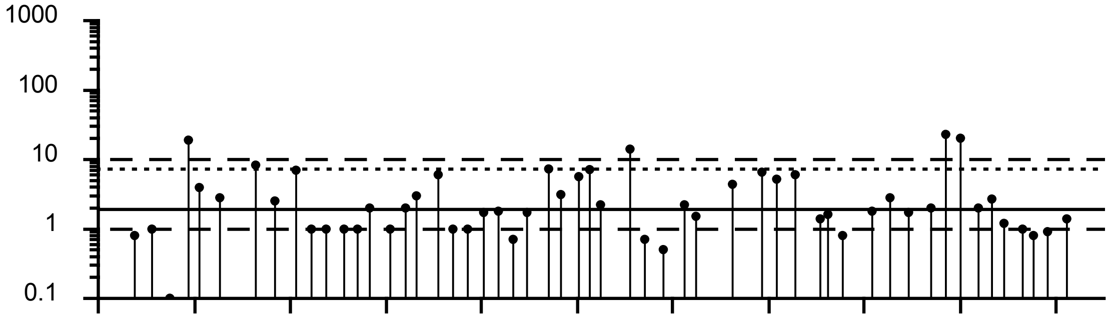
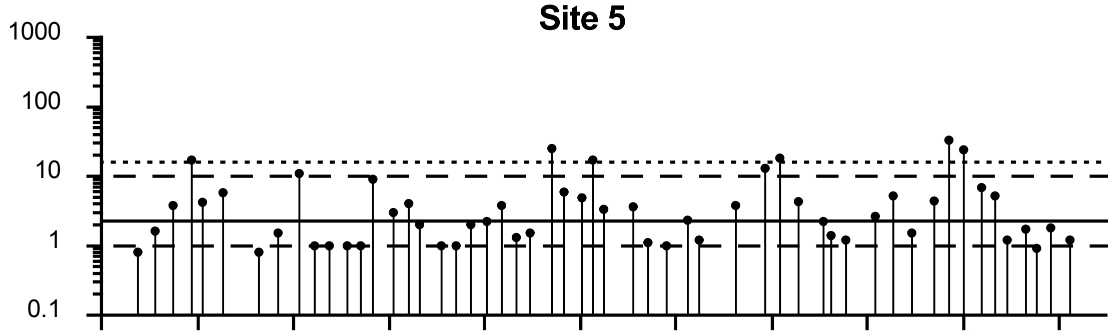


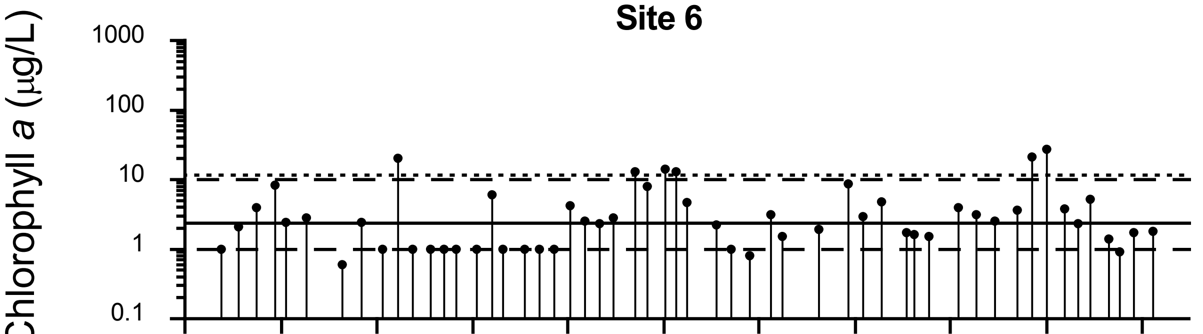
Figure 40 Chlorophyll *a* concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile compared to South Australian EPA guidelines. Value (y) axis is a log 10 scale.



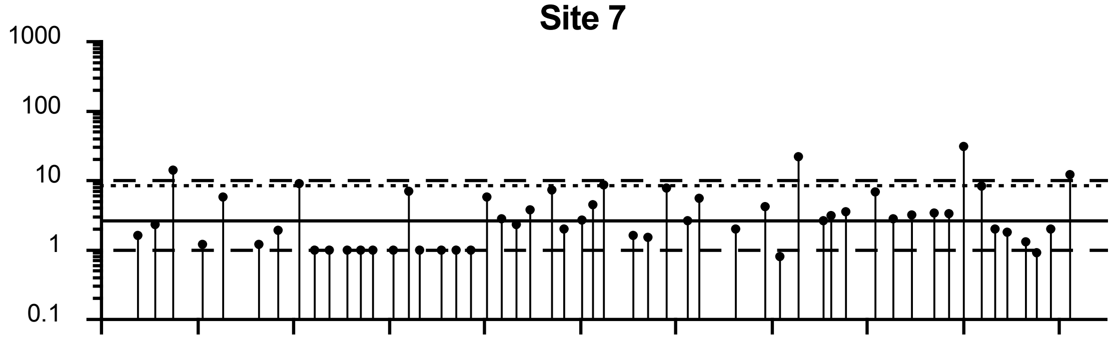
Site 5



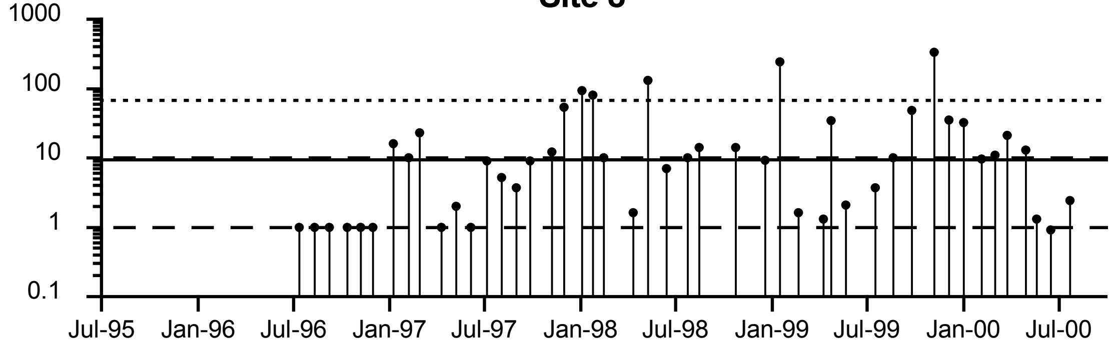
Site 6



Site 7



Site 8



Site 9

Microbiology

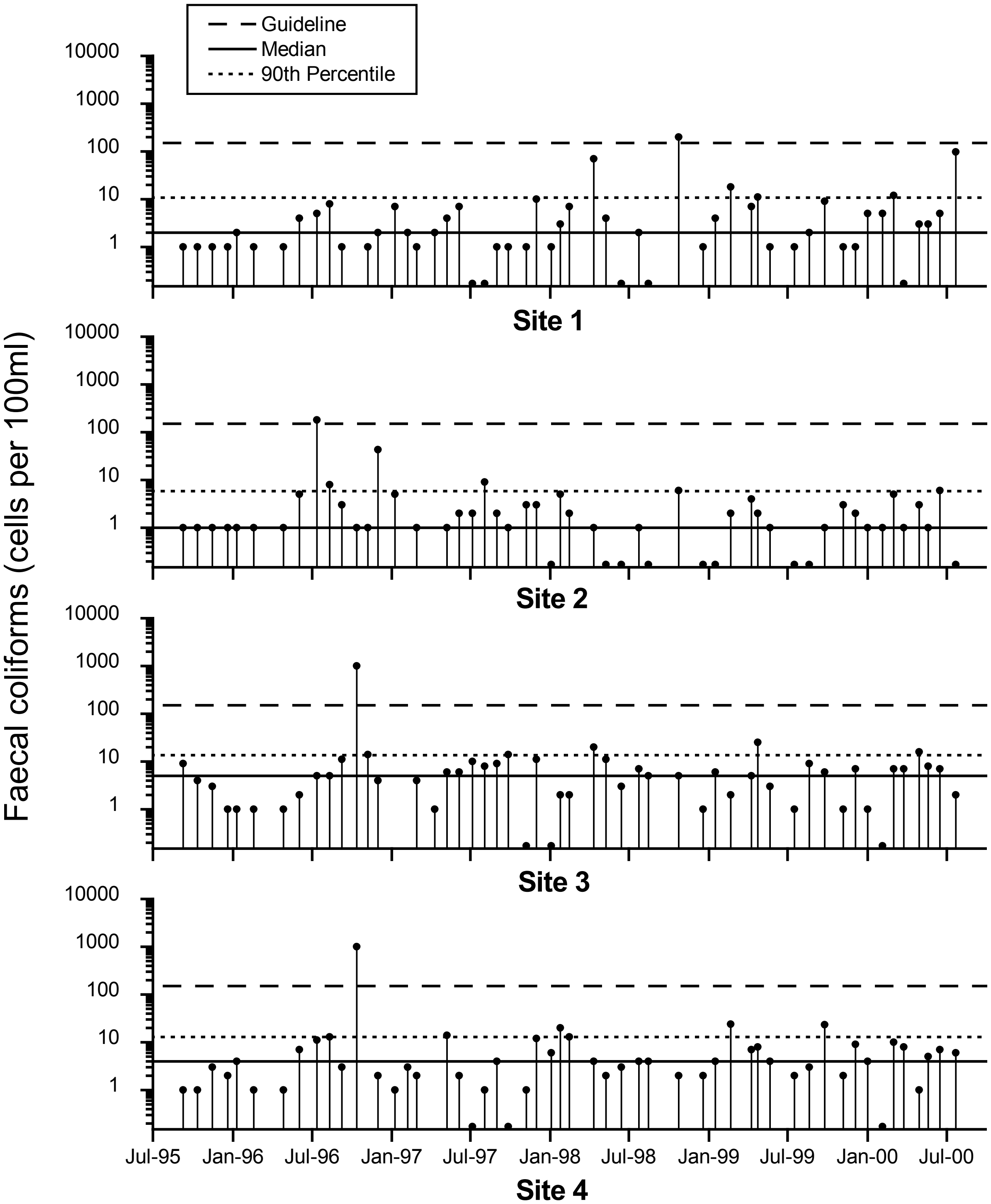
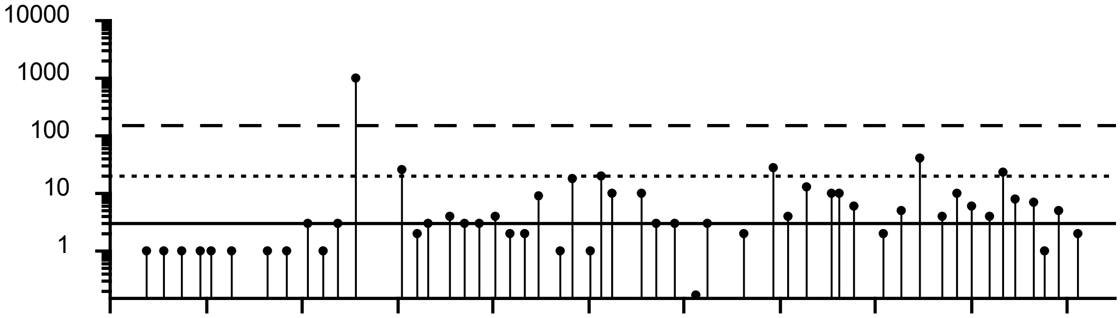
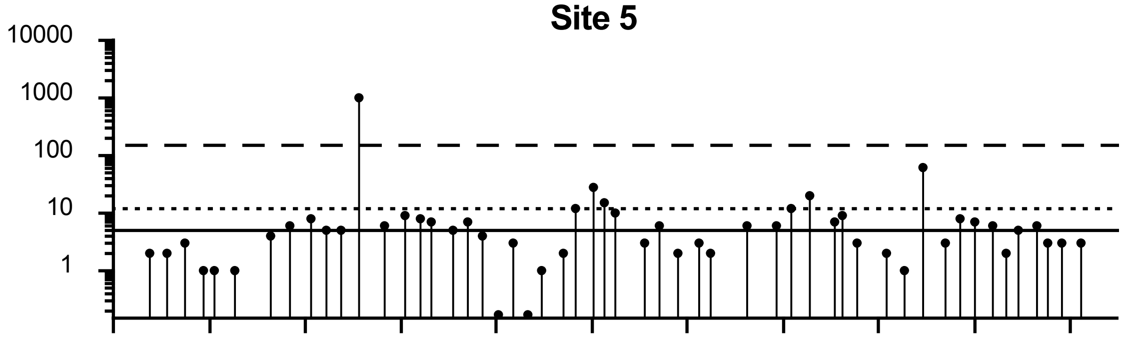


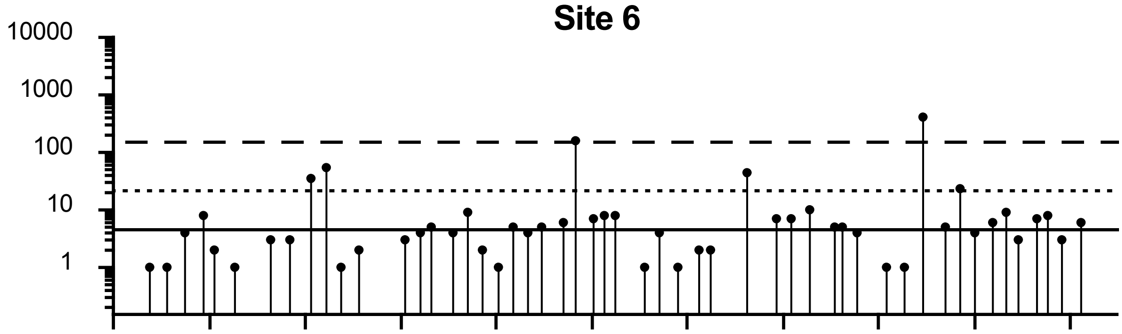
Figure 41 Faecal coliform concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile compared to South Australian EPA guidelines. Value (y) axis is a log 10 scale.



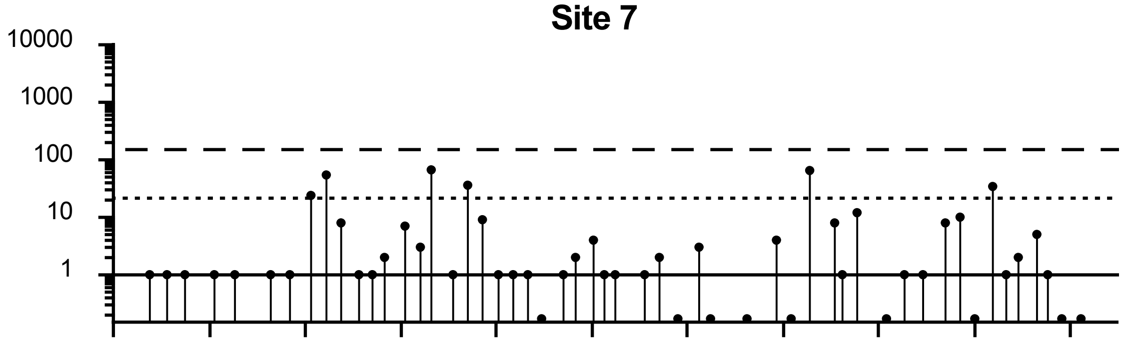
Site 5



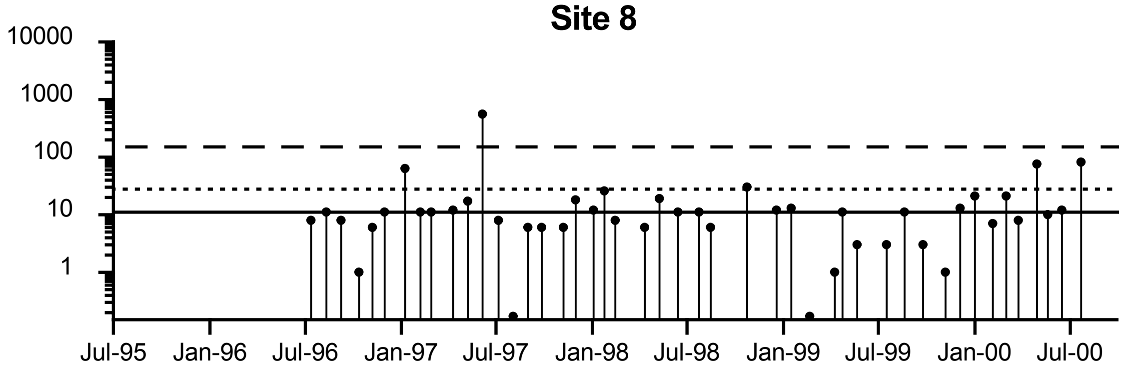
Site 6



Site 7



Site 8



Site 9

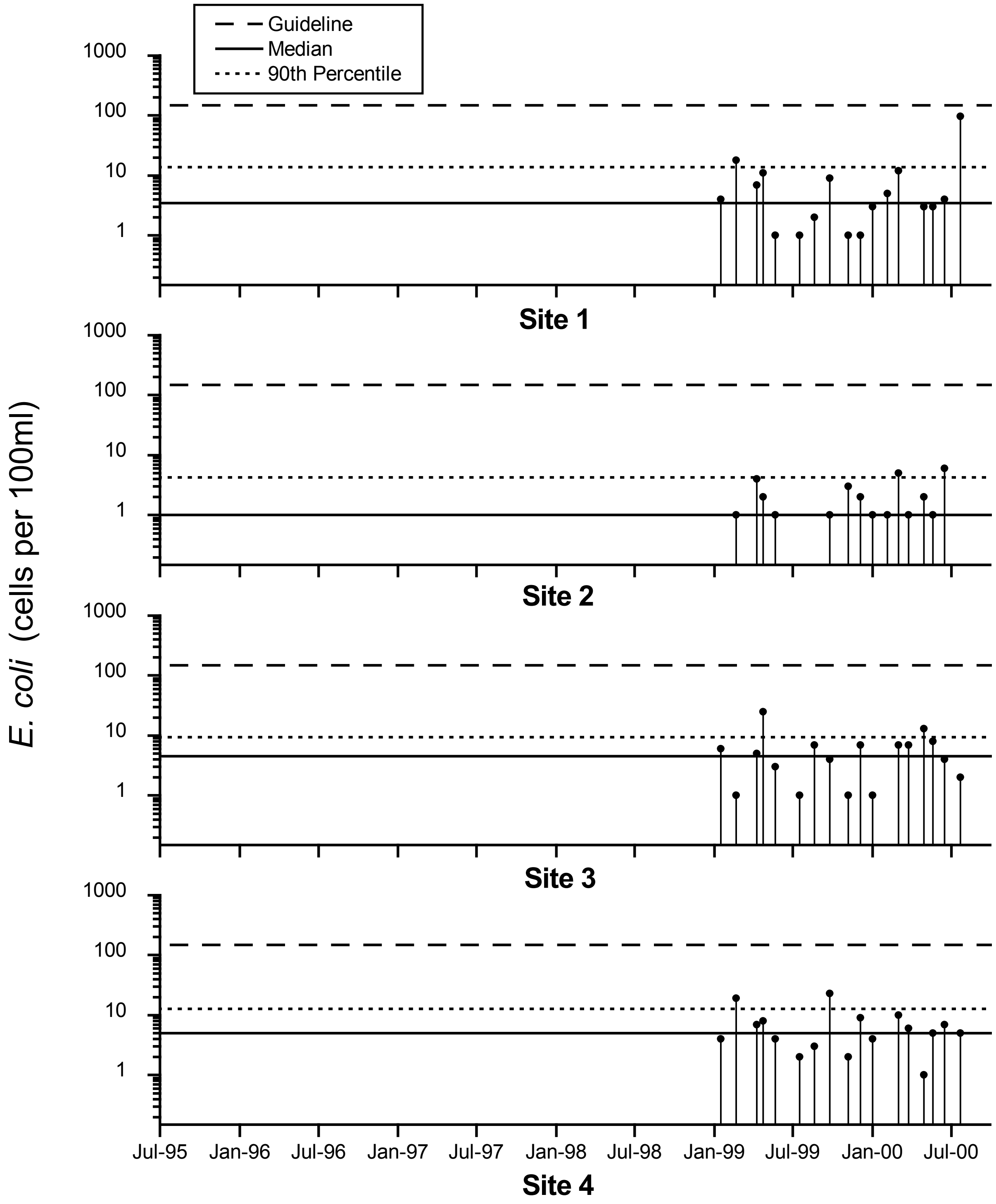
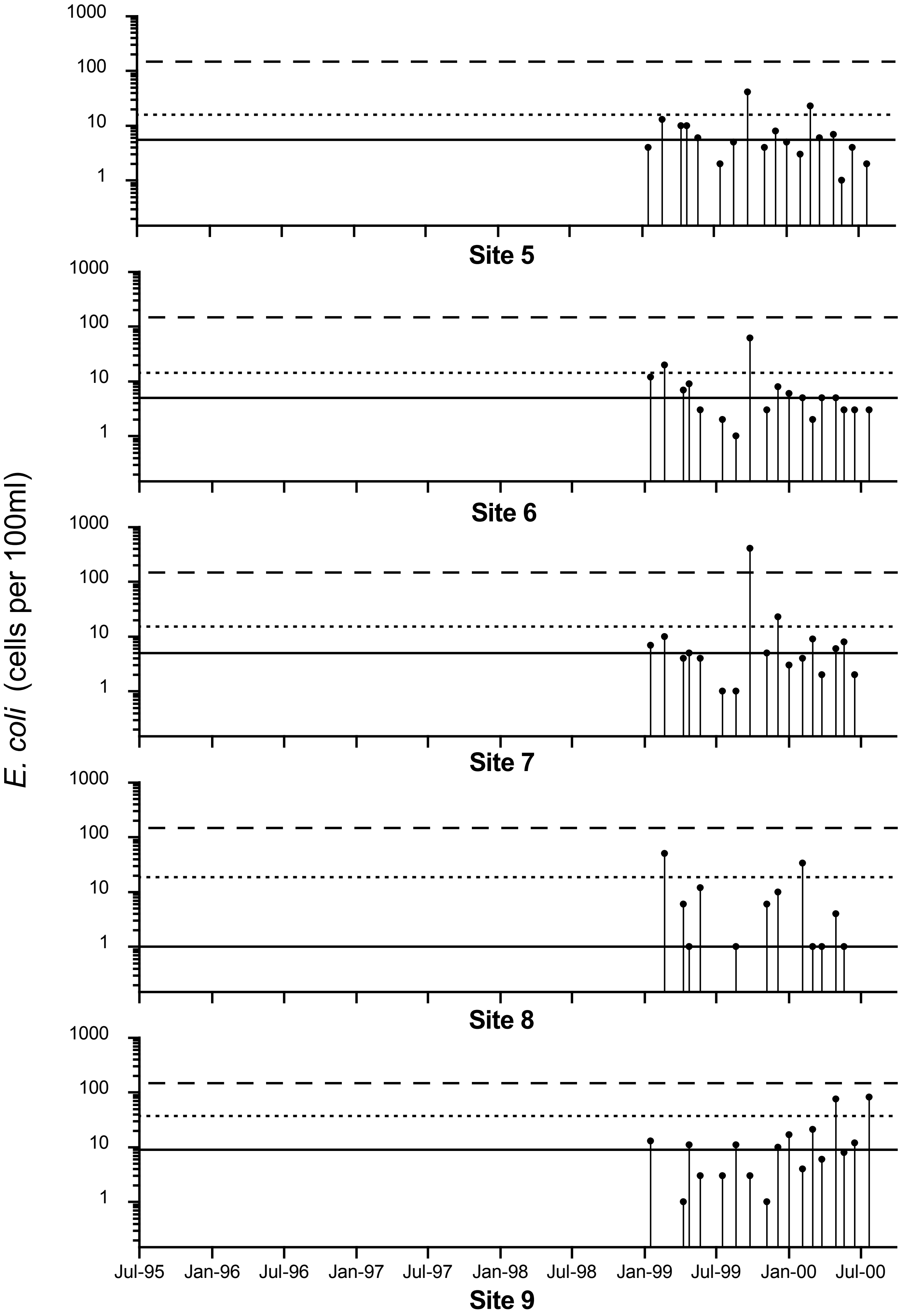


Figure 42 *Escherichia coli* concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile compared to South Australian EPA guidelines. Value (y) axis is a log 10 scale.


E. coli (cells per 100ml)
1000
100
10
1
Site 5
Site 6
Site 7
Site 8
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Site 9

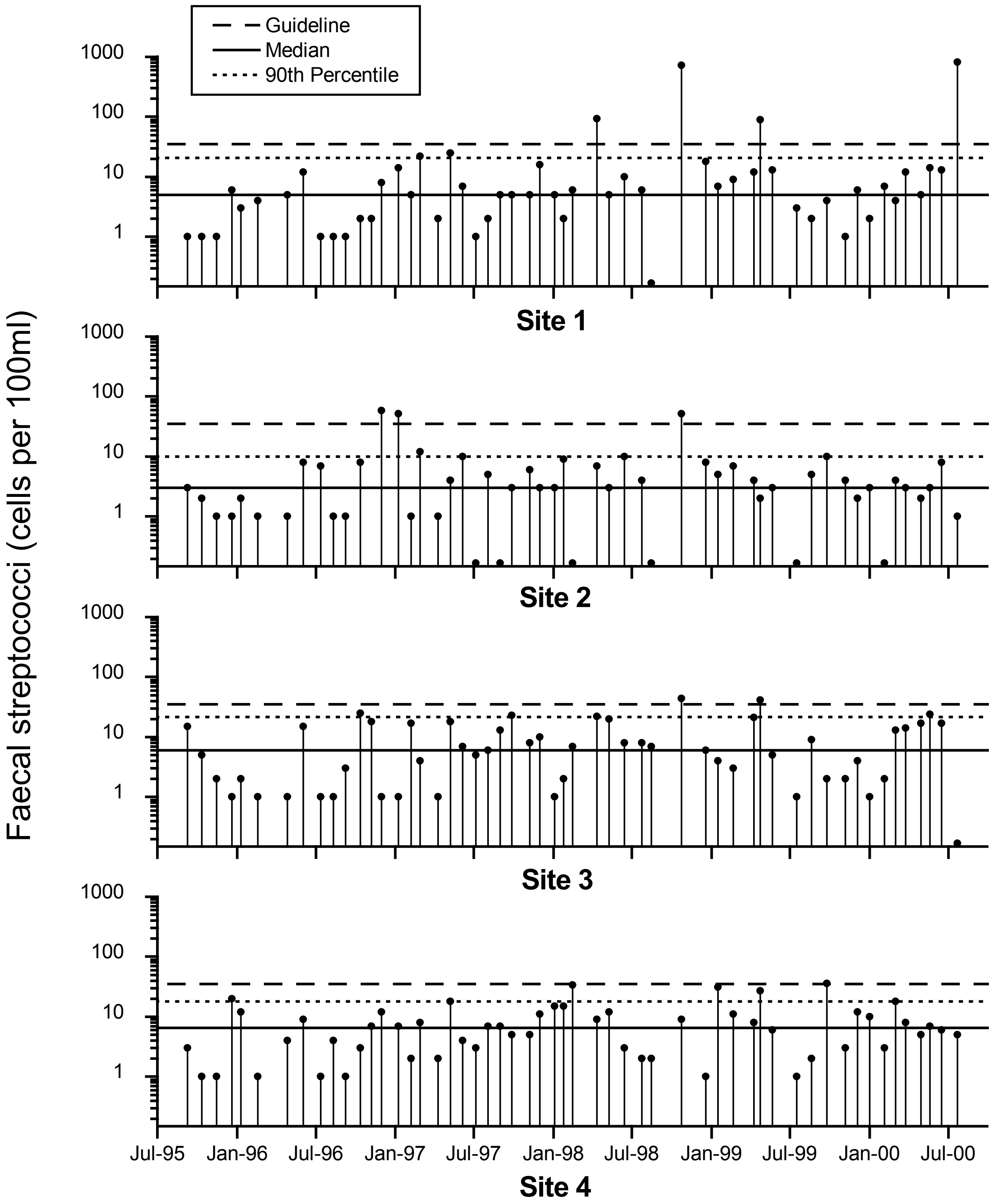
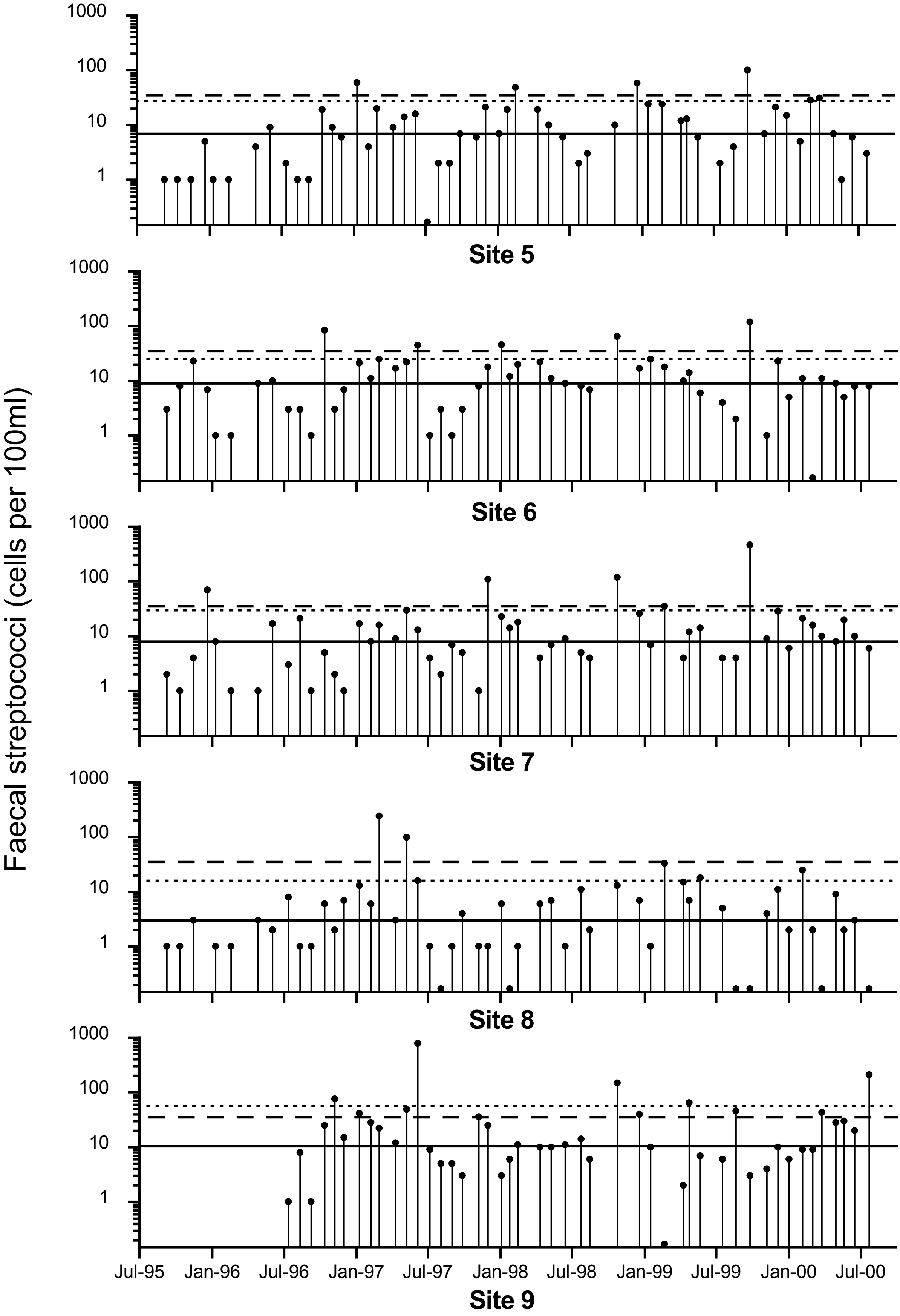


Figure 43 Faecal streptococci concentrations at nine sites in the Port River estuary, September 1995–August 2000 (site 9 data first collected July 1996): time series data with median and 90th percentile. There are no guidelines for faecal streptococci, enterococci guideline included for comparison. Value (y) axis is a log 10 scale.


Faecal streptococci (cells per 100ml)
1000
100
10
1
Site 5
Site 6
Site 7
Site 8
Site 9
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00

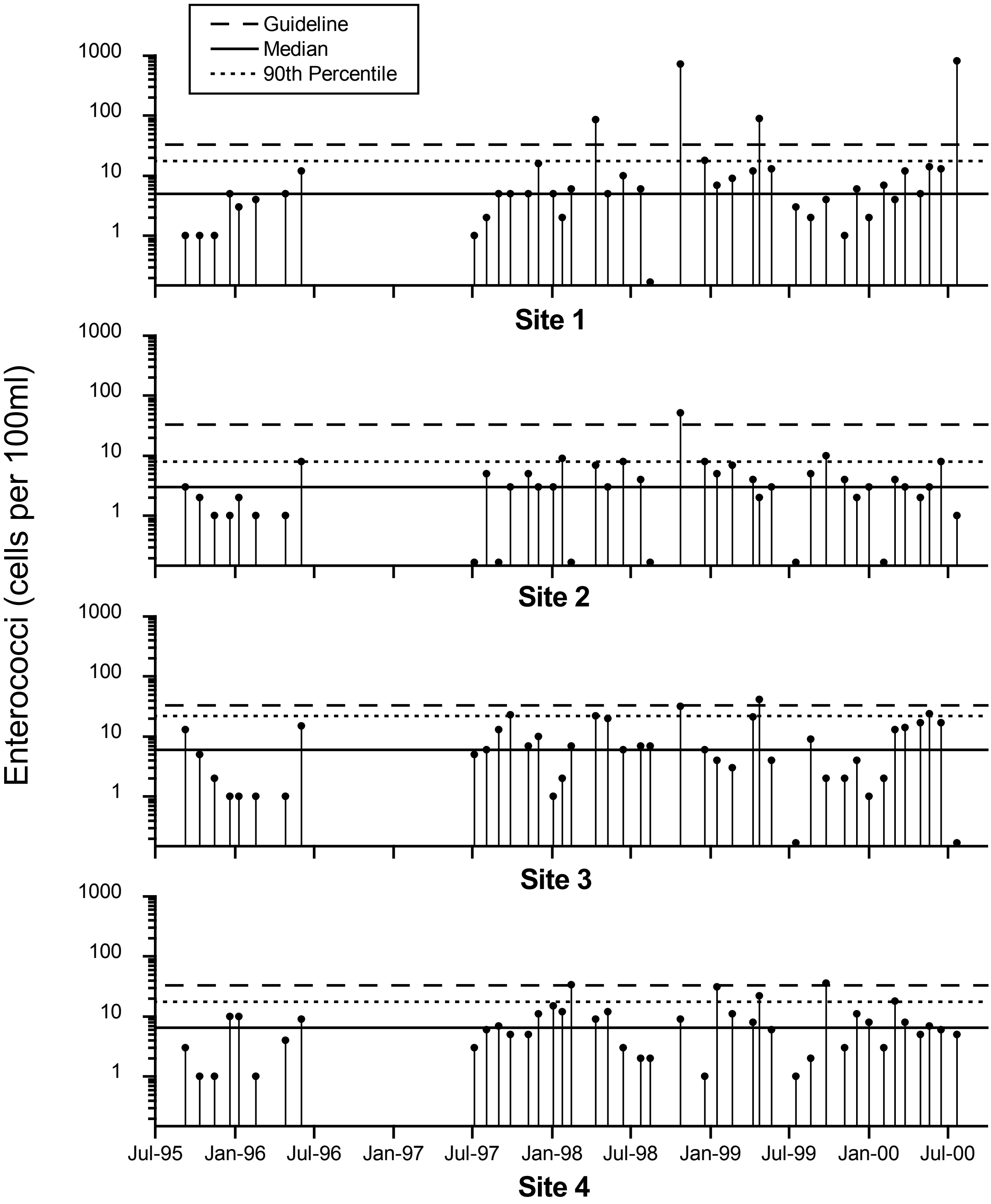
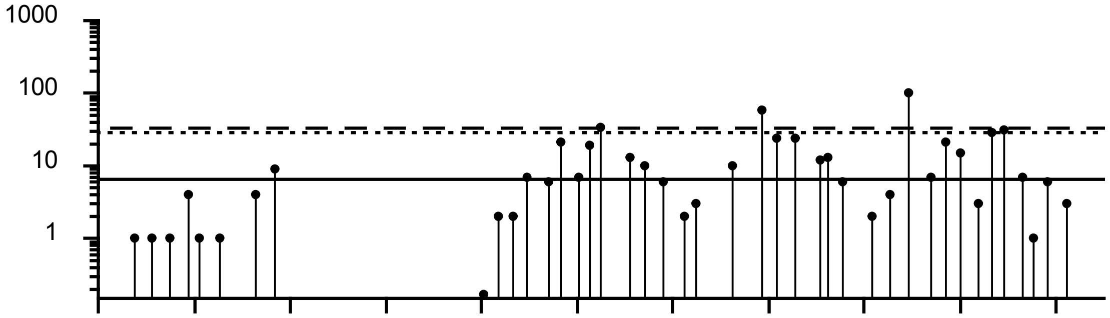
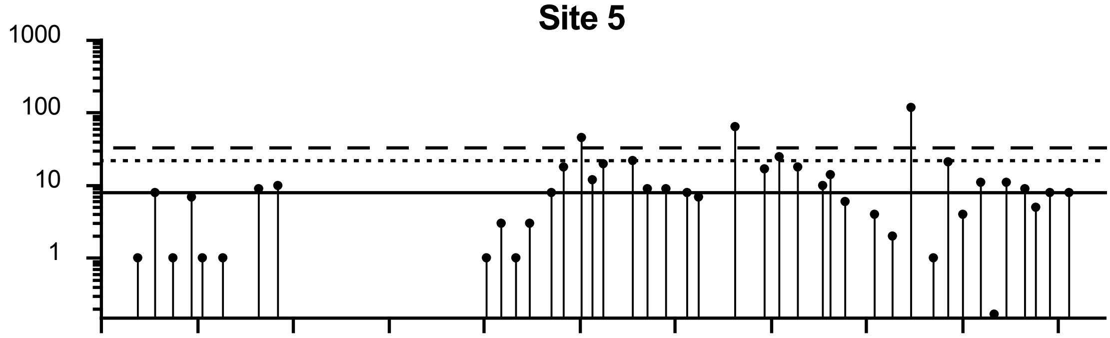


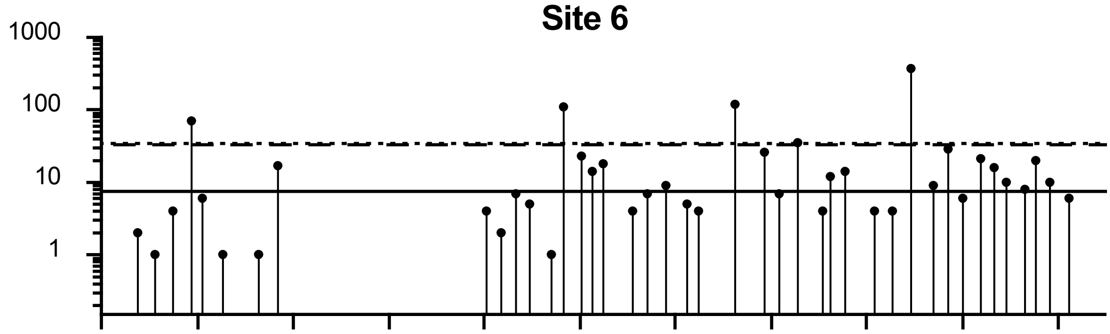
Figure 44 Enterococci concentrations at nine sites in the Port River estuary, September 1995–August 2000 (data not collected July 1996–July 1997 at all sites; site 9 data first collected July 1996): time series data with median and 90th percentile compared to South Australian EPA guidelines. Value (y) axis is a log 10 scale.



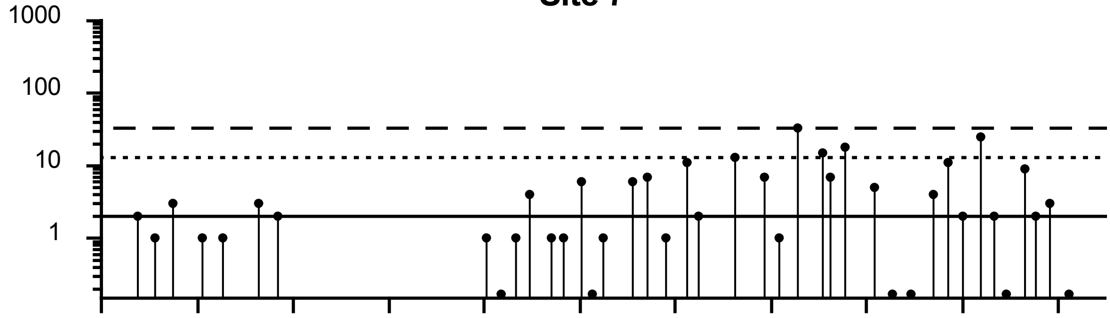
Site 5



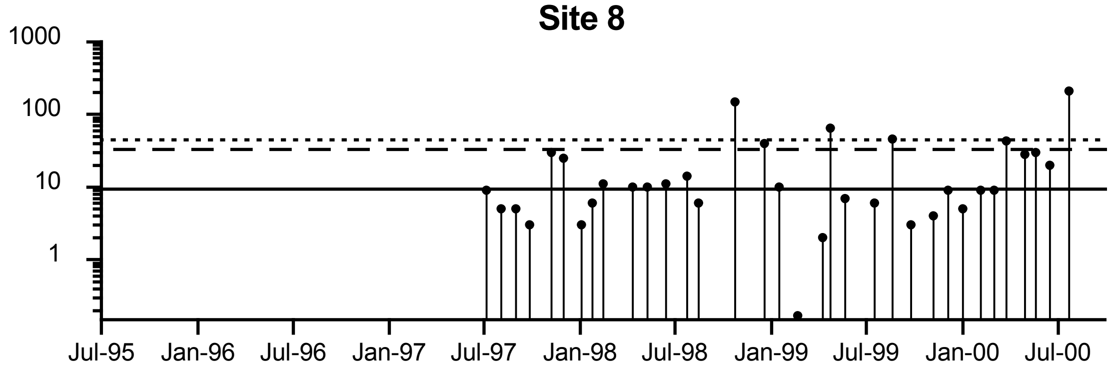
Site 6



Site 7



Site 8



Site 9

REFERENCES

Ault, T., Velzeboer, R., & Zammit, R. 2000. Influence of nutrient availability on phytoplankton growth and community structure in the Port Adelaide River, Australia: bioassay assessment of potential nutrient limitation. *Hydrobiologia*, 429, 89-103.

Australian and New Zealand Environment and Conservation Council. 1992. *National Water Quality Management Strategy-Australian Water Quality Guidelines for Fresh and Marine Waters*: Canberra, Author.

Department of Environment Protection. 1996. *Southern Metropolitan Coastal Waters Study (1991-1994)*: Report 17. Perth: Author.

Environment Protection Authority. 1997a. *Ambient Water Quality Monitoring of the Port River Estuary*. Adelaide: Author.

Environment Protection Authority. 1997b. *Sediment quality monitoring of the Port River estuary.* Adelaide: Author.

Environment Protection Authority. 2000. *Special survey of the Port River: Heavy metals and PCBs in dolphins, sediments and fish.* Adelaide: Author.

Holmes, J. W., & Iversen, M. B. 1976. Hydrology of the Cowandilla Plains, Adelaide, before 1836. In C. R. Twidale & M. J. Tyler & B. P. Webb (Eds), *Natural History of the Adelaide Region* (pp. 91-97). Adelaide: Royal Society of South Australia.

National Health and Medical Research Council. 1990. *Australian Guidelines for Recreational Use of Water*. Canberra: Author.

Sokal, R., & Rohlf, J. 1995. *Biometry* (3rd ed.). New York: W. H. Freeman and Company.

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