

# 2002 Report



## Health of the Gold Coast Waterways

Prepared by the Catchment Management Unit  
Gold Coast City Council

November 2002



Gold Coast City Council

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## EXECUTIVE SUMMARY

The health and quality of Gold Coast waterways, using historical water quality information (beginning in 1985 for some waterways), has been presented within this report from 192 monitoring sites across 20 of the City's natural and constructed waterways. All water quality information presented within this report has been assessed in comparison with the Australian and New Zealand Environment Conservation Council (ANZECC) 1992 water quality guidelines for the protection of aquatic ecosystems and primary contact recreational waters. In addition to compliance testing, water quality information has been statistically examined using univariate and multivariate techniques to determine variations (*ie* decline or improvement) for each water quality variable amongst monitoring sites in each waterway and to also assess water quality across the City using all water quality variables.

The results from this investigation have shown that the majority of monitoring sites continue to maintain a standard that complies with the ANZECC (1992) water quality guidelines for the protection of aquatic ecosystems. A summary of the key points for each waterway/survey is presented below.

Waterway	Key Points
ALBERT RIVER	<ul style="list-style-type: none"> <li>• Generally high phosphorus</li> <li>• No obvious change in any parameter over time</li> <li>• Peaks in nutrients correlated with turbidity in summer, probably from rain events</li> </ul>
BEACHES	<ul style="list-style-type: none"> <li>• Burleigh higher <i>E. coli</i> than other beach sites</li> <li>• Enclosed swimming areas higher in <i>E. coli</i> than open beaches</li> <li>• Paradise Pt swimming enclosure higher in <i>E. coli</i> and possibility deteriorating in last 2 years, possibly from bird faeces</li> </ul>
BIGGERA CREEK	<ul style="list-style-type: none"> <li>• Good water quality in lower estuary</li> <li>• Northern tributary higher nutrients, turbidity and <i>E. coli</i></li> </ul>
BROADWATER	<ul style="list-style-type: none"> <li>• Good water quality for <i>E. coli</i></li> <li>• Elevated <i>E. coli</i> at confluence sites with the Broadwater, probably related to rain events</li> </ul>
CLEAR ISLAND WATERS	<ul style="list-style-type: none"> <li>• Good water quality</li> <li>• Nutrients comply with guidelines, however, excessive growth of aquatic plants and algae suggests current loads are high</li> </ul>
COOMBABAH CREEK	<ul style="list-style-type: none"> <li>• High nitrogen and turbidity at freshwater and upper estuary sites</li> <li>• Chlorophyll-<i>a</i> and <i>E. coli</i> high in lake</li> <li>• Wetland sites have higher nutrients and <i>E. coli</i></li> <li>• Lower estuary recorded good water quality</li> </ul>
CURRUMBIN CREEK	<ul style="list-style-type: none"> <li>• Generally good water quality</li> <li>• High <i>E. coli</i> at freshwater and upper estuary sites, with a gradual increase in concentrations at freshwater sites</li> <li>• Lower estuary good water quality, probably related to greater tidal exchange with ocean</li> </ul>
HOTHAM CREEK	<ul style="list-style-type: none"> <li>• Good water quality within acceptable limits</li> <li>• Reductions in dissolved oxygen recorded</li> <li>• Higher <i>E. coli</i> at upper freshwater site</li> </ul>
LAKES - NORTH	<ul style="list-style-type: none"> <li>• High nitrogen at Pizzey Park lake</li> <li>• Higher phosphorus at Lake Hugh Muntz</li> <li>• Higher turbidity at Lake Heron and Royal Palm Lake</li> <li>• Good water quality at other lakes</li> </ul>
LAKES - SOUTH	<ul style="list-style-type: none"> <li>• Good water quality at all lakes</li> <li>• Higher turbidity at Nineteenth Ave Lake Influence, possibly Tallebudgera Creek</li> </ul>

Waterway	Key Points
LODERS CREEK	<ul style="list-style-type: none"> <li>• Upper and middle estuary sites high nutrients and very high <i>E. coli</i></li> <li>• Lower dissolved oxygen in southern tributary</li> <li>• No general improvement in water quality over time</li> </ul>
NERANG RIVER - DOWNSTREAM OF HINZE DAM	<ul style="list-style-type: none"> <li>• Generally good water quality</li> <li>• Higher <i>E. coli</i> between lower freshwater and middle estuary</li> <li>• Reductions in dissolved oxygen at several upper freshwater and middle estuary sites</li> <li>• Canal network is not influencing on water quality in lower estuary</li> <li>• Very low conductivity recorded at lower estuary sites possibly influenced by significant rain events</li> </ul>
NERANG RIVER - NUMINBAH VALLEY	<ul style="list-style-type: none"> <li>• High nutrient and higher <i>E. coli</i> recorded at NGN 4</li> <li>• Phosphorus and <i>E. coli</i> have generally improved at NGN 4</li> <li>• <i>E. coli</i> generally increased over time at NGN 6</li> <li>• Generally good water quality at all other sites</li> </ul>
NERANG RIVER - SPRINGBROOK	<ul style="list-style-type: none"> <li>• Reductions in pH at most sites, probably related to highly fertile red volcanic soils</li> <li>• Generally good water quality at all sites</li> </ul>
PIMPAMA RIVER	<ul style="list-style-type: none"> <li>• Generally good water quality</li> <li>• Higher nitrogen in lower freshwater</li> <li>• Peaks in nutrients, <i>E. coli</i> and turbidity probably related to rain events</li> </ul>
ROBINA LAKES	<ul style="list-style-type: none"> <li>• Good water quality</li> <li>• Nutrients comply with guidelines, however, excessive growth of aquatic plants and algae suggest current loads are high</li> <li>• Higher pH in West Lake probably related with algal blooms</li> </ul>
SALTWATER CREEK	<ul style="list-style-type: none"> <li>• High nutrient, <i>E. coli</i> and turbidity at freshwater sites, highest at SWC 1 and SWC 4</li> <li>• High nutrient and chlorophyll-<i>a</i> in middle estuary</li> <li>• Reductions in dissolved oxygen at upper and lower freshwater sites</li> <li>• Peaks in nutrients, <i>E. coli</i> and turbidity at sites probably from rain events</li> <li>• No significant improvement in water quality over time</li> </ul>
TALLEBUDGERA CREEK	<ul style="list-style-type: none"> <li>• Good water quality generally</li> <li>• Higher nutrients and <i>E. coli</i> in canal sites</li> <li>• Reductions in dissolved oxygen at canal sites</li> <li>• Significant improvement in nutrient and <i>E. coli</i> in upper estuary over time</li> <li>• Significant improvement in <i>E. coli</i> at TBC 6A over time</li> </ul>

The information presented within this report will assist Council in formulating effective waterway management plans and strategies that will protect, and where possible, enhance waterways within the City. It is envisaged that this report will provide a framework to assist with developing site specific water quality objectives, that will protect those environmental values of all waterways (*ie* swimming, fishing, boating etc) considered important by local catchment stakeholders. This report has shown that water quality conditions are generally maintaining a standard that will protect aquatic ecosystems. In areas where recreational swimming is promoted or popular (*eg* enclosed swimming areas and beaches) bacterial concentrations regularly comply with the national standard considered important for safe swimming.

However, it was found in several waterway areas that water quality conditions do not meet the national guidelines for the protection of aquatic ecosystems. In most cases, nutrients, turbidity and *E. coli* concentrations are the water quality variables that contributed to these poorer water quality conditions. Pressures on the Gold Coast waterways appear to be primarily related to significant changes to catchment land use. In particular, stormwater runoff from urban areas would appear to be contributing to reduced water quality conditions. Gold Coast City Council recognises that a decline in water quality could potentially impact on the available habitat for the wildlife that utilise these waterways. The decline in water quality could also result in the loss of the visual amenity and ability for Gold Coast waterways to provide suitable conditions for the various water related activities expected and enjoyed by residents and visitors to the Gold Coast.

Gold Coast City Council is committed to managing the City's waterways through the continuation of an effective water quality monitoring program. However, water quality monitoring is only a component of ecosystem monitoring, and this report recognises the importance of combining water quality information with additional indicators of ecosystem health (i.e. biological monitoring and modelled predictions of past, current and future land use impacts). The inclusion of additional ecosystem health indicators will provide a means to improve our understanding of the ecological processes and waterway responses to changes in the City's land use. This information will provide an enhanced level of ecosystem understanding, so that appropriate water quality management strategies and decisions can be implemented and the environmental values of Gold Coast waterways be protected.

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## CHAPTER 1 INTRODUCTION

### 1.1 BACKGROUND

Following the Health of the Waterways Report 1996, a second edition has been completed in response to an increase in water quality inquiries from the public, State government departments, Universities, media, students and an intra-Council departmental desire to have a clear understanding of the health and quality of the City's waterways. This second edition examines water quality data from those waterways investigated in the 1996 report and several additional waterways.

The report presents an overview of the current water quality monitoring program undertaken by Catchment Management Unit (CMU) of Gold Coast City Council's (GCCC) Community Services Directorate. This report includes:

- The assessment of water quality information from recreational monitoring sites throughout the City's natural and constructed waterways;
- Compliance analysis with the Australian and New Zealand Environment Conservation Council (ANZECC) (1992) national water quality guidelines for the protection of aquatic ecosystems and primary contact recreational waters;
- An enhanced level of water quality reporting through statistical analysis on a site specific basis within each waterway and across all waterways;
- Establishment and assessment of water quality monitoring programs for several additional waterways; and
- Recommendations for future improvements for the monitoring, management and protection of the health and quality of Gold Coast waterways.

### 1.2 CATCHMENT MANAGEMENT UNIT OF GOLD COAST CITY COUNCIL

Australia's coastal environment has been the focus of many scientific studies to understand the structure, dynamics and function of this important natural resource (eg Moreton Bay Study - Tibbets *et al*, 1998). These studies are valuable as land use changes, associated with catchment clearing for urban growth, are recognised as contributing to changes in the health of the coastal environment, particularly in terms of water quality (Cosser, 1989; Gabric and Bell, 1993; Hillman *et al*, 1990; Young, *et al*, 1996).

A catchment is a geographical area of land where all runoff following rain flows to a particular discharge area (eg rivers and estuaries) (Department of Primary Industries, 1991). Integrated Catchment Management (ICM) is the process of coordinated management of land, water, vegetation and all other biological resources in a catchment area (Department of Primary Industries, 1991). This process incorporates community, landholders, business, industry and government agencies working together to develop and implement management strategies to protect catchment areas.

The CMU operates under the principles of ICM, undertaking projects and studies that involve research, planning, policy formulation, implementation and restorative actions with respect to waterway and catchment management. The waterways of the Gold Coast are a focal point for sustainable growth in tourism, recreation, industry and the City's population. It is vital that GCCC, in collaboration with state government agencies and the community, manages the City's waterways, so that water quality standards are achieved and Environmental Values (EVs) for the City's waterways are protected. This commitment is fundamental for meeting the principles of Ecologically Sustainable Development (ESD).

The primary roles of the CMU include:

- The protection and enhancement of aquatic ecological health in all natural and constructed waterways throughout the City;
- Implementation of water quality, sediment and biological monitoring programs;
- Identification and development of EVs through Catchment Management Plans for waterways within the City;

- Implementation of the principles of integrated catchment management;
- Control and management of stormwater quality;
- Investigate fish kill and algal bloom occurrences;
- Management and monitoring of acid sulfate soils; and
- Conduct public awareness programs of environmental management, enhancement and protection.

### **1.3 HISTORY OF WATER QUALITY MONITORING**

Prior to the amalgamation of the former Albert Shire Council and Gold Coast City Council in 1995, achieving an integrated, catchment-based approach towards the management of all the City's waterways was a difficult task. This was because numerous waterways crossed through both local authority boundaries. Water quality monitoring within the region was at the discretion of each Council and the State government. Therefore, the extent of water quality monitoring varied between each waterway.

Waterways located within the former Gold Coast City region were monitored on a regular basis with some programs beginning as early as 1975. Waterways regularly monitored included: Gold Coast beaches and swimming areas from Hope Island to Point Danger, Currumbin Creek, the ocean and Broadwater, Coombabah Lake, Tallebudgera Creek, Nerang River and the Benowa flood channel.

Regular water quality monitoring within the Albert Shire began in 1987 with the lakes survey. This survey included such lakes as the Nineteenth Avenue Lake (Elanora), the Robina Lakes System and the waterways of the Merrimac/Carrara Floodplain. Tallebudgera Creek was also monitored on a regular basis. The Albert Shire Council also monitored residential and commercial properties, which drew potable water from either waterways or tanks.

With amalgamation of the Councils, the two previous monitoring programs were combined and any duplication of monitoring was eliminated. As a result, the current water quality monitoring program provides results for a monitoring program that was designed by two independent bodies and then combined. The CMU reviewed the existing monitoring program following the Health of the Waterways Report 1996 and implemented changes to provide an improved water quality monitoring program.

### **1.4 NEW WATER QUALITY MONITORING SITES**

Following the Health of the Waterways Report 1996, additional water quality monitoring sites and surveys have been included in this program to provide a greater understanding of the health and quality of Gold Coast waterways. The additional monitoring sites/waterways include:

- Saltwater Creek (Oxenford);
- Three (3) additional sites in Coombabah Creek;
- Landfill Facilities;
- Three (3) additional sites in Mudgeeraba Creek;
- Bonogin Creek;
- Wyangan Creek;
- McCoys Creek (Pimpama); and
- Additional Beach survey and Broadwater survey monitoring sites.

#### **1.4.1 SALTWATER CREEK (OXENFORD)**

Saltwater Creek is located between Coombabah catchment and the Coomera River. The headwaters of Saltwater Creek begin in the upper reaches of the Nerang State Forest, where it flows down through Oxenford, under the Pacific Highway, meanders through Hope Island and joins with Coombabah Creek before entering the Coomera River. A monthly water quality monitoring program began in March 1999 to assess the health of this creek system, particularly since the catchment has recently come under pressure from development.

#### **1.4.2 COOMBABAH CREEK**

In addition to the water quality monitoring sites that existed downstream of the Pacific Highway, three additional sites have been included upstream of the Pacific Highway within the freshwater region of the catchment. These additional sites were included to assess the health of the freshwater region of this catchment, particularly since the catchment has recently experienced increased development.

#### **1.4.3 LANDFILL MONITORING**

A water quality monitoring program has been established to assess potential impacts on water quality and fulfil compliance with licence requirements of the City's landfill sites. This program incorporates six operating landfills across the City. In January 2000, a 12 month intensive water quality, sediment and biological monitoring program of identified Runaway Bay canals and Runaway Lake was undertaken to assess the potential impacts of a former landfill site. This program found the former landfill site was not impacting on the health and quality of the adjacent Runaway Bay canals. However, several contaminants were found in oysters, which were likely to originate from urban stormwater (Keys and Mortimer, 2001).

#### **1.4.4 MUDGEERABA CREEK/BONOGIN CREEK/WYANGAN CREEK**

A water quality monitoring program has been established in Bonogin and Wyangan Creeks to assess the health and quality of each creek. In Mudgeeraba Creek, three (3) additional sites have been included upstream of Summerset Drive to assess water quality in the upper reaches of Mudgeeraba Creek.

#### **1.4.5 McCOYS CREEK**

McCoys Creek is located within the Pimpama River catchment near Coomera. This shallow, mangrove-lined creek has been designated a Marine Park Protection Zone area due to the diversity and significance of mangrove species along its banks. Water quality monitoring within this creek began in June 2000 and has been designed to monitor and assess the health of this waterway.

#### **1.4.6 ADDITIONAL BEACHES AND BROADWATER SITES**

Several water quality monitoring sites have been included within the Beaches and Broadwater monitoring program to assess the quality of popular recreational swimming areas across the Gold Coast.

#### **1.4.7 RESPONSE MONITORING**

Additional water quality monitoring programs have been undertaken throughout the City in response to public enquiries regarding water quality within a particular waterway. These have included:

- 1/ Carrara Lake;
- 2/ Flat Rock Creek (Currumbin);
- 3/ Harley Park Swimming Area (Labrador);
- 4/ Morie Ball Lake (Pizzey Park);
- 5/ Dunlops Canal;
- 6/ Swan Lake and Burleigh Lakes;
- 7/ Bienvenue Lake (Currumbin).

### **1.5 NATIONAL WATER QUALITY MANAGEMENT STRATEGY**

The Australian and New Zealand Environment and Conservation Council (ANZECC), the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and the National Health and Medical Research Council (NHMRC) have been working together to develop a coordinated approach to national water quality management. The aim of this strategy is to pursue the sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development (ARMCANZ & ANZECC, 1994).

The National Water Quality Management Strategy (NWQMS) recognises that management decisions are made on the basis of sometimes inadequate data. Consequently, an 'interactive' or 'feedback' type process is recommended whereby the efficacy of the progressive implementation of management activities is measured or monitored. This information can then be used in comparisons with predicted achievement of management objectives. In the event of either failure to achieve the desired objectives, or 'over' achievement, appropriate modifications can then be made to the management strategy.

The NWQMS cannot apply to the whole range of water environments across Australia without modification to address local conditions. In some instances different water quality results reflect natural variations, while others reflect degradation of waters through a lack of awareness of environmental implications associated with historical water and land use management practices. Water quality objectives should therefore take into account natural variations within the aquatic environment, when they are established, to support and protect the designated uses of water within a specific region.

Included in the NWQMS are the ANZECC (1992) guidelines for the protection of aquatic systems, which GCCC officers use for assessing the health and quality of water quality conditions within the City. CMU recognises the importance of local based specific water quality guidelines and will develop in the future detailed water quality objectives for the City's waterways.

## 1.6 INTERIM ENVIRONMENTAL VALUES

The desired health and quality for a particular water body is related to the purpose/s of that water body as determined by the local community. Once the purpose/s or value/s of a waterway has been identified, there is a corresponding set of water quality objectives (guidelines), which prescribe the limits for a range of parameters to maintain or achieve the desired value/s.

The CMU has assigned interim EVs to each water quality monitoring site for initial investigative purposes. It is the intention of CMU to coordinate a community consultation program in combination with industry, community groups and state government agencies in the future to develop specific EVs for all waterways across the City. This process has commenced in several waterways within the City. In the short term, interim EVs have included;

- **Primary contact recreation:** Human bodily immersion or submersion where there is direct contact with the water, and includes activities such as swimming, diving, water skiing and surfing.
- **Secondary contact recreation:** Some direct contact with water but where the probability of swallowing water is unlikely. Activities include paddling activities of children, kayaks, watercrafts, wading, boating and fishing.
- **Visual Use:** Aesthetic enjoyment is the primary consideration for visual use or passive recreation. Activities include scenic appreciation, picnicking and walking.
- **Protection of Aquatic Ecosystems:** The protection of biological diversity and maintenance of ecological processes in an aquatic environment.

Waterways have been analysed in this report in terms of primary contact recreational waters. In some waterways, the perceived environmental value of a particular waterway by the community may differ to the value or level of protection considered important for a waterway. Analysing each waterway for compliance with primary contact recreational waters standardises results from sites and analyses bacterial concentrations for the most direct form of human contact.

## CHAPTER 2 MONITORING PROGRAM AND METHODOLOGY

### 2.1 OVERVIEW OF MONITORING PROGRAM

The waterways of the Gold Coast, including Southern Moreton Bay, cover over 6% of the City (not including the beaches) (GCCC, 1997). One hundred and ninety-two (192) sampling sites from twenty (20) of the City's major waterways have been incorporated into this report, encompassing freshwater, estuarine and ocean environments (Figure 2.1). Specific monitoring details for each waterway are summarised in Table 2.1.

**Table 2.1** Summary of each waterway including survey code, number of sites, monitoring frequency and period of monitoring for each waterway within the City.

Waterway	Survey Code	Number of Sites	Period	Frequency
Albert River	ABR	3	Jan 1996 - Present	Monthly
Bonogin Creek	BNG	5	Sep 2000 - Present	Monthly
Boobegan Creek	BBC	1	Jul 1997 - Present	Monthly
Broadwater	BDW	10	Jan 1995 - Present	Monthly
Biggera Creek	BGC	4	Jul 1997 - Present	Monthly
Beaches	BCH	18	Feb 1995 - Present	**
Carrara Main Drain	CMD	3	Jul 1997 - Present	Monthly
Coolangatta Creek	COO	1	Feb 993 - Present	Monthly
Coombah Creek	CBL/CBC	11	Aug 1992 - Present	Monthly
Curumbin Creek	CRC	9	Feb 1993 - Present	Monthly
Gardiners Creek	GDC	1	Mar 1987 - Present	Monthly
Gin House Creek	GH	1	Jan 1995 - Present	Monthly
Hotham Creek	HTC	3	Jan 1996 - Present	Monthly
Loders Creek	LDC	5	Aug 1994 - Present	Monthly
McCoys Creek	MCC	4	Jun 2000 - Present	Monthly
Mudgeeraba Creek	MGB	8	Dec 1993 - Present	Monthly
Nerang (Springbrook)	NGS	7	Jun 1995 - Present	Monthly
Nerang (Numinbah)	NGN	8	May 1995 - Present	Monthly
Nerang (below Hinze Dam)	NGR	11	Mar 1987 - Present	Monthly
Pimpama River	PMR	3	Jan 1996 - Present	Monthly
Saltwater Creek	SWC	7	Apr 1999 - Present	Monthly
Tallebudgera Creek	TBC	12	Nov 1986 - Present	Monthly
Witt Avenue	WA	2	Jan 1995 - Present	Monthly
Worongary Creek	WC	1	Oct 1994 - Present	Monthly
Wyangan Creek	WYN	3	Sep 2000 - Present	Monthly
Clear Island Waters <sup>+</sup>	CIW	7	Jul 1997 - Present	Monthly
Robina Lake <sup>#</sup>	RWL/MDL	6	Mar 1994 - Present	Monthly
Royal Palm Lake <sup>#</sup>	RPL	2	Jul 1997 - Present	Quarterly
Runaway Lake <sup>#</sup>	RBL	1	Jan 1995 - Present	Quarterly
Monterey Keys <sup>+</sup>	MBL	4	Jul 1997 - Present	Quarterly
Lake Rosser <sup>+</sup>	LKR	2	Jan 1995 - Present	Quarterly
Benowa Flood Channel	BFC	2	Jan 1995 - Present	Quarterly
Lake Rudd	LRD	3	Sep 2000 - Present	Monthly
Lake Hugh Muntz <sup>+</sup>	LHM	2	Apr 1987 - Present	Quarterly
Pizze Park Lake <sup>+</sup>	PPL	1	Dec 1993 - Present	Quarterly
Silvabank Lake <sup>#</sup>	SBL	4	Dec 1993 - Present	Quarterly
Lake Heron <sup>#</sup>	LKH	1	Dec 1993 - Present	Quarterly
Miami Lake <sup>#</sup>	PML	1	Jan 1987 - Present	Quarterly
Pelican Lake <sup>#</sup>	PML	1	Jan 1987 - Present	Quarterly
Burleigh Lake <sup>#</sup>	BUR	2	Jan 1987 - Present	Quarterly
Swan Lake <sup>#</sup>	SWL	3	Dec 1993 - Present	Quarterly
Nineteenth Ave Lake <sup>#</sup>	NAL	2	Apr 1987 - Present	Quarterly
Murtha Drive Lake (Pine Lake) <sup>#</sup>	MTL	5	Jan 1987 - Present	Quarterly
Cyclades Lake <sup>#</sup>	CCL	2	Jul 1997 - Present	Quarterly

(\*) waterways not included in this report due to limited information (#)tidal lake; (+) freshwater lake.

(\*\*) beach sampling occurs weekly during summer, fortnightly during autumn and spring and monthly during winter months.

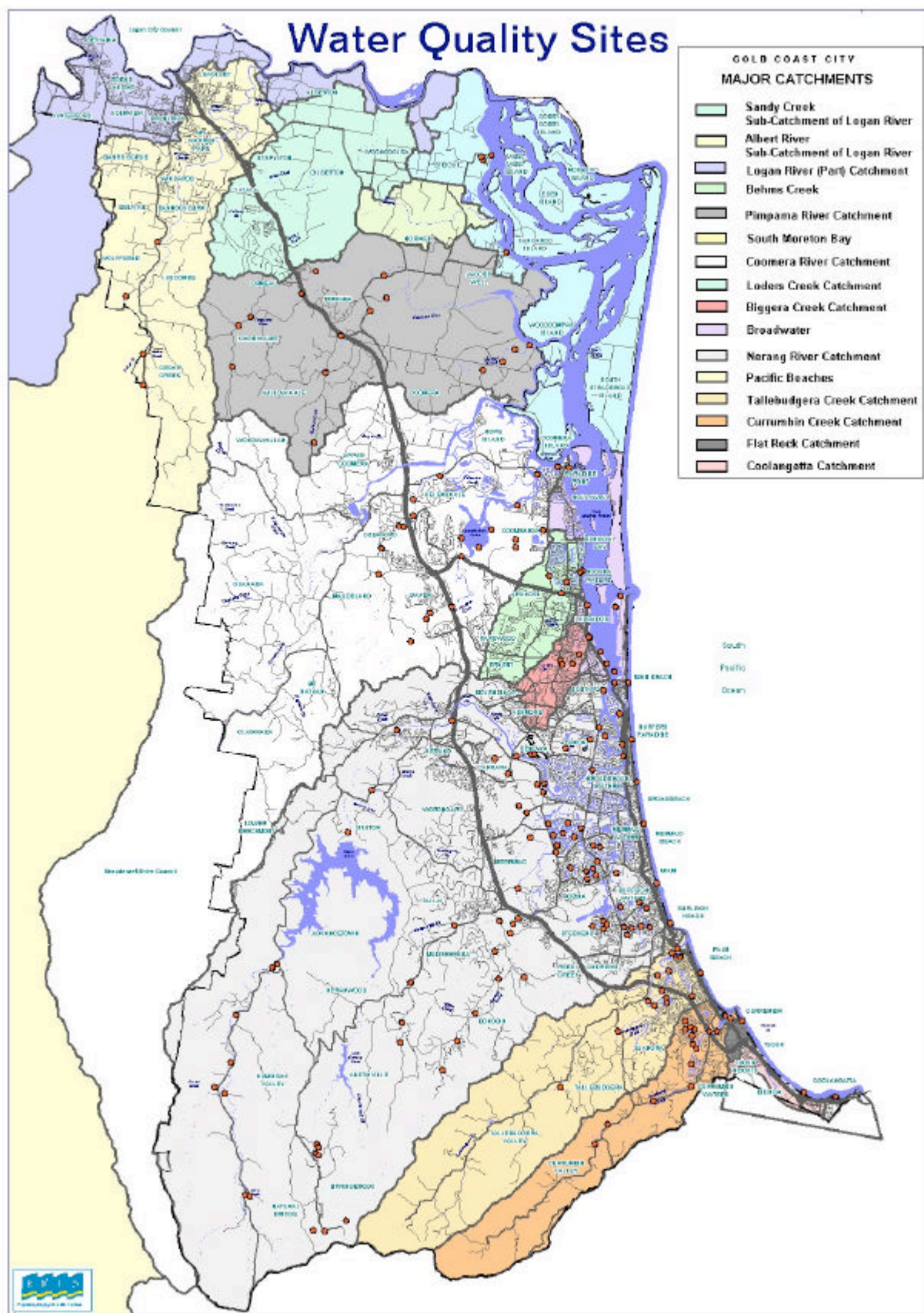


Figure 2.1 Location map of water quality monitoring sites within Gold Coast City.

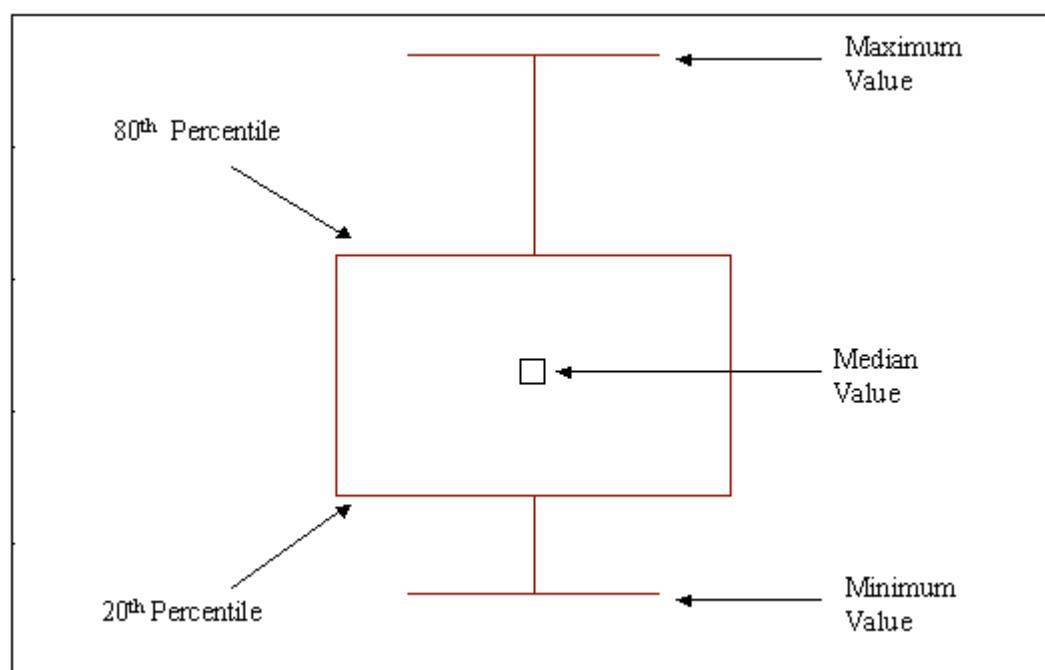


## 2.2 SAMPLING METHODS

The collection method and *in-situ* field testing of water quality conditions is undertaken in accordance with the 'Water Quality Sampling Manual' (Environmental Protection Agency (EPA), 1999), which is used to test compliance with the Environmental Protection Act 1994. The Scientific Services Section of GCCC performs laboratory analysis of collected water samples. The laboratory is a National Association of Testing Authority (NATA) registered facility.

## 2.3 PRESENTATION OF WATER QUALITY DATA

Water quality results for all monitoring sites (excluding several discontinued sites and sites where monitoring is targeting other environmental issues) from the beginning of monitoring (Table 2.1.1) to October 2001 have been presented in box and whisker plots. Box and whisker plots are widely used in reporting water quality information (Cox and Moss, 2000). This technique shows where the data points are concentrated (the box) along with the outlying values in the data set. The top of the box in these plots is the 80<sup>th</sup> percentile (80% of the data fall below this line), while the bottom of the box represents the 20<sup>th</sup> percentile (20% of the data fall below this line). The square located between the 80<sup>th</sup> and 20<sup>th</sup> percentile represents the median (50% of the data fall above and 50% below this number). The whiskers in each box plot represent the minimum and maximum concentrations recorded over the monitoring period (Figure 2.2).



**Figure 2.2** Example box and whisker plot used in this report to assess compliance of water quality conditions recorded at each site with the appropriate guidelines.

## 2.4 COMPARISON WITH GUIDELINES

Water quality conditions recorded at each site across the City were assessed against the ANZECC (1992) guidelines for the protection of aquatic ecosystems. The ANZECC (1992) guidelines for primary contact have been used in comparison with *E. coli* concentrations recorded at monitoring sites. It is acknowledged that the ANZECC (1992) guidelines for bacterial contamination in fresh and marine waters stipulate analysis of faecal coliform concentrations. However, *E. coli* usually comprises around 97% of the faecal coliform count in all warm blooded animals (ANZECC, 1992). It is therefore acceptable to use *E. coli* as an indicator of bacterial contamination to assess compliance with the guidelines. CMU have begun assessing both faecal coliform and *E. coli* concentrations in several surveys to correlate the results and begin the implementation of only faecal coliform analysis at all monitoring sites to become more consistent with the guidelines.

The ANZECC (1992) guidelines recommend that samples are collected weekly for analysis of bacterial contamination, however, in the absence of weekly samples, monthly samples are collected to assess the suitability of the waters for recreational activities. It is important to note that the ANZECC (1992) guidelines for microbiological concentrations in areas used for swimming (*ie* primary contact), stipulate that for a minimum of five samples, with the period between sample collection not exceeding one month, the median value should be less than 150 faecal coliforms per 100mL, with four out of five samples containing less than 600 faecal coliforms per 100mL. *E. coli* concentrations were therefore assessed by calculating a "rolling median". This rolling calculation has been extended over the entire monitoring period where five consecutive samples were collected. The discussion and statistical analyses in this report are therefore based on these median values. However, *E. coli* concentrations have also been presented for individual sampling occasions to illustrate the variability of concentrations recorded at each monitoring site.

At the time of preparing this report, the ANZECC (2000) guidelines had not been officially released. While it is recognised that the new ANZECC 2000 guidelines provide a more enhanced level of ecosystem protection, for the purposes of this report, the nationally recognised ANZECC (1992) guidelines have been applied. It is also recognised that the Queensland Water Quality Guidelines (Version 2 - Environmental Protection Agency 2001) are being prepared from recommendations in the Draft Australian Water Quality Guidelines for Fresh and Marine Waters (2000) for localised water quality guidelines. While the Queensland Water Quality Guidelines remain in draft format, they have not been formally adopted and therefore were not used for comparison with water quality presented in this report.

Compliance with the ANZECC (1992) guidelines for all indicators was assessed by comparing the median value for each indicator with the recommended water quality guidelines for the protection of aquatic ecosystems (presented in Table 2.2). The ANZECC (1992) guidelines provide different protection levels for nutrients and pH within freshwater and marine environments. For example, nutrient guidelines for the prevention of nuisance algal blooms in a freshwater environment have been expressed as total nitrogen and total phosphorus concentrations. However, nutrient guidelines for a marine environment are expressed as dissolved nutrients (*eg* phosphate-phosphorus, nitrate and ammonium-nitrogen). The current water quality monitoring program does not monitor dissolved forms of nutrients in marine or estuarine waterways, which makes assessment in terms of the guidelines difficult. As a result, total nitrogen and total phosphorus concentrations have been assessed in all waterways against the freshwater criteria. Results for waterways that contain portions of or are marine environments, should be viewed with this in mind.

Future reports will incorporate where possible, Water Quality Objectives (WQOs) developed through catchment management plans. In the case where specific WQOs have not been established for a waterway, the Queensland Water Quality Guidelines will be applied, which assess water quality against Queensland reference waterway types (*eg* ocean, open coastal, enclosed coastal/lower estuary, mid estuary, upper estuary, lower catchment and upper catchment).

**Table 2.2** Water quality indicators measured as part of this program. (Table adopted from Cox and Moss (2000) with permission).

Category	Indicator	Explanation	ANZECC 1992 Guidelines
Nutrients	Nitrogen - Organic Nitrate plus nitrite Ammonia (NH <sub>4</sub> N) Total (TN)  Phosphorus - Total (TP) Filterable reactive	The major nutrients (nitrogen and phosphorus) are essential for plant growth. High nutrient concentrations in waters indicate the potential for excessive plant and algal growth. Total nutrients are made up of a dissolved component (nitrate plus nitrite, ammonia and filterable reactive phosphorus) and an organic component, which is bound to carbon (organic nitrogen). Nutrients in the dissolved state can be readily used by plants	<b>Freshwater</b> TN < 0.75mg/L TP < 0.1mg/L  <b>Marine Waters</b> NH <sub>4</sub> H < 0.05mg/L PO <sub>4</sub> P < 0.15mg/L
Algal biomass	Chlorophyll-a	An indicator of algal biomass in the water. An increase in chlorophyll-a indicates potential eutrophication of the system. Consistently high or variable chlorophyll-a concentrations indicate the occurrence of algal blooms, which can be harmful to other aquatic organisms.	Chloro-a < 10ug/L
Water Clarity	Turbidity	A measure of light scattering by suspended particles in the water column; provides an indirect indicator of light penetration.	< 10% below a seasonal mean
Oxygen	Dissolved oxygen (DO)	Essential for life processes of most aquatic organisms. Low concentrations usually indicate the presence of excessive organic loads in the system, while very high values can indicate excessive plant production (ie eutrophication). Very low concentrations of oxygen can cause suffocation of aquatic organisms.	DO > 6mg/L
pH	pH	A measure of the acidity or alkalinity of the water. Changes to pH can be caused by a range of potential water quality problems (eg low values due to acid sulfate runoff or high values due to excessive plant growth). Extremes of pH (less than 6.5 or greater than 9) can be toxic to aquatic organisms.	<b>Freshwater</b> pH > 6.5 and < 9.0  <b>Marine Water</b> < 0.2 unit seasonal change
Temperature	Temperature degrees celsius °C	Is the thermal measure of the water body. Temperature can influence the dissolved oxygen levels and change the toxicity of water components. A large seasonal change in the temperature can detrimentally effect the composition of an entire aquatic community. Large scale fish kills may also occur.	< 2°C variation
Salinity	Conductivity	A measure of the amount of dissolved salts in the water, therefore an indicator of salinity. In freshwater conductivity indicates suitability for agricultural use while in salt water it is an indicator of freshwater flow.	<b>Freshwater</b> < 1mS/cm  <b>Brackish Water</b> 15mS/cm  <b>Marine Water</b> 60mS/cm

## 2.5 DATA ANALYSIS OF WATER QUALITY

### 2.5.1 UNIVARIATE STATISTICAL ANALYSIS

A difference in water quality amongst monitoring sites was undertaken by pooling all results for each monitoring site over the sampling period (more detailed analysis accounting for seasonal patterns and spatial autocorrelation amongst sites is planned for future reports). The Kruskal Wallis non-parametric test was used to analyse differences amongst sites. This test is based on ordinal data and therefore examines differences amongst medians rather than means. As all water quality information presented within this report has illustrated and compared the median value with the guidelines for compliance, the Kruskal Wallis analysis therefore fits with the water quality plots in the report.

Where significant differences were found amongst sites using Kruskal Wallis tests, multiple comparisons amongst all possible pairs of medians were used to determine which sites were significantly different at the 0.05 probability level. These post hoc analyses used Dunn's non-parametric test. Dunn's test is an extension of Nemenyi's test that accounts for unequal sample sizes between sites (Zar, 1999).

### 2.5.2 WATER QUALITY TREND ASSESSMENT

The assessment of water quality trends was undertaken using the raw data from those sites in each waterway that were considered to have poorer conditions in comparison with other monitoring sites. This information was used to visually determine if water quality has generally declined or improved since monitoring began in each waterway. This information is important for resource managers as it provides an opportunity to determine which waterway sections are affected or degraded. Trend assessment techniques are available (see Moss and Cox, 1999; Cox and Moss, 2000) to determine if a statistically significant trend exists over the study period at monitoring sites. This analysis will be undertaken in future reports.

### 2.5.3 MULTIVARIATE ANALYSIS

In addition to analysing the relationships amongst monitoring sites within individual catchments based on univariate measures (*ie* one water quality variable at a time), multivariate analysis was undertaken to assess the relationships amongst monitoring sites within catchments taking into account all water quality variables (*ie* temperature, conductivity, dissolved oxygen, pH, total nitrogen, total phosphorus, median *E. coli* and turbidity). Due to inconsistencies in water quality information, sites from all waterways, excluding Broadwater, Beaches and all lake systems, were compared in a single multivariate analysis. Once similarities amongst sites across all catchments were displayed, the water quality variables important for grouping and differentiating sites were able to be determined. Separate multivariate analyses of data from certain time periods (all years, last 5 years and last 2 years) were also undertaken to compare how the relationship amongst sites had changed over time.

Data for each water quality variable was standardised using a range standardisation so that each variable ranged between 0 and 1 (minimum value 0, maximum 1). This was necessary to ensure equal weighting for each variable regardless of the units in which measurements were recorded and to address the range of values recorded for each variable (*eg* pH and *E. coli*). Eighty-three (83) sites were analysed from 12 waterways across the City. For each site, the mean over the entire monitoring period was used. It is acknowledged that the analyses presented in this report are not intended to account for aspects of temporal variation such as seasonality, but such temporal variation will be the subject of investigation in future reports.

Similarities amongst sites were calculated as Euclidean distances, which are considered appropriate for the multivariate analysis of water quality data (Clarke and Warwick, 1994). The relationship amongst sites was displayed as 2-dimensional ordination plots using the multidimensional scaling (MDS) function within the PRIMER statistical package from Plymouth Marine Laboratory, England. Ordination is a preferred statistical method to classification methods because it illustrates groups based on similarities in water quality performance and also data gradients within groups. Stress values were determined for each MDS plot, in order to measure how well the MDS plot represented the distance between sites. Clarke (1993) suggests values < 0.1 correspond to a good ordination with little chance of a misleading interpretation and < 0.2 gives a potentially useful interpretation of the data.

Two approaches were used to identify water quality variables explaining patterns in the relationship amongst sites. Firstly, certain groups clearly evident in ordination plots were identified. The SIMPER routine in the PRIMER program was used to determine the water quality variables contributing to the largest influence between groups. Secondly, the matrix of similarities amongst sites was correlated with matrices of water quality variables (each variable individually) using the BioEnv routine in the PRIMER program (Clarke & Ainsworth, 1993). This determines the strength of correlation (expressed as a Spearman rho coefficient, between 0 and 1) between a variable and any continuous gradient pattern in the similarity matrix. Variables found to have a strong correlation were displayed by overlaying the value of the variable at each site on the ordination plot.

## CHAPTER 3 WATERWAY RESULTS AND DISCUSSION

This chapter presents the water quality information on a catchment basis, excluding the lakes surveys, which are grouped according to their region (North or South). For ease of reading, the format is similar for each waterway/survey. Water quality data for each survey has been presented and compared to ANZECC (1992) guidelines for the protection of aquatic ecosystems and primary contact recreational waters. Secondly, at sites where water quality is performing differently from other sites, the data has been presented over time, to determine the trend in water quality over the monitoring period. This simple trend analysis assists with understanding if water quality is generally deteriorating or improving at a site. A summary and conclusion section is included at the end of this chapter, which draws together the general trends in water quality performance for each waterway or survey.

### 3.1 ALBERT RIVER

#### 3.1.1 INTRODUCTION

The Albert River begins its northern flow via two main tributaries in the central western section of the Lamington National Park, located on the Queensland and NSW Border Ranges. The river then flows approximately 110km through the Beaudesert Shire and then approximately 24km through Gold Coast City, before joining with the Logan River and discharging into southern Moreton Bay (Figure 3.1.1).

Agriculture is the primary land use activity within the catchment consisting of beef and dairy cattle, piggeries and a variety of field crops. The lower catchment region, within Gold Coast City, also supports several aquaculture ventures, which supply their products to both local and overseas areas (Low Choy, 1997).

The tidal limit for this system is located approximately 17km upstream from its confluence with the Logan River, near the junction of Stanmore and Beenleigh/Beaudesert Road. Land use within the lower region of the catchment consists of various grain and sugar cane fields.

Water quality monitoring within this river focuses on the freshwater region that flows through Gold Coast City and therefore does not provide a quantitative assessment of water quality performance and catchment characteristics for the entire Albert River. Water quality within the tidal region of the catchment is not monitored in this survey, however, is monitored by the EPA (see Semple and Dunlop, 1996).

Table 3.1.1 Site classification and distance details for each monitoring site.

Region/Site Type	Distance <sup>#</sup> (km)	Site
Lower Freshwater	28.45	ABR 1 ( <i>Discontinued</i> )
	26.18	ABR 2
	22.28	ABR 3
Upper Estuary	17.89	ABR 4

<sup>#</sup> Measured as distance in kilometres from the mouth (Albert River and Logan River confluence)

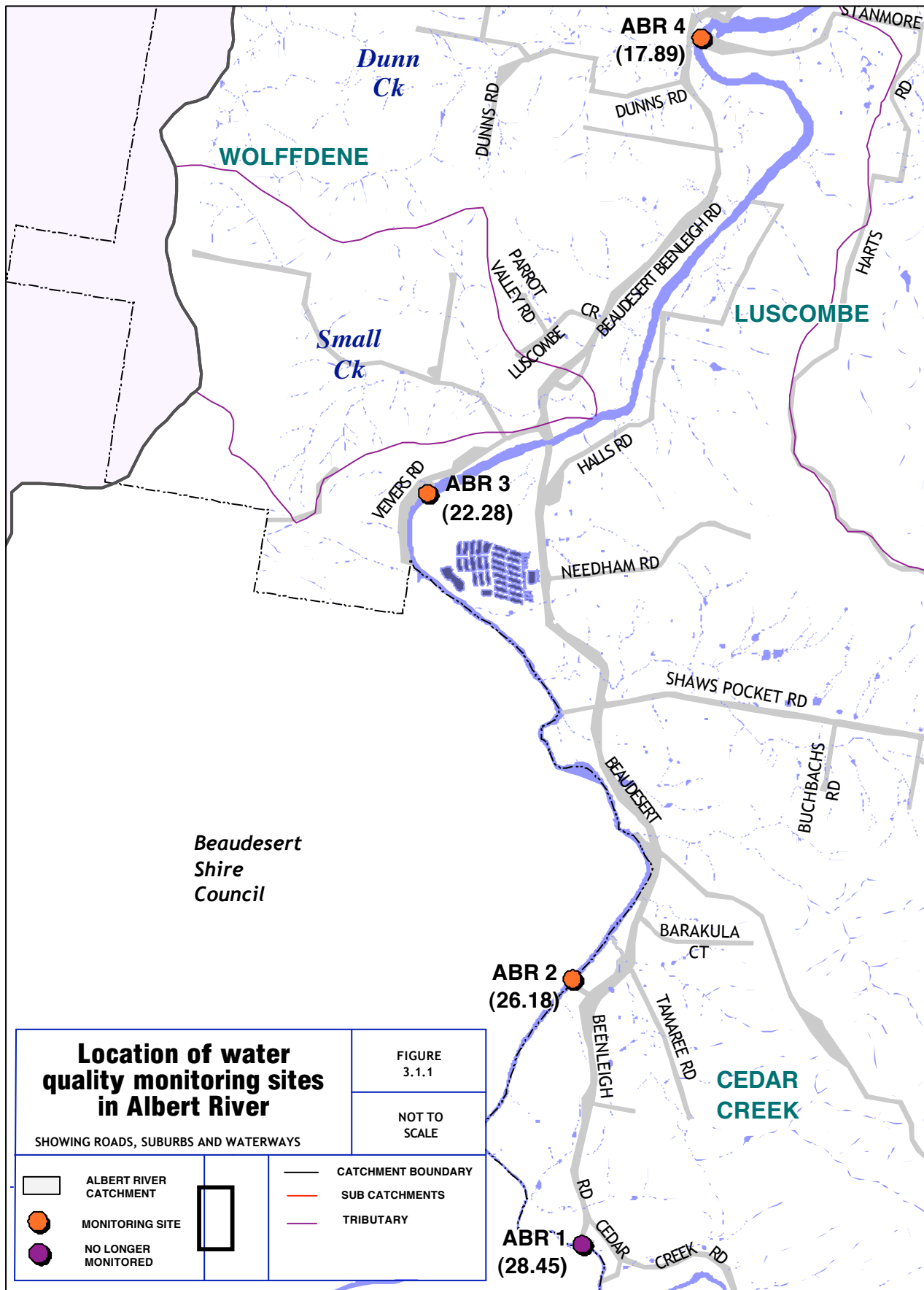
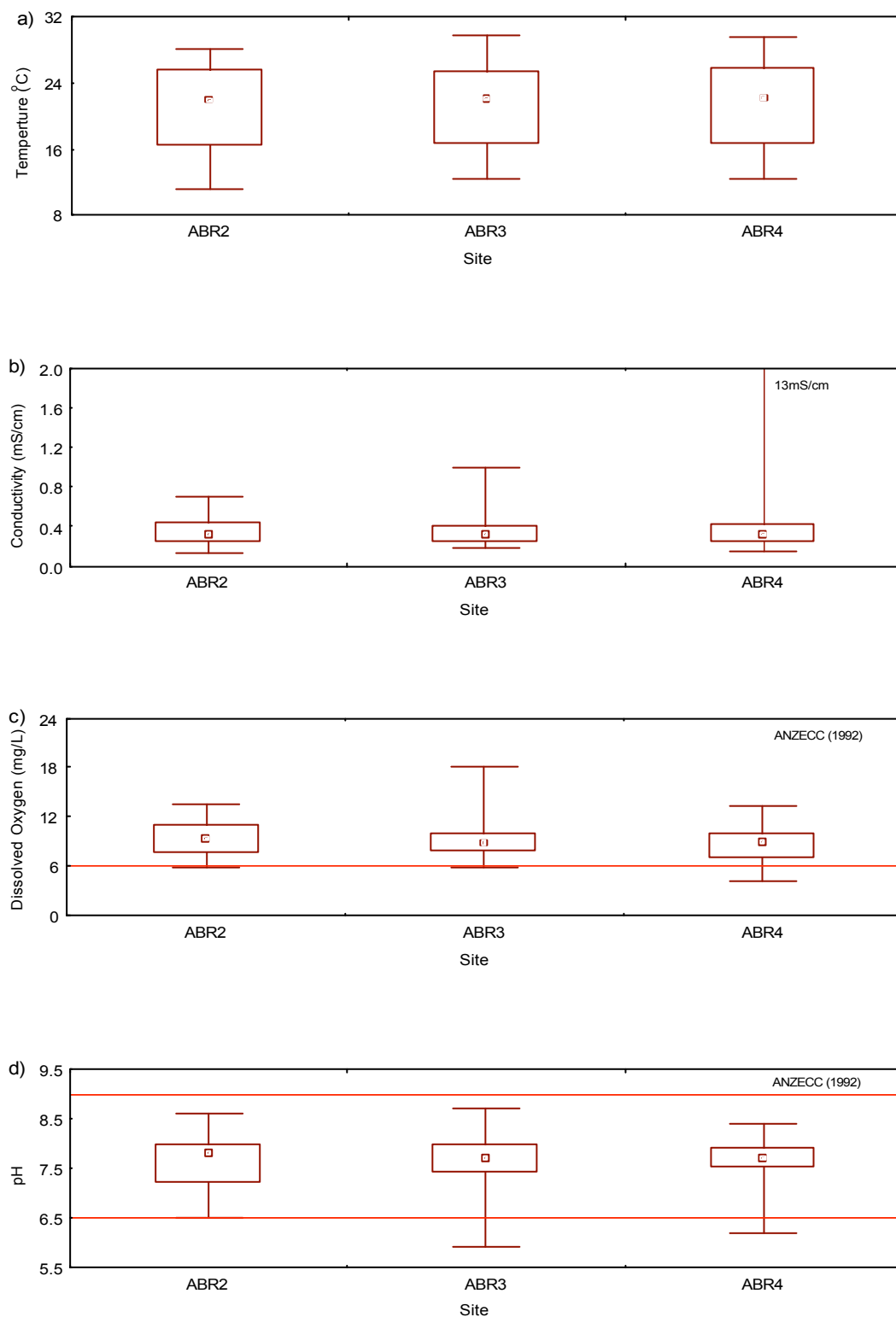
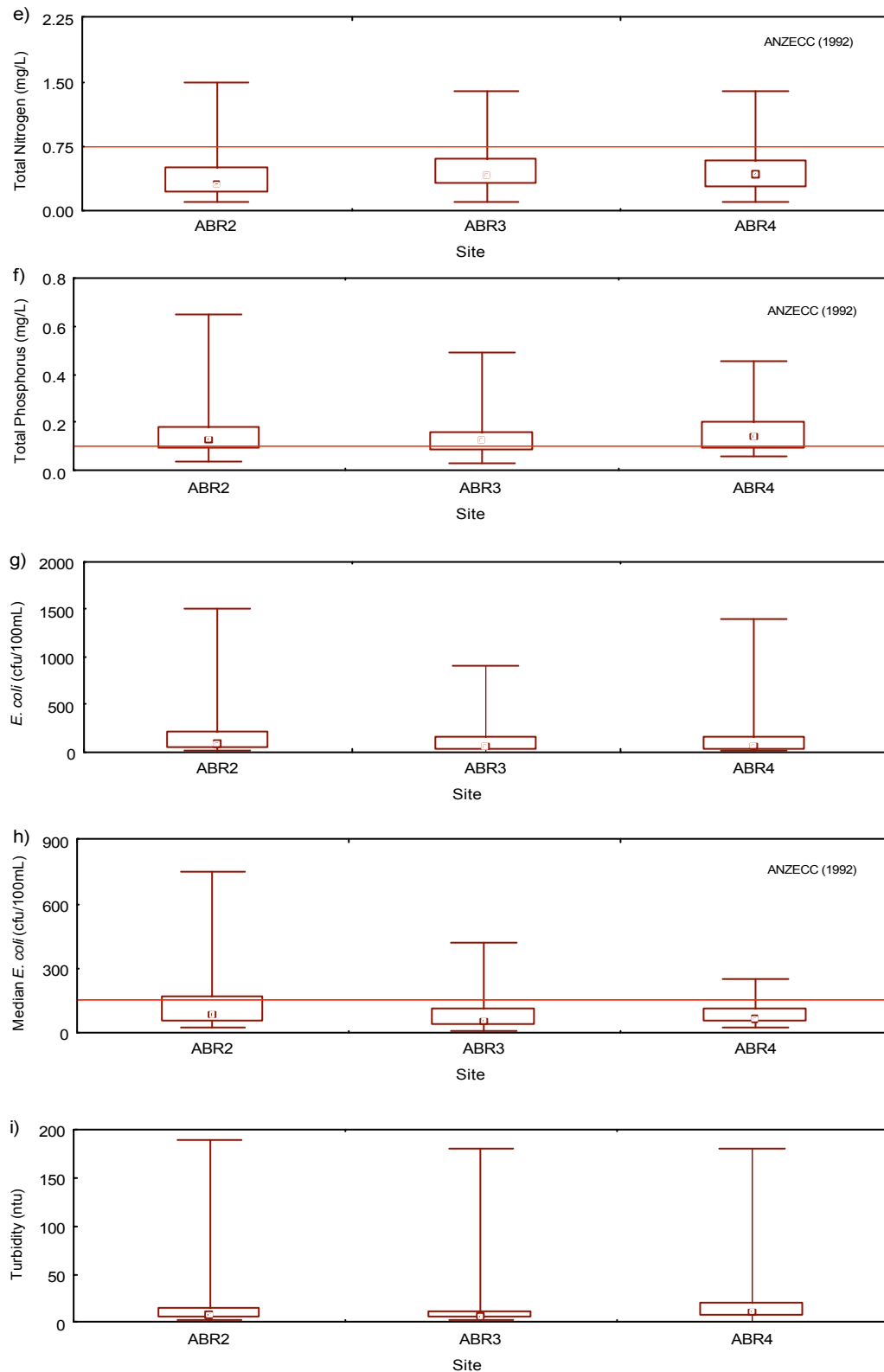


Figure 3.1.1 Location of water quality monitoring sites in Albert River.





**Figure 3.1.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen and (d) pH recorded sites within the Albert River over the monitoring period. ANZECC (1992) compliance guidelines for the protection of aquatic ecosystems have been included for dissolved oxygen and pH.



**Figure 3.1.2 (cont)** (e) total nitrogen, (f) total phosphorus, (g) raw data for *E. coli* concentrations, (h) rolling median *E. coli* concentrations and (i) turbidity recorded at sites within Albert River over the monitoring period. ANZECC (1992) compliance guidelines for both nutrient parameters have been included for the protection of aquatic ecosystems. Recreational guidelines for primary contact waters have been included for comparison with median *E. coli* concentrations.

### 3.1.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Water temperature has ranged between 11°C and 29°C in the Gold Coast portion of the Albert River (Figure 3.1.2a). This range in water temperature could be influenced by seasonal conditions, water depth, flow rates, time of day when measurements were recorded or the presence and density/nature of riparian vegetation. Water temperatures did not vary significantly amongst sites (KW :  $p = 0.93$ ).

#### CONDUCTIVITY

Conductivity at ABR 2 and ABR 3 ranged between 0.14mS/cm and 1mS/cm. Site ABR 4 recorded conductivity up to 13mS/cm over the monitoring period, which is likely to be related to the influence of the estuarine section of the Albert River, particularly during extended low rain periods (Figure 3.1.2b). Conductivity did not vary significantly amongst sites (KW :  $p = 0.79$ ).

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations regularly complied with the ANZECC (1992) guidelines, despite reductions below the guidelines at all sites (Figure 3.1.2c). Dissolved oxygen concentrations did not vary significantly amongst monitoring sites (KW :  $p = 0.27$ ).

#### pH

pH regularly complied with the ANZECC (1992) guidelines, despite several recordings below the guidelines at ABR 3 and ABR 4 (Figure 3.1.2d). pH did not vary significantly amongst sites (KW :  $p = 0.57$ ).

#### TOTAL NITROGEN

Total nitrogen concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.3.2e), with the 80<sup>th</sup> percentile at each site below the guidelines. All sites recorded elevated total nitrogen concentrations above the guidelines. Total nitrogen concentrations varied significantly amongst sites (KW :  $p < 0.01$ ), with significantly lower concentrations recorded at ABR 2 than at ABR 3 and ABR 4.

#### TOTAL PHOSPHORUS

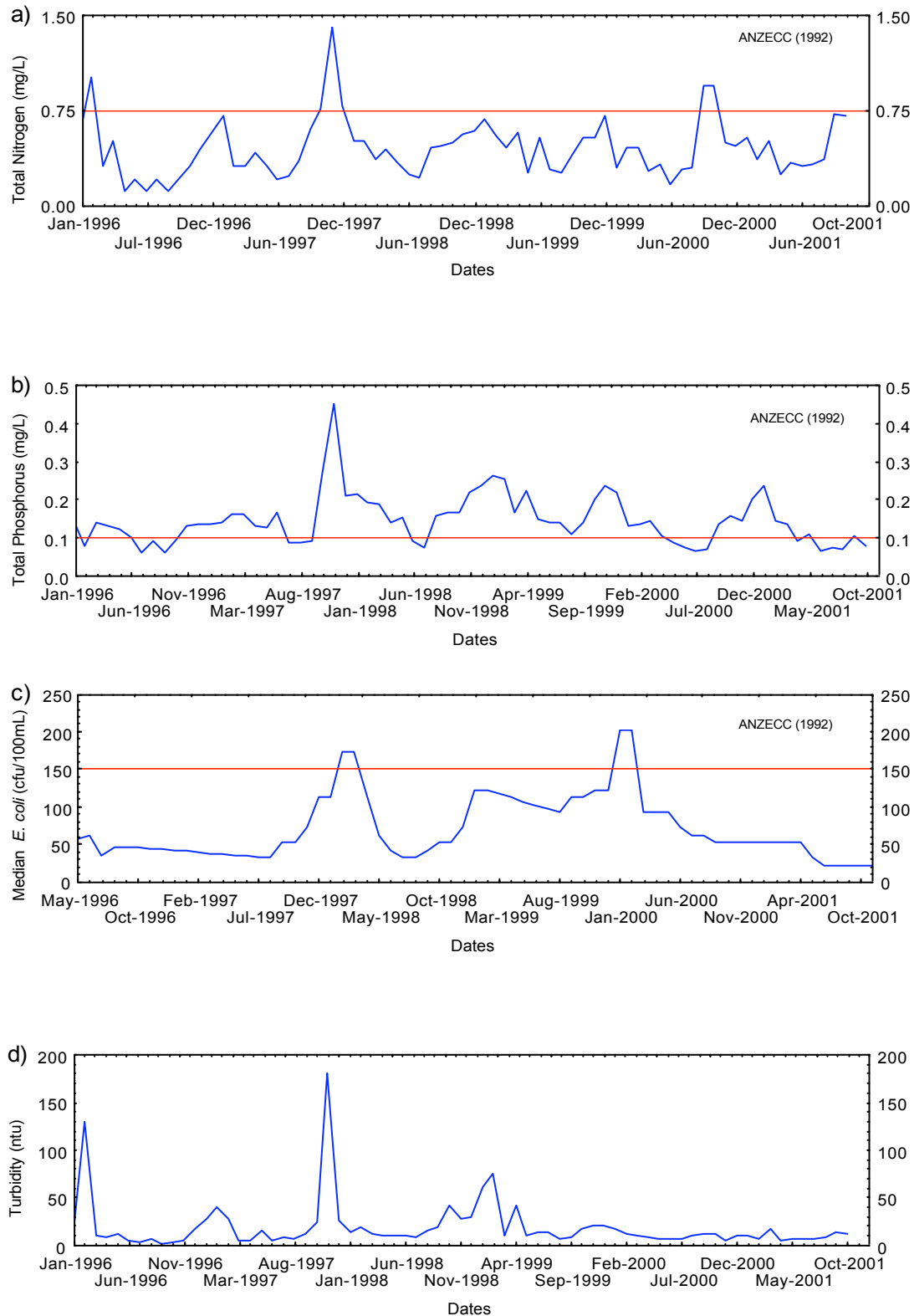
Total phosphorus concentrations regularly did not comply with the ANZECC (1992) guidelines (Figure 3.3.2f), with the 20<sup>th</sup> percentile at each site almost exceeding the guidelines. Total phosphorus concentrations did not vary significantly amongst sites (KW :  $p = 0.19$ ).

#### E. COLI

*E. coli* concentrations, calculated as a rolling median, regularly complied with the ANZECC (1992) guidelines (Figure 3.3.2h). Elevated concentrations above the guidelines have been recorded at all sites. *E. coli* concentrations did not vary significantly amongst sites (KW :  $p < 0.06$ ).

#### TURBIDITY

Turbidity generally remained below 20ntu at each site over the monitoring period (Figure 3.3.2g). Turbidity varied significantly amongst sites (KW :  $p < 0.01$ ), with significantly higher turbidity recorded at ABR 4 than at ABR 2 and ABR 3.



**Figure 3.1.3** Water quality trends for (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at ABR 4 over the monitoring period.

### 3.1.3 WATER QUALITY TRENDS

Water quality recorded at ABR 4 was assessed for trends over the monitoring period (Figure 3.3.3). This site represents only a small section of this river system and should be viewed with this in mind.

Water quality parameters assessed at this site showed seasonal patterns, with higher concentrations generally recorded between December and February and lower concentrations recorded between May and August. Concentrations for both nutrients generally remained consistent over the monitoring period (despite seasonal variation), however, total phosphorus concentrations regularly exceeded the guidelines. *E. coli* concentrations varied also between seasons and exceeded the guidelines between March and April in 1998 and 2000. Turbidity has not increased over the monitoring period, despite higher recordings between December and February and lower concentrations between May and August. This was most evident in December 1997, where turbidity, along with both nutrient parameters dramatically increased and then declined in January 1998. This is likely to be associated with a significant rainfall event.

### 3.1.4 DISCUSSION

Water quality conditions in the section of the Albert River that flows through Gold Coast City, has shown that most parameters generally comply with the ANZECC (1992) guidelines. This is however, not true for total phosphorus concentrations, which regularly exceeded the guidelines at all sites.

The data has shown a distinct variation in water quality conditions associated with seasonal summer and winter patterns. Importantly, water quality has not declined notably within this section of the river. However, poor land use management within the upper and middle catchment area, may result in the future decline of water quality, if appropriate best land use management practices are not carried out by landholders.

### 3.1.5 CONCLUSIONS AND RECOMMENDATIONS

The management of the Albert River and its catchment will require cooperation amongst the several Council authorities in which the river traverses. Key pressures within this catchment will need to be addressed including riparian vegetation, erosion and sediment control, water quality, flow modification, water harvesting and the various land use activities within this catchment. It is evident from the limited water quality monitoring in the section of the Albert River that traverses Gold Coast City, that total phosphorus concentrations appear to be of concern and require further investigation. The management of the upper catchment area is considered a priority in order to achieve or sustain water quality conditions that protect the values of the lower Albert River catchment.

## 3.2 BEACHES SURVEY

### 3.2.1 INTRODUCTION

The Gold Coast City has approximately 52km of beachfront to the Pacific Ocean, extending from the top of South Stradbroke Island to the Queensland/New South Wales border at Point Danger.

The beaches are a focal point for local residents of the City for the purposes of swimming, surfing, fishing and various other recreational activities. The beaches also provide an attraction and coastal recreational area for many tourists that visit the Gold Coast.

Monitoring water quality along Gold Coast beaches and popular enclosed swimming areas is important in assessing the health of these popular swimming and other water sport activity areas. Microbiological sampling is conducted at 10 popular swimming beaches and eight enclosed swimming areas across the City (Table 3.2.1 and Figure 3.2.1). The ANZECC (1992) guidelines consider several micro-organisms as indicators for pathogen contamination within a waterway. Faecal bacteria are considered the most appropriate measurement of faecal contamination within a water body (although *E. coli* concentrations have also been recognised as a measure of faecal bacteria conditions within a waterway). CMU has begun the process of incorporating faecal coliform testing at all beaches and swimming enclosures to ensure that testing complies with the ANZECC (1992) guidelines. For the purposes of this report, *E. coli* data has been used for comparison with the guidelines.

**Table 3.2.1** Monitoring sites along Gold Coast beaches and popular swimming enclosures.

Site Code	Location
BCH 1	Southport/Main Beach
BCH 2	Surfers Paradise
BCH 3	Broadbeach
BCH 4	Mermaid
BCH 5	Miami
BCH 6	Burleigh
BCH 7	Palm Beach
BCH 8	Currumbin
BCH 9	North Kirra
BCH 10	Rainbow Bay
BCH 11	Evandale Lake
BCH 12	Currumbin Creek Swimming Enclosure
BCH 13	Washington Waters Swimming Enclosure
BCH 14	Paradise Point Swimming Enclosure
BCH 15	Harley Park Swimming Enclosure
BCH 16	Tallebudgera Swimming Enclosure
BCH 17	Budds Beach
BCH 18	Currumbin Cove



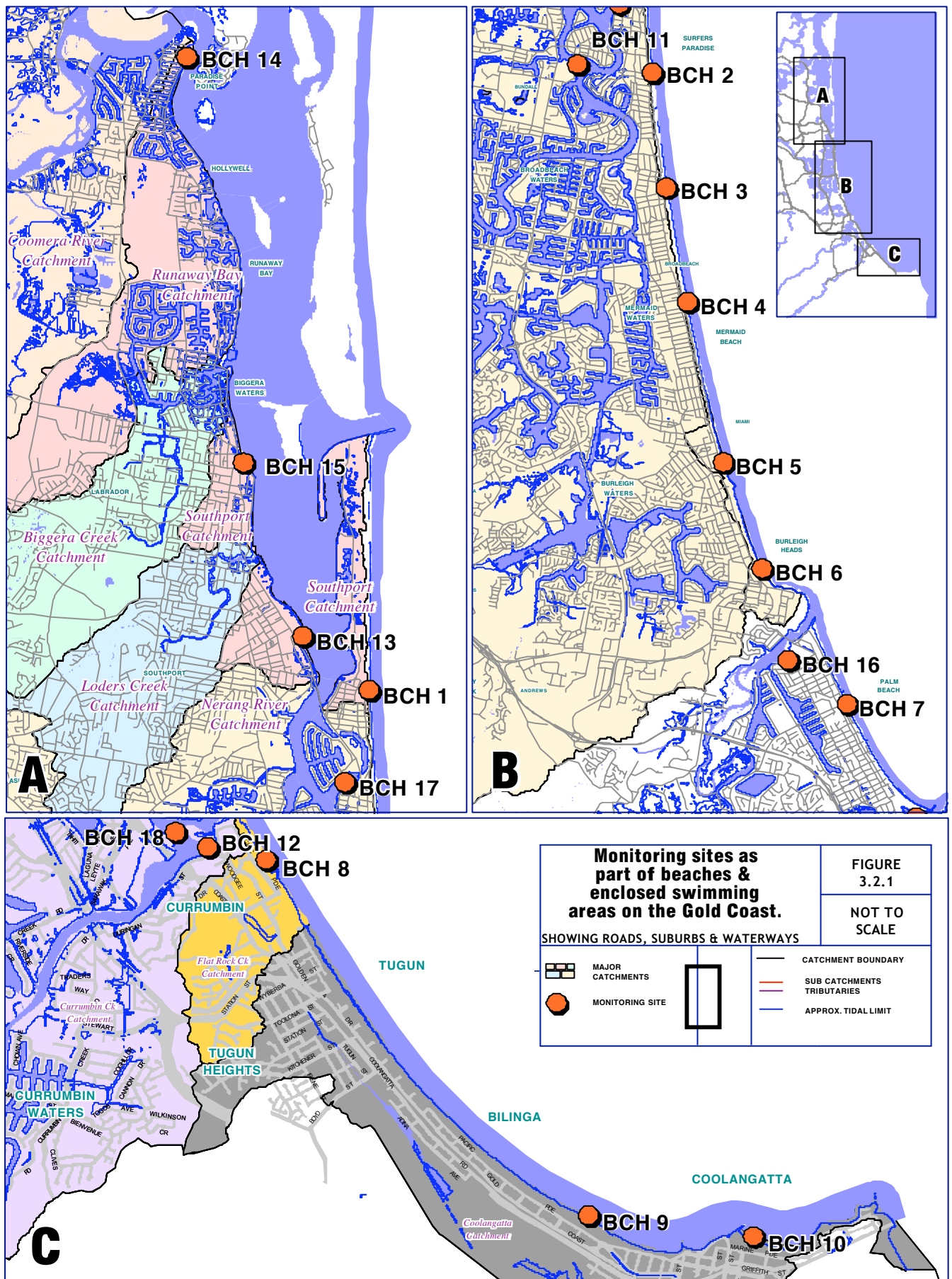
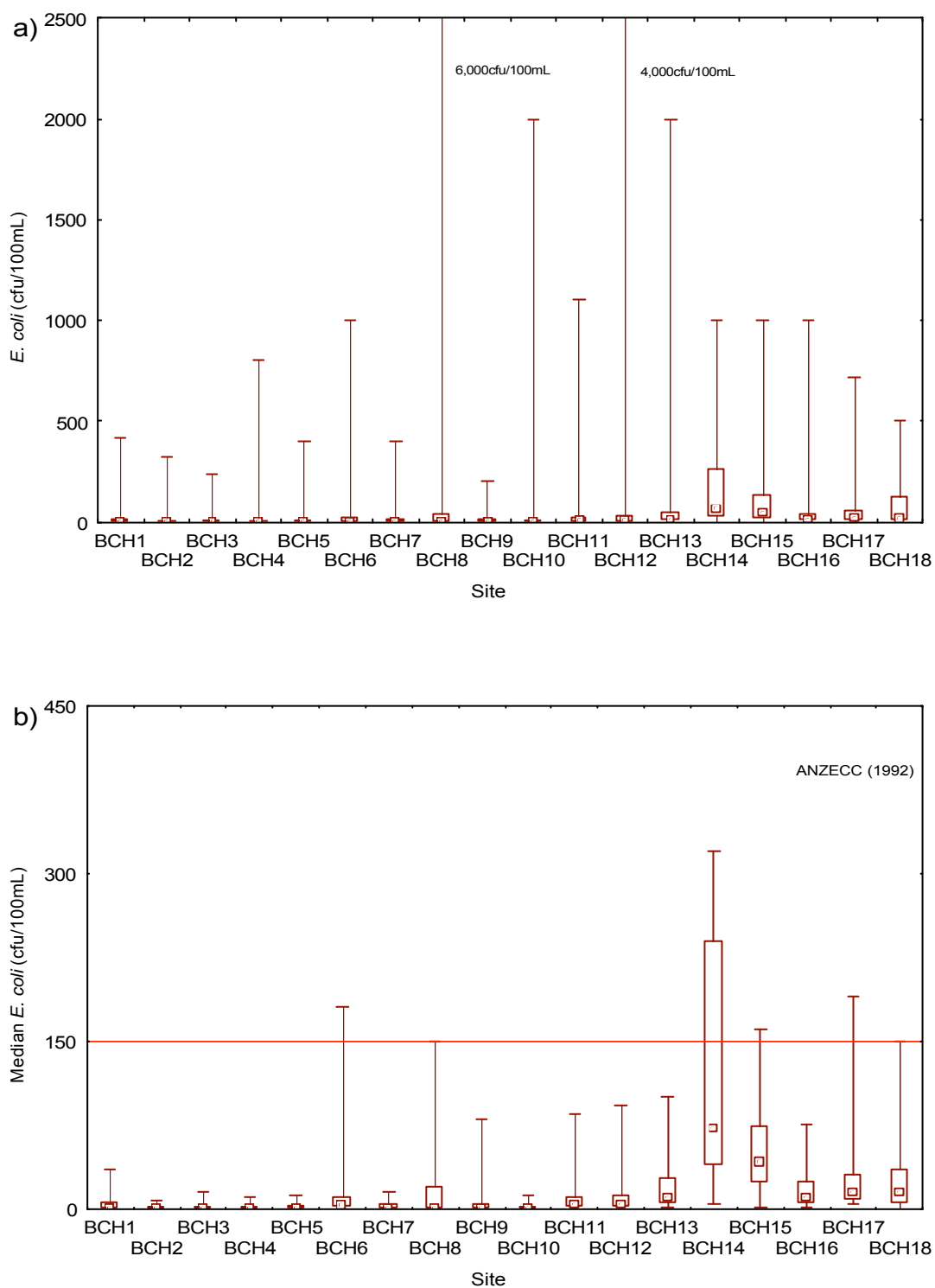
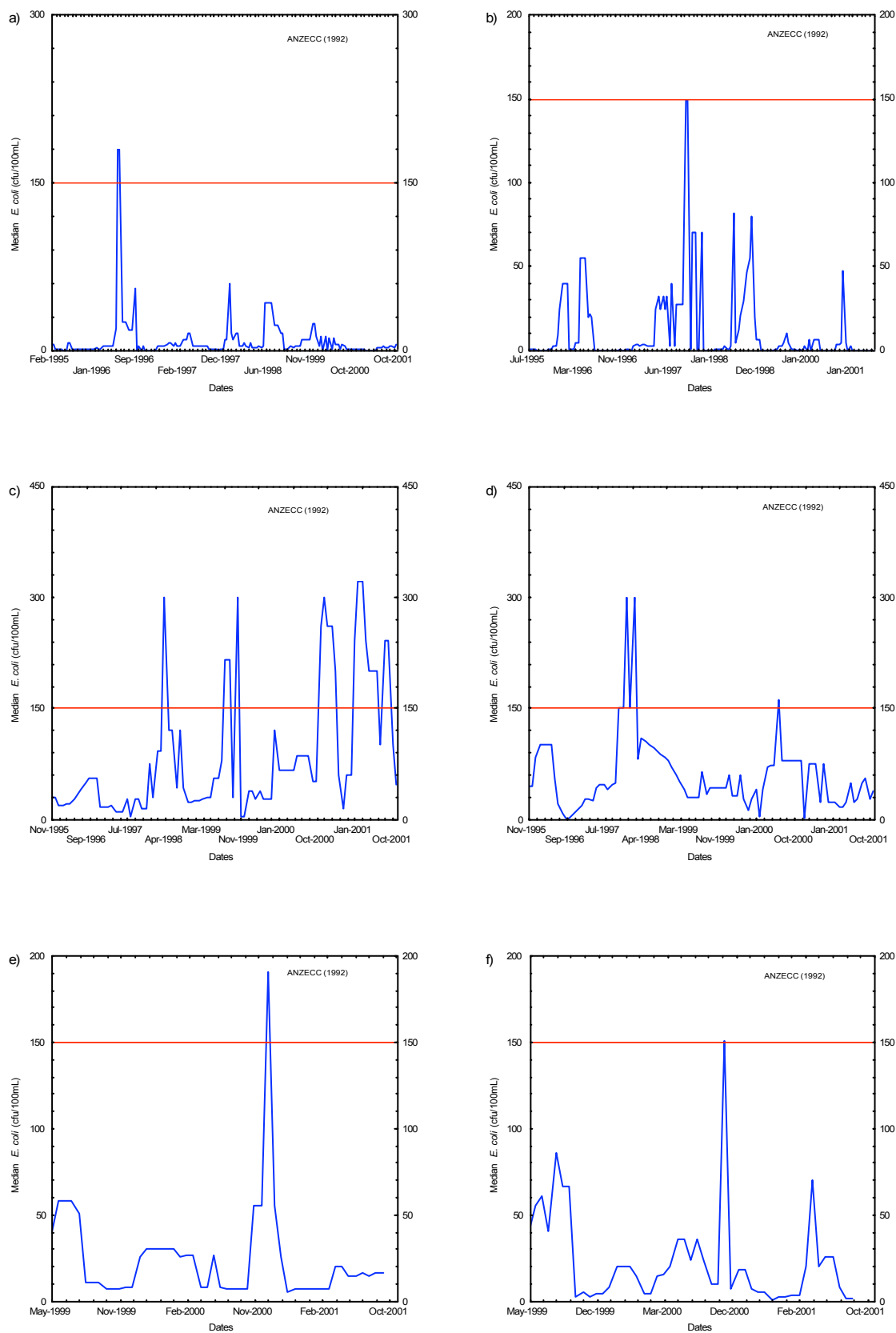


Figure 3.2.1 Monitoring sites along beaches and enclosed swimming areas on the Gold Coast.



**Figure 3.2.2** Box plots for (a) raw data for *E. coli* concentrations and (b) rolling median *E. coli* concentrations recorded at each site. ANZECC (1992) recreational guidelines for primary contact waters have been included for comparison with median *E. coli* concentrations.



**Figure 3.2.3** Trends for median *E. coli* concentrations at (a) BCH 6, (b) BCH 8, (c) BCH 14, (d) BCH 15, (e) BCH 17 and (f) BCH 18 recorded over the monitoring period.

### 3.2.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### *E. COLI*

*E. coli* concentrations, calculated as a rolling median at each site, have consistently complied with the ANZECC (1992) guidelines for primary contact recreational waters, with the 80<sup>th</sup> percentile complying with the primary contact recreational guidelines at all sites, except at Paradise Point swimming enclosure (BCH 14) (Figure 3.2.2a). *E. coli* concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly lower concentrations at all beach sites than at enclosed swimming areas, with intermediate concentrations at Burleigh Beach (BCH 6). These lower *E. coli* concentrations are likely to be related to water movement and dilution along the ocean beaches, whereas the swimming enclosures are more likely to be influenced by runoff from the surrounding catchment areas. Burleigh Beach (BCH 6) recorded significantly higher concentrations than other beach sites, but significantly lower concentrations than all swimming enclosures. This may be linked to the influence of stormwater runoff from the Burleigh Heads district during rain periods.

### 3.2.3 WATER QUALITY TRENDS

The sites chosen to assess water quality trends have regularly complied with the primary contact recreational guidelines over the monitoring period (Figure 3.2.3a - f). Peaks in *E. coli* concentrations above the primary contact recreational guidelines have been recorded at Burleigh Beach (BCH 6), Currumbin (BCH 8), Budds Beach (BCH 17) and Currumbin Cove (BCH 18) over the monitoring period, which is likely to be related to rain events. Elevated *E. coli* concentrations at Paradise Point swimming enclosure (BCH 14) exceeded the primary contact recreational guidelines between October 2000 and December 2000. GCCC and EPA Officers investigated these high concentrations and the preliminary results have indicated the influence is from increased bird populations in the vicinity of this monitoring site. GCCC is continuing investigations into this issue. Of the sites assessed for trends in water quality, there does not appear to be a declining trend in conditions over the monitoring period.

### 3.2.4 DISCUSSION

The sampling regime for the Beaches survey has been designed to provide a quantitative assessment of bacterial concentrations at the popular swimming areas along the Gold Coast Beaches and all enclosed GCCC swimming areas within the City. Beach sites have been shown to continually comply with the ANZECC (1992) guidelines for primary contact recreation. In general, higher concentrations, but still complying with the primary contact recreational guidelines, have been recorded in enclosed swimming areas. This is likely to be related to stormwater runoff from the surrounding urban areas. Importantly, these elevations are generally episodic and there appears to be no declining trend in bacterial concentrations at any monitoring site within the City.

### 3.2.5 CONCLUSIONS AND RECOMMENDATIONS

Water quality monitoring at the popular beach areas and GCCC enclosed swimming areas will continue to assess faecal bacteria concentrations. Should faecal bacteria concentrations increase over an extended period of time, faecal sterol sampling will be undertaken to determine the source of the faecal bacteria. The results suggest that water quality in the swimming enclosures is affected in the same way as most other waterways following rainfall events. Following rain, various water quality parameters can fall below the ANZECC (1992) guidelines.

### 3.3 BIGGERA CREEK

#### 3.3.1 INTRODUCTION

Biggera Creek is located north of Southport (Figure 3.3.1). Its upper catchment area is located in Ernest Junction. The creek then meanders through Parkwood, Musgrave Hill and Labrador before entering into the Broadwater near Biggera Waters. A second tributary, flows from the Arundel Hills area, joins with the main creek near Oxley Drive, before discharging into the Broadwater. Biggera Creek also enters the Broadwater via a northern arm that flows through a series of canals near Runaway Bay.

The freshwater region of this creek receives stormwater runoff from the surrounding residential areas. During periods of low rainfall, both freshwater tributaries are ephemeral, consisting of a series of small stagnant pools. The lower tidal region of the creek receives stormwater input from surrounding urban and industrial areas. The area surrounding the northern entrance to the Broadwater consists of a series of canals, which receives stormwater runoff from the surrounding urban areas.

**Table 3.3.1** Site classifications and distance details for each monitoring site.

Region/Site Type	Distance <sup>#</sup> (km)	Site
Upper Estuary	2.51	BGC 4 (Southern Tributary)
	2.98	BGC 3 (Northern Tributary)
Middle Estuary	1.68	BGC 2
Lower Estuary	0.00	BGC 1

<sup>#</sup> Measured as distance in kilometres from the mouth

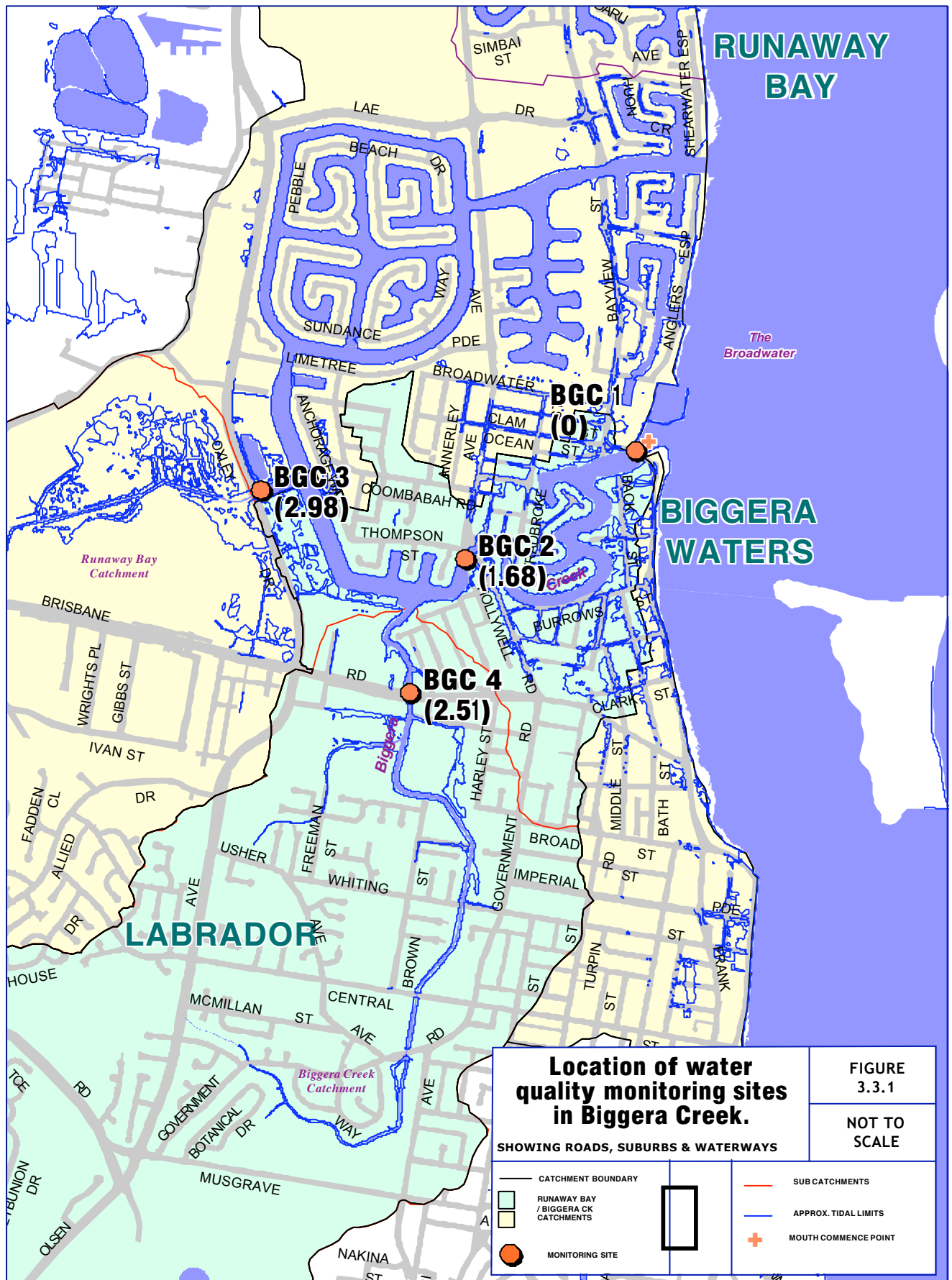
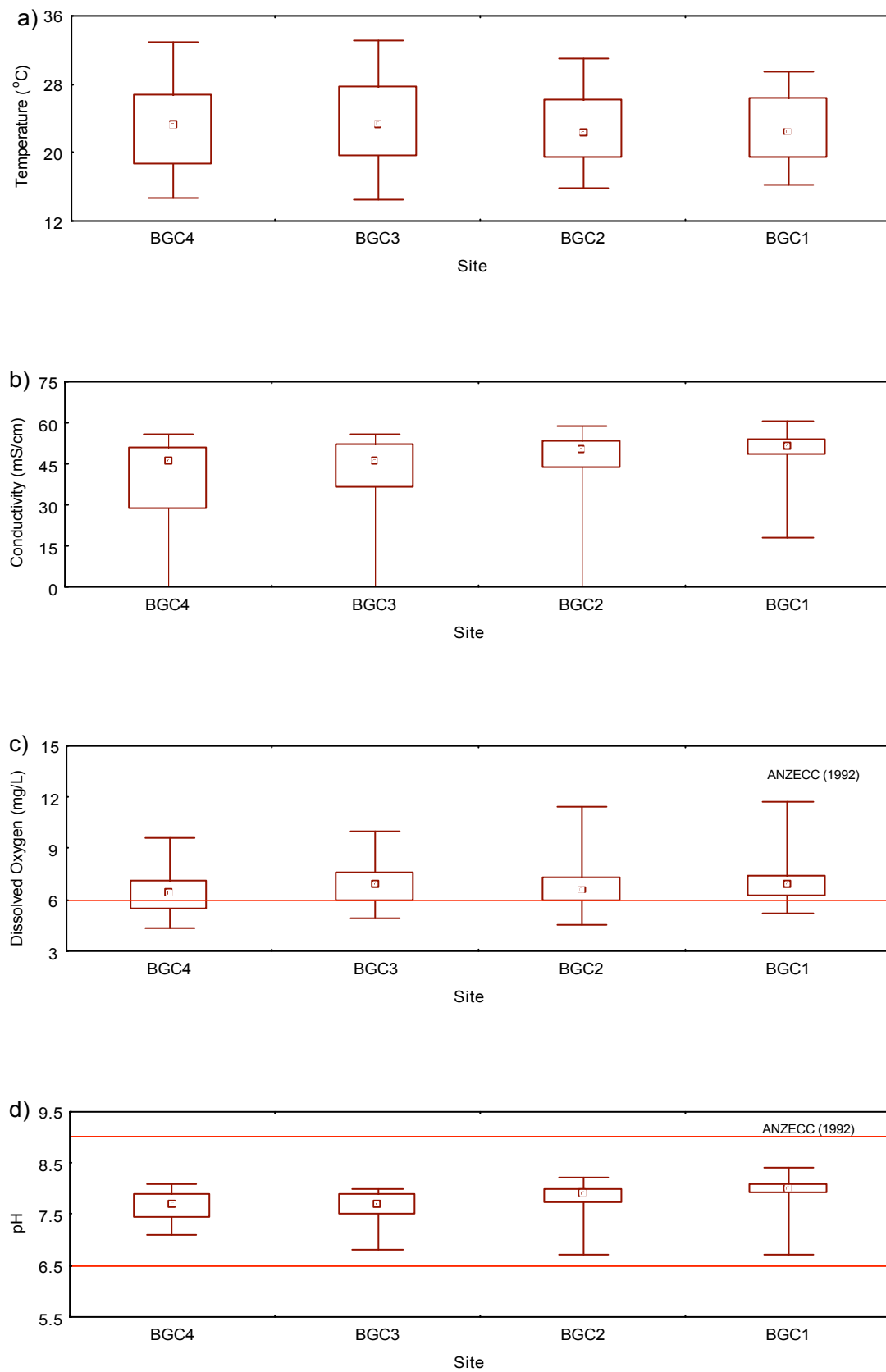
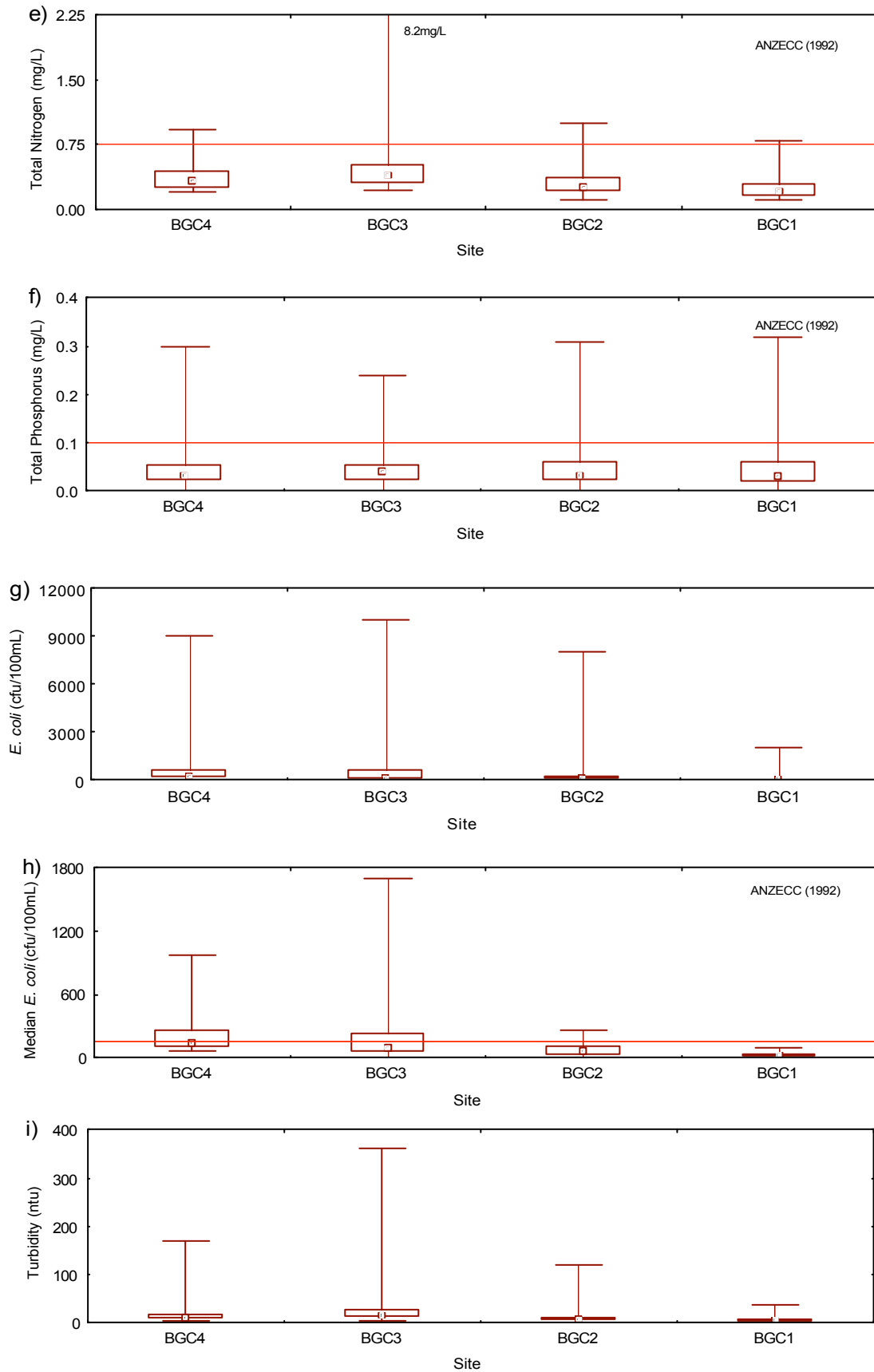


Figure 3.3.1 Location of water quality monitoring sites in Biggera Creek.



**Figure 3.3.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen and (d) pH recorded at each site within Biggera Creek. ANZECC (1992) compliance guidelines have been included for comparison with dissolved oxygen and pH.



**Figure 3.3.2 (cont)** (e) total nitrogen, (f) total phosphorus, (g) raw data for *E. coli* concentrations, (h) rolling median *E. coli* and (i) turbidity recorded at each site within Biggera Creek. ANZECC (1992) compliance guidelines for both nutrient parameters have been included for comparison. Recreational guidelines for primary contact recreational waters have been included for comparison with median *E. coli* concentrations.



### 3.3.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Water temperature has ranged between 16°C and 33°C in Biggera Creek (Figure 3.3.2a). This range in water temperature could be influenced by seasonal conditions, water depth, flow rates, time of day when measurements were recorded or the presence and state of riparian vegetation. Water temperatures did not vary significantly amongst sites (KW :  $p = 0.81$ ).

#### CONDUCTIVITY

Conductivity varied significantly amongst sites (KW :  $p < 0.05$ ), with significantly higher conductivity recorded at BGC 1 than all other sites (Figure 3.3.2b). Significantly higher conductivity was recorded at BGC 2 than BGC 3 and BGC 4. At certain times, conductivity below 20mS/cm at the lower estuary site and below 5mS/cm at both upper and the middle estuary sites were recorded. This is likely to be associated with freshwater runoff during significant rain periods.

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.3.2c), although all sites recorded concentrations below the guidelines, particularly at BGC 4. Dissolved oxygen concentrations varied significantly amongst sites (KW :  $p < 0.05$ ), with significantly higher dissolved oxygen recorded at BGC 1 than at BGC 4 and intermediate concentrations at all other sites.

#### pH

pH complied with the ANZECC (1992) guidelines at each site (Figure 3.3.2d). pH varied significantly amongst sites (KW :  $p < 0.05$ ), with significantly higher pH at BGC 1 than at all other sites. Site BGC 2 also recorded significantly higher pH than at both upper estuary sites. This trend is to be expected, as pH in marine waters is usually higher in comparison with freshwater and is generally less varied.

#### TOTAL NITROGEN

Total nitrogen concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.3.2e). Elevated concentrations above the guidelines have been recorded at each site, particularly at BGC 3 with concentrations above 8mg/L recorded. Concentrations varied significantly amongst sites (KW :  $p < 0.05$ ), with significantly higher concentrations at BGC 3 than at BGC 1 and BGC 2. Site BGC 1 has recorded significantly lower concentrations than BGC 2 and BGC 4, with BGC 2 recording significantly lower concentrations than BGC 4. High total nitrogen concentrations recorded at both BGC 3 and BGC 4, are likely to be influenced by stormwater runoff from the surrounding urban residential areas. Total nitrogen concentrations were found to improve downstream, which maybe related to greater flushing of the lower estuary with the Broadwater.

#### TOTAL PHOSPHORUS

Total phosphorus concentrations regularly complied with the ANZECC (1992) guidelines, with the 80<sup>th</sup> percentile below the guidelines at each site (Figure 3.3.2f). Concentrations above the guidelines have been recorded at each site. Total phosphorus concentrations did not vary significantly amongst sites (KW :  $p = 0.21$ ).

#### E. COLI

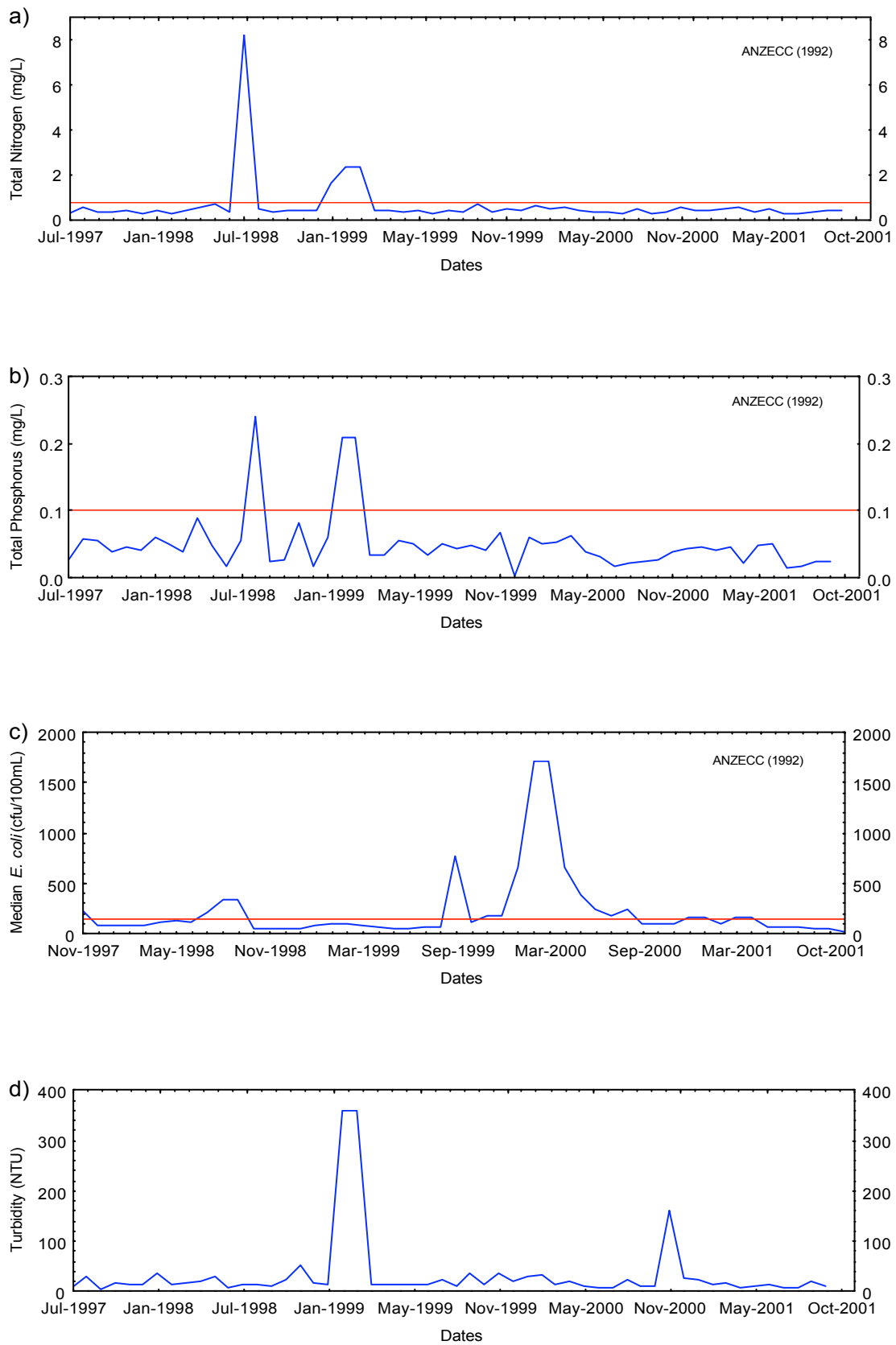
*E. coli* concentrations, calculated as rolling medians at each site, regularly complied with the ANZECC (1992) guidelines for primary contact recreational waters (Figure 3.3.2h). Sites BGC 3 and BGC 4 recorded concentrations exceeding the primary contact recreational guidelines, with several concentrations at BGC 3 exceeding the secondary contact recreational guidelines. *E. coli* concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher *E. coli* concentrations at BGC 4 than all other sites. Significantly lower concentrations were recorded at BGC 1 and BGC 2 than at BGC 3. *E. coli* concentrations were found to be highest at BGC 3 and BGC 4 and appear to have generally improved downstream.

## **TURBIDITY**

Turbidity varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher turbidity at BGC 3 and BGC 4 than at BGC 1 and BGC 2 (Figure 3.3.2i). Site BGC 1 recorded significantly lower turbidity than at BGC 2. High turbidity recorded at upper estuary sites and an improvement downstream was similar to total nitrogen and *E. coli* concentrations and is also likely to be related to limited exchange with the Broadwater.

### **3.3.3 WATER QUALITY TRENDS**

Water quality recorded at BGC 3 has been assessed to determine trends over the monitoring period (Figure 3.3.3). Total nitrogen and total phosphorus concentrations regularly complied with the guidelines, particularly since March 1999. A peak in nutrient concentrations occurred during February and March 1999. This increase in concentrations is likely to be related to a significant rain event. Total nitrogen concentration significantly exceeded the guidelines during July 1998, however, was not observed for total phosphorus concentrations during this month. This trend is unclear and may suggest that a data or sampling entry error or a pollution event has occurred during this month. *E. coli* concentrations generally complied with the primary contact recreational guidelines. Several peaks in concentrations above the primary contact recreational guidelines were recorded at this site. The rolling median for *E. coli* concentrations exceeded the guidelines between September 1999 and June 2000, with concentrations between February 2000 and April 2000 exceeding the secondary contact recreational guidelines. Turbidity generally remained below 50ntu over the monitoring period. A peak in turbidity between February and March 1999 was recorded, similar to both nutrient parameters. Overall there does not appear to be a decline in water quality at this monitoring site, despite fluctuations in concentrations, probably associated with rain events.



**Figure 3.3.5** Water quality trends for (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at site BGC 3 over the monitoring period.

### 3.3.4 DISCUSSION

Water quality within Biggera Creek has generally complied with the ANZECC (1992) guidelines for the protection of aquatic ecosystems. Elevated nutrient and *E. coli* concentrations have been recorded at both upper estuary sites, which each monitoring runoff from the two main tributaries in this catchment. Both tributaries receive runoff primarily from urban residential areas, which may contribute to these periods of poor water quality. Site BGC 3 generally recorded poorer water quality conditions than BGC 4. This was particularly evident for turbidity. These poorer results suggest that activities within the northern catchment greatly influence water quality within the northern tributary.

Water quality appears to improve downstream of the upper estuary monitoring sites. Water quality conditions within the middle and lower section of the creek would be influenced by stormwater runoff from the adjacent residential areas and from upper catchment areas. It is however, considered that tidal exchange between the lower estuary and the Broadwater greatly assists with water quality conditions in lower Biggera Creek.

### 3.3.5 CONCLUSIONS AND RECOMMENDATIONS

Generally good water quality conditions have been shown in Biggera Creek, although, slightly higher nutrient, *E. coli* and turbidity conditions are regularly recorded at both upper estuary sites. This may require further investigation through event based monitoring or additional intensive water sampling to determine the source of these high recordings. The management and improvement of stormwater runoff from upper catchment areas, through the development of a detailed stormwater management plan, is considered necessary in ensuring water quality conditions and EVs of this creek are maintained. CMU will develop a CMP for this catchment in the coming years. This study will identify the EVs considered important by the community stakeholders. This information will be used to develop a land use specific stormwater management plan for Biggera Creek. A community catchment management group in Biggera Creek has already implemented rehabilitation works in riparian areas along the creek. The group has also begun a program to educate the local community on the values of Biggera Creek.

### 3.4 BROADWATER SURVEY

#### 3.4.1 INTRODUCTION

The Broadwater provides an important recreational and economic resource for many residents and visitors to the Gold Coast. This body of water is the point to which several of the City's major catchments drain. Some of this flow drains urban areas that could potentially transport various pollutants including sediments, nutrients, organic material, heavy metals, hydrocarbons, pesticides and other toxicants into the Broadwater.

The EPA, in conjunction with GCCC, monitors water quality in the Broadwater and the adjacent Pacific Ocean. This program has been designed to monitor and assess the discharge of treated wastewater at the Gold Coast Seaway. A report published by EPA concluded that the discharge of treated wastewater at the Seaway has no apparent impact on water quality within the Broadwater and the adjacent Pacific Ocean (Moss and Cox, 1999).

Another EPA/GCCC collaborative water quality monitoring program focuses on the northern Broadwater and southern Moreton Bay region. This monitoring program has been designed to monitor the bacteriological quality at popular recreational swimming areas within the northern part of the City. The results from the EPA/GCCC program found bacterial concentrations within the northern Broadwater and Coomera River region were within the ANZECC (1992) guidelines for primary contact recreation waters (Semple and Dunlop, 1996).

This survey focuses on key locations within the Broadwater to monitor and assess *E. coli* concentrations.

**Table 3.4.1** Site details for monitoring sites within the Broadwater

Site	Location
BDW 2	Gardiners Creek
BDW 3	Pelican Beach
BDW 4	Tuesley Park
BDW 5	Loders Creek
BDW 7	Biggera Creek
BDW 9	Coomera Inlet
BDW 10	Seaway
BDW 11	Marine Stadium
BDW 12	Jacobs Well Beach
BDW 13	Cabbage Tree Point

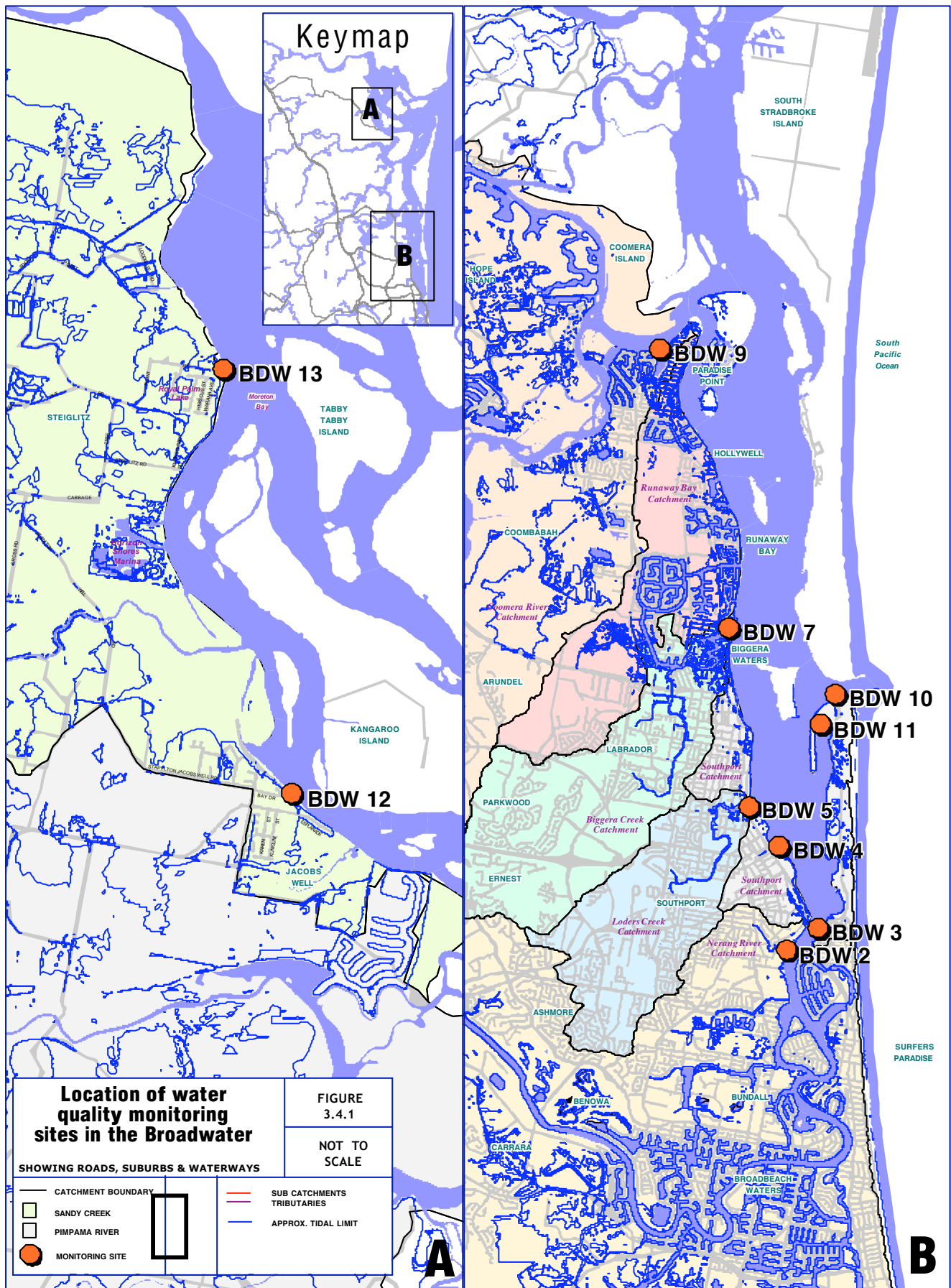
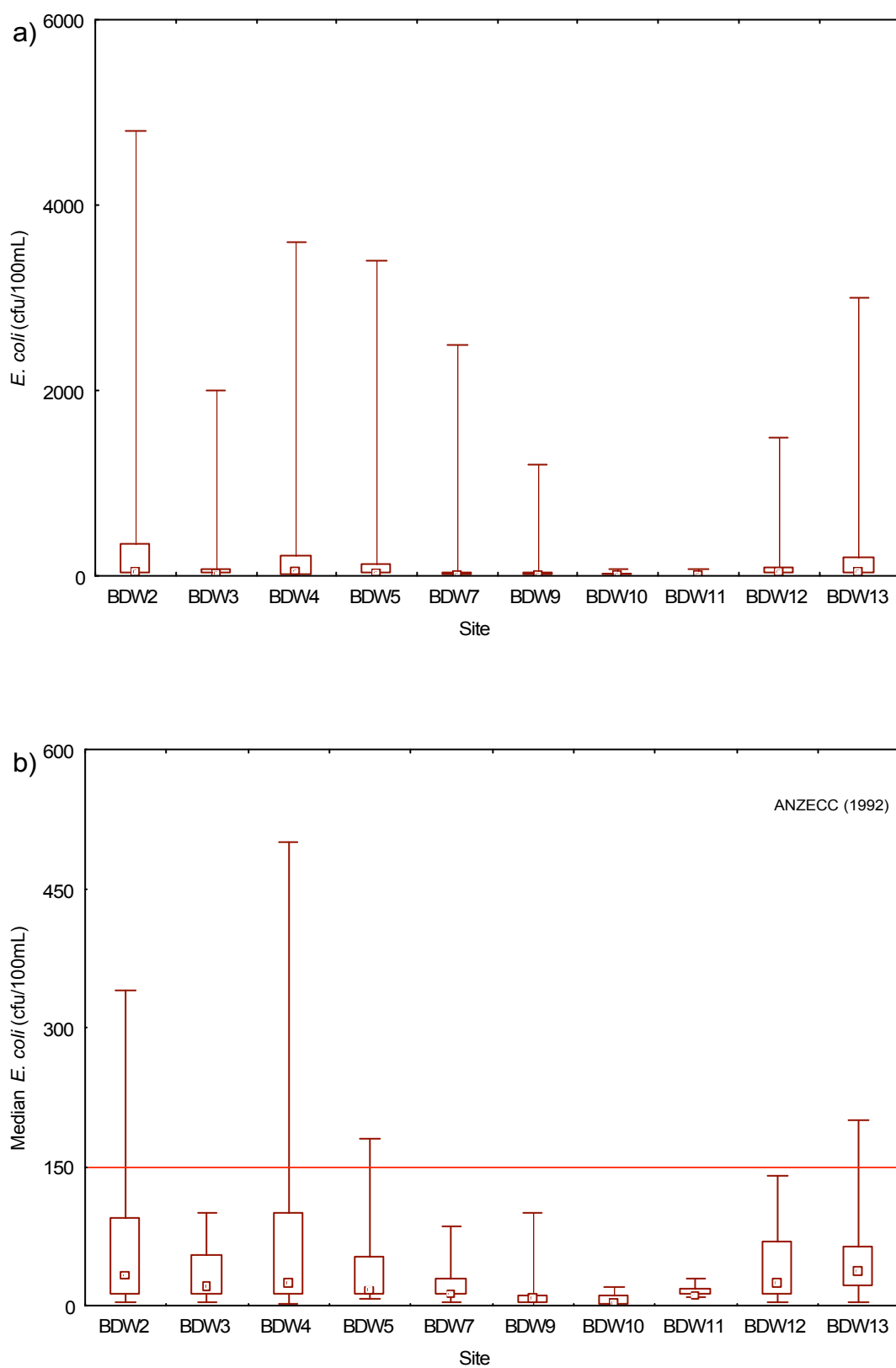
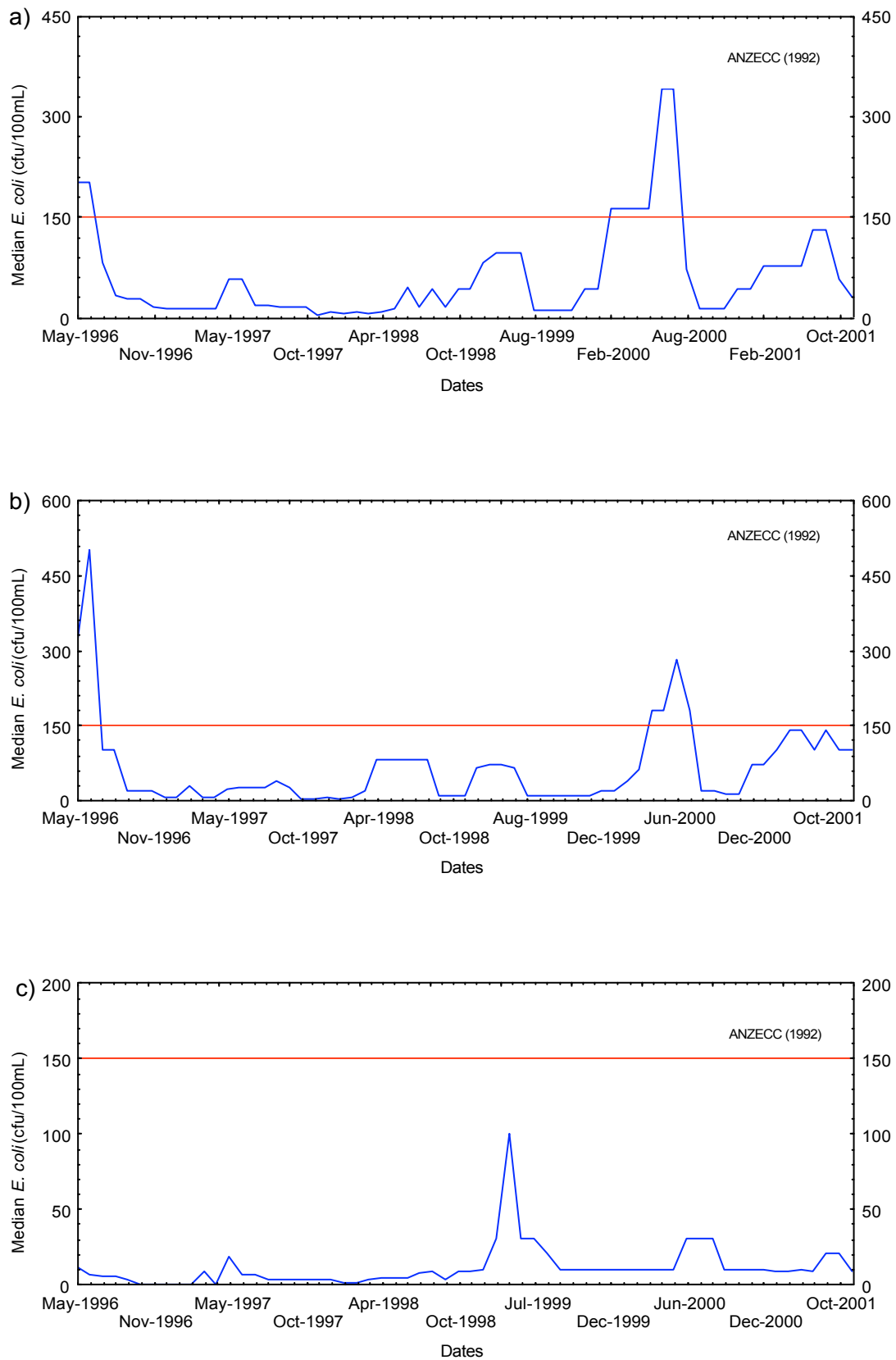


Figure 3.4.1 Location of water quality monitoring sites in the Broadwater.



**Figure 3.4.2** Box plots for *E. coli* concentrations recorded at each site within the Broadwater survey. (a) Raw data for *E. coli* concentrations and (b) rolling median *E. coli* concentrations for each site including ANZECC (1992) guidelines for primary contact recreational waters for comparison



**Figure 3.4.3** Trends in median *E. coli* concentrations recorded at sites (a) BDW 2, (b) BDW 4 and (c) BDW 9 to assess changes in water quality over the monitoring period.



### 3.4.2 COMPLIANCE AND WATER QUALITY ASSESSMENT

*E. coli* concentrations, calculated as a rolling median, have regularly complied with the ANZECC (1992) guidelines for primary contact recreation (Figure 3.4.2b). For all sites, the 80<sup>th</sup> percentile was below the primary contact recreational guidelines. At sites in Pelican Beach (BDW 3), Biggera Creek (BDW 7), Coomera Inlet (BDW 9), Seaway (BDW 10), Marine Stadium (BDW 11), Jacobs Well beach (BDW 12) and Cabbage Tree Point (BDW 13) all median *E. coli* concentration complied with the primary contact recreational guidelines.

On several occasions, Gardiners Creek (BDW 2), Tuesley Park (BDW 4), Loders Creek (BDW 5) and Cabbage Tree Point (BDW 13) recorded concentrations above the primary contact recreational guidelines. Stormwater runoff may contribute to these high concentrations. This is most apparent at Gardiners Creek (BDW 2) and Tuesley Park (BDW 4), which are located in close proximity to stormwater outlet pipes that collect stormwater runoff from surrounding urban and industrial areas.

*E. coli* concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with Coomera Inlet (BDW 9) and Seaway (BDW 10) recording significantly lower concentrations than other sites, except Biggera Creek (BDW 7) and Marine Stadium (BDW 11) respectively. Cabbage Tree Point (BDW 13) also recorded significantly higher concentrations than Biggera Creek (BDW 7).

### 3.4.3 WATER QUALITY TRENDS

Rolling median *E. coli* concentrations recorded at Gardiners Creek (BDW 2) and Tuesley Park (BDW 4) has remained consistent following the commencement of this survey in 1996 (Figure 3.4.3a and b). An increase in concentrations during March 1999 and in June 2000 above the primary contact recreational guidelines has occurred, however, concentrations again improved to comply with the guidelines.

The rolling median *E. coli* concentration recorded at Coomera Inlet (BDW 9) has consistently complied with the primary contact recreational guidelines (Figure 3.4.3c). Similar to Gardiners Creek (BDW 2) and Tuesley Park (BDW 4), a small peak was recorded during March 1999 and June 2000, which suggests the influence of a rain event.

### 3.4.4 DISCUSSION

The results from this monitoring have shown the Broadwater generally complies with the guidelines for primary contact recreational waters (*ie* swimming). Several monitoring sites, located at the confluence of small tributaries and the Broadwater, have however, recorded elevated *E. coli* concentrations. This is likely to be associated with rain events.

Moss and Cox (1999) reported similar conclusions, whereby water quality in the Broadwater was not influenced by the discharge of treated wastewater at the Gold Coast Seaway. Moreover, water quality conditions in the Broadwater are likely to be influenced by runoff from adjacent catchments.

### 3.4.5 CONCLUSIONS AND RECOMMENDATIONS

Maintaining suitable water quality conditions, to continue supporting the various recreational activities undertaken by residents and tourists within the Broadwater, will require the management of land use activities in tributaries that flow into the Broadwater (*ie* Loders Creek, Gardiners Creek, Biggera Creek, Nerang River). Importantly, land use specific stormwater quality management plans and the possibility of retrofitting stormwater quality improvement devices (SQIDS), in areas identified as contributing to poor water quality conditions is required in the future. This is considered important in order for the Broadwater to maintain those EVs expected of this area by residents and tourists. CMPs are currently being developed for Coombabah and Saltwater Creeks to protect the EVs for each waterway. In each study, the possible impact on the Broadwater has been considered in the development of each CMP.

### 3.5 CLEAR ISLAND WATERS

#### 3.5.1 INTRODUCTION

The Clear Island Waters system has a catchment area of approximately 120km<sup>2</sup>. This system receives flow from Mudgeeraba, Bonogin, Wyangan and Worongary Creek catchments along with stormwater runoff from the surrounding residential area of Clear Island Waters (Figure 3.5.1).

Three weir systems located in Lake Intrepid, Lake Wonderland and Boobegan Creek prevent saltwater tidal intrusion into Clear Island Waters from the Nerang River. Floodwaters following significant rain events are permitted to flow through these weirs into the Nerang River.

The Clear Island Waters system supports a diverse range of native aquatic plants, fish species, crustaceans and bird species. The lakes also provide an important visual and recreational amenity for the local community (WBM Oceanics Australia, 1998).

The input of nutrient material associated with urban runoff over time has led to increased algal and aquatic plant growth within this system (WBM Oceanics Australia, 1998). Increased algal production within a waterway can have implications on other aquatic communities including diurnal fluctuations on dissolved oxygen concentrations, effects on pH and also health implications depending on the species of algae (Wetzel, 1989).

The management of Clear Island Waters is an intricate and complex process that involves understanding a number of factors including water quality, hydrology, plant and animal communities and maintenance required to ensure a balanced ecology within this system.

The lakes of Clear Island Waters are categorised in Table 3.5.1 based on their geographical location. Measurements at the surface and at 0.5m intervals (profile) are recorded for water temperature, conductivity, pH and dissolved oxygen concentrations at each site. A composite surface water sample is collected from the three west and eastern sites (CWW and CWE) and a single water sample is collected at CWM 3 for nutrient, *E. coli* and turbidity analysis.

Table 3.5.1 Water quality monitoring sites within Clear Island Waters.

Region	Distance #	Site (Code)
Clear Island West (CWW)	3.0	CWW 1
	2.4	CWW 2
	2.16	CWW 4
Clear Island Middle (CWM)	2.68	CWM 3
Clear Island East (CWE)	3.62	CWE 1
	3.74	CWE 3
	3.57	CWE 4

# Measured as distance in kilometres from the Nerang River

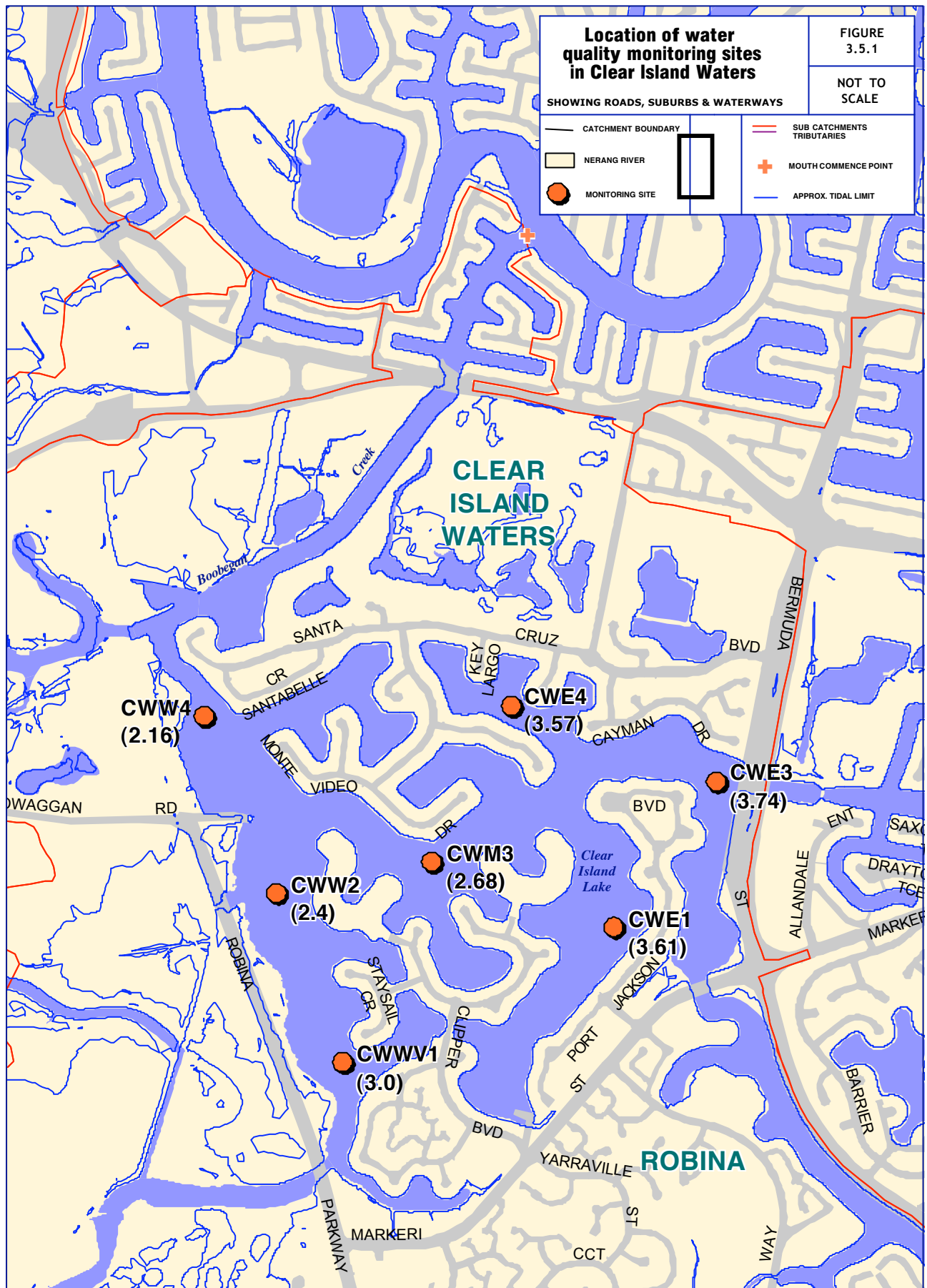
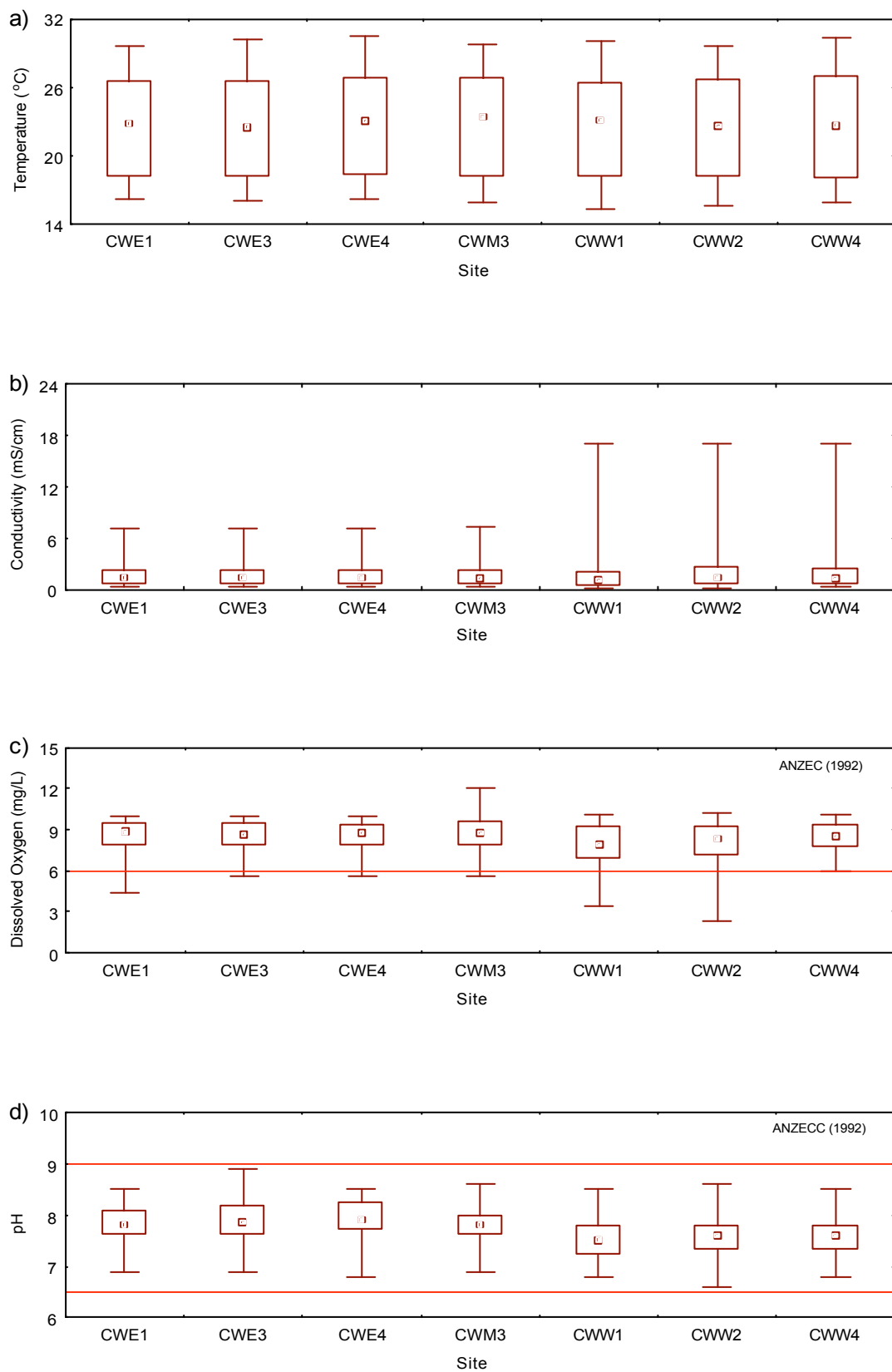
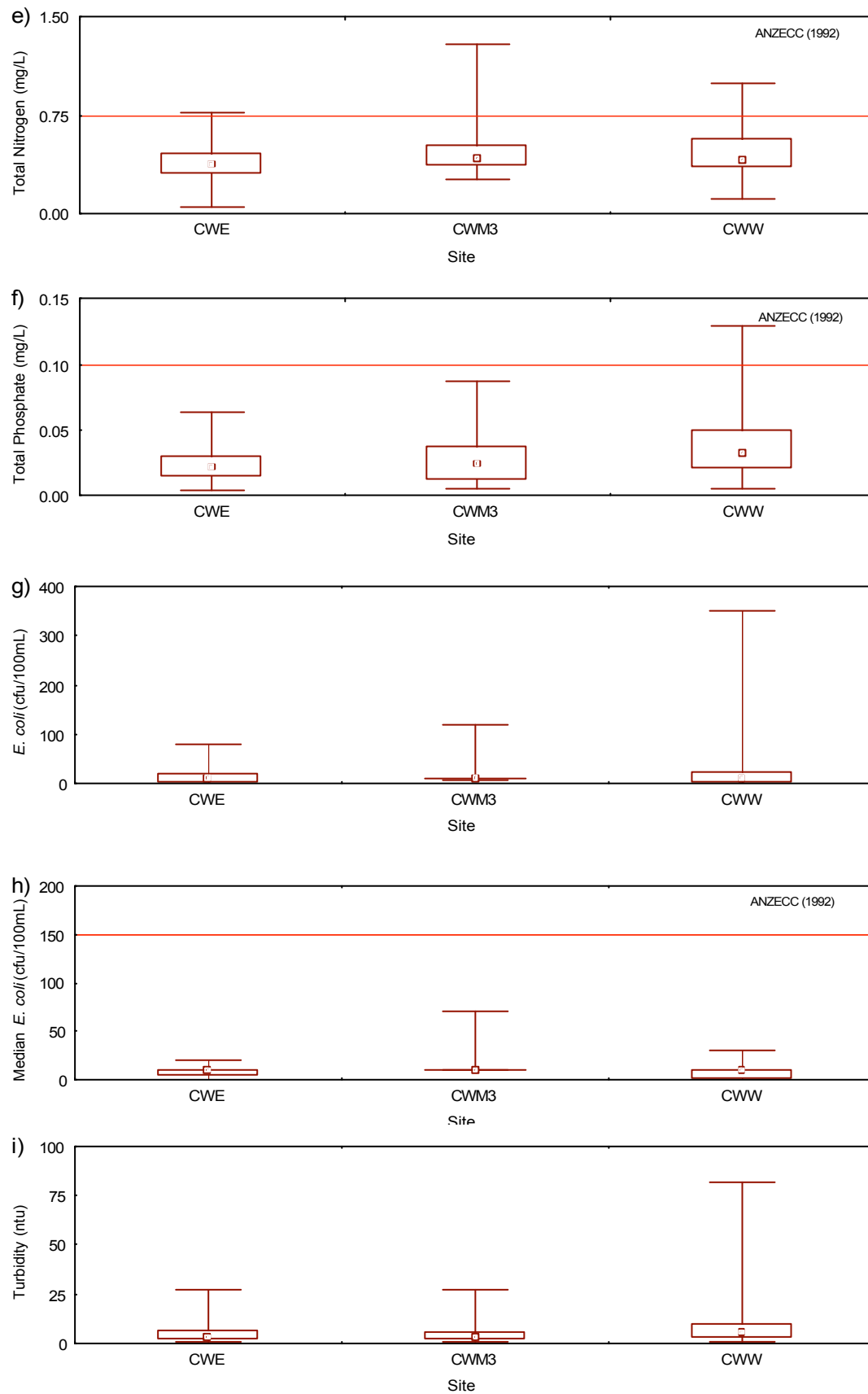


Figure 3.5.1 Water quality monitoring sites located within Clear Island Waters.



**Figure 3.5.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen, and (d) pH recorded at each site. ANZECC (1992) compliance guidelines for the protection of aquatic ecosystems have been included for dissolved oxygen and pH.



**Figure 3.5.2 (cont)** (e) total nitrogen, (f) total phosphorus, (g) raw data for *E. coli* concentrations, (h) rolling median *E. coli* and (i) turbidity recorded at each site. ANZECC (1992) guidelines have been included for both nutrient parameters. Recreational guidelines for primary contact waters have been included for comparison with median *E. coli* concentrations.

### 3.5.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Water temperature has ranged between 16°C and 30°C in Clear Island Waters (Figure 3.5.2a). This range in water temperature could be influenced by seasonal conditions, flow rates or the time of day when measurements were recorded. Surface water temperatures did not vary significantly amongst sites (KW :  $p = 0.98$ ).

#### CONDUCTIVITY

Conductivity generally remained below 2mS/cm at each site over the monitoring period, excluding CWW1, CWW2 and CWW4 where conductivity has been recorded up to 18mS/cm (Figure 3.5.2b). These higher recordings could be related to saltwater intrusion through the Boobegan Creek tidal weir during periods of maintenance or where the saltwater seepage into the lake has occurred. Conductivity conditions did not vary significantly amongst sites (KW :  $p = 0.93$ ).

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations regularly complied with the ANZECC (1992) guidelines, with the 20<sup>th</sup> percentile above the guidelines at all sites (Figure 3.5.2c). Reductions below the guidelines have been recorded at all sites, except at CWW 4. If occurring over extended periods of time, low concentrations can lead to implications on the health of aquatic organisms. Dissolved oxygen concentrations did not vary significantly amongst sites (KW :  $p = 0.09$ ).

#### pH

pH complied with the ANZECC (1992) guidelines at all sites over the monitoring period (Figure 3.5.2d). Conditions up to 9.0 have been recorded, which is likely indicative of increased algal activity within this lake system. pH varied significantly amongst sites (KW :  $p < 0.01$ ), with significantly higher pH at CWE sites than at all CWW sites. CWM3 recorded significantly higher pH than at CWW1.

#### TOTAL NITROGEN

Total nitrogen concentrations regularly complied with the ANZECC (1992) guidelines, with the 80<sup>th</sup> percentile below the guidelines within all regions (Figure 3.5.2e). Elevated concentrations above the guidelines have been recorded within each region, which is likely to be related to runoff from the surrounding residential or floodplain area. Total nitrogen concentrations varied significantly between lake regions (KW :  $p < 0.03$ ), with significantly higher concentrations recorded at CWW than at CWE. This may be due to the influence of runoff from the floodplains and/or Mudgeeraba Creek catchment.

#### TOTAL PHOSPHORUS

Total phosphorus concentrations regularly complied with the ANZECC (1992) guidelines, with the 80<sup>th</sup> percentile below the guidelines within each region (Figure 3.5.2f). Concentrations varied significantly between lake regions (KW :  $p < 0.001$ ), with significantly higher concentrations recorded at CWW than other regions of the system. Higher total phosphorus concentrations in the western region may be due to the influence of runoff from the floodplains and/or Mudgeeraba Creek catchment. A similar trend was also found for total nitrogen concentrations within this lake.

#### E. COLI

*E. coli* concentrations, calculated as a rolling median, complied with the ANZECC (1992) guidelines for primary contact recreational waters (Figure 3.5.2h). High individual *E. coli* concentrations have been recorded within the western region of the lake (CWW) (Figure 3.5.2g), which may also be related to flow from the floodplains and Mudgeeraba Creek catchment. *E. coli* concentrations did not vary significantly amongst sites (KW :  $p = 0.06$ ).

## TURBIDITY

Turbidity within this lake system was generally below 10ntu (Figure 3.5.2i). Turbidity varied significantly between regions of this lake (KW :  $p < 0.001$ ), with significantly higher turbidity in the western region of the lake than at both other regions. This trend was also found for nutrient and *E. coli* concentrations.

### 3.5.3 DISCUSSION

Water quality monitoring in Clear Island Waters has provided a quantitative assessment of water quality performance and a qualitative assessment of catchment land use surrounding this lake system. While water quality conditions regularly complied with the ANZECC (1992) guidelines, problems associated with the growth of aquatic plants, along with algal blooms occurring during summer months, has occurred in the past.

While these aquatic plants provide an important habitat for many fish and water bird species and play a role in removing nutrients from the water column, the excessive growth of these plants may reduce the available space for other aquatic organisms. It can also reduce the aesthetic amenity and produce odours if left to dry on the rock walls of the lake. The present aquatic plant harvesting program implemented by GCCC assists with the control of the plant growth, whilst still allowing for the processing of nutrients transported into this waterway from the surrounding catchment. At present the net removal of nutrient is from weed harvesting, with an average of 4,200m<sup>3</sup> of weed removed each year from the Robina and Clear Island Waters lake system. This equates to approximately 152,500kg and 21,200kg of total phosphorus and total nitrogen respectively each year (WBM Oceanics, 18<sup>th</sup> October, 1999).

The development of a CMP for the surrounding catchment area to Clear Island Waters is an important component for the effective management of this lake system. GCCC is actively working with various government and scientific agencies to develop appropriate water management strategies, CMPs and environmental strategies. The aim is to balance water quality conditions between recreational desires of the local community, with conditions that are suitable for protecting those aquatic and terrestrial animals that inhabit this lake system.

### 3.5.4 CONCLUSIONS AND RECOMMENDATIONS

The lakes of Clear Island Waters have generally recorded good water quality conditions suitable for the protection of aquatic ecosystems. The growth of aquatic plants and algal blooms, however, is a common occurrence in this lake system particularly during the summer months. This growth of aquatic plants is a direct result of excessive nutrient loads entering this lake system. The management and improvement of stormwater quality runoff from the surrounding catchment, particularly residential areas, is considered necessary to promote good water quality conditions. In particular, nutrient loadings entering the lake need to be addressed to ensure EVs of this lake system are maintained. GCCC is in the process of developing a CMP for the Mudgeeraba Creek catchment (includes Mudgeeraba, Bonogin, Wyangan and Worongary Creeks). The study will be designed to focus on a range of environmental issues/indicators to establish the ecological health of each waterway that discharge into the Robina and Clear Island Waters system. Of particular interest in this study, will be to determine the current and future nutrient export loadings associated with proposed residential development in each catchment. This information is fundamental in the design of a land use specific stormwater management plan to protect the values of each catchment, and to protect the values of Clear Island Waters. Event based monitoring in upper and lower Bonogin has been undertaken over the past few years to determine nutrient and sediment loads and relationships to varying rain events. This information forms part of a larger City wide modelling program and will also be used in the Mudgeeraba Creek catchment study. A community catchment management group in Mudgeeraba Creek has implemented rehabilitation works in riparian areas along the creek. The group has also begun a program to educate the local community on the values of Mudgeeraba/Bonogin and Wyangan Creek.

### 3.6 COOMBABAH CREEK

#### 3.6.1 INTRODUCTION

Coombabah Creek is a small, approximately 17km in length, tributary of the Coomera River (Figure 3.6.1). The upper catchment begins in the Nerang State Forest, where it flows through encroaching residential development and under the Pacific Highway, which is the tidal limit for this system. At this point the creek flows into the Coombabah estuary and lake, and finally into the Coomera River. The creek and its catchment have a high conservation value despite the close proximity of residential development. Coombabah Lake is classified as a 'conservation' and 'habitat' zone under the Marine Parks (Moreton Bay) Zoning Plan 1997, declared Fish Habitat Area under the Fisheries Act 1994 and has RAMSAR, China-Australia Migratory Bird Agreement (CAMBA) & Japan-Australia Migratory Bird Agreement (JAMBA) status.

Coombabah Lake is a restricted estuarine lake that has formed in a minor drowned valley on the landward margin of the vast 'tidal basin' estuary that has formed in the lee of South Stradbroke Island (Graham, 1999). The lake is very shallow with depths of approximately 0.2m, deepening to 0.9m in the thalweg of the current stream course (Sinclair Knight Merz, 1997).

A major concern expressed by residents living in Coombabah catchment is the perceived siltation of Coombabah Lake. Land use changes in Coombabah catchment over the last fifty years have been numerous. The clearing of Gaven Forest from a pine plantation in the 1960s and the development of the Helensvale residential estate (1970s to 1990s) are considered major contributors of sediment loads to this waterway. In addition, the opening of Jumpinpin Bar in the 1890s and the stabilisation of the Nerang River Seaway in 1986 has had a significant effect on the tidal regime in this lake (Graham, 1999).

A formal investigation into the state of Coombabah Creek was undertaken in 1997 following community concern in relation to sedimentation of Coombabah Lake and the lake's associated ecological degradation. This project entitled "*Coombabah Creek Catchment Management Study November 1997*" revealed that Coombabah Creek/Lake was experiencing considerable stress from elevated sediment and nutrient loads. Increasing pressure from development continues to place further stress on the ecological health of this system. However, a requirement for development now incorporates the inclusion of stormwater quality controls to reduce sediment and other pollutant transportation from the upper catchment.

The wetland area adjacent to the lake (Coombabah Wetlands Reserve) has significant natural, cultural, conservational, educational and recreational value for the local community. This stems from the diversity and quality of this area in close proximity to intensive residential areas. The area supports an important habitat for a diverse range of bird life, which has been reported to exceed 160 species (GCCC, 1999). This wetland would also effectively filter nutrients, suspended solids and other contaminants that are washed into this area.

**Table 3.6.1** Water quality monitoring sites within the five regions of Coombabah Creek.

Region	Distance #	Site
Freshwater Sites	17.62	CBC 1
	15.27	CBC 2
	14.83	CBC 3
Upper Estuary	13.22	CBL 1a
Lake	8.02	CBL 2
	7.00	CBL 3
Lower Estuary	3.48	CBL 4
	1.23	CBL 5
Wetland Sites	6.12	CBL 6
	7.67	CBL 7
	8.11	CBL 8
Discontinued Lake Site	7.54	CBL 9

# Measured as distance in kilometres from the mouth



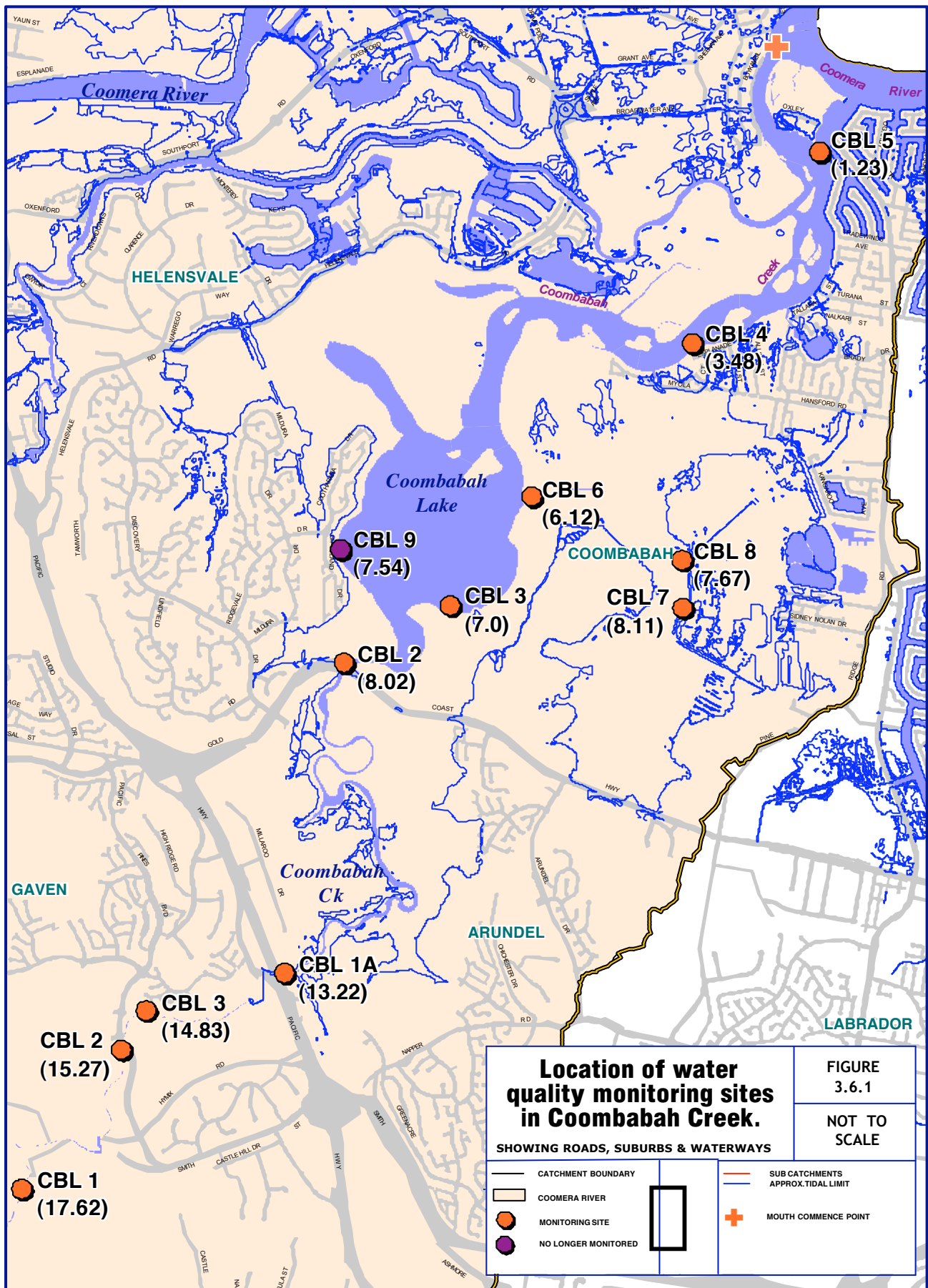
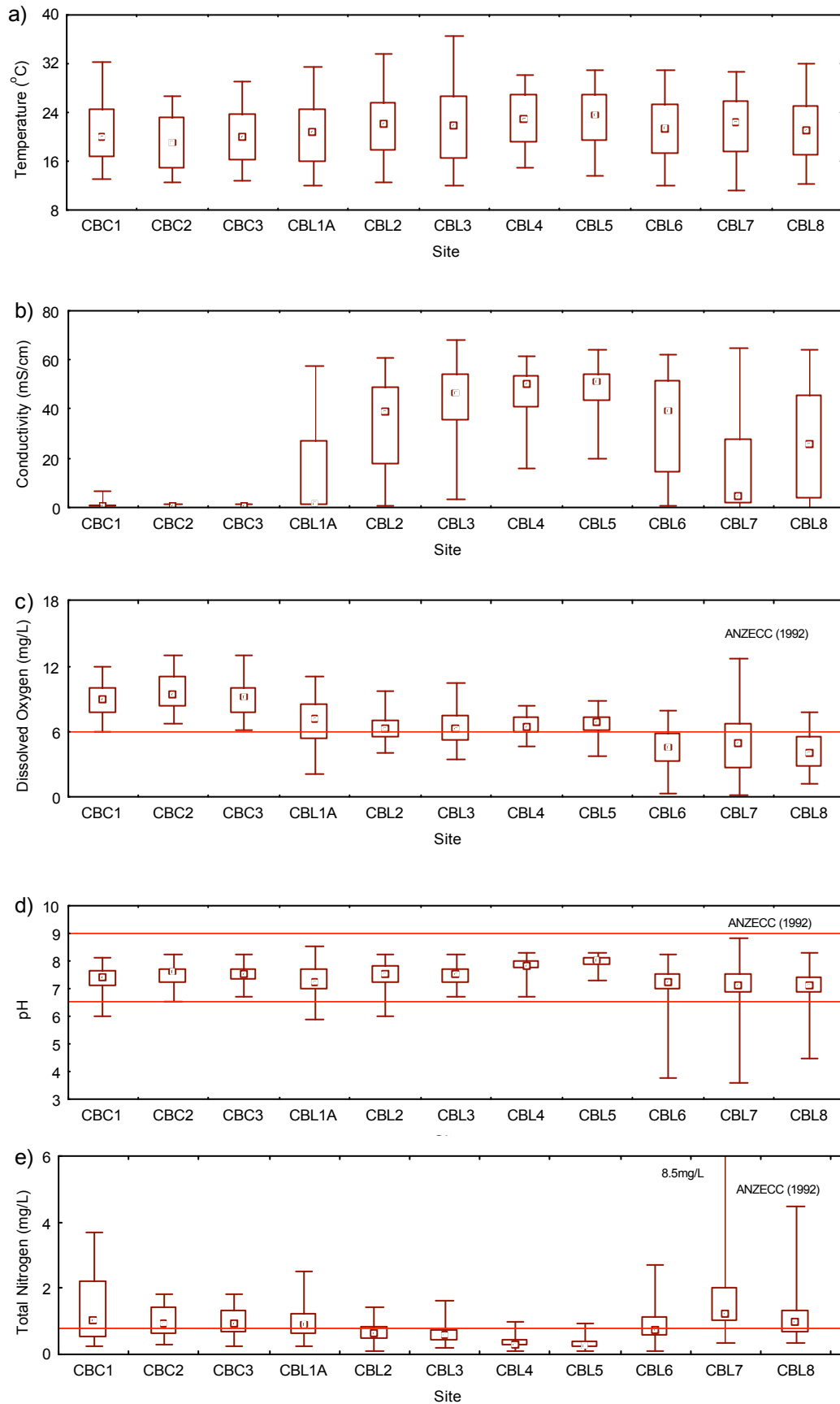
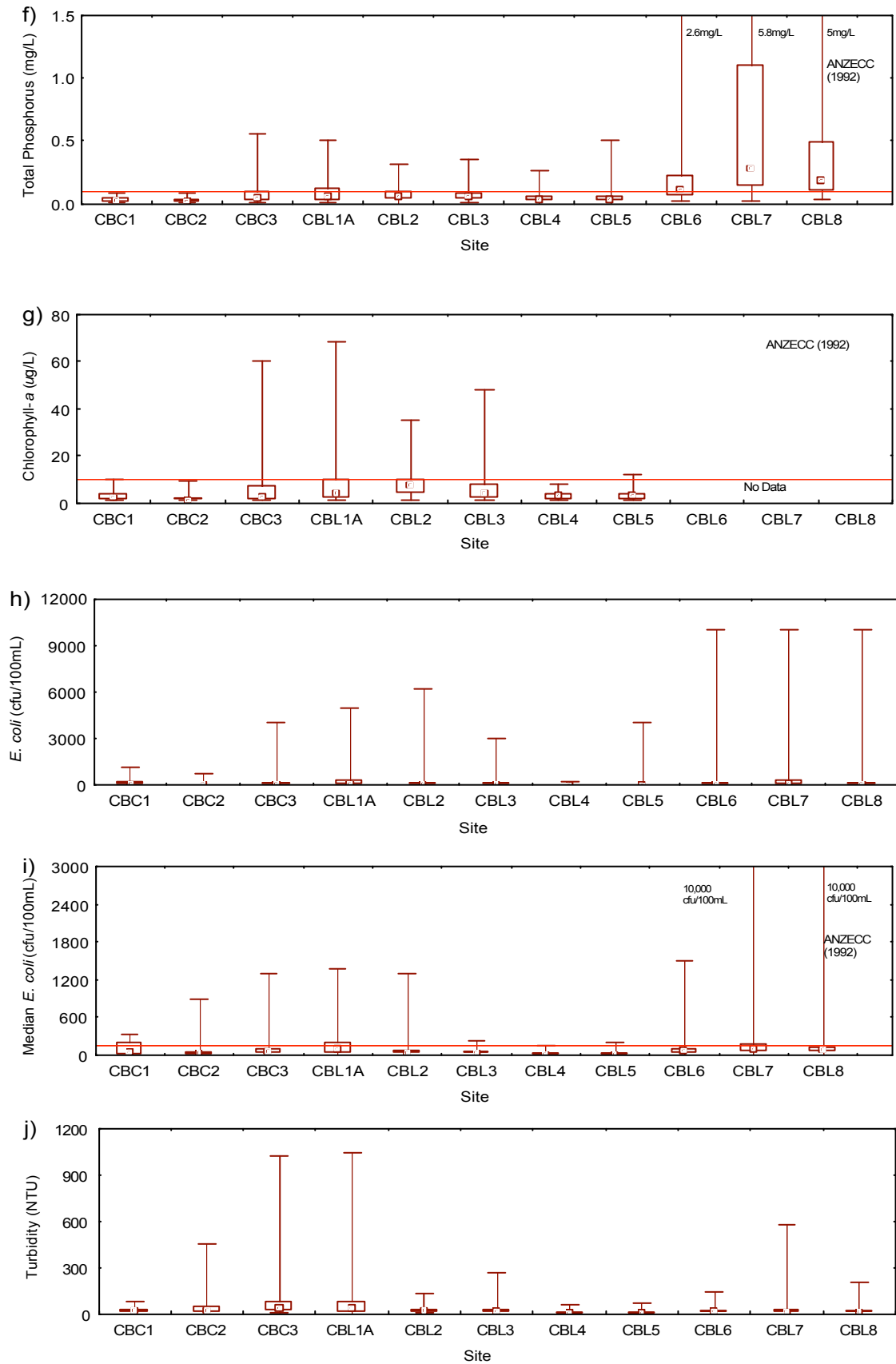


Figure 3.6.1 Water quality monitoring sites located of in Coombabah Creek.



**Figure 3.6.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen, (d) pH and (e) total nitrogen concentrations recorded at each site. ANZECC (1992) compliance guidelines have been included for dissolved oxygen, pH and total nitrogen.



**Figure 3.6.2 (cont)** (f) total phosphorus, (g) chlorophyll-a, (h) raw data for *E. coli* concentrations, (i) rolling median *E. coli* concentration, and (j) turbidity recorded at each site. ANZECC (1992) compliance guidelines have been included for total phosphorus and chlorophyll-a. Recreational guidelines for primary contact have also been included for comparison with median *E. coli* concentrations.

### 3.6.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Water temperature has ranged between 12°C and 36°C in Coombabah Creek (Figure 3.6.2a). This range in water temperature could be influenced by seasonal conditions, water depth, flow rates, time of day when measurements were recorded or the presence and density/nature of riparian vegetation at each site. Water temperatures varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher water temperatures at CBL 5 than at CBC 1 - CBC 3, CBL 1a and CBL 8.

#### CONDUCTIVITY

Conductivity varied significantly amongst sites (KW :  $p < 0.001$ ) (Figure 3.6.2b), with significantly higher conductivity at CBL 5 than all other sites, except CBL 3 and CBL 4. Significantly lower conductivity was recorded at freshwater, upper estuary sites and CBL 7 than all other sites. Sites CBL 2, CBL 6 and CBL 8 recorded significantly lower conductivity than CBL 3 and CBL 4. The increasing conductivity gradient downstream from the upper freshwater region towards the lower estuary region is expected due to increased tidal exchange with the Broadwater. Site CBL 6 recorded lower conductivity than other lower estuary sites, which is likely to be influenced by freshwater flow from the Coombabah Wetland Reserve. At certain times, conductivity decreased below 5mS/cm at lower estuarine sites, which is probably associated with freshwater runoff from the upper catchment area during rainfall periods.

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations regularly complied with the ANZECC (1992) guidelines, except at CBL 6 - CBL 8 where concentrations were regularly below the guidelines (Figure 3.6.2c). These lower concentrations are likely to be associated with the location of each site in Coombabah Wetland Reserve, as wetlands generally experience low dissolved oxygen concentrations (Wetzel, 1989). Dissolved oxygen concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at CBC 1 - CBC 3 than all other sites. Significantly lower concentrations were recorded at CBL 6 - CBL 8 than all other sites, with intermediate concentrations recorded at CBL 1a - CBL 5. High dissolved oxygen concentrations recorded at sites within the upper freshwater region and a general decrease in concentrations downstream towards the lower estuarine region of the creek is unusual in comparison to other waterways. This reason for this trend is unclear.

#### pH

pH regularly complied with the ANZECC (1992) guidelines (Figure 3.6.2d). Reductions in pH below the lower limit guidelines have been recorded at several monitoring sites. pH varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher pH at CBL 4 and CBL 5 than all other monitoring sites. Sites CBL 6 - CBL 8 recorded significantly lower pH than all other tidal monitoring sites, except for CBL 1a. This trend is to be expected, as pH in marine waters is usually higher than pH in freshwater and generally less varied.

#### TOTAL NITROGEN

Total nitrogen concentrations regularly complied with the ANZECC (1992) guidelines at all lake and lower estuary sites, however, concentrations recorded at CBC 2, CBC 3, CBL 1a and both wetland sites did not comply with the guidelines (Figure 3.6.2e). Elevated concentrations above the guidelines have been recorded at all monitoring sites, particularly at CBC 1 where the 80<sup>th</sup> percentile exceeded 2mg/L. Total nitrogen concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at CBL 7 than at all other sites, except all freshwater sites and CBL 8. Significantly lower concentrations were recorded at CBL 4 and CBL 5 than all other sites. Sites CBC 2, CBC 3 and CBL 1a recorded higher concentrations than lake and lower estuary monitoring sites. High total nitrogen concentrations recorded at CBL 7 and 8 are probably associated with the location of these sites within Coombabah Wetland Reserve. High nitrogen concentrations recorded at freshwater and upper estuary sites may have been influenced by land use changes, particularly recent urban development within this region of the catchment. Concentrations appear to improve toward sites within the lower estuary, which may be due to increased tidal flushing.

### **TOTAL PHOSPHORUS**

Total phosphorus concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.6.2f), except at CBL 6 - CBL 8. Elevated concentrations were recorded at all sites, except CBC 1 and CBC 2. Concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at CBL 7 and CBL 8 than all other sites. Significantly lower concentrations were recorded at CBL 4 and CBL 5 than all other sites, except at CBC 1 and CBC 2, with intermediate concentrations recorded at CBC 3 and CBL 1a - CBL 3. High total phosphorus concentrations recorded at CBL 7 and CBL 8 are likely to be associated with the location of these sites within Coombabah Wetland Reserve.

### **CHLOROPHYLL-A**

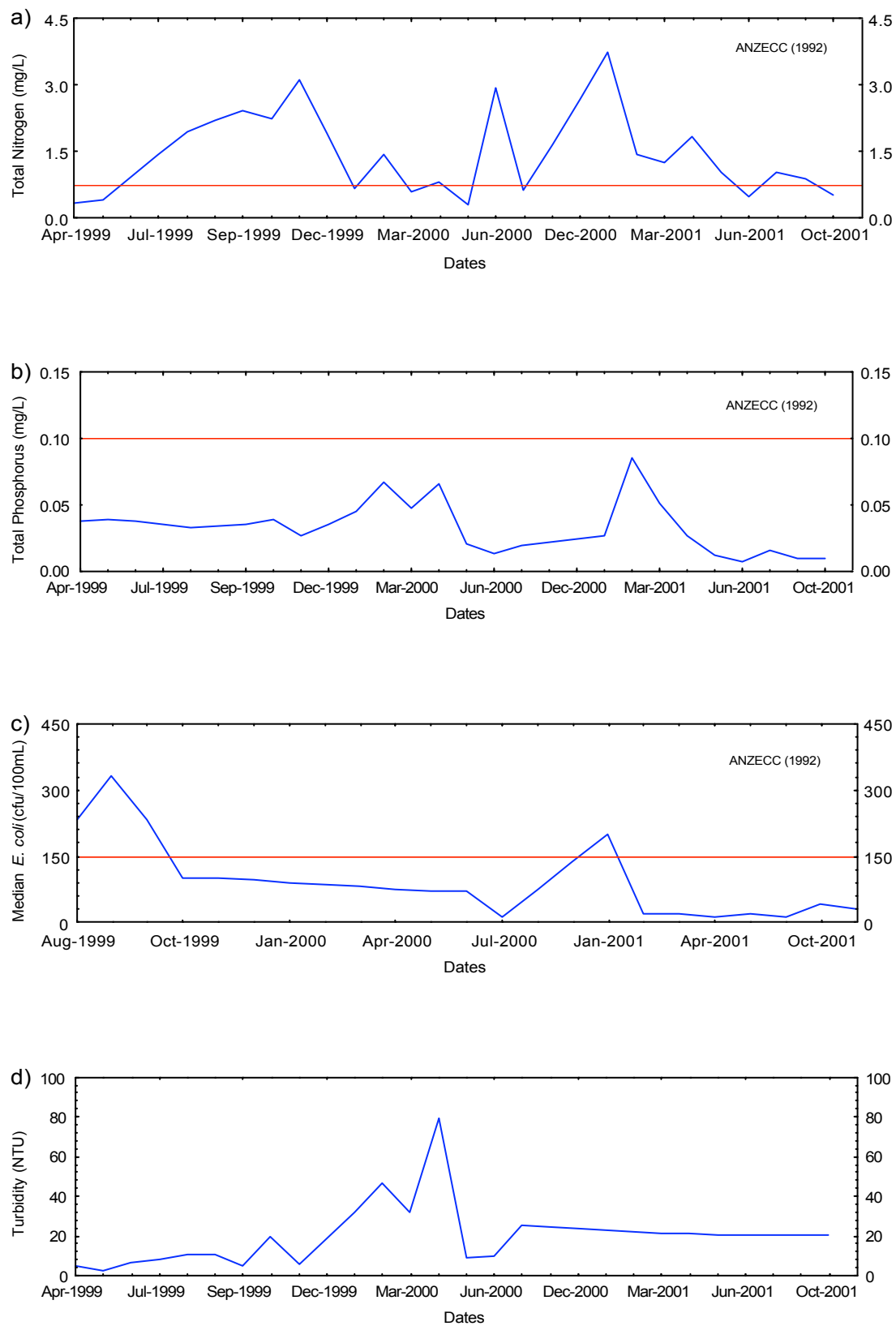
Chlorophyll-*a* concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.6.2g). Elevated concentrations have been recorded at several sites. Chlorophyll-*a* concentrations varied significantly amongst sites (KW :  $p < 0.01$ ), with significantly higher concentrations at CBL 2 than at all other sites. Significantly lower concentrations were recorded at CBC 1 and CBC 2 than all other sites. It was found that chlorophyll-*a* concentrations were generally higher between the lower freshwater and lake region of the creek. These higher concentrations are likely linked to the availability of nutrients within this region of the creek.

### **E. COLI**

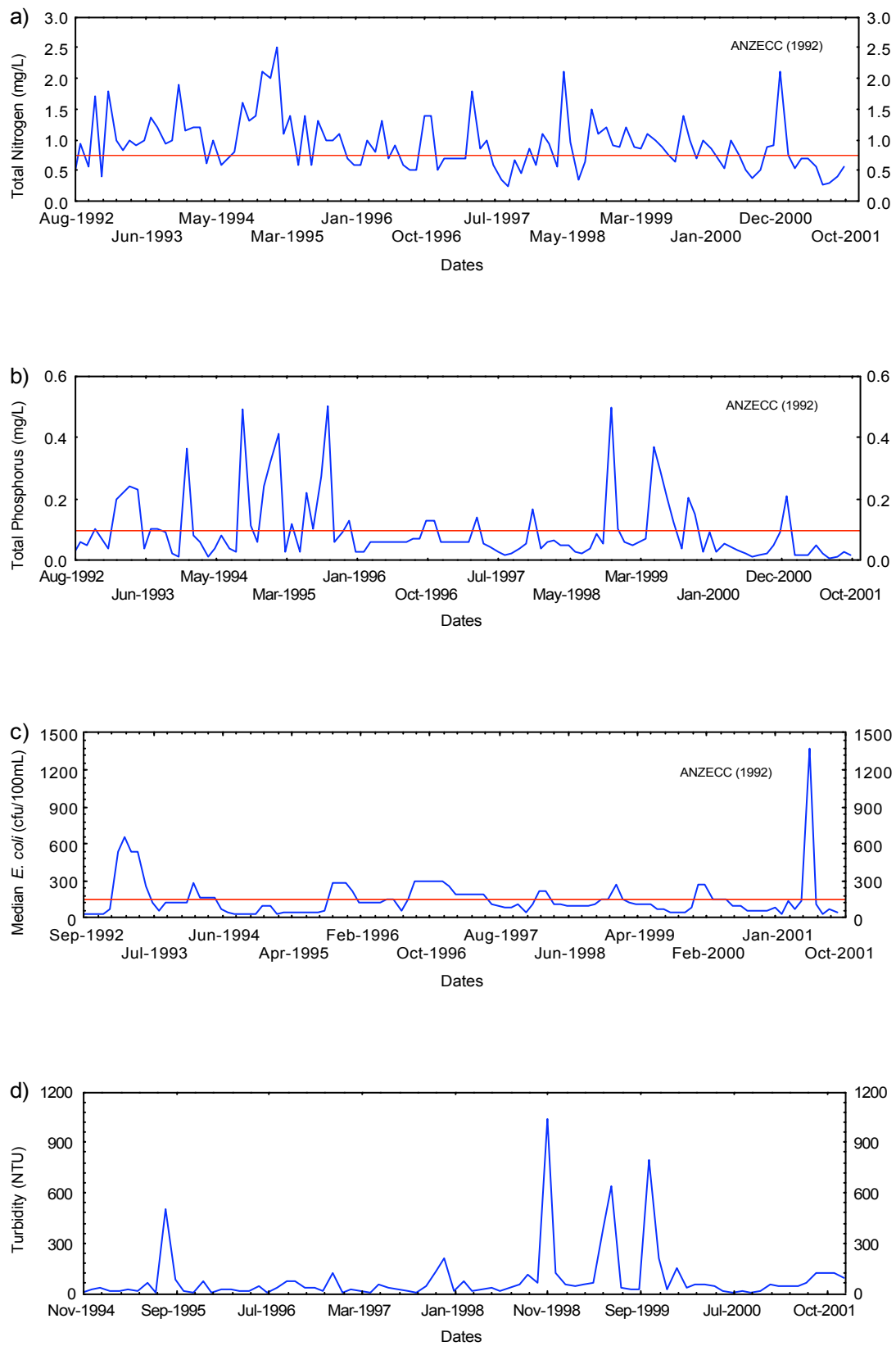
*E. coli* concentrations, calculated as a rolling median, regularly complied with the ANZECC (1992) primary contact recreational guidelines (Figure 3.6.2i). Elevated concentrations have been recorded at all sites over the monitoring period. Concentrations varied significantly amongst monitoring sites (KW :  $p < 0.001$ ), with significantly higher concentrations at CBL 7 than all other monitoring sites, except at freshwater, upper estuary sites and CBL 8. Sites CBL 4 and CBL 5 recorded significantly lower concentrations than all other sites, except CBC 3 and CBL 1a. *E. coli* concentrations were generally highest at CBL 7 and CBL 8, which is likely to be related to the presence of bird life within the wetland area. CBC 1 recorded significantly higher concentrations than other freshwater sites. The reason for this pattern is unclear, particularly as CBC 1 monitors direct runoff from the Nerang State Forest.

### **TURBIDITY**

Turbidity varied significantly amongst sites (KW :  $p < 0.001$ ), with values above 1,000ntu recorded at sites (Figure 3.6.2j). Site CBC 3 and CBL 1a recorded significantly higher turbidity than all other sites, except CBC 1 and CBC 2. Significantly lower turbidity was recorded at lower estuary sites than all other sites. Higher turbidity recorded at freshwater sites and a general improvement downstream, except for conditions at CBL 3, may support the perception of sediment deposition within Coombabah Lake.



**Figure 3.6.4** Trends in (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at CBC 1 over the monitoring period.



**Figure 3.6.5** Trends in (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at CBL 1a over the monitoring period.

### 3.6.3 WATER QUALITY TRENDS

Water quality recorded at CBC 1 and CBL 1a has been presented to assess trends over the monitoring period (Figure 3.6.4 and 3.6.5). Both sites have shown that water quality has fluctuated. Total nitrogen concentrations at both sites regularly exceeded the guidelines over the monitoring period, particularly at CBL 1a. Total phosphorus concentrations complied with the guidelines at CBC 1, whereas, CBL 1a experienced several peaks in concentrations above the guidelines. These peaks in total phosphorus concentrations were generally consistent with elevated total nitrogen concentrations at this site. *E. coli* concentrations regularly exceeded the primary contact recreational guidelines at CBL 1a, with peaks exceeding the secondary contact recreational guidelines. These peaks in concentrations were recorded during months where elevated nutrient concentrations were recorded. Turbidity recorded at CBC 1 has remained lower than conditions recorded at CBL 1a. This is probably due to limited catchment disturbance upstream of CBC 1, whereas changes in catchment and land use upstream of CBL 1a is likely to be related to higher turbidity recorded at this site. Peaks in turbidity were generally consistent with elevated nutrient and *E. coli* concentrations recorded at CBL 1a.

### 3.6.4 DISCUSSION

Water quality monitoring in Coombabah Creek has provided a quantitative assessment of waterway health and responses to changing land use over the monitoring period. Water quality conditions appear to generally comply with the relevant water quality guidelines for the protection of aquatic ecosystems.

While monitoring in the freshwater region has been limited to approximately 18 months, data analysis has shown that conditions generally decline downstream from the upper freshwater site. Turbidity and nutrient concentrations were highest at CBC 3, which is downstream from an area of the catchment that has been significantly modified in association with urban development in recent years.

The upper estuary region of the creek has been shown to experience poor water quality with conditions improving downstream toward sites in the lower estuary. Site CBL 1a has regularly recorded high nutrient, turbidity and *E. coli* concentrations over the monitoring period. Land use within this area of the creek has been extensively modified to accommodate upgrades to the Pacific Highway. This area would also be influenced by land use activities associated with urban development upstream of this site.

Water quality recorded within the wetland area adjacent to Coombabah Lake, generally experienced poor water quality in comparison with other regions of this creek. While nutrients, *E. coli* and dissolved oxygen concentrations varied markedly, it was apparent that water draining from this area does not influence water quality in Coombabah Lake and estuary.

The lake and lower estuary region of this creek has regularly recorded water quality conditions in accordance with the guidelines for the protection of aquatic ecosystems. This was particularly evident for both nutrient and *E. coli* concentrations. Turbidity was also significantly lower in comparison to upper estuary and lower freshwater sites. These good water quality conditions are probably related to increased tidal flushing with the Broadwater. However, while this may be the case, land use management, public education, erosion and sediment control and stormwater management programs should continue to focus on the entire catchment. This will reduce the reliance on tidal flushing and/or dilution of contaminants within the lower estuary, which is not sustainable in the long-term.



### **3.6.5 CONCLUSIONS AND RECOMMENDATIONS**

Water quality in Coombabah Creek show that land use changes over the past decades have impacted on the health and quality in most sections of this waterway. To examine the pressures associated with residential development, in particular, the concern of sedimentation and eutrophication of the lake and estuary area, GCCC implemented a catchment management study of Coombabah Creek catchment in 2000 (Coombabah Catchment Environmental Inventory). The study will examine the pressures of current and proposed development of the catchment in combination with biotic condition assessments (*ie* fish, plankton, plant species). This information will be important in order to establish the EVs of the creek. GCCC, in the coming years, will begin implementing the management action plan outlined in the study. This will include a specific land use stormwater management plan, which will focus on areas that require the installation of stormwater quality improvement devices. A community catchment management group for Coombabah Creek has already implemented rehabilitation works in riparian areas along the creek. The group has also begun a program to educate the local community on the values of Coombabah Creek.

### 3.7 CURRUMBIN CREEK

#### 3.7.1 INTRODUCTION

Currumbin Creek is approximately 24km in length (Figure 3.7.1). The upper catchment is located within the Mt Cougal National Park. Runoff then flows through encroaching adjacent rural and farming areas (banana plantations and dairy farming). The clearing of this vegetation, including riparian vegetation, has led to the invasion of the Camphor laurel (*Cinnamomum camphora*), a recognised environmental weed of which control is recommended (Department of Lands, 1995).

Land use within the middle region of this catchment has been modified to accommodate rural residential development. The creek flows through this region as a narrow, shallow creek with deeper pool areas separated by infrequent short riffles. This region of the creek has been found to support platypus populations (Muscat and Luxmoore, 2000).

Large areas of the lower catchment have been cleared for urban residential development. Riparian vegetation in this area of the creek has been generally lost or is under pressure from human related activities.

**Table 3.7.1** Site classification and distance details for each monitoring site.

Region/Site Type	Distance # (km)	Site
Middle Freshwater	13.12	CRC 1
Lower Freshwater	11.10	CRC 2
Upper Estuary	7.71	CRC 3
	5.45	CRC 4
Middle Estuary	3.82	CRC 5A
	3.02	CRC 9A
Lower Estuary	1.84	CRC 10
	1.45	CRC 11
	0.41	CRC 13

# Distance measured in kilometres from the mouth

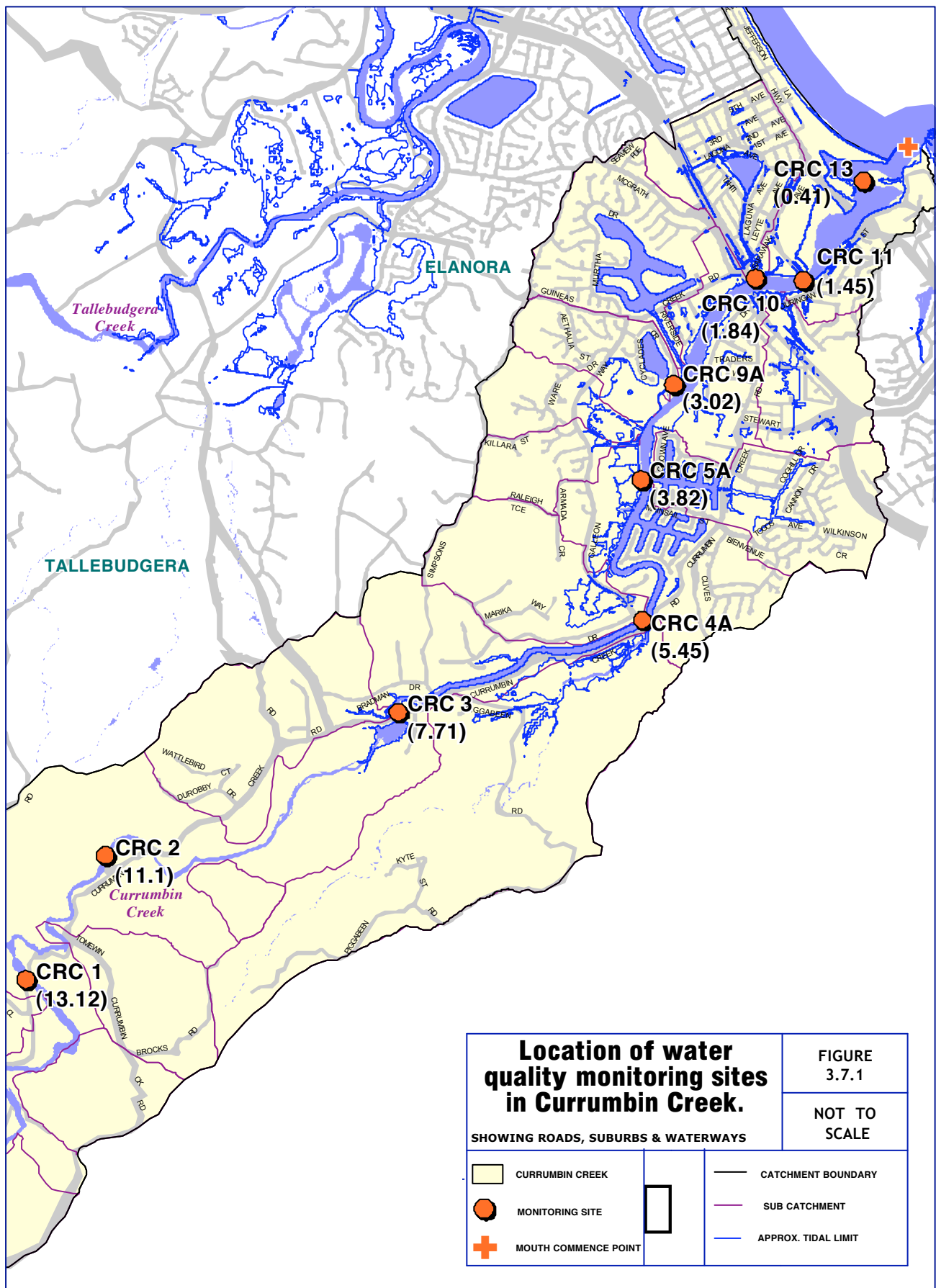
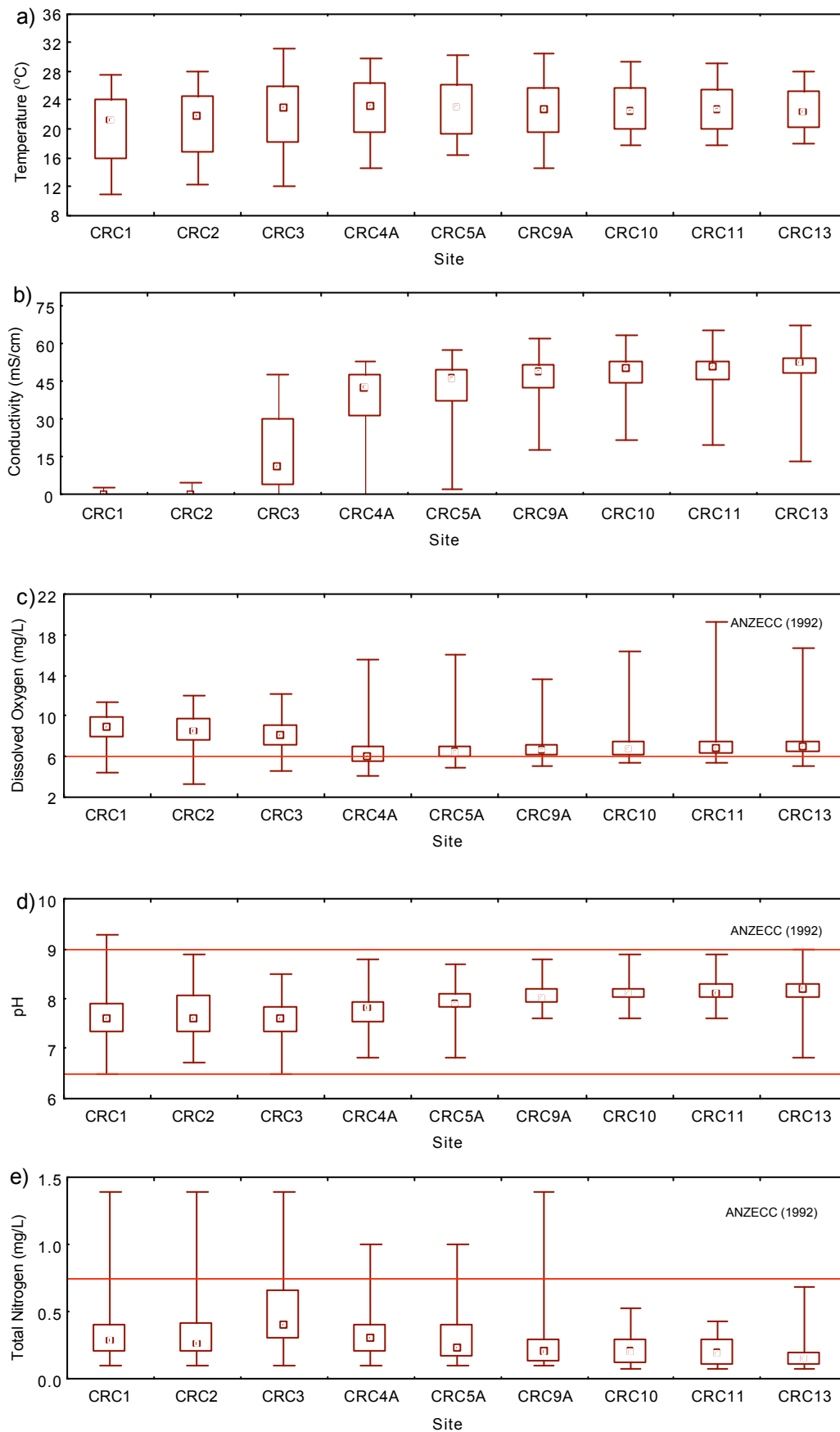
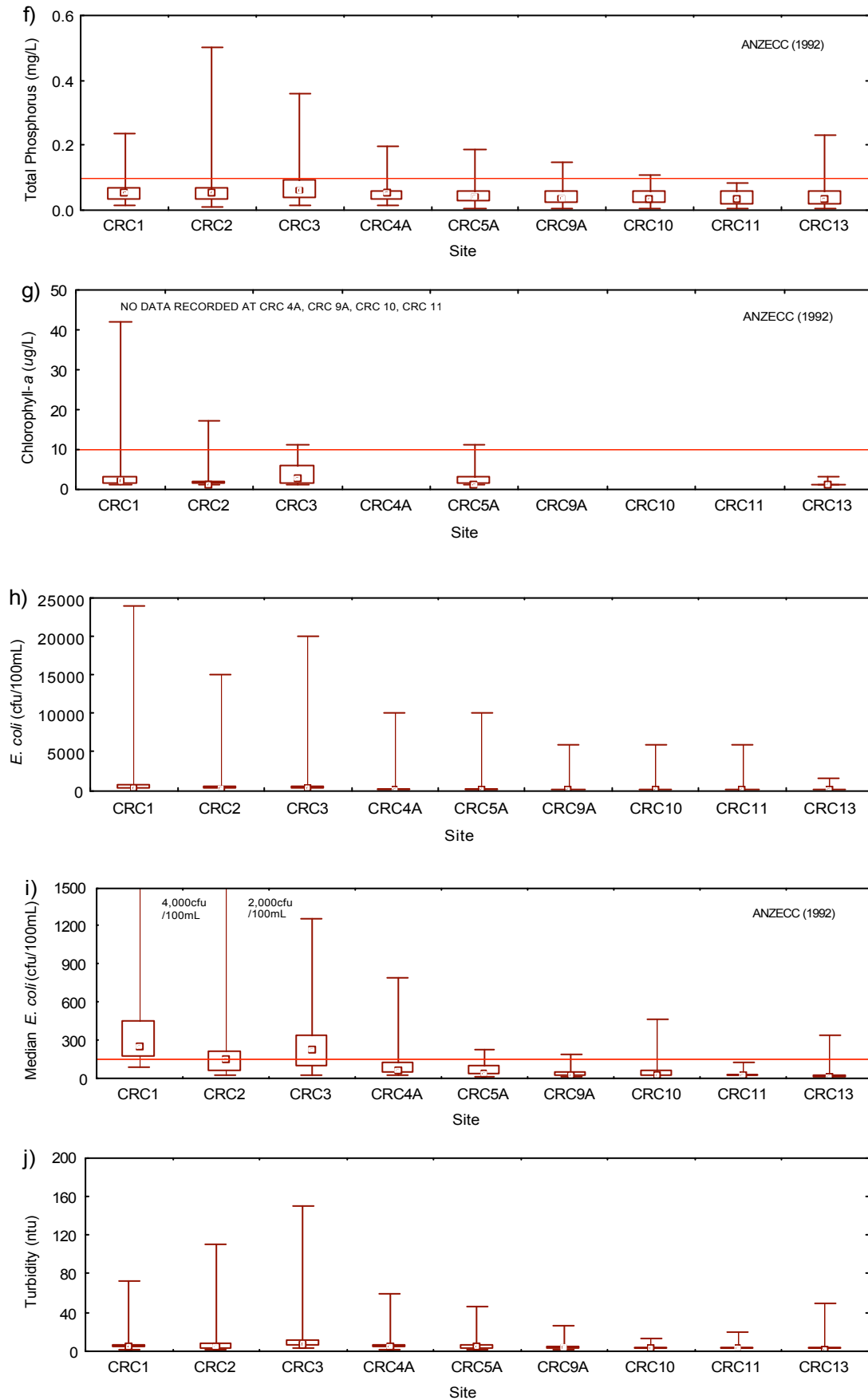


Figure 3.7.1 Water quality monitoring sites located in Currumbin Creek.



**Figure 3.7.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen, (d) pH and (e) total nitrogen concentrations recorded at sites in Currumbin Creek. ANZECC (1992) compliance guidelines for the protection of aquatic ecosystems have been included for dissolved oxygen and pH.



**Figure 3.7.2 (cont)** (f) total phosphorus, (g) chlorophyll-a, (h) raw data for *E. coli*, (i) rolling median *E. coli*, and (j) turbidity recorded at sites in Currumbin Creek. ANZECC (1992) compliance guidelines for nutrients and chlorophyll-a have been included for the protection of aquatic ecosystems. Recreational guidelines for primary contact waters have been included for median *E. coli* concentrations.

### 3.7.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Water temperature has ranged between 15°C and 31°C in Currumbin Creek (Figure 3.7.2a). This range could be influenced by seasonal conditions, water depth, flow rates, time of day when measurements were recorded or the presence and density/nature of riparian vegetation. Water temperature varied significantly amongst sites (KW :  $p < 0.001$ ), with a gradual increase in water temperatures occurring at sites along the creek towards the mouth. This could be related to changing riparian vegetation conditions along the creek. Significantly lower temperatures were recorded at CRC 1 than at all other sites and CRC 2 recorded significantly lower water temperature than CRC 4 and CRC 5a. All other sites have recorded intermediate water temperature conditions.

#### CONDUCTIVITY

Conductivity ranged between 5mS/cm and 50mS/cm within the upper estuary and between 15mS/cm and 65mS/cm within the lower estuary region over the monitoring period (Figure 3.7.2b). This range is probably due to freshwater runoff from the upper catchment area during rain periods. Conductivity varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly lower conductivity at both freshwater sites and CRC 3 than with all other monitoring sites. Site CRC 4A and both middle estuarine monitoring sites recorded significantly higher conductivity than both freshwater sites and significantly lower conditions than lower estuary sites. This gradient in conductivity along the creek is to be expected as tidal exchange with the Pacific Ocean increases towards the lower catchment.

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.7.2c). At all monitoring sites the 20<sup>th</sup> percentile complied with the guidelines, except at CRC 4A and 5A. Dissolved oxygen concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at freshwater sites and CRC 3 than all other sites. This is probably related to the physical creek characteristics at each site (*ie* stream rapids). Site CRC 4A recorded significantly lower concentrations than at CRC 11 and CRC 13. It is unclear as to the reason for these low dissolved oxygen concentrations within this area of the creek.

#### pH

pH at each site regularly complied with the ANZECC (1992) guidelines (Figure 3.7.2d). pH varied significantly between sites (KW :  $p < 0.001$ ), with significantly higher pH at CRC 13 than at all sites within this creek. All freshwater sites recorded significantly lower pH than all middle estuary sites and CRC 10 and CRC 11, with intermediate values recorded at upper estuary sites. This trend is to be expected, as pH in marine waters is usually higher than pH in freshwater and is generally less varied. This however was not true at CRC 13, where pH was generally more varied in comparison to similar lower estuarine monitoring sites for other waterways. It is unclear as to the cause of this trend.

#### TOTAL NITROGEN

Total nitrogen concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.7.2e). All sites recorded elevated concentrations above the guidelines, except all lower estuary sites. Concentrations vary significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at CRC 3 in comparison with other sites. Both freshwater sites and CRC 4a recorded significantly higher concentrations than at CRC 9a - CRC 13. Significantly higher concentrations were recorded at CRC 9a than at CRC 13. High total nitrogen concentrations recorded at CRC 3 and a general improvement downstream may be related to increased tidal flushing of the lower estuary with the Pacific Ocean.

### **TOTAL PHOSPHORUS**

Total phosphorus concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.7.2f). Elevated concentrations above the guidelines have been recorded at all sites. Total phosphorus varied significantly amongst sites (KW :  $p < 0.001$ ). Similar to total nitrogen, significantly higher concentrations at CRC 3 were recorded than all other sites (excluding both freshwater sites and CRC 4A). All freshwater and upper estuary sites recorded significantly higher concentrations than all lower estuary sites. Similar to total nitrogen concentrations, high total phosphorus concentrations recorded at CRC 3 and a general improvement downstream may be related to increased tidal flushing of the lower estuary with the Pacific Ocean.

### **CHLOROPHYLL-A**

Chlorophyll-*a* at sites where concentrations are recorded, regularly complied with the ANZECC (1992) guidelines (Figure 3.7.2g). Elevated concentrations above the guidelines have been recorded at all sites. Chlorophyll-*a* concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations recorded at CRC 3 than at other sites. These higher concentrations may be related the availability of nutrients at this site.

### ***E. COLI***

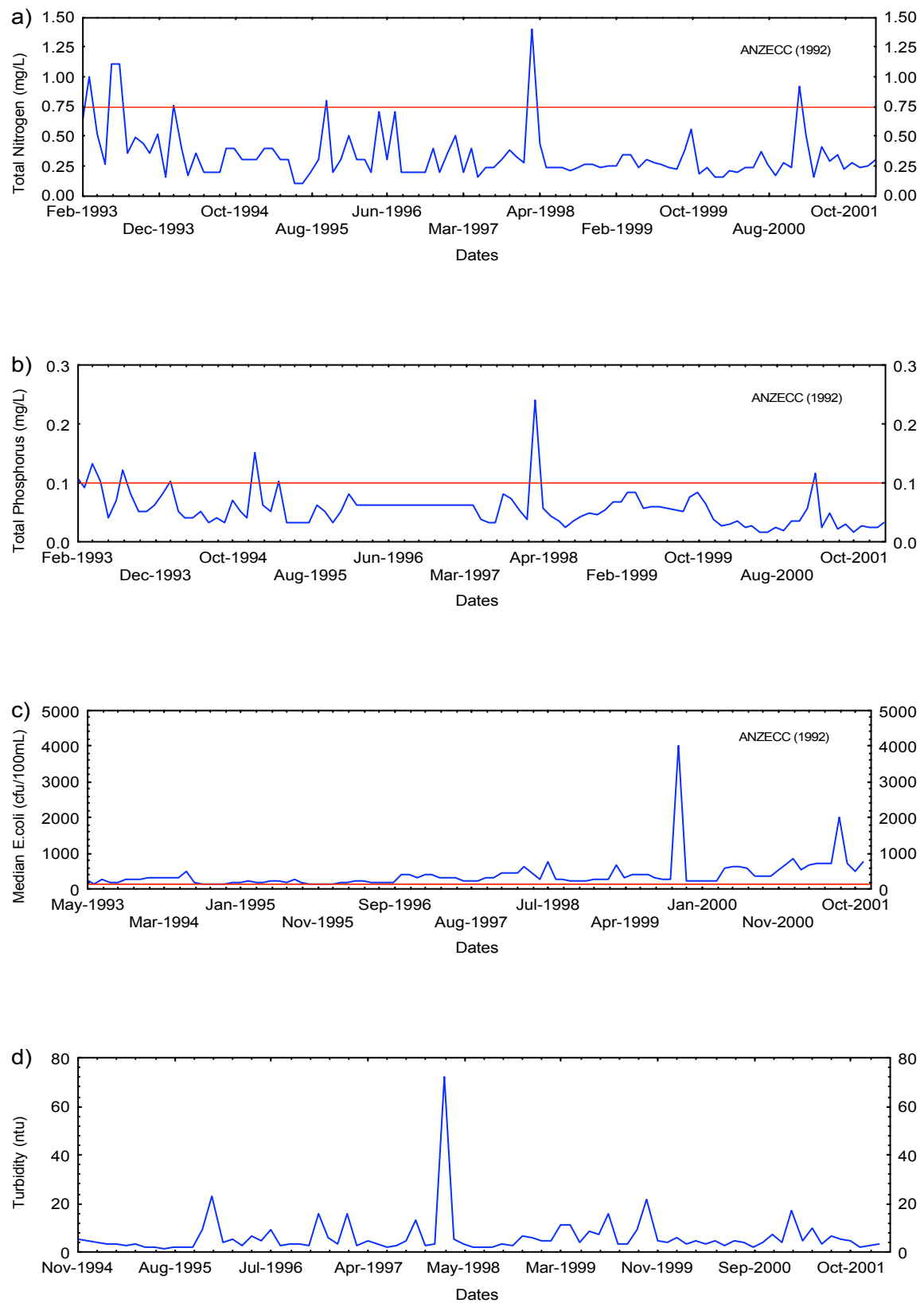
*E. coli* concentrations, calculated as a rolling median, regularly complied with the ANZECC (1992) guidelines for primary contact recreational waters, excluding CRC 1 and CRC 3 (Figure 3.7.2i). Concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at CRC 1 than at all other sites, excluding CRC 2. All lower estuarine sites had significantly lower *E. coli* concentrations than at all other sites. Sites CRC 9A and CRC 10 recorded significantly higher concentrations than at CRC 13. Similar to both nutrient concentrations, high *E. coli* concentrations recorded at CRC 3 and a general improvement downstream may be related to increased tidal flushing of the lower estuary with the Pacific Ocean.

### **TURBIDITY**

Turbidity generally remained below 20ntu at all monitoring sites (Figure 3.7.2j). Turbidity varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher turbidity at CRC 3 than all other sites. Significantly lower turbidity was recorded at lower estuary sites than all freshwater and upper estuary sites. Sites CRC 10 and CRC 11 recorded significantly lower turbidity than at CRC 13.

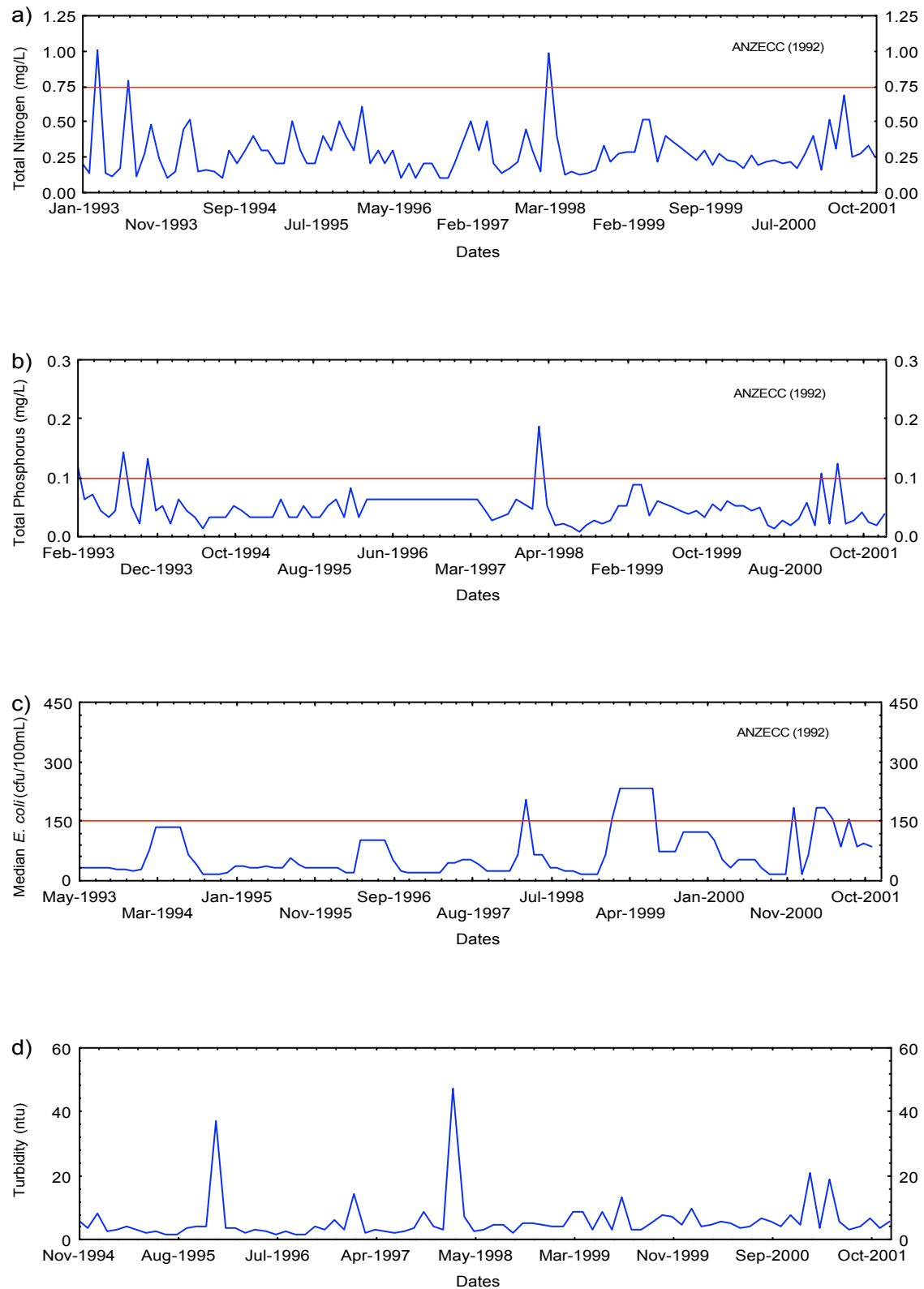
### **3.7.3 WATER QUALITY TRENDS**

Water quality recorded at CRC 1 and CRC 5a has been presented to assess trends over the monitoring period (Figure 3.7.3 and 3.7.4). Nutrient concentrations appear to have fluctuated over the monitoring period at each site. A peak in nutrient concentrations was recorded during March 1998 at both sites, which may be related to a rain event. This was consistent with peaks in *E. coli* concentrations and turbidity during this time. *E. coli* concentrations recorded at CRC 5a has generally complied with the primary contact recreational guidelines and have not increased over time. *E. coli* concentrations recorded at CRC 1, however, has increased over time, particularly following September 1996 where the rolling median has continually exceeded the primary contact recreational guidelines. Turbidity has also fluctuated at both sites with higher recordings probably associated with rain events. Turbidity has not increased (more turbid) over the monitoring period at both sites assessed in this waterway.



**Figure 3.7.3** Water quality trends for (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at CRC 1 over the monitoring period.





**Figure 3.7.4** Water quality trends for (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at CRC 5A over the monitoring period.

### 3.7.4 DISCUSSION

The assessment of water quality data in Currumbin Creek has shown that conditions have regularly complied with the ANZECC (1992) guidelines for the protection of aquatic ecosystems and for primary contact recreational waters. Sites CRC 1 and CRC 3 were the only sites that did not comply with the primary contact recreational guidelines and for CRC 1 has continually exceeded these guidelines following September 1996.

The freshwater region of this creek was found to have higher nutrient, turbidity and *E. coli* concentrations in comparison with lower estuary monitoring sites. Land use activities and changes to the catchment area within the upper catchment may have contributed to these trends, although importantly, water quality has generally not declined over time.

Modification to the lower creek to support urban development and industrial activities has occurred in the past, however, water quality, particularly within the lower estuary region, regularly complies with the ANZECC (1992) guidelines. Both nutrients (excluding several elevated total phosphorus recordings) and the rolling median calculation for *E. coli* have not exceeded the guidelines over the monitoring period. Increased tidal exchange with the Pacific Ocean could explain this trend within the lower estuary.

### 3.7.5 CONCLUSIONS AND RECOMMENDATIONS

Currumbin Creek has generally recorded good water quality conditions, with nutrient and chlorophyll-*a* concentrations within the standards for the protection of aquatic ecosystems. The growth of residential areas in this catchment over the past decades and subsequent change in land use, may however potentially reduce water quality conditions in the future. In order to ensure that the current good health and quality of Currumbin Creek is maintained in the future, GCCC plan to undertake a catchment management investigation in the coming years. This study will assist with understanding the dynamics and status of this creek, identify the EVS considered important by local community stakeholders and also assist with the design of a land use specific stormwater management plan to protect the values of the creek. A community catchment management group in Currumbin Creek does not currently exist, however, the establishment of a group is planned in the coming years.

### 3.8 HOTHAM CREEK

#### 3.8.1 INTRODUCTION

Hotham Creek is a small, approximately 15km in length, tributary of the Pimpama River. The headwaters are situated along the eastern edge of the Darlington Ranges where it channels through rural residential areas near Willowvale, under the Pacific Highway and onto the floodplain near Pimpama. Hotham Creek then meanders its way through the floodplain, which is farmed for sugar cane, before joining with the Pimpama River, which flows a further 7km (Preda and Cox, 1999) before discharging into Southern Moreton Bay.

Large areas of the upper catchment have been cleared for various farming practices including dairy and beef cattle, banana and various other crops. Large riparian areas have been cleared for access to the creek to harvest water for irrigation and livestock. This clearing has allowed for the establishment of various environmental weeds including Camphor laurel (*Cinnamomum camphora*).

The floodplain region of Hotham Creek has been identified as having pH problems associated with the disturbance of acid sulfate soils (Preda and Cox, 1999). A disturbance of the soils within the lower catchment has the potential to rapidly change the physio-chemistry of the aquatic environment. This can lead to fish kills, disease and other disturbances in the aquatic community (Sammut *et al*, 1993).

**Table 3.8.1** Site classifications and distance details for each monitoring site.

Region/Site Type	Distance # (km)	Site
Upper Freshwater	14.67	HTC 1
	10.06	HTC 2
	6.23	HTC 3
Lower Freshwater	3.92	HTC 4 ( <i>Discontinued</i> )
	1.35	HTC 5 ( <i>Discontinued</i> )

# Measured as distance in kilometres from the confluence with Pimpama River

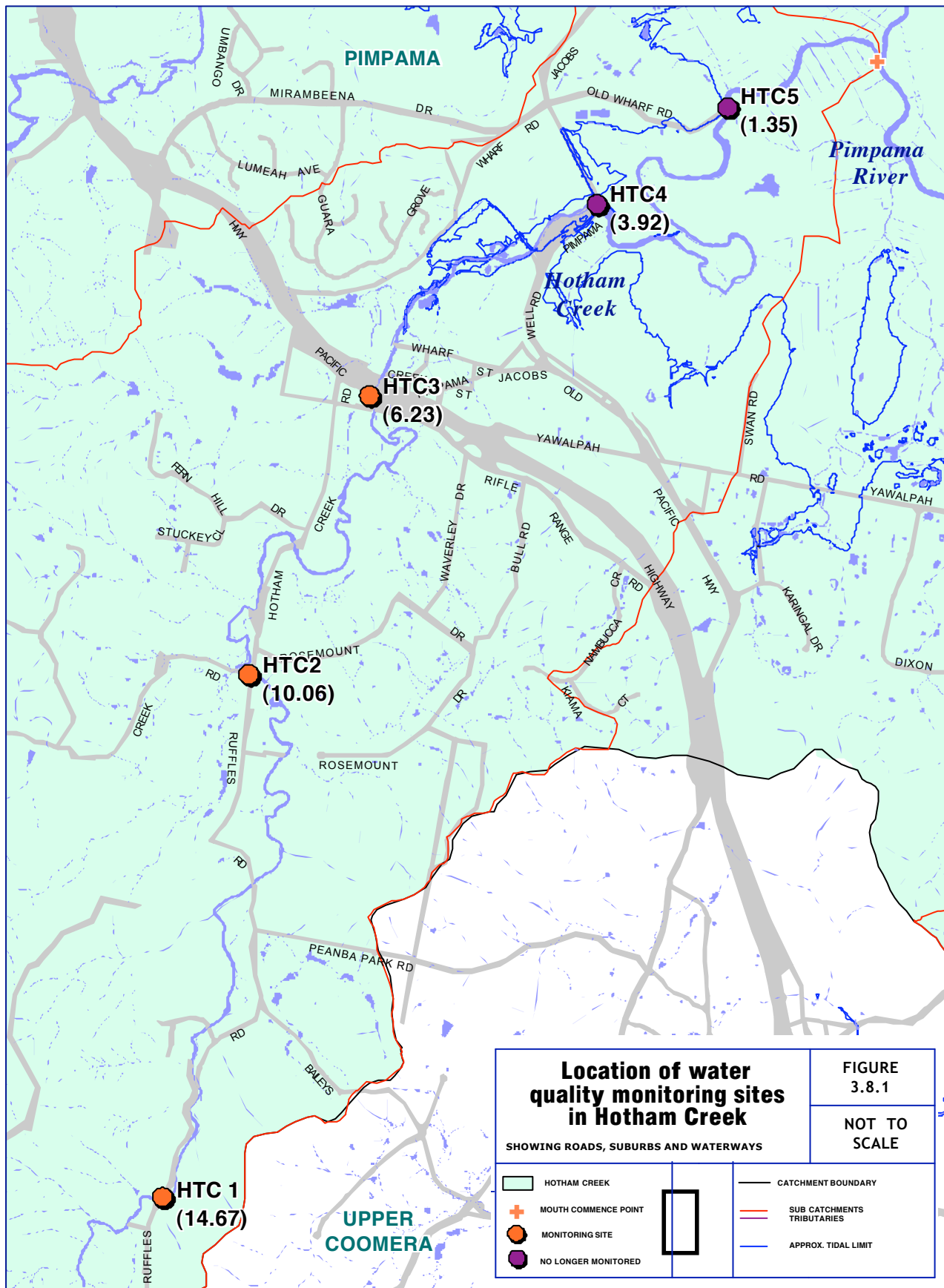
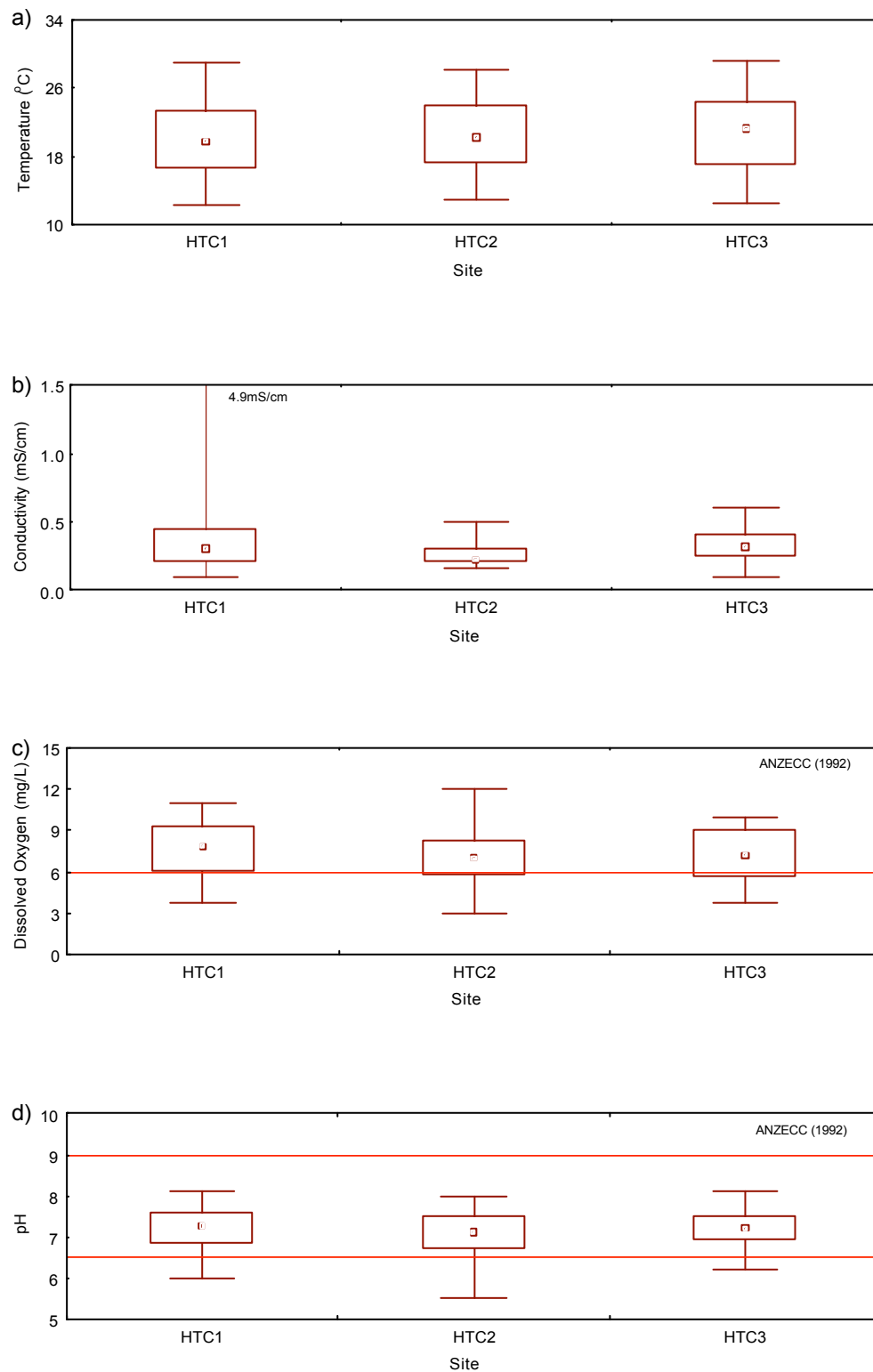
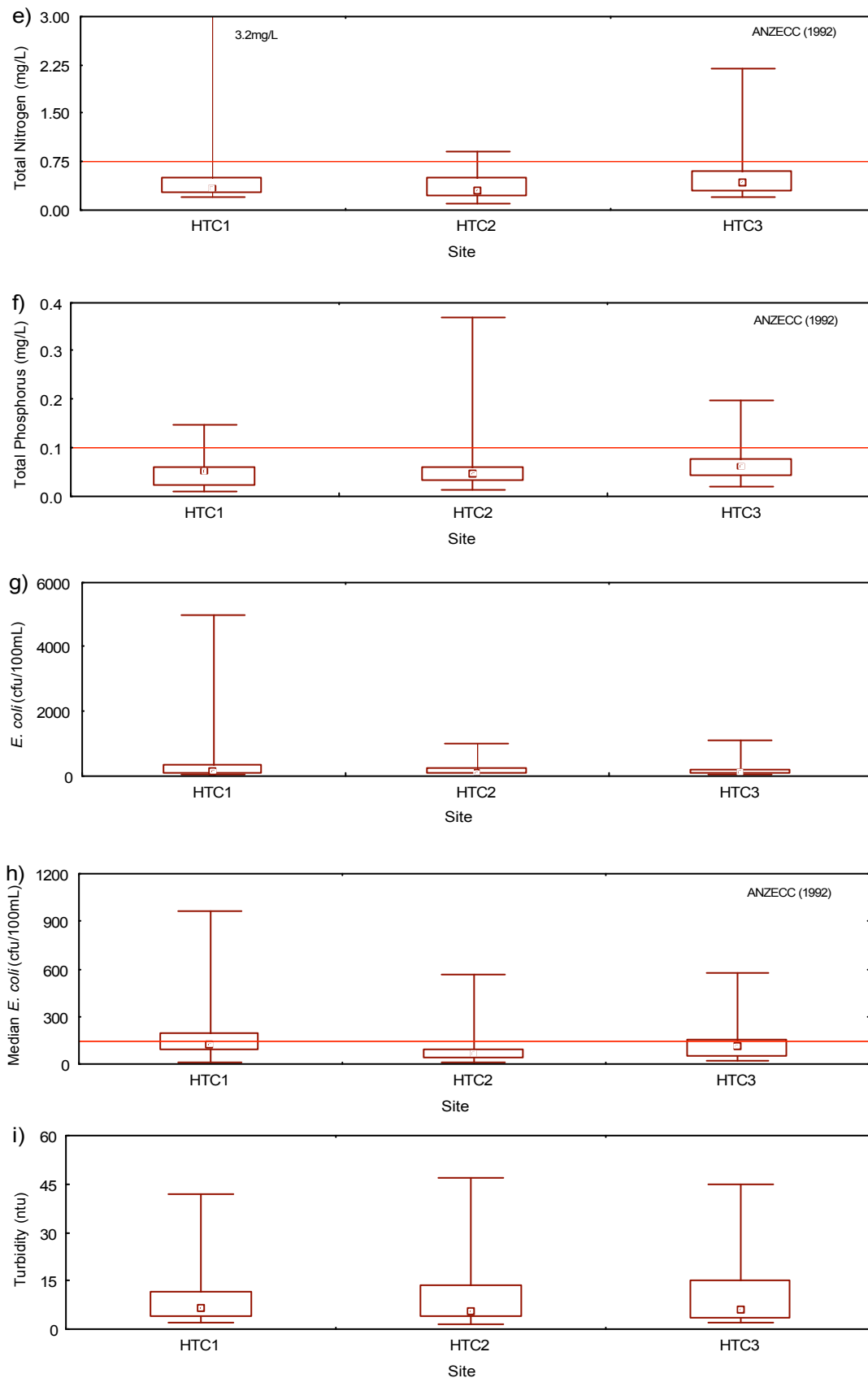


Figure 3.8.1 Water quality monitoring sites located in Hotham Creek.



**Figure 3.8.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen and (d) pH recorded at each site within Hotham Creek. ANZECC (1992) compliance guidelines for the protection of aquatic ecosystems have been included for dissolved oxygen and pH.



**Figure 3.8.2 (cont)** (e) total nitrogen, (f) total phosphorus, (g) raw data for *E. coli* concentrations, (h) rolling median *E. coli* and (i) turbidity recorded at sites within Hotham Creek. ANZECC (1992) compliance guidelines for both nutrients have been included for the protection of aquatic ecosystems. Recreational guidelines for primary contact waters have been included for comparison with median *E. coli* concentrations.

### 3.8.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Water temperature has ranged between 12°C and 30°C in Hotham Creek (Figure 3.8.2a). This range in water temperature could be influenced by seasonal conditions, depth, flow rates, time of day when measurements were recorded or the presence and density/nature of riparian vegetation. Water temperatures did not vary significantly amongst sites (KW :  $p = 0.54$ ).

#### CONDUCTIVITY

Conductivity has ranged between 0.1mS/cm and 0.6mS/cm in Hotham Creek (Figure 3.8.2b). Conductivity varied significantly amongst sites (KW :  $p < 0.05$ ), with significantly lower conductivity recorded at HTC 1 than HTC 3.

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.8.2c). Reductions in concentrations below 4mg/L have been recorded at each site. Dissolved oxygen concentrations did not vary significantly amongst sites (KW :  $p = 0.18$ ).

#### pH

pH regularly complied with the ANZECC (1992) guidelines (Figure 3.8.2d). pH conditions below the lower limit have been recorded at all sites. pH did not vary significantly amongst sites (KW :  $p = 0.33$ ).

#### TOTAL NITROGEN

Total nitrogen concentrations regularly complied with the ANZECC (1992) guidelines, with the 80<sup>th</sup> percentile complying with the guidelines at all sites (Figure 3.8.2e). Elevated concentrations have been recorded at all sites, with HTC 3 recording concentrations up to 3.2mg/L. Total nitrogen concentrations varied significantly amongst sites (KW :  $p < 0.01$ ) with significantly higher concentrations recorded at HTC 3 than at HTC 2.

#### TOTAL PHOSPHORUS

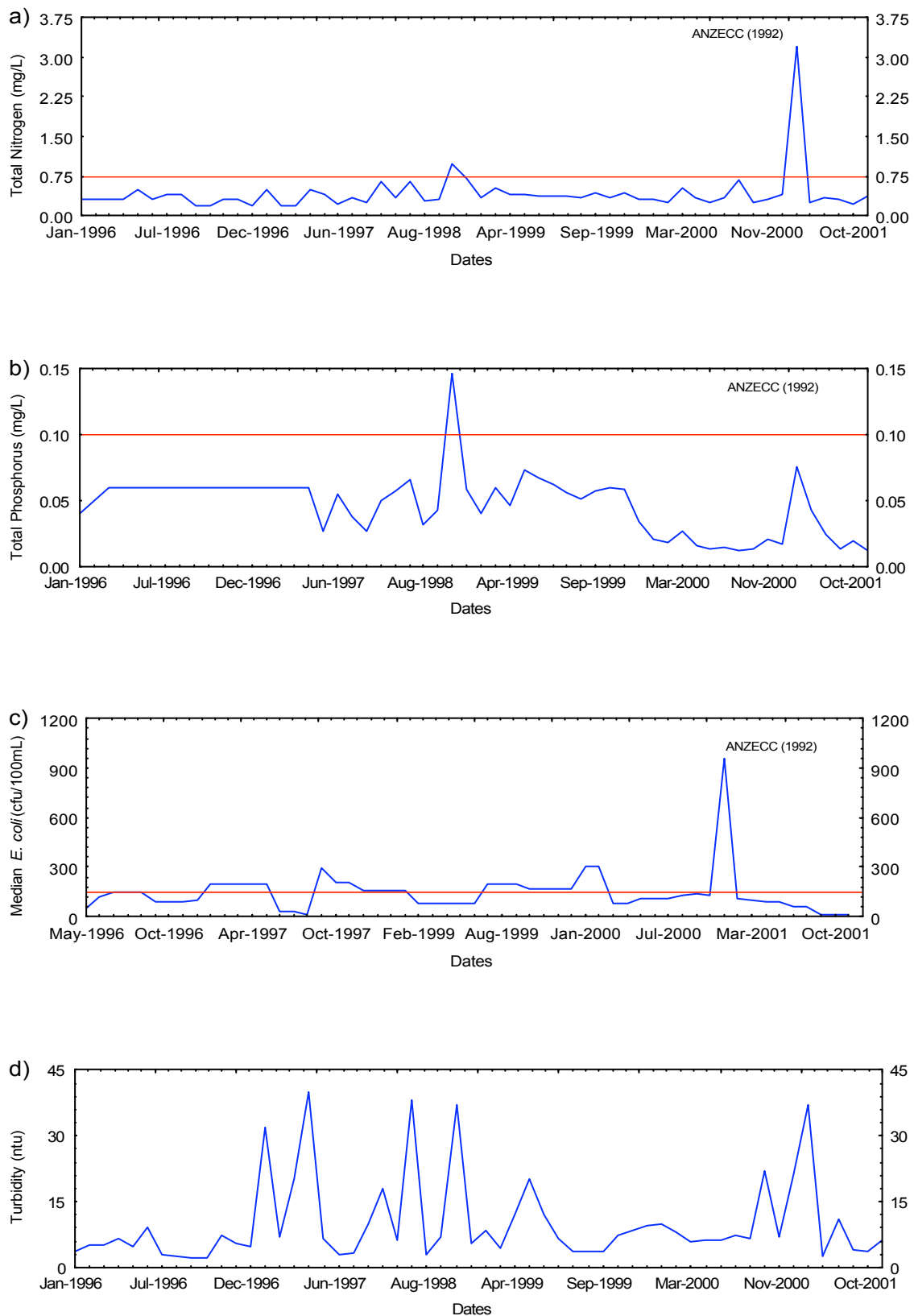
Total phosphorus concentrations regularly complied with the ANZECC (1992) guidelines, with the 80<sup>th</sup> percentile complying with the guidelines at all sites (Figure 3.8.2f). Elevated concentrations have been recorded at all sites within this creek. Total phosphorus varied significantly amongst sites (KW :  $p < 0.01$ ), with significantly higher concentrations recorded at HTC 3 than at the two other sites.

#### E. COLI

*E. coli* concentrations, calculated as a rolling median, regularly complied with the ANZECC (1992) guidelines for primary contact recreational waters (Figure 3.8.2h). Concentrations exceeding the primary contact recreational guidelines have been recorded at each site. *E. coli* concentrations varied significantly amongst sites (KW :  $p < 0.05$ ), with significantly lower *E. coli* concentrations recorded at HTC 2 than at HTC 1 and HTC 3.

#### TURBIDITY

Turbidity has ranged between 2ntu and 45ntu in Hotham Creek (Figure 3.8.2i). These relatively low conditions, in comparison to other freshwater sites within the City, is likely to be associated with land use practices within the upper Hotham Creek catchment (particularly limited development). Turbidity did not vary significantly amongst sites (KW :  $p = 0.86$ ).



**Figure 3.8.3** Trends in (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at HTC 1 to assess changes in water quality over the monitoring period.



### 3.8.3 WATER QUALITY TRENDS

Trends in water quality at HTC 1 (Figure 3.8.3) have fluctuated over the monitoring period. These fluctuations are probably related to rain events and are particularly evident in October 1998 for both nutrient parameters. Total nitrogen concentrations do not appear to have increased or decreased over the monitoring period. Total phosphorus has shown a downward trend in concentrations since November 1999.

*E. coli* concentrations have, during several periods, exceeded the primary contact recreational guidelines. This is particularly evident between June 1999 and May 2000. Concentrations have complied with the guidelines since this period. Turbidity has also fluctuated over the monitoring period, however, has generally remained below 20ntu. Peaks in turbidity are likely to be related to rain events.

### 3.8.4 DISCUSSION

The assessment of water quality in Hotham Creek has shown that water quality generally complies with the ANZECC (1992) guidelines. Elevations for several water quality variables, namely nutrients, turbidity and *E. coli* concentrations have been recorded in Hotham Creek. This is particularly evident during summer months and is likely associated with increases in rainfall. Changes in land use for this catchment in the future associated with farming activities and/or rural development, has the potential to deteriorate water quality if appropriate land use management are not managed correctly in this catchment.

Water quality monitoring in Hotham Creek downstream of the Pacific Highway was discontinued in 1996 (Table 3.8.1). The recommencement of monitoring in lower Hotham Creek should be reviewed, as it would provide information on the health and quality of the entire Hotham Creek and would assist in determining any influence Hotham Creek may have on Pimpama River. Further, any proposed future residential development in the lower Hotham Creek could also be monitored to ensure the health of Hotham Creek is not impacted.

### 3.8.5 CONCLUSIONS AND RECOMMENDATIONS

Water quality conditions in Hotham Creek have generally complied with guidelines suitable for the protection of aquatic ecosystems. However, impacts on water quality may exist within this catchment, particularly with proposed future residential development within both Hotham Creek and Pimpama River catchments. The management of catchment runoff through best land use management practices, in conjunction with the management of water harvesting and environmental flows, is considered necessary in the short term for Hotham Creek. This will ensure that water quality conditions and EVs of the creek are maintained. CMU plans to implement a catchment management study in this catchment, as part of a Pimpama River catchment study in the coming years. This study will identify the EVs important to the local community. This information will then be used to develop a land use specific stormwater management plan to protect the values of Hotham Creek. A community Landcare group in Hotham Creek plan to implement rehabilitation projects in riparian areas along the creek in the coming years. The group has also implemented various educational programs/workshops for local farmers on the various best land use management practices available.

### 3.9 LAKES - NORTHERN

#### 3.9.1 INTRODUCTION

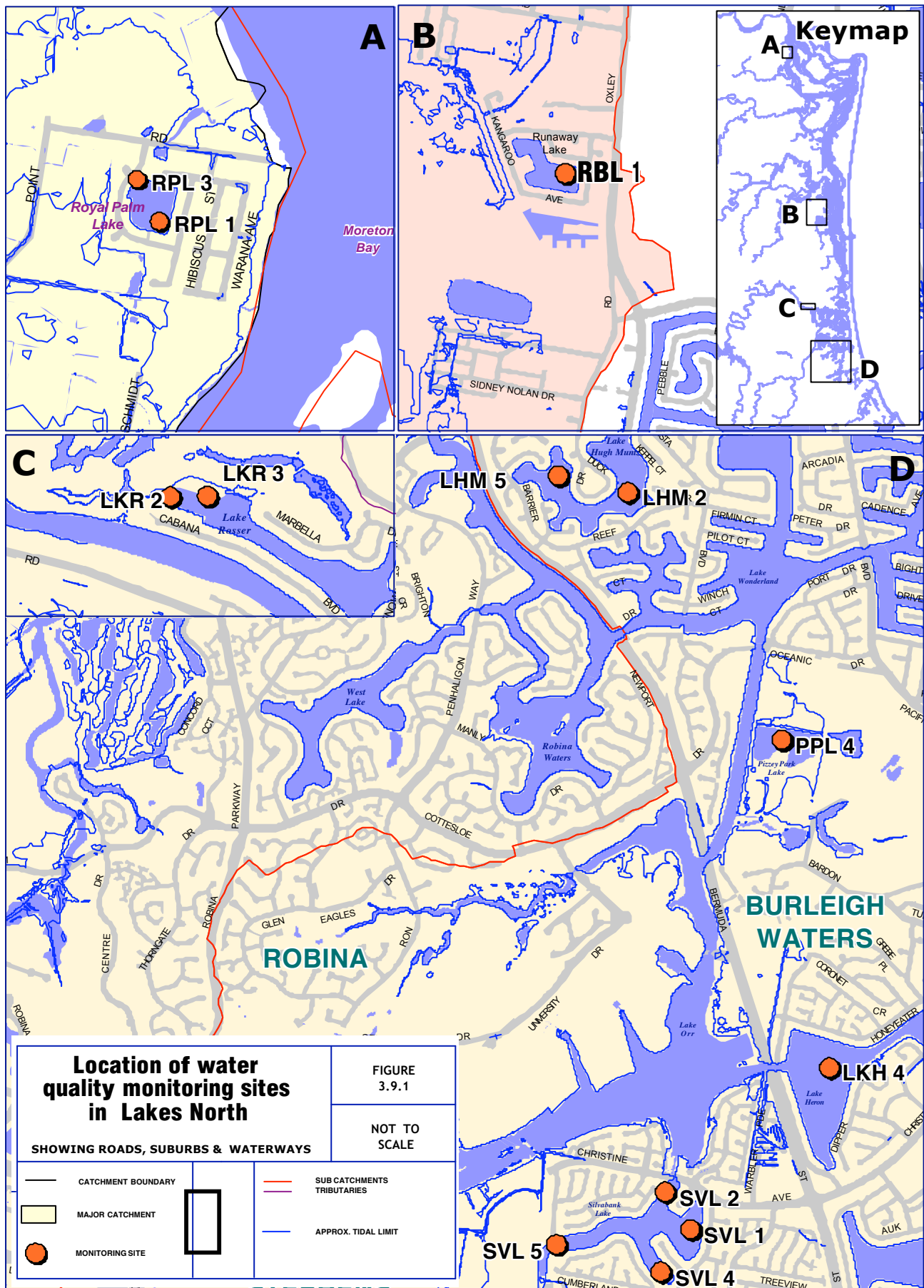
The northern lakes survey incorporates seven constructed waterways (Table 3.9.1). These include Royal Palm Lake, Runaway Bay Lake, Pizzey Park Lake, Silvabank Lake and Heron Lake that are tidal, Lake Hugh Muntz as a freshwater lake and Lake Rosser as a lake that receives tidal waters during spring high tides (Figure 3.9.1). These lakes provide an opportunity for a variety of recreational activities (swimming, sail boating, fishing), aesthetic amenity for the local community and lake front residents, a habitat for many wildlife (fish, birds, plants etc.) and assist with flood storage during significant rain events.

Stormwater runoff is potentially the most significant contributing factor to water quality problems to each lake, particularly given reduced tidal exchange with a primary waterway (eg Nerang River) or the Pacific Ocean. Urban stormwater following rain events is widely recognised for its potential in conveying nutrients, sediments and various other contaminants from a catchment into an adjacent waterway. If not managed, stormwater has the potential to reduce the health and subsequently the ability for these lakes to provide a habitat for those wildlife communities that inhabit each lake and also reduce the recreational opportunities for local residents.

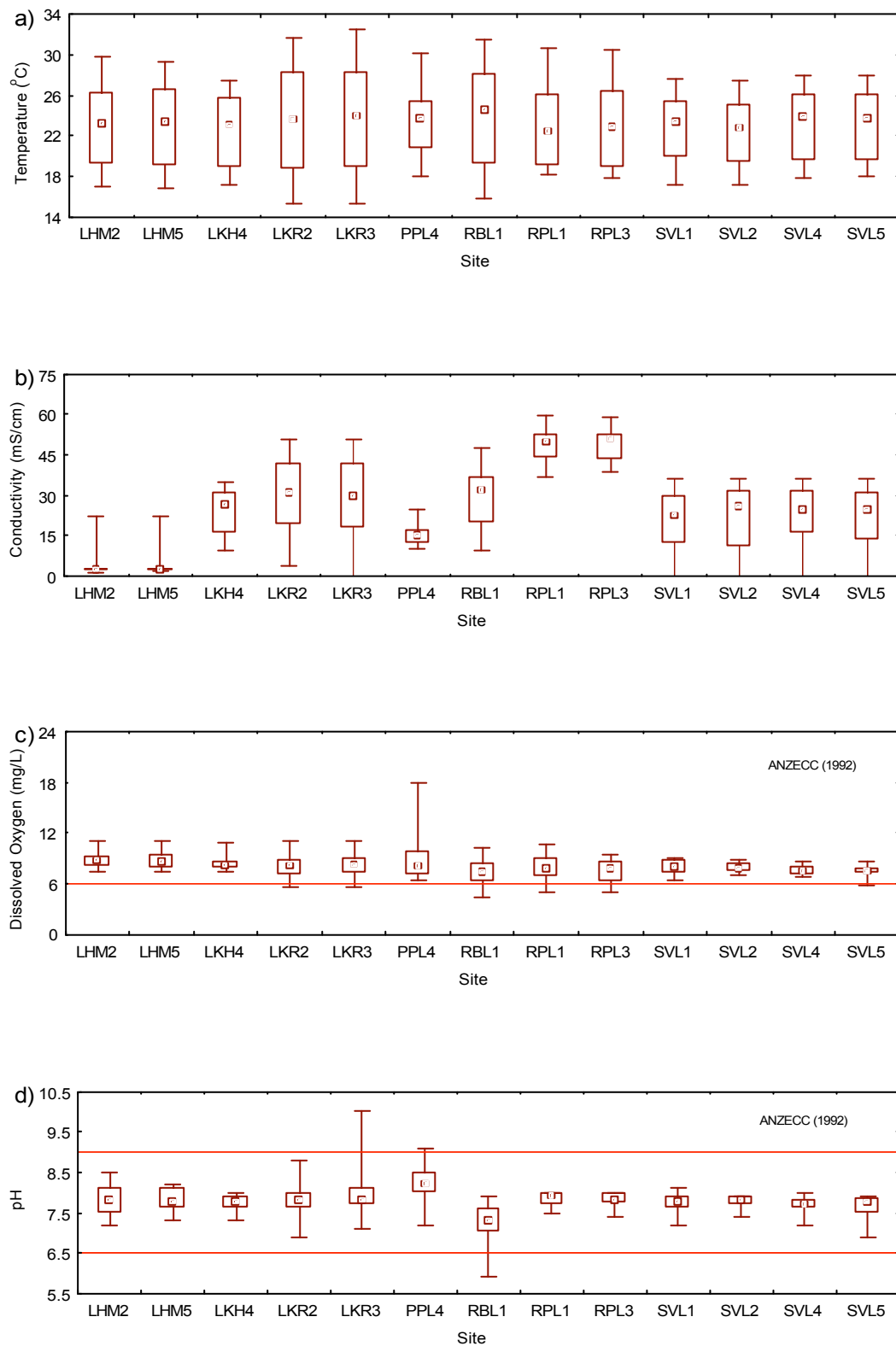
The information presented within this section is based on surface water quality measurements recorded at each site. Profiling of water quality conditions for temperature, conductivity, dissolved oxygen and pH is undertaken in each lake, however, has not been presented within this report. Those lakes that have been included within this section are shown in the table below.

**Table 3.9.1** Water quality monitoring sites and codes as a part of the Northern Lakes survey.

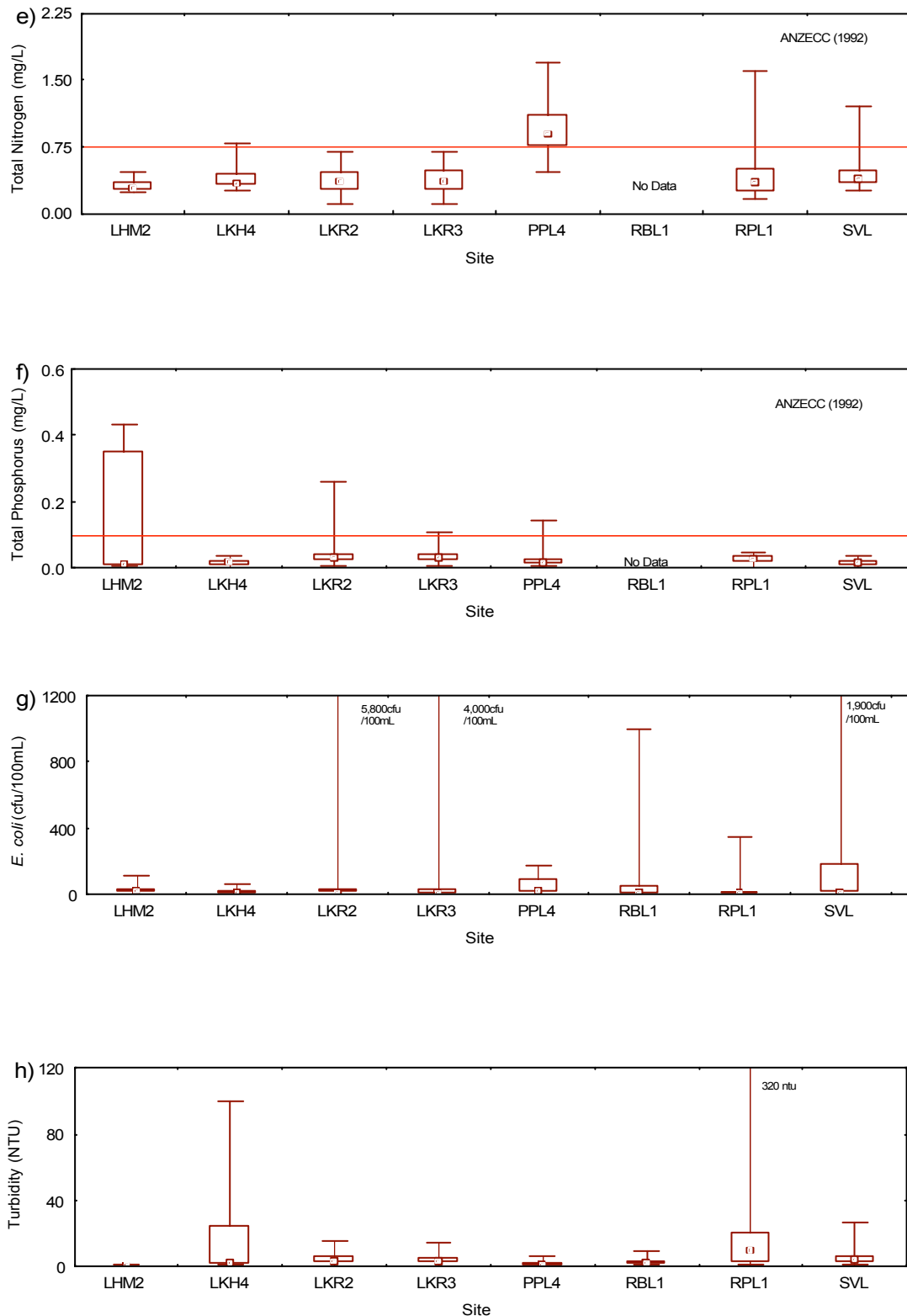
Lake	Site (Code)
Royal Palm Lake	RPL
Runaway Bay Lake	RBL
Lake Rosser	LKR
Lake Hugh Muntz	LHM
Pizzey Park Lake	PPL
Silvabank Lake	SVL
Heron Lake	LKH



**Figure 3.9.1** Water quality monitoring sites located in each lake as part of the Northern Lakes survey.



**Figure 3.9.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen and (d) pH recorded at sites in each lake. ANZECC (1992) compliance guidelines for the protection of aquatic ecosystems have been included for dissolved oxygen and pH.



**Figure 3.9.2 (cont)** (e) total nitrogen, (f) total phosphorus, (g) raw data for *E. coli* concentrations and (h) turbidity recorded at sites in each lake. ANZECC (1992) guidelines have been included for comparison with both nutrients.

### 3.9.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Water temperature has ranged between 15°C and 34°C across lake sites monitored in this survey (Figure 3.9.2a). This range in water temperature could be influenced by seasonal conditions, time of day when measurements were recorded or flow rates experienced in each lake.

#### CONDUCTIVITY

Conductivity varied markedly amongst lakes, with Royal Palm Lake (RPL 1, RPL 3) generally experiencing higher conductivity than other lakes. This is probably associated with its closer proximity to a tidal waterway (Figure 3.9.2b). Runaway Lake (RBL 1), Lake Rosser (LKR2, LKR 3), Pizzey Park Lake (PPL4), Lake Heron (LKH 4) and Silvabank Lake (SVL1, SVL 2, SLV 4 and SVL 5) generally recorded intermediate conductivity between marine and freshwater, which reflects their distance from tidal waters and the influence of stormwater runoff. Lake Hugh Muntz (LHM 2 and LHM 5) is maintained as a freshwater system, which is reflected with its low conductivity.

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations regularly complied with the ANZECC (1992) guidelines, with the 20<sup>th</sup> percentile at all sites above the guidelines (Figure 3.9.2c). Episodic reductions in dissolved oxygen below the guidelines have been recorded in several lakes. However, this is generally not considered to be of concern for the survival of aquatic wildlife.

#### pH

pH regularly complied with the ANZECC (1992) guidelines at all sites (Figure 3.9.2d). On several occasions pH decreased below the guidelines in Runaway Lake (RBL 1), while several recordings exceeded the upper guidelines limit in Lake Rosser (LKR 3). It is unclear as to the cause of these pH recordings below/above the guidelines. All other sites have generally had more stable pH.

#### TOTAL NITROGEN

Total nitrogen regularly complied with the ANZECC (1992) guidelines, except in Pizzey Park Lake (PPL 4) where the 20th percentile has exceeded the guidelines (Figure 3.9.2e). Total nitrogen concentrations in Lake Rosser (LKR 2 and LKR 3) and Lake Hugh Muntz (LHM 2) have consistently complied with the guidelines. These low total nitrogen concentrations would indicate a limited potential for aquatic plant growth and algal blooms.

#### TOTAL PHOSPHORUS

Total phosphorus concentrations regularly complied with the ANZECC (1992) guidelines, except in Lake Hugh Muntz (LHM 2) where the median has exceeded the guidelines (Figure 3.9.2f). Total phosphorus concentrations recorded in Lake Heron (LKH 4), Royal Palm Lake (RPL 1) and Silvabank Lake (SVL) have continually complied with the guidelines. Pizzey Park Lake (PPL 4) also regularly complies with the guidelines, unlike for total nitrogen concentrations in this lake.

#### E. COLI

The ANZECC (1992) guidelines for primary contact recreational waters have not been applied to *E. coli* data collected at lakes in this survey (Figure 3.9.2g). This is due to the sampling regime not complying with the guidelines (i.e. the program is undertaken on a three monthly basis). *E. coli* concentrations were generally low, indicating minimal faecal contamination in these lakes. Lake Rosser (LKR 2 and LKR 3), Runaway Lake (RBL 1) and Silvabank Lake (SVL) were found on occasions to record high concentrations above 1,000cfu/100mL.

### **TURBIDITY**

Turbidity in each lake was generally low (good water clarity) in comparison with other waterways within the City (Figure 3.9.2h). Royal Palm Lake and Lake Heron were found on occasions to record high turbidity than generally recorded in other lakes. These peaks are likely to be associated with rain.

### **3.9.3 DISCUSSION**

The water quality information shown in this section has provided a quantitative assessment of water quality performance in each lake and an indication of the degree to which land use modification/activities has had on each lake. The data has shown that water quality conditions in each lake generally comply with the ANZECC (1992) guidelines for the protection of aquatic ecosystems. This is important given each lake provides a recreational opportunity for local residents and a habitat for aquatic organisms.

In Lake Heron, Silwabank Lake and Lake Rosser, which have limited tidal exchange with the Nerang River due to their design or geographical location, reductions in conductivity below 5mS/cm have been recorded. These low conductivity recordings suggest rain events has significantly alter water quality conditions in each lake. It is during these rainfall periods where catchment contaminants can be transported into each lake. The effect of rain events may be most evident in Pizzey Park Lake and Lake Hugh Muntz where poor water quality conditions, in terms of nutrients, was observed. Increases in nutrient availability, combined with appropriate environment conditions (warm water temperatures), could result in these lakes experiencing problems associated with aquatic plant growth and/or algal blooms in the future, similar to Clear Island Waters and Robina Lakes.

### **3.9.4 CONCLUSIONS AND RECOMMENDATIONS**

It is considered that the continuation of good water quality conditions in each lake will require catchment management plans, detailing specific stormwater management options and/or measures available within each catchment. CMU do not plan to develop stormwater management strategies in the short term for the catchment area surrounding each lake, however, educational programs implemented by CMU, as part of a City wide program targeting general activities undertaken by local residents, may indirectly assist with the protection of each lake.

### 3.10 LAKES - SOUTHERN

#### 3.10.1 INTRODUCTION

The southern lakes survey incorporates six constructed lakes within the southern region of the City. Each lake is maintained as a tidal system through a connection pipe/weir to a primary waterway (eg Nineteenth Ave Lake - Tallebudgera Creek) (Figure 3.10.1). The lakes provide an opportunity for a variety of recreational activities (swimming, sail boating, fishing etc.) for local residents, an aesthetic amenity for the local community and lakefront residents, a habitat for wildlife (eg fish, birds and plants) and also assist with flood storage during significant rain events.

Stormwater runoff is potentially the most contributing factor that may lead to water quality problems in each lake. Urban stormwater following rain events is widely recognised for its potential in conveying nutrients, sediments and various other contaminants from a catchment into an adjacent waterway. If not managed, this could reduce the recreational opportunities for the community and lake front residents or reduce the health and subsequently the ability for these waterways to continue providing a habitat for aquatic animals.

The information presented within this section is based on surface water quality measurements recorded at each site. Profiling of water quality conditions for temperature, conductivity, dissolved oxygen and pH is undertaken in each lake to assess for stratification, however, has not been presented within this report.

Table 3.10.1 Water quality monitoring sites and codes as part of the Southern Lake survey.

Lake	Site (Code)
Burleigh Lake	BUL
Swan Lake (Extension)	SWL SWE
Cyclades Lake	CCL
Murtha Lake	MTL
Nineteenth Avenue Lake (Influence - Connection pipe)	NAL NAI
Pelican Lake/Miami Lake	PML



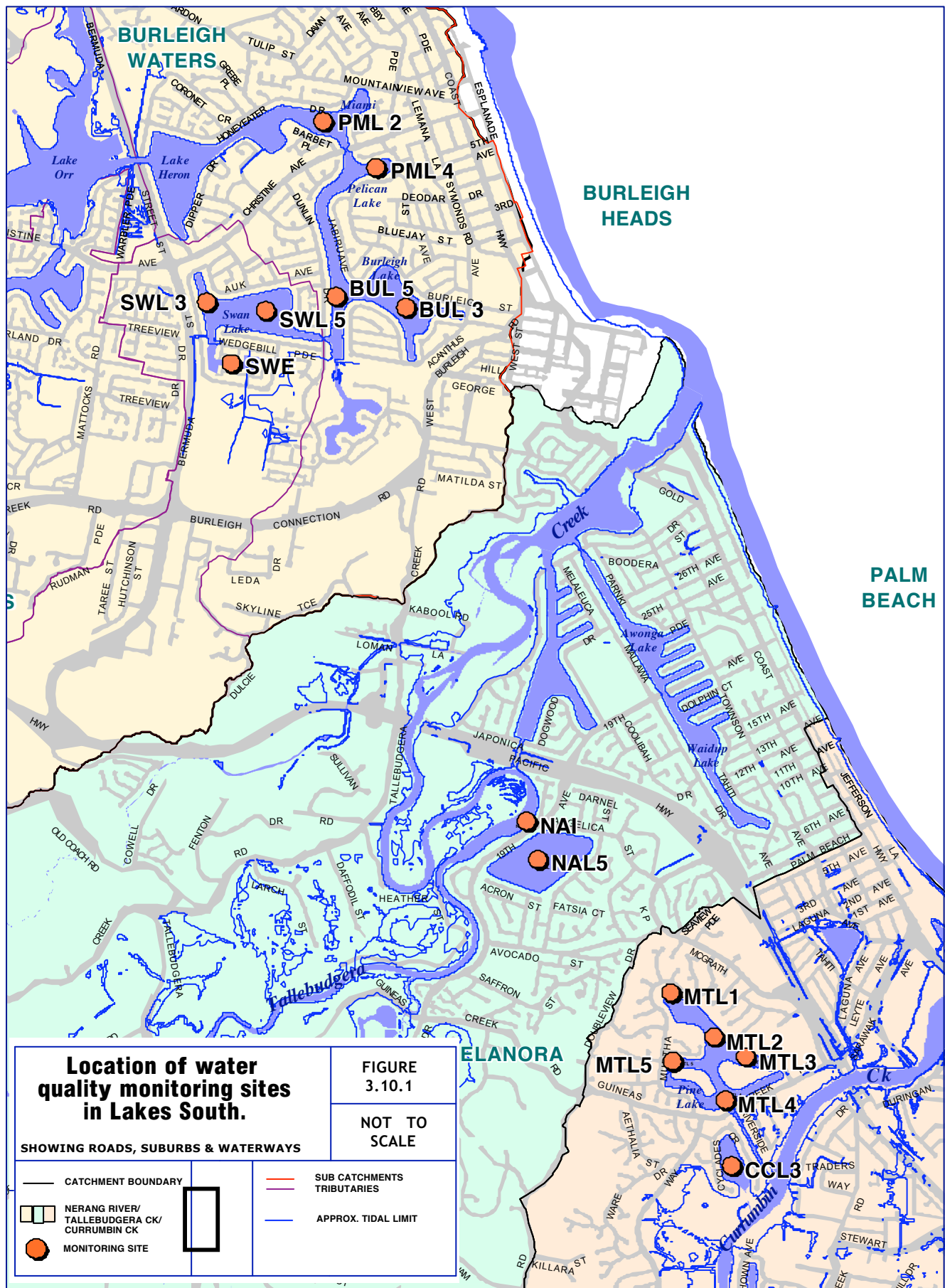
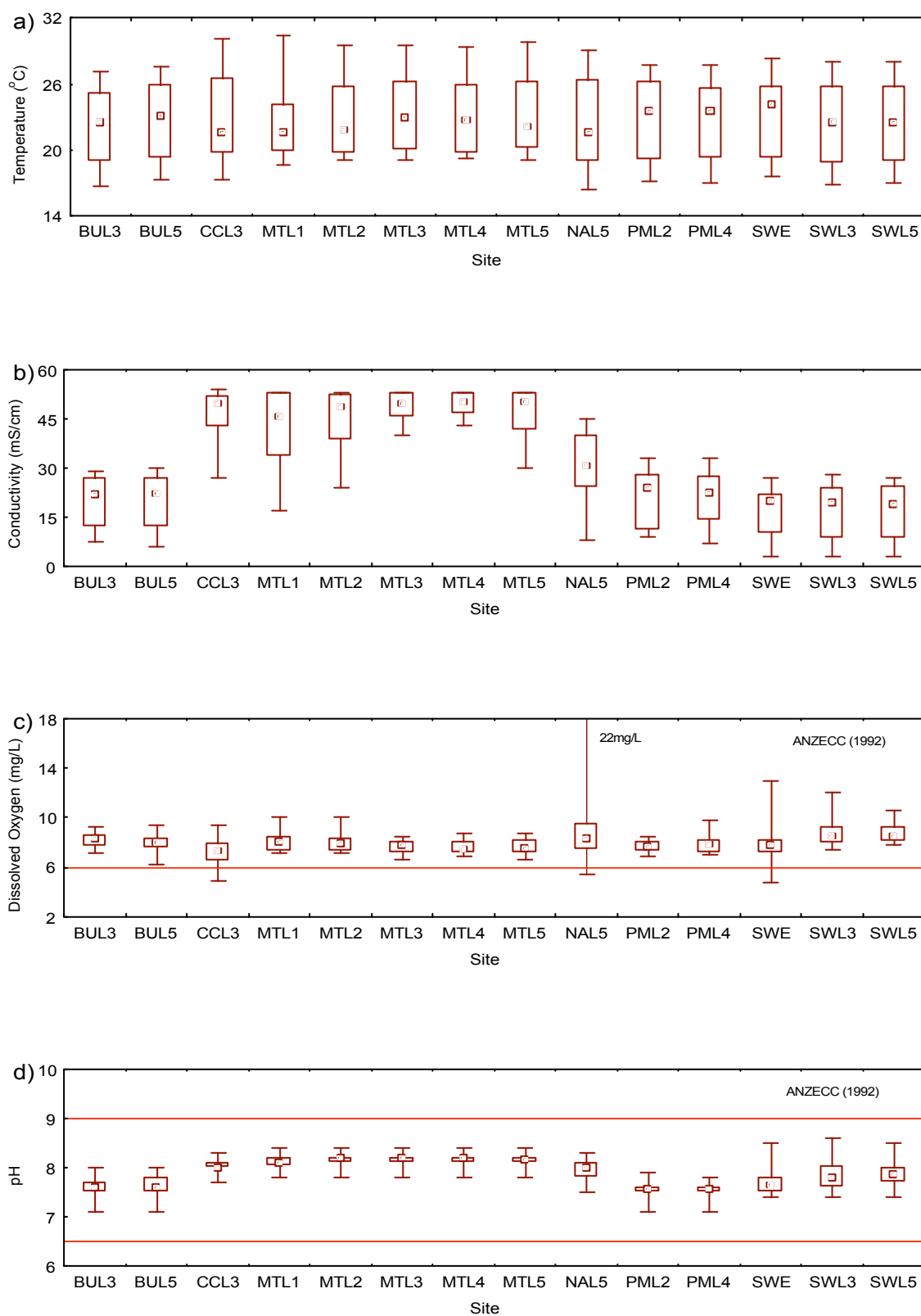
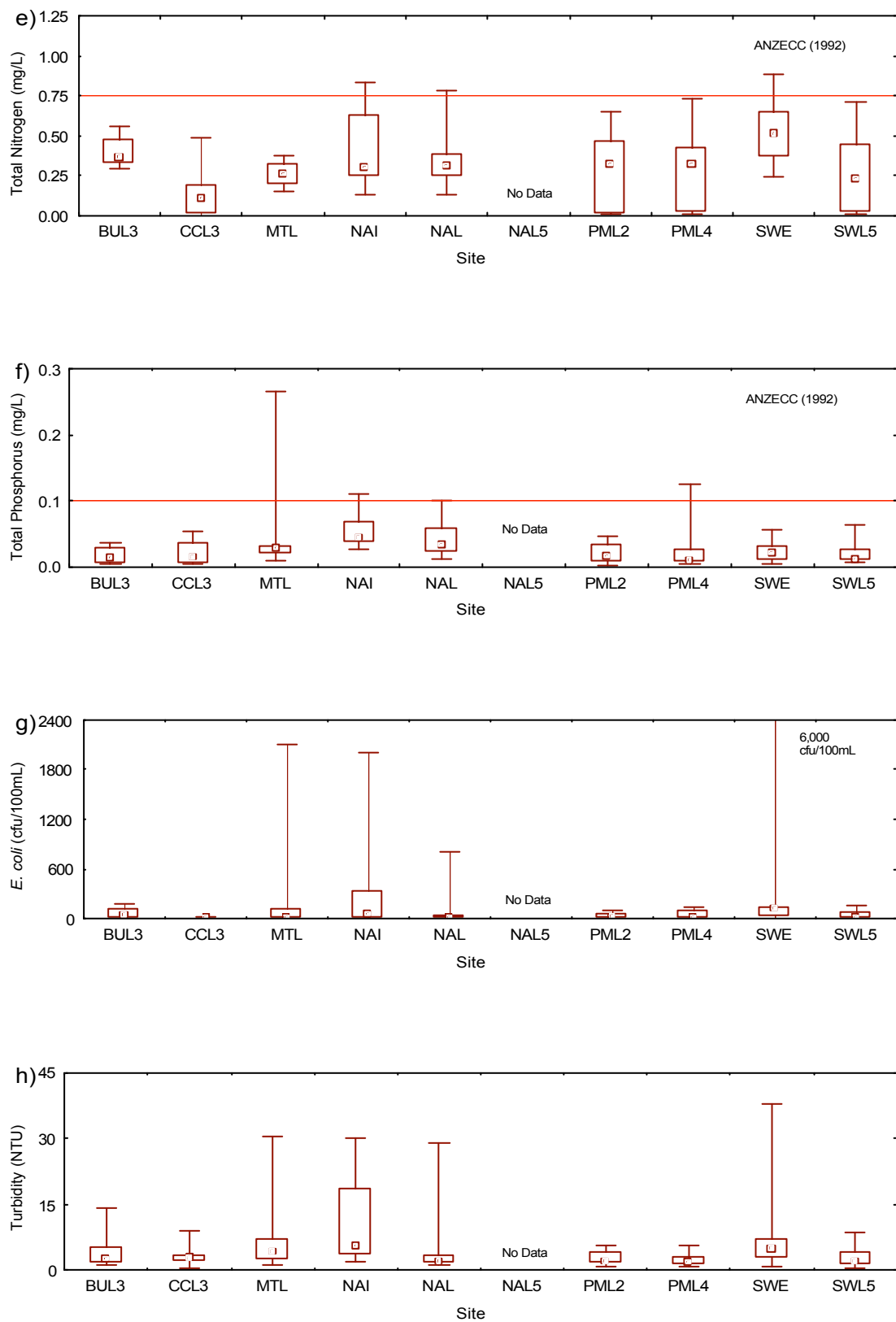


Figure 3.10.1 Water quality monitoring sites located in each lake system as part of the Southern Lakes survey.



**Figure 3.10.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen and (d) pH recorded at sites in each lake system. ANZECC (1992) compliance guidelines for the protection of aquatic ecosystems have been included for dissolved oxygen and pH.



**Figure 3.10.2 (cont)** Box plots for (e) total nitrogen, (f) total phosphorus, (g) *E. coli* concentrations and (h) turbidity recorded at sites in each lake. ANZECC (1992) guidelines for the protection of aquatic ecosystems have been included for both nutrient parameters.

### 3.10.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Water temperature has ranged between 15°C and 30°C across lake sites monitored in this survey (Figure 3.10.2a). This range in water temperature could be influenced by seasonal conditions, time of day when measurements were recorded or flow rates within each lake.

#### CONDUCTIVITY

Conductivity fluctuated markedly at each site (Figure 3.10.2b). Murtha Lake (MTL) and Cyclades Lake (CCL) generally recorded higher conductivity than other lakes, with conductivity regularly above 40mS/cm. Burleigh Lake (BUL), Swan Lake (SWL and SWE), Pelican/Miami Lake (PML) has generally recorded lower conductivity in comparison with other lakes. This is probably indicative of the geographical location of these lakes, several kilometres from the Nerang River. Reductions in conductivity below 30mS/cm in Murtha Lake (MTL) and Cyclades Lake (CCL) and below 10mS/cm in Burleigh Lake (BUR), Nineteenth Ave Lake (NAL), Swan Lake (SWL and SWE), Pelican/Miami Lake (PML) have been recorded over the monitoring period. These reductions show the ability for each lake to be influenced by rainfall and thus catchment runoff.

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations regularly complied with the ANZECC (1992) guidelines at all sites (Figure 3.10.2c). Reductions below the guidelines have been recorded in Cyclades Lake (CCL), Swan Lake extension (SWE) and Nineteenth Ave Lake (NAL). It is uncertain as to the cause of these reductions.

#### pH

pH regularly complied with the ANZECC (1992) guidelines at all sites (Figure 3.10.2d). pH was generally higher and less variable in Cyclades Lake (CCL) and Murtha Lake (MTL), which is to be expected as pH is generally less variable where conductivity is generally constant. All other sites have shown pH to fluctuate, which may also be related to conductivity patterns.

#### TOTAL NITROGEN

Total nitrogen concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.10.2e), despite elevated concentrations recorded on occasions in Nineteenth Ave Lake (NAL and NAI) and in the Swan Lake extension (SWE). Concentrations shown for Murtha Lake (MTL) represent a composite water sample collected from MTL 1 - MTL 5. This therefore suggests that Murtha Lake generally experiences total nitrogen concentrations acceptable for the protection of aquatic ecosystems.

#### TOTAL PHOSPHORUS

Total phosphorus concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.10.2f), despite elevated concentrations recorded in Nineteenth Ave Lake (NAL and NAI), Murtha Lake (MTL) and Pelican/Miami Lake (PML). Similar to total nitrogen concentrations in Murtha Lake, total phosphorus concentrations represent a composite from water samples taken at MTL 1 - MTL 5. Therefore, elevated total phosphorus concentrations recorded in Murtha Lake is difficult to assess given the sampling regime.

#### E. COLI

The ANZECC (1992) water quality guidelines for primary contact waters were not applied to the *E. coli* data collected at sampling sites within the southern lake survey (Figure 3.10.2h). This is due to the sampling regime not complying with the ANZECC (1992) guidelines (*ie* the program is undertaken on a three monthly basis).

The *E. coli* concentrations recorded at sites within the southern lake survey have generally remained below 150cfu/100mL. However, high *E. coli* concentrations have, on occasions, exceeded 1,000cfu/100mL in Swan Lake extension (SWE), Murtha Lake (MTL) and Nineteenth Avenue Lake (NAL) connection pipe with Tallebudgera Creek.

### **TURBIDITY**

Turbidity generally remained below 10ntu across all sites over the monitoring period (Figure 3.10.2i). The site located at the connection pipe between Tallebudgera Creek and Nineteenth Ave Lake (NAL) has generally recorded higher turbidity than other sites. This could therefore suggest that water quality in Tallebudgera Creek can influence water quality in Nineteenth Ave Lake (NAL).

### **3.10.3 DISCUSSION**

Water quality monitoring in the lakes within the southern region of the City, has provided a quantitative measure of water quality performance and responses to a change in land use surrounding each lake. The data has indicated that water quality has generally complied with the relevant ANZECC (1992) guidelines for the protection of aquatic ecosystems. This is important, given these lakes provide an important recreational opportunity for many local residents and an important habitat for many aquatic and terrestrial communities.

Nineteenth Avenue Lake, Swan Lake and Murtha Lake where found, on occasions, to experience high nutrient concentrations. Algal blooms in Nineteenth Ave Lake have been observed in recent years, which is a sign of increased nutrient loads within this lake system. Increased nutrient concentrations are likely to be influenced by land use activities within the surrounding catchment area. Stormwater runoff from surrounding residential areas, could contribute to the transportation of nutrients into each lake. In addition, adjacent waterways may also be influencing water quality in these lakes. For example, Tallebudgera Creek could be influencing water quality conditions in Nineteenth Ave Lake. This was most apparent with the connection pipe between Tallebudgera Creek and Nineteenth Ave Lake recording higher nutrient, turbidity and *E. coli* concentrations than Nineteenth Ave Lake.

### **3.10.4 CONCLUSIONS AND RECOMMENDATIONS**

It is considered that the continuation of good water quality conditions in each lake, similar to those lake in the northern lakes survey, will require specific catchment management plans, detailing specific stormwater management options and/or measures available within each catchment area. CMU do not plan to develop stormwater management strategies in the short term for the catchment area surrounding each lake. However, educational programs implemented by CMU as part of a City wide educational program targeting general catchment activities undertaken by local residents, may indirectly assist with the management of the City's southern lakes.

### 3.11 LODERS CREEK

#### 3.11.1 INTRODUCTION

Loders Creek drains a small catchment that has been extensively modified in response to urbanisation (Figure 3.11.1). The creek is approximately 8.3km in length and flows through Ashmore, Southport and Labrador before entering the Broadwater near Southport.

Greater than 25% of the creek within the upper catchment has been converted into open or underground stormwater drain systems. Areas within the freshwater region of the catchment have also been re-profiled to facilitate flood mitigation. This has led to the loss of the riparian vegetation along regions of the creek (Loders Creek Integrated Catchment Management Community Association, 1999).

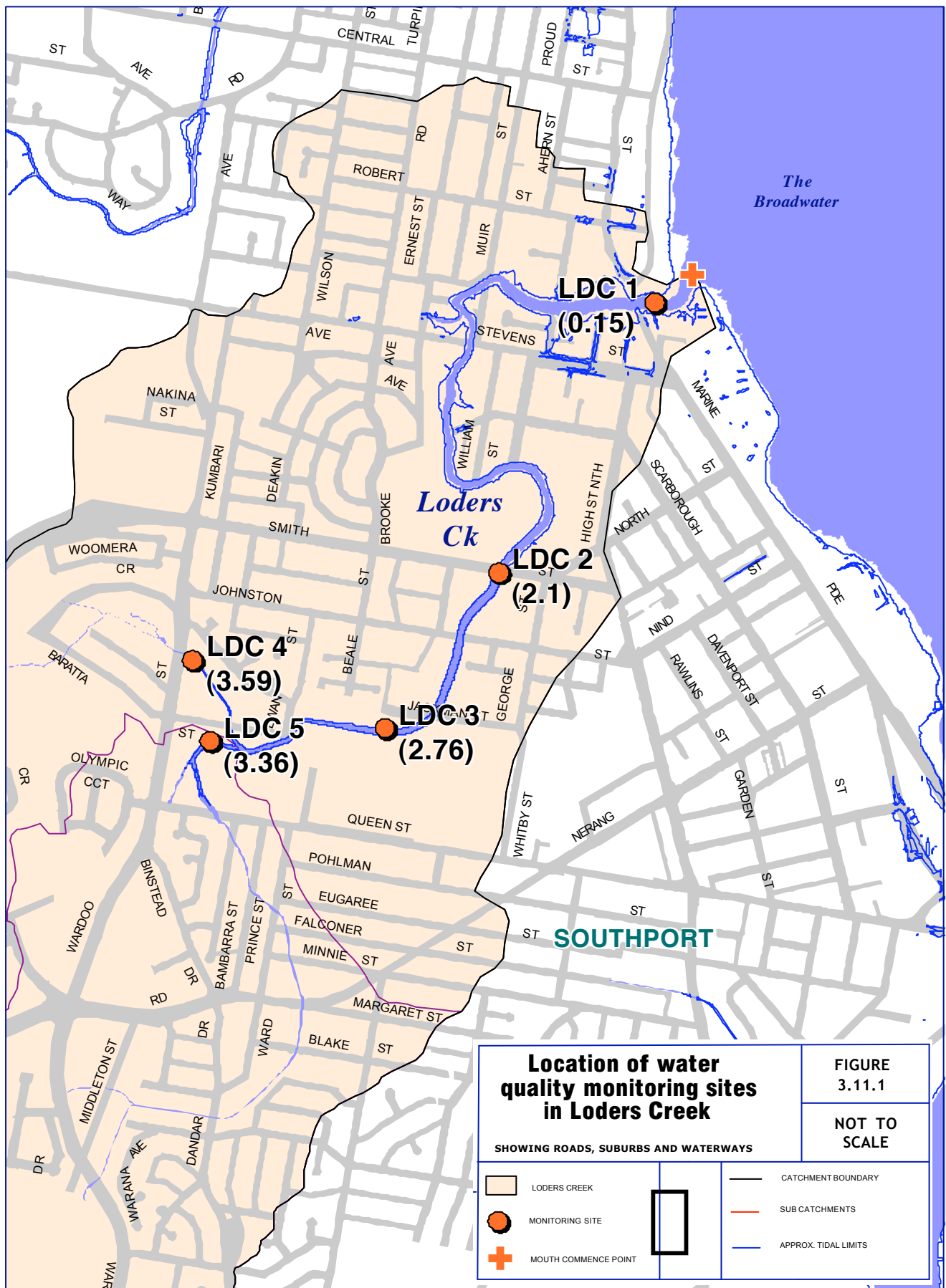
The freshwater region of the creek consists of two main tributaries. The southern tributary has been extensively modified from a natural watercourse and exists as an ephemeral, open, concrete stormwater drain. The northern tributary begins as an open, concrete stormwater system, and then forms a more natural slow meandering pool/riffle system, before joining with the southern tributary. This series of pool/riffle areas along the northern tributary has been identified as supporting an important habitat for the endangered Wallum Froglet (*Crinia tinnula*) (Hero *et al*, 2000).

The tidal limit for this system is located at the junction of the northern and southern tributaries, approximately 3km upstream from its confluence with the Broadwater. The estuarine region of this system is the focus for this monitoring program, due to a limited opportunity to monitor water quality within the freshwater region of the creek.

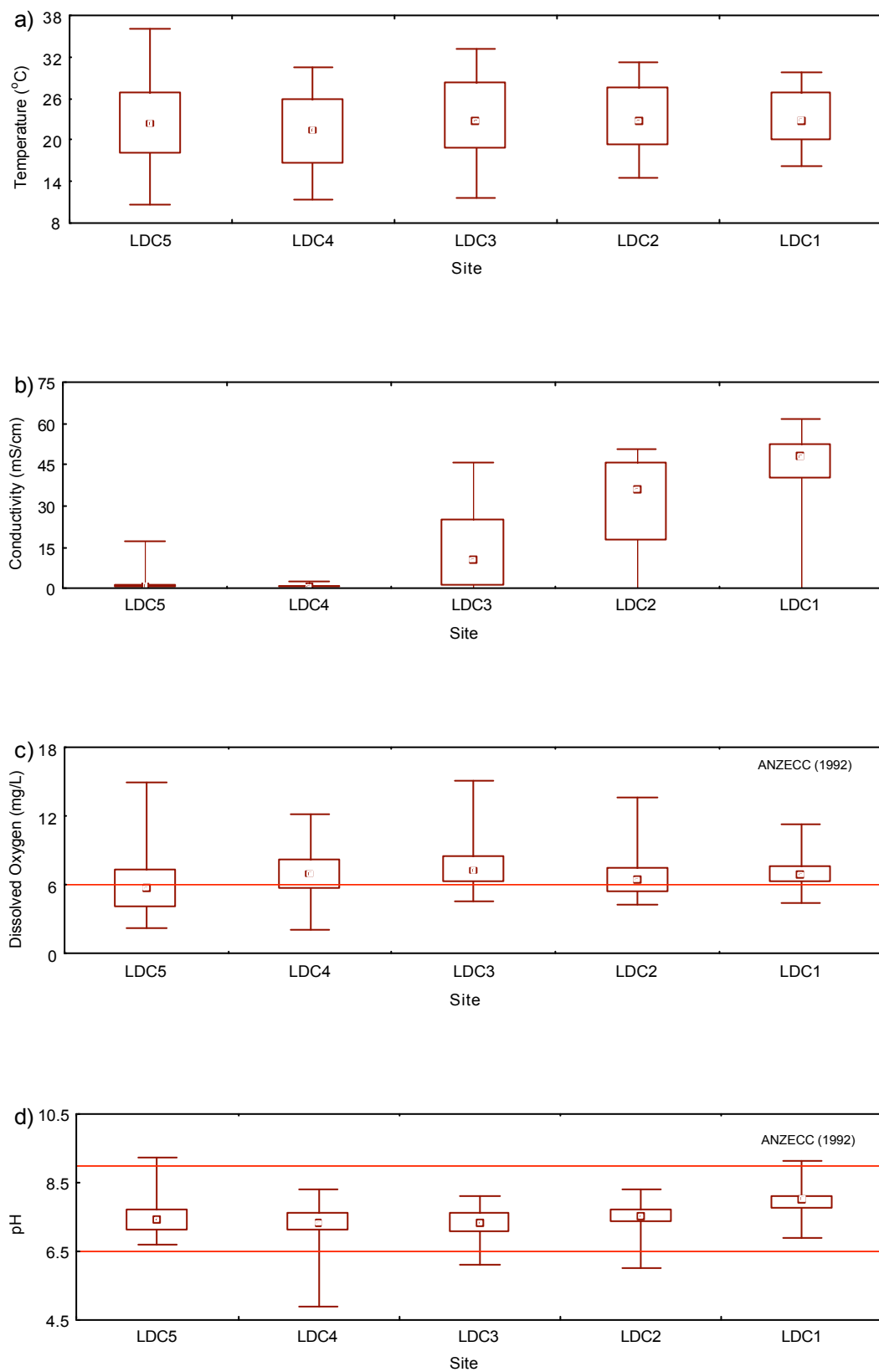
Table 3.11.1 Site classifications and distance details for each monitoring site.

Region/Site Type	Distance # (km)	Site
Lower Estuary	0.15	LDC 1
Middle Estuary	2.10	LDC 2
	2.76	LDC 3
Upper Estuary (Northern)	3.59	LDC 4
Upper Estuary (Southern)	3.36	LDC 5

# Measured as distance in kilometres from the mouth

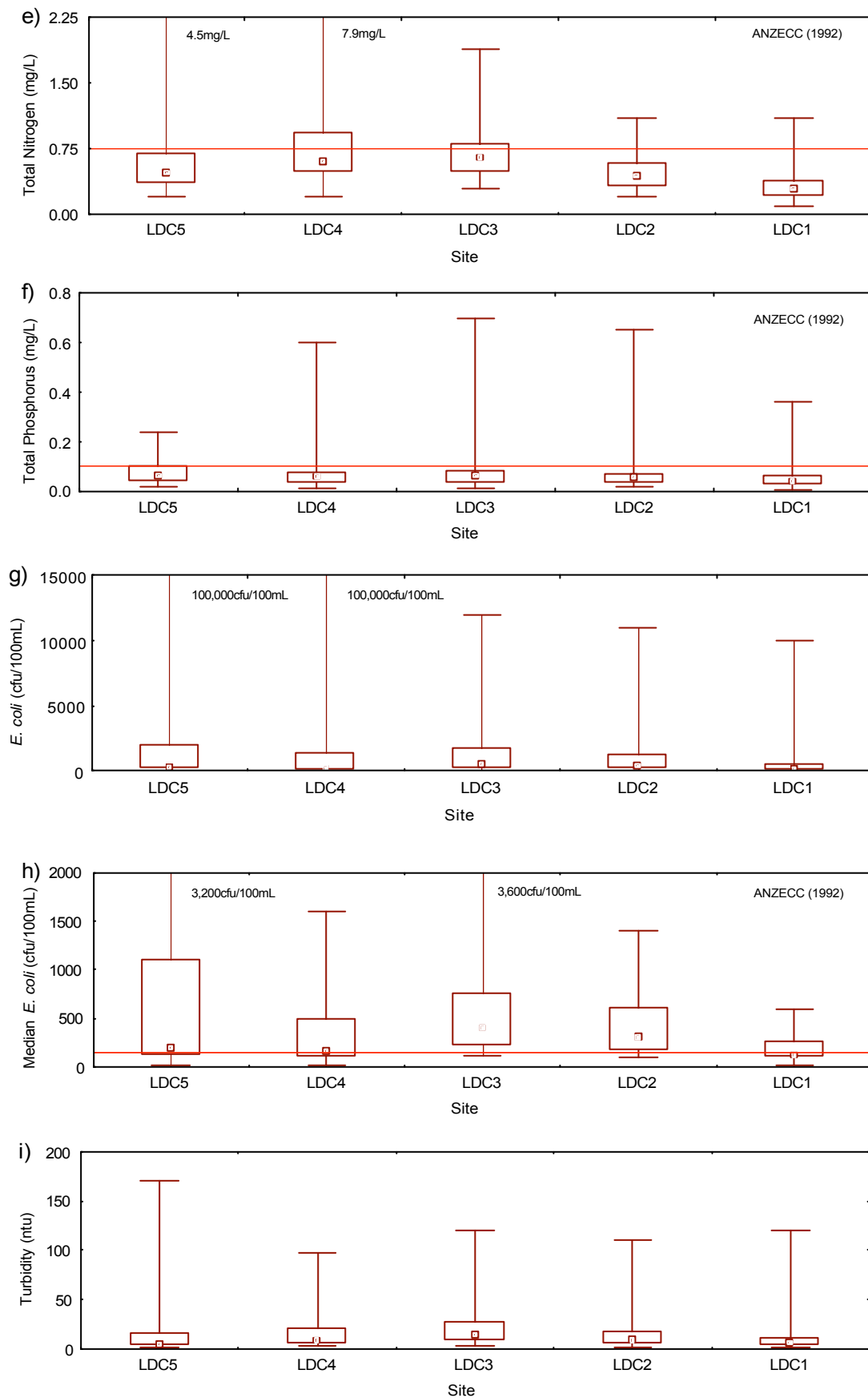


**Figure 3.11.1** Water quality monitoring sites located in Loders Creek.



**Figure 3.11.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen and (d) pH recorded at each site within Loders Creek. ANZECC (1992) compliance guidelines for the protection of aquatic ecosystems have been included for dissolved oxygen and pH.





**Figure 3.11.2 (cont)** (e) total nitrogen, (f) total phosphorus, (g) raw data for *E. coli* concentrations, (h) rolling median *E. coli* and (i) turbidity recorded at each site within Loders Creek. ANZECC (1992) compliance guidelines for both nutrients have been included for comparison with the protection of aquatic ecosystems. Recreational guidelines for primary contact waters have been included for comparison with median *E. coli* concentrations.

### 3.11.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Water temperature has ranged between 10°C and 35°C in Loders Creek (Figure 3.11.2a). This range in water temperature could be influenced by seasonal conditions, depth, flow rate, time of day when measurements were recorded or the presence and density/state of riparian vegetation. Water temperatures did not vary significantly amongst sites (KW :  $p = 0.06$ ).

#### CONDUCTIVITY

Conductivity has ranged between 0.1mS/cm and 61mS/cm in Loders Creek (Figure 3.11.2b). Conductivity varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher conductivity recorded at LDC 1 than all other sites. Site LDC 2 recorded significantly higher conductivity than at LDC 3, LDC 4 and LDC 5, while LDC 3 recorded significantly higher conductivity than at LDC 4 and LDC 5. This conductivity gradient is to be expected, as tidal exchange increased within the lower estuary. At certain times, conductivity was recorded below 5mS/cm at LDC 1, which is likely to be related to freshwater runoff from the upper catchment during rain events.

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations regularly complied with the ANZECC (1992) guidelines, excluding LDC 5 where the median was below the guidelines (Figure 3.11.2c). Reductions in concentrations below the guidelines were recorded at all sites. Dissolved oxygen concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at LDC 1, LDC 3 and LDC 4 than at LDC 5, with intermediate concentrations at LDC 2. Site LDC 3 recorded significantly higher dissolved oxygen concentrations than at LDC 2.

#### pH

pH regularly complied with the ANZECC (1992) guidelines (Figure 3.11.2d). Reductions below the lower limit were recorded at LDC 2, LDC 3 and LDC 4 while elevations above the upper limit were recorded at LDC 1 and LDC 5. pH varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher pH at LDC 1 than all other sites. Site LDC 2 recorded significantly higher pH than at LDC 3 and LDC 4. This trend is to be expected, as pH in marine and brackish waters is usually higher than pH in freshwater and is generally less varied.

#### TOTAL NITROGEN

Total nitrogen concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.11.2e). Elevated total nitrogen concentrations were recorded at all sites, particularly at LDC 3 and LDC 4. Concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher total nitrogen at LDC 3 than at LDC 2, LDC 4 and LDC 5. Site LDC 4 recorded significantly higher concentrations than at LDC 2 and LDC 5. Site LDC 1 recorded the lowest concentrations of all sites, which is likely to be related to greater tidal exchange with the Broadwater. High concentrations at both upper estuary sites are likely to be related to runoff within each sub-catchment area.

#### TOTAL PHOSPHORUS

Total phosphorus concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.11.2f). Elevated concentrations were recorded at all sites above the guidelines. Total phosphorus concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at LDC 3 and LDC 5 than at LDC 1, with intermediate concentrations recorded at LDC 2 and LDC 4.

### **E. COLI**

*E. coli* concentrations, calculated as a rolling median, regularly complied with the ANZECC (1992) guidelines for primary contact recreational waters at LDC 1. Median *E. coli* concentrations at all other sites did not comply with the primary contact recreational guidelines (Figure 3.11.2h). *E. coli* concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at LDC 3 than at LDC 1, LDC 4 and LDC 5. Significantly lower concentrations were recorded at LDC 1 than at LDC 2 and LDC 5, while LDC 2 recorded significantly higher concentrations than at LDC 4 and LDC 5.

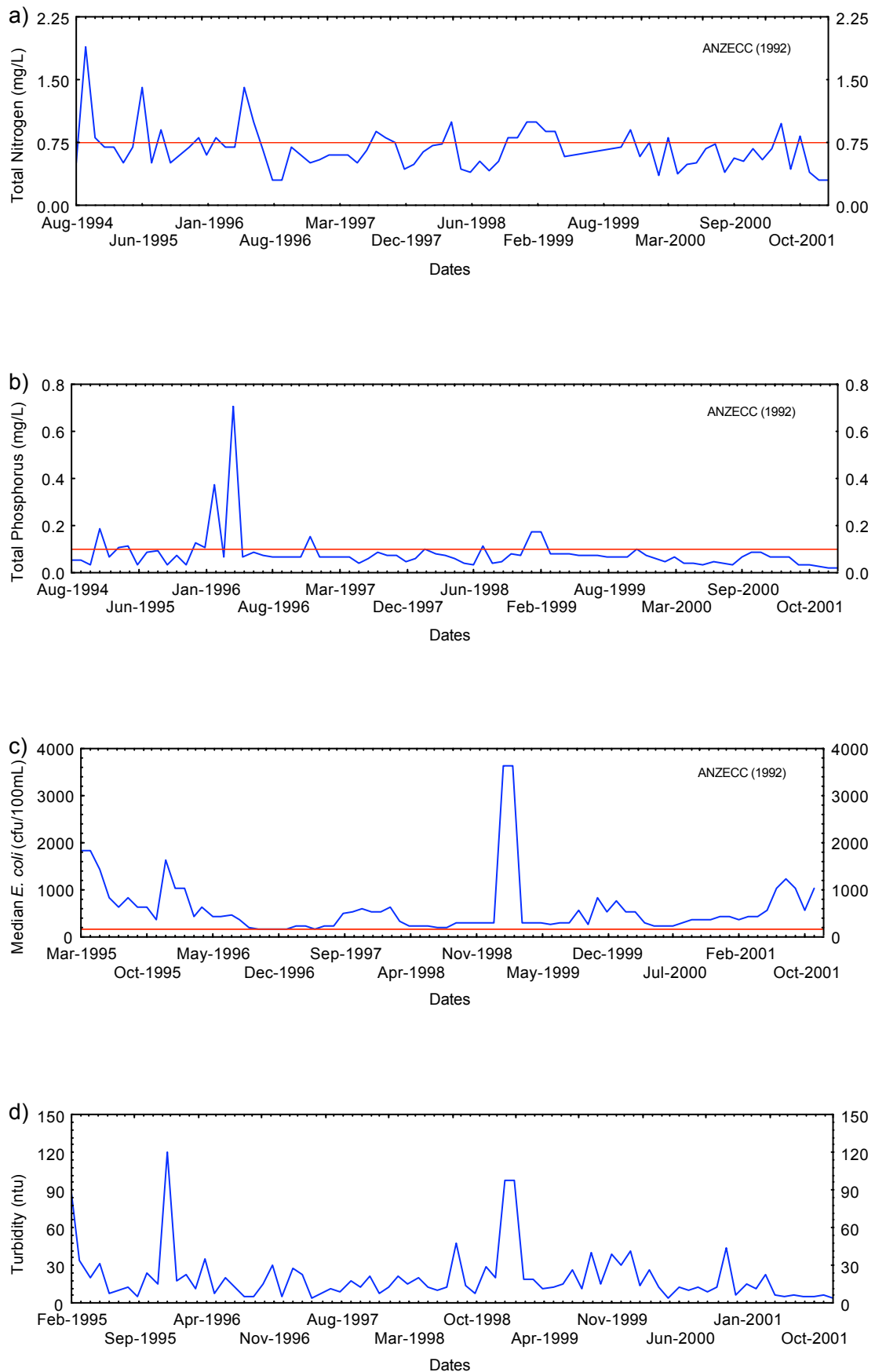
### **TURBIDITY**

Turbidity ranged between 1ntu and 170ntu for all sites combined in Loders Creek (Figure 3.11.2i). Turbidity varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher turbidity at LDC 3 than at all other sites. This is unusual given that LDC 4 and LDC 5 assess water quality conditions from each tributary. This suggests that a sediment point source exists within this section of the creek. Site LDC 5 recorded significantly lower turbidity than LDC 2 and LDC 4, while LDC 1 recorded significantly lower turbidity than LDC 2 and LDC 4.

#### **3.11.3 WATER QUALITY TRENDS**

Water quality recorded at LDC 3 has been presented to assess trends over the monitoring period (Figure 3.11.3). At this site, despite fluctuating water quality conditions, both nutrient concentrations do not appear to have deteriorated over the monitoring period. Rather, in the case of total phosphorus, concentrations have improved at this site and have continually complied with the guidelines following February 1999.

It was found at this site for the period between November 1998 and March 1999, both nutrient parameters exceeded the guidelines. This was also found for *E. coli* concentrations and turbidity, which suggests that an extended period of rainfall has occurred. *E. coli* concentrations have regularly exceeded the primary contact recreational guidelines at this site, with several peaks exceeding secondary contact recreational guidelines. Median *E. coli* concentrations have shown a steady increase following August 1997 and would appear to be close to regularly exceeding secondary contact recreational guidelines. Turbidity has also fluctuated over the monitoring period at this site, with peaks probably associated with rainfall events. Importantly, there does not appear to have been a decline (more turbid) in conditions at this site over time.



**Figure 3.11.3** Trends in (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at site LDC 3 over the monitoring period.

#### 3.11.4 DISCUSSION

Water quality conditions recorded within the upper estuary region have regularly recorded higher nutrient and bacterial concentrations than sites within the lower estuary section of Loders creek. Reductions in pH and dissolved oxygen have also been recorded at these sites. The southern tributary has generally recorded poorer water quality conditions in comparison to the northern tributary. The loss of riparian vegetation, urbanisation and the nature of the southern tributary as a concrete, open, stormwater drain, would be a significant factor in contributing to poor water quality conditions in this tributary of Loders Creek.

Nutrient concentrations within the middle region of the creek generally complied with the ANZECC (1992) guidelines, whereas *E. coli* concentrations regularly exceed the guidelines for primary contact recreational waters. Nutrient concentrations and turbidity appear to improve in the lower estuarine region of Loders Creek. It would seem likely that increased tidal exchange with the Broadwater assists water quality conditions in this section of the creek. *E. coli* concentrations more regularly comply with the primary contact recreational guidelines in the lower estuary, despite occasional elevations above the guidelines. These elevated concentrations are probably influenced by upstream land use activities, including commercial and industrial uses and the highly urbanised nature of this catchment.

#### 3.11.5 CONCLUSIONS AND RECOMMENDATIONS

The water quality trends in Loders creek show that the urbanised nature of this catchment contributes considerably to water quality conditions in this creek. Both upper estuary sites that assess water quality from each tributary show similar degraded conditions. Further investigation through event based monitoring or the addition of monitoring sites in each tributary may be necessary to determine the source/s of these pollutants. The management and improvement of stormwater runoff from upper catchment areas, through the development of a stormwater management plan, is necessary to ensure water quality conditions and EVs of the waterway are protected. GCCC will develop a catchment management plan for this catchment in the coming years. This study will identify the EVs considered important by the local community and then use this information to design a land use specific stormwater management plan to protect the values of Loders Creek. A community catchment management group in Loders Creek has already implemented rehabilitation works in riparian areas along the creek and rehabilitated wetland areas identified as supporting a habitat for the endangered Wallum Froglet (*Crinia tinnula*). The group has also begun a program to educate the local community on the values of Loders Creek.

### 3.12 NERANG RIVER (DOWNSTREAM OF HINZE DAM)

#### 3.12.1 INTRODUCTION

The Nerang River catchment is the largest and most significant river system within Gold Coast City. Its upper reaches, within the McPherson Range and the Springbrook Plateau, deliver rainfall through rural areas and into two dams (Hinze Dam and Little Nerang Dam) that provide a large percentage of the Gold Coast's drinking water supply.

The Nerang River continues its course from the Hinze Dam wall, flowing approximately 36km through rural residential and agricultural land use areas, reaching its tidal limit just upstream from Weedons Crossing (Nerang). The tidal or estuarine region of the system traverses much of its length through encroaching urban residential areas and receives runoff from the Carrara/Merrimac floodplain area before joining the Broadwater system and flowing into the Pacific Ocean via the Gold Coast Seaway.

Multi-branched canal developments and a number of tidal and freshwater lake systems have influenced much of the lower catchment. These canal developments provide a range of recreational opportunities for many residents including boating, swimming and recreational fishing. These canal systems also provide an important function for the drainage of stormwater and flood mitigation. Therefore, these canal systems could potentially become susceptible to contamination via stormwater drainage.

A number of tributaries exist within the Nerang River catchment downstream from the Hinze Dam. These include Bridge Creek, Crane Creek, Bonogin Creek, Mudgeeraba Creek (via Clear Island Waters and Boobegan Creek), Birmingham Creek, Worongary Creek, Witt Ave and Carrara Main drains, Benowa flood channel and Mooyumbin Creek. Each of these sub-catchments has pressures associated with varying land use activities and can each influence water quality conditions in the Nerang River.

Table 3.12.1 Site classification and distance details for each monitoring site.

Region/Site Type	Distance # (km)	Site
Freshwater	35.59	NGR 0B
	30.48	NGR 0
	22.59	NGR 0C
Upper Estuary	19.53	NGR 0A
	14.14	NGR 1
	11.90	NGR 1B
Middle Estuary	7.23	NGR 2A
	5.02	NGR 3
	5.29	NGR 4
Lower Estuary	2.48	NGR 6
	-0.67	NGR 8

# Measured as distance in kilometres from the mouth (Gold Coast highway bridge, Southport)

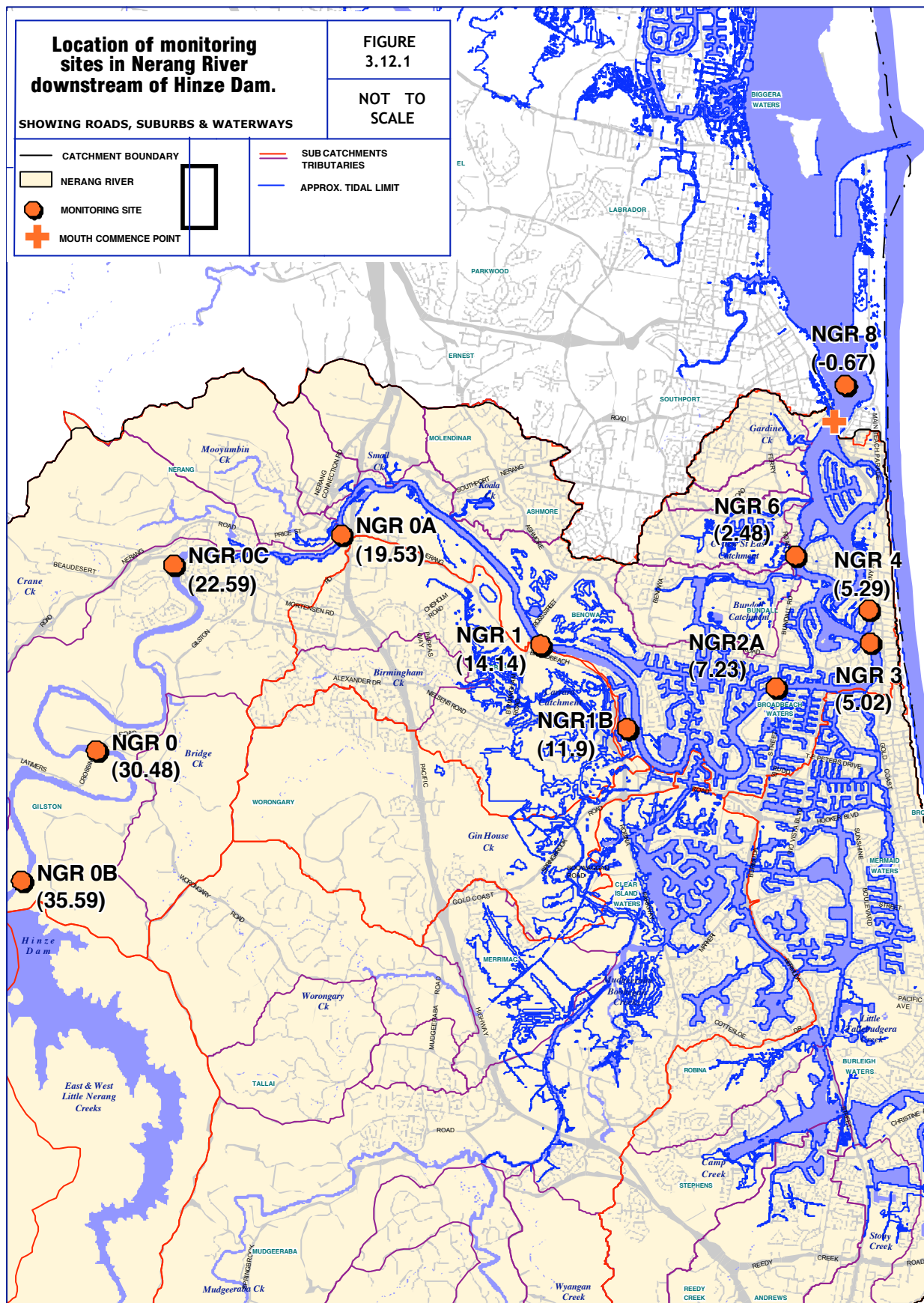
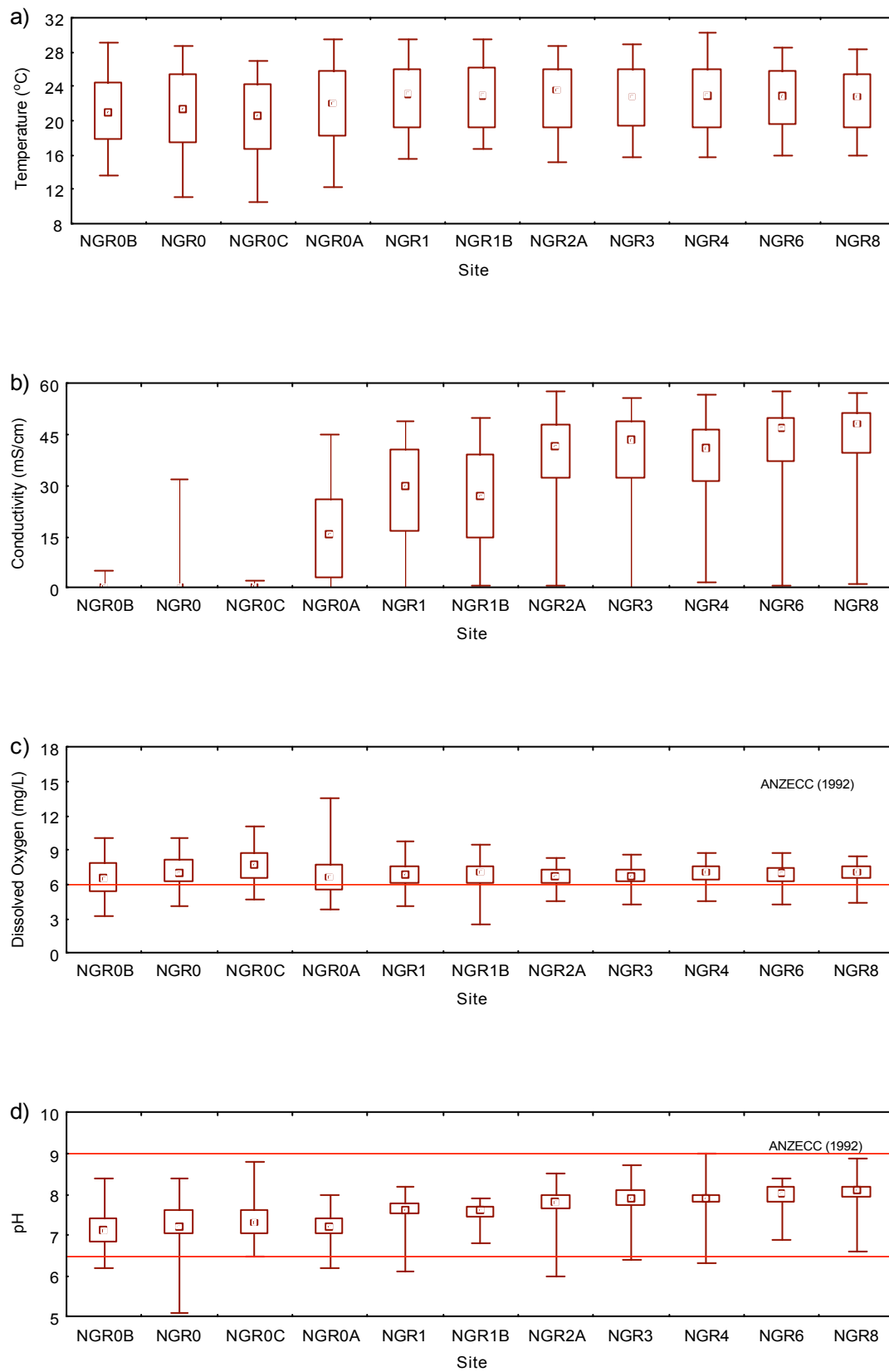
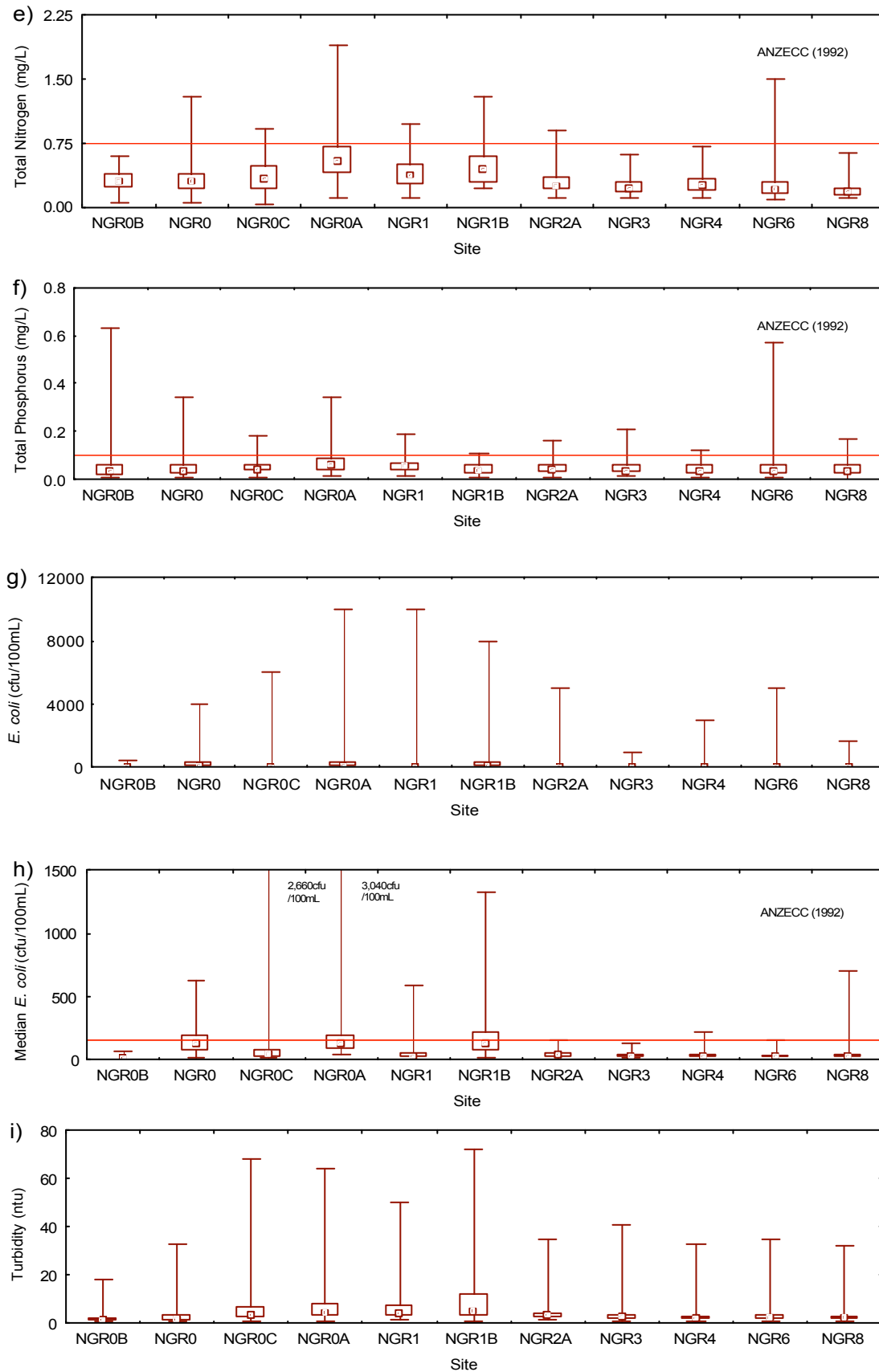


Figure 3.12.1 Location of monitoring sites in Nerang River downstream of Hinze Dam.



**Figure 3.12.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen, and (d) pH recorded at each site within the Nerang River (downstream of Hinze Dam). ANZECC (1992) guidelines for the protection of aquatic ecosystems have been included for dissolved oxygen and pH.





**Figure 3.12.2 (cont)** (e) total nitrogen, (f) total phosphorus, (g) raw data for *E. coli* concentrations (h) rolling median *E. coli* and (i) turbidity recorded at each site within the Nerang River (downstream of Hinze Dam). ANZECC (1992) compliance guidelines for both nutrients have been included for the protection of aquatic ecosystems. Recreational guidelines for primary contact waters have been included for comparison with median *E. coli* concentrations.

### 3.12.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Water temperature has ranged between 10°C and 34°C in the Nerang River (Figure 3.12.2a). This range in water temperature could be influenced by seasonal conditions, depth, flow rates, time of day when measurement was recorded or the presence and/or density/nature of riparian vegetation. Water temperature varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly lower water temperature at NGR 0C than at NGR 1, NGR 2A and NGR 3 - NGR 8. Significantly lower water temperatures were recorded at NGR 0B than at NGR 1, NGR 2A and NGR 4. Site NGR 2A recorded significantly higher water temperature than at NGR 0. It was found in this system that lower water temperatures were generally recorded at freshwater sites, with a gradual increase in water temperatures moving downstream towards lower estuary sites. Estuarine monitoring sites are sampled with the use of a boat and within the middle region of the river, whereas, freshwater sites are sampled from the bank and may therefore be influenced by riparian vegetation shading.

#### CONDUCTIVITY

Conductivity varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher conductivity at all estuarine sites than at all freshwater sites. Significantly lower conductivity was recorded at upper estuary sites than at middle and lower estuary sites. This salinity gradient along the creek is to be expected as tidal exchange increases with the Broadwater. At certain times, conductivity decreased below 5mS/cm at lower estuary sites, which is probably due to freshwater runoff from the upper catchment and surrounding urban areas, during rainfall periods (Figure 3.12.2b).

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.12.2c). All sites have been shown to experience concentrations below the guidelines, particularly at NGR 0B, NGR 0A and NGR 1B. Dissolved oxygen concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at NGR 0C than at NGR 0B and NGR 0A. Concentrations recorded at NGR 0B were significantly lower than at NGR 0 and NGR 8, with intermediate concentrations recorded at all other sites.

#### pH

pH regularly complied with the ANZECC (1992) guidelines (Figure 3.12.2d). Several sites recorded pH below the lower limit guidelines over the monitoring period. pH varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly lower pH in freshwater sites than at all estuary sites. Upper estuary monitoring sites recorded significantly lower pH than at middle and lower estuary sites. NGR 2A recorded significantly lower pH than at NGR 6. The gradual increase in pH along the river is to be expected, as pH in marine waters is usually higher than pH in freshwater and generally less varied.

#### TOTAL NITROGEN

Total nitrogen concentrations regularly complied with the ANZECC (1992) guidelines, with the 80<sup>th</sup> percentile complying with the guidelines at all sites (Figure 3.12.2e). Several sites have recorded concentrations above the guidelines. Concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at upper estuary sites than all other monitoring sites., with NGR 2A recording intermediate concentrations. Total nitrogen concentrations were highest at sites within the upper estuary and appear to improve downstream towards the lower estuary. These lower concentrations recorded within the middle to lower estuary region are likely related to increased tidal exchange and dilution with the Broadwater.

## TOTAL PHOSPHORUS

Total phosphorus concentrations regularly complied with the ANZECC (1992) guidelines, with the 80<sup>th</sup> percentile complying with the guidelines at all sites (Figure 3.12.2f). Concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at NGR 0A and NGR 1 than all other sites. Significantly higher concentrations were recorded at NGR 0C than at other freshwater sites and NGR 8. Similar to total nitrogen, total phosphorus concentrations generally improved downstream of NGR 0A towards the lower estuary. This is likely associated with increased tidal exchange with the Broadwater.

## E. COLI

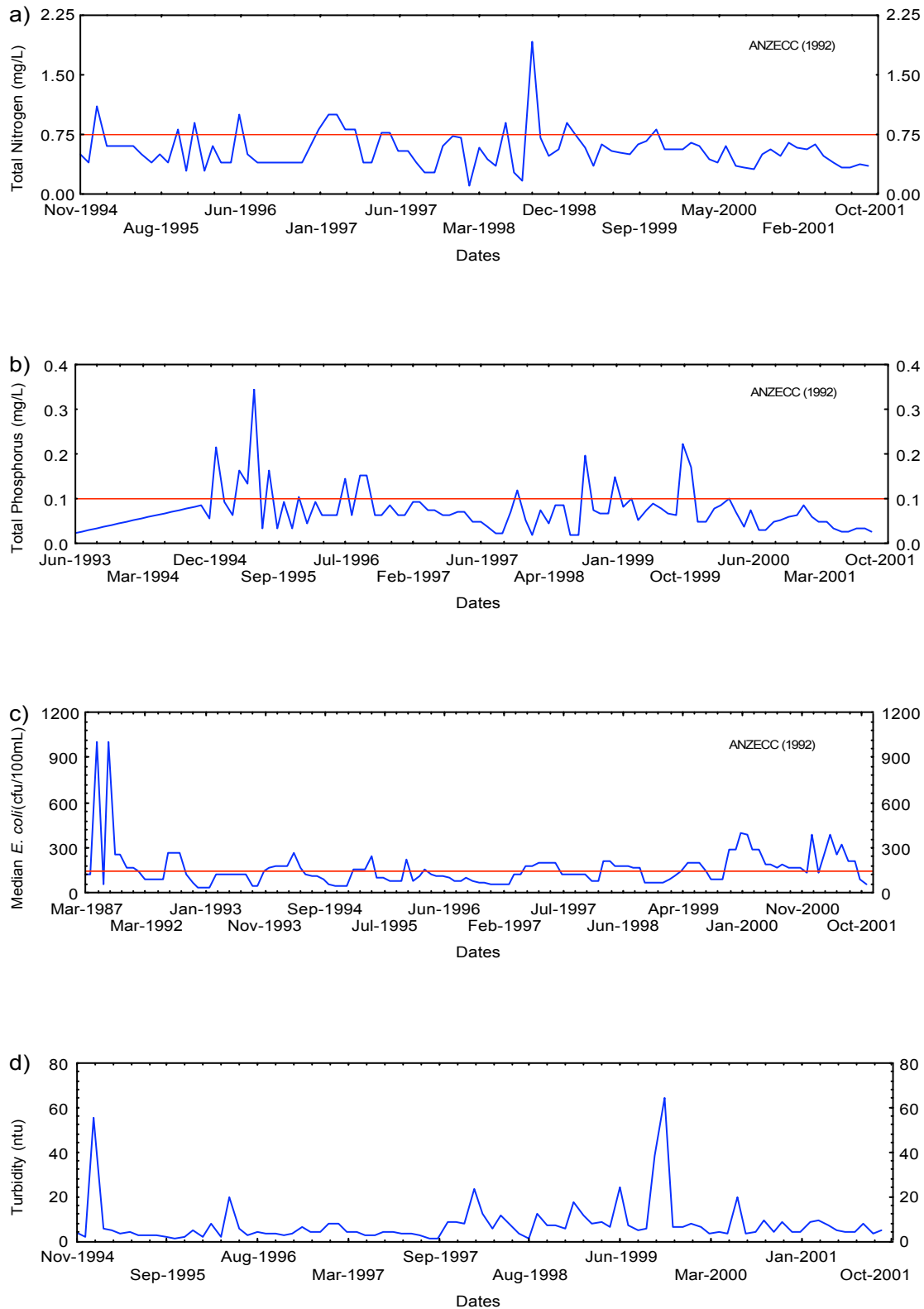
*E. coli* concentrations, calculated as a rolling median, regularly complied with the primary contact recreational guidelines (Figure 3.12.2g). At NGR 0B, NGR 2A, NGR 3 and NGR 6 the rolling median concentrations have continually complied with the guidelines. Concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at NGR 0, NGR 0A and NGR 1B than all other sites. Significantly higher *E. coli* concentrations were recorded at NGR 0 than at all middle and lower estuary monitoring sites, with intermediate concentrations recorded at NGR 1B. Higher *E. coli* concentrations recorded at NGR 0, NGR 0A and NGR 1B are probably influenced by the surrounding catchment land use practices as concentrations improved immediately downstream from each site. All middle and lower estuary sites regularly complied with the primary contact recreational guideline, which is probably due to the increased flushing with the Broadwater.

## TURBIDITY

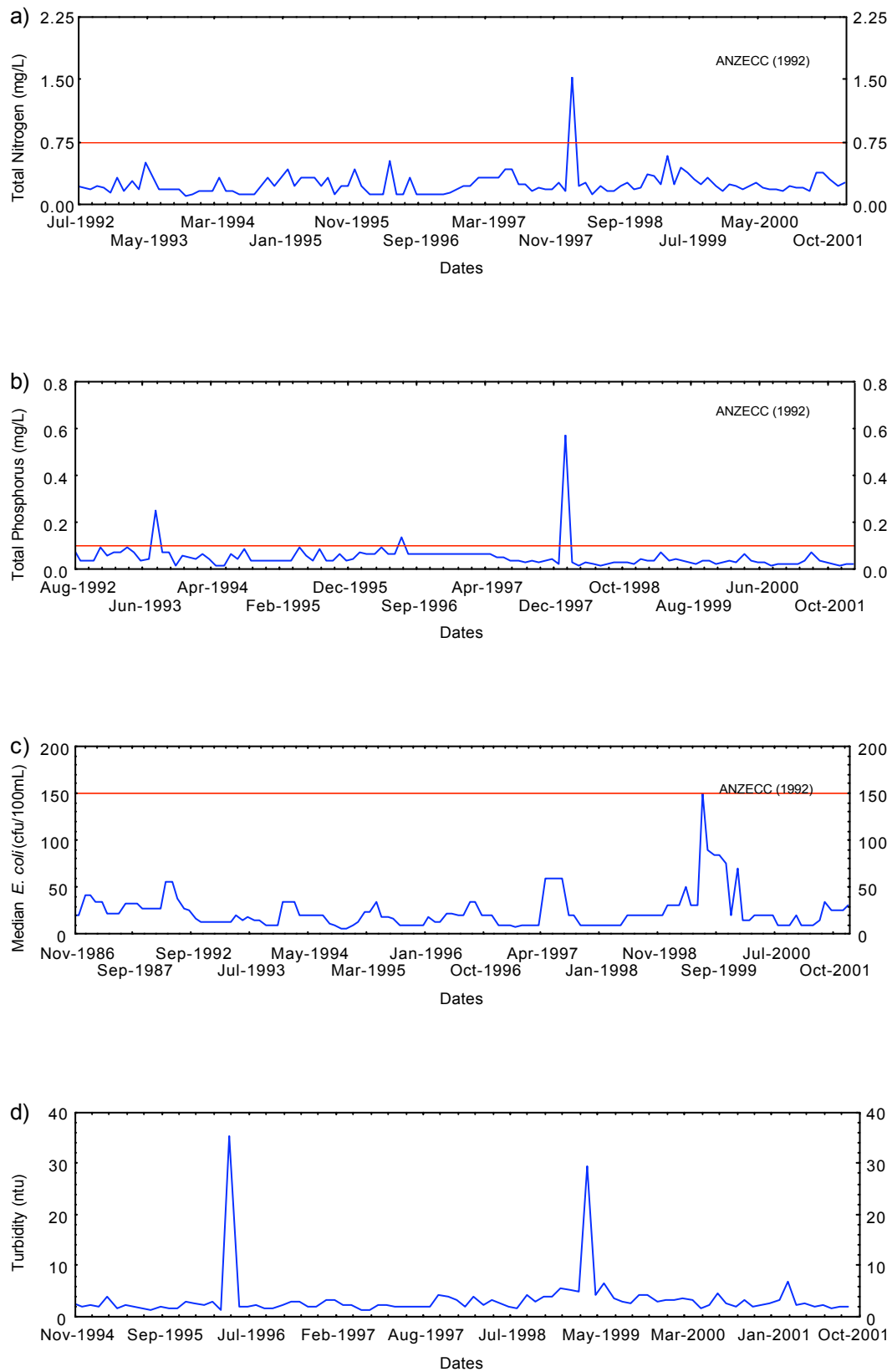
Turbidity varied significantly amongst sites (KW :  $p < 0.001$ ) (Figure 3.12.2i), with significantly lower turbidity at NGR 0B and NGR 0 than at NGR 0C, all upper estuary sites and NGR 2A. Turbidity was significantly higher at upper estuary sites than at all middle and lower estuary sites, with NGR 2A recording significantly higher turbidity than at NGR 4 and NGR 8. Turbidity appears to follow a similar trend found in other waterways throughout the City, with lower turbidity at sites within the freshwater and lower estuary, and highest at upper and middle estuary sites.

### 3.12.3 WATER QUALITY TRENDS

Water quality recorded at NGR 0A and NGR 6 has been presented to assess trends over the monitoring period (Figure 3.12.4 and 3.12.5) in the Nerang River. Both sites have shown that water quality has fluctuated over the monitoring period. Nutrient concentrations at both sites, whilst regularly complying with the ANZECC (1992) guidelines, have shown several peaks in concentrations, which is likely to be related to rain events, although, elevated nutrient concentrations in June 1998 at NGR 0A were not observed at NGR 6. This irregularity between sites could be associated to differences in land use and/or varying rainfall patterns across the catchment. Similarly, a peak in nutrient concentrations at NGR 6 was not observed at NGR 0A during February 1998. Median *E. coli* concentrations recorded at both sites fluctuated over the monitoring period, with NGR 0A regularly above the primary contact recreational guidelines. Concentrations remained above the primary contact recreational guidelines between April 1999 and December 2000 (except between July 1999 and December 1999), which suggests that bacterial concentrations have generally worsened (increased) than in previous years. *E. coli* concentrations at NGR 6 have consistently complied with the primary contact recreational guidelines. Turbidity at both sites generally remained below 20ntu. Turbidity peaks were however, recorded at each site and are likely to be related to rain events. These peaks were generally not during similar periods at each site, suggesting differences in land use and/or differing rainfall patterns. Turbidity at both sites appears to not have increased over the monitoring period.



**Figure 3.12.3** Trends in (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at NGR 0A over the monitoring period.



**Figure 3.12.4** Trends in (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at NGR 6 over the monitoring period.

### 3.12.4 DISCUSSION

Water quality in the Nerang River, downstream of Hinze Dam, has provided an opportunity to assess water quality in response to land use changes within this catchment. Water quality conditions within the freshwater region have regularly complied with the ANZECC (1992) guidelines. Water quality trends also have shown that conditions appear to have not declined over time, which is important as it shows that this region of the catchment is in good health. The upper estuary region of the Nerang River, despite generally complying with the ANZECC (1992) guidelines, has shown signs of declining water quality in recent years, particularly for *E. coli* concentrations. Total nitrogen, total phosphorus, turbidity and *E. coli* concentrations were generally highest at sites within this region of the river, which is likely to be associated with the extensive modification of the surrounding catchment area to accommodate urban development. Sites within the middle estuary region have also recorded elevated nutrient and *E. coli* concentrations. These concentrations may be linked with stormwater runoff from the surrounding urban areas after rain.

The lower estuary region has generally recorded water quality that complied with the ANZECC (1992) guidelines. While water quality in this area of the river system is influenced by runoff from the upper catchment and from the extensive canal network, tidal exchange with the Broadwater appears to assist with water quality conditions in the lower Nerang River. However, while this may be the case, land use management, public education, erosion and sediment control and stormwater management programs should continue to focus on the entire catchment. This will reduce the reliance on tidal flushing and/or dilution of contaminants within the lower estuary, which is not sustainable in the long-term.

### 3.12.5 CONCLUSIONS AND RECOMMENDATIONS

The geographical size and extent of land uses within the Nerang River catchment downstream of Hinze Dam, makes the management of this catchment area difficult from a whole of catchment perspective. It is considered that each region or tributary would require a detailed catchment management plan, addressing specific catchment related land use characteristics and issues. This information could then be used in developing specific land use stormwater management plan for each sub-catchment. GCCC plan to investigate and develop a catchment management plan for the Nerang catchment, downstream of Hinze Dam, in the coming years. A community catchment management group for this region of the Nerang catchment does not currently exist, however, the establishment of a group/s, will be considered in the coming years.

### 3.13 NERANG RIVER - NUMINBAH VALLEY (UPSTREAM OF HINZE DAM)

#### 3.13.1 INTRODUCTION

Numinbah Valley is located within the upper western region of the Nerang River catchment. This area of the Nerang catchment forms a major source of water supply for the City. It receives approximately 1447mm of rainfall annually (based on rainfall data between 1941 - 1999 recorded at the Numinbah Correctional Centre rainfall station, Bureau of Meteorology, *perr. comm.*). Numinbah Valley is also influenced by drainage from the western Springbrook escarpment and the Darlington Ranges (Lamington National Park), which both have elevations above 1,000m and receive significantly higher rainfall than Numinbah Valley (GCCC, 1996).

Approximately 60% of the Numinbah Valley is held by the State government or owned by GCCC. Approximately 1% of the catchment is described as being urban developed (GCCC, 1996) and a large amount of the remaining area is utilised for agricultural purposes.

Agricultural land use activities operating within the valley have been identified as contributing nutrient and bacterial input into the Nerang River and will continue to be a source in the future (GCCC, 1996). Fortunately most of the land within this area consists of pastoral and forage lands which uptake nutrients for growth and also provides important soil erosion control. Much of the riparian vegetation zone along the creek has been left intact, with some areas cleared for agricultural purposes (GCCC, 1996).

Table 3.13.1 Site classification and distance details for sites in Nerang River upstream of Hinze Dam.

Region/Site Type	Distance <sup>#</sup> (km)	Site
Upper Freshwater	62.35	NGN 1
	62.42	NGN 2
	55.60	NGN 3
	55.34	NGN 4
	53.21	NGN 5
	50.28	NGN 6
Lower Freshwater	45.56	NGN 7
	45.23	NGN 8

<sup>#</sup> Measured as distance in kilometres from the Nerang River mouth (Gold Coast highway bridge, Southport)

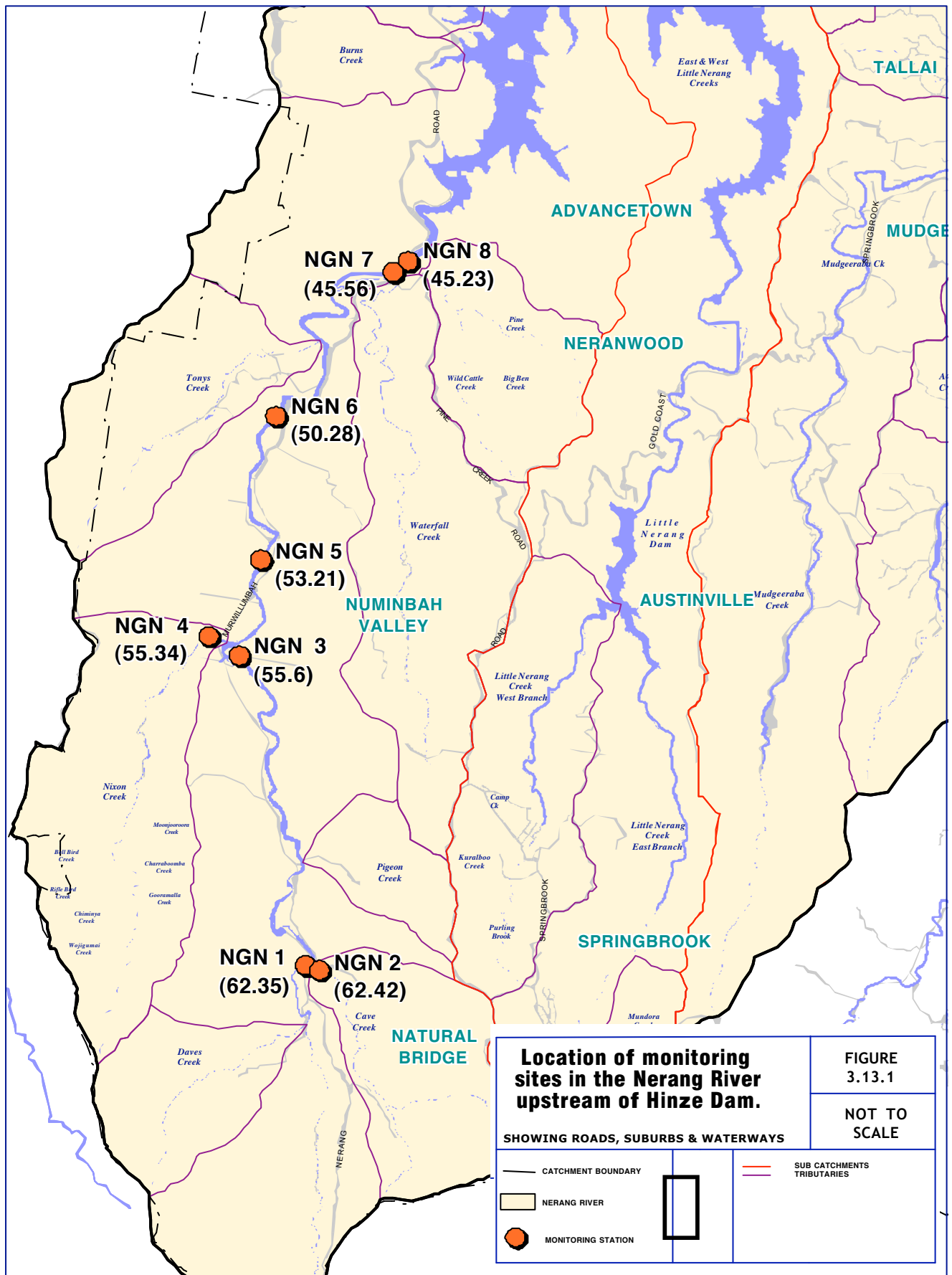
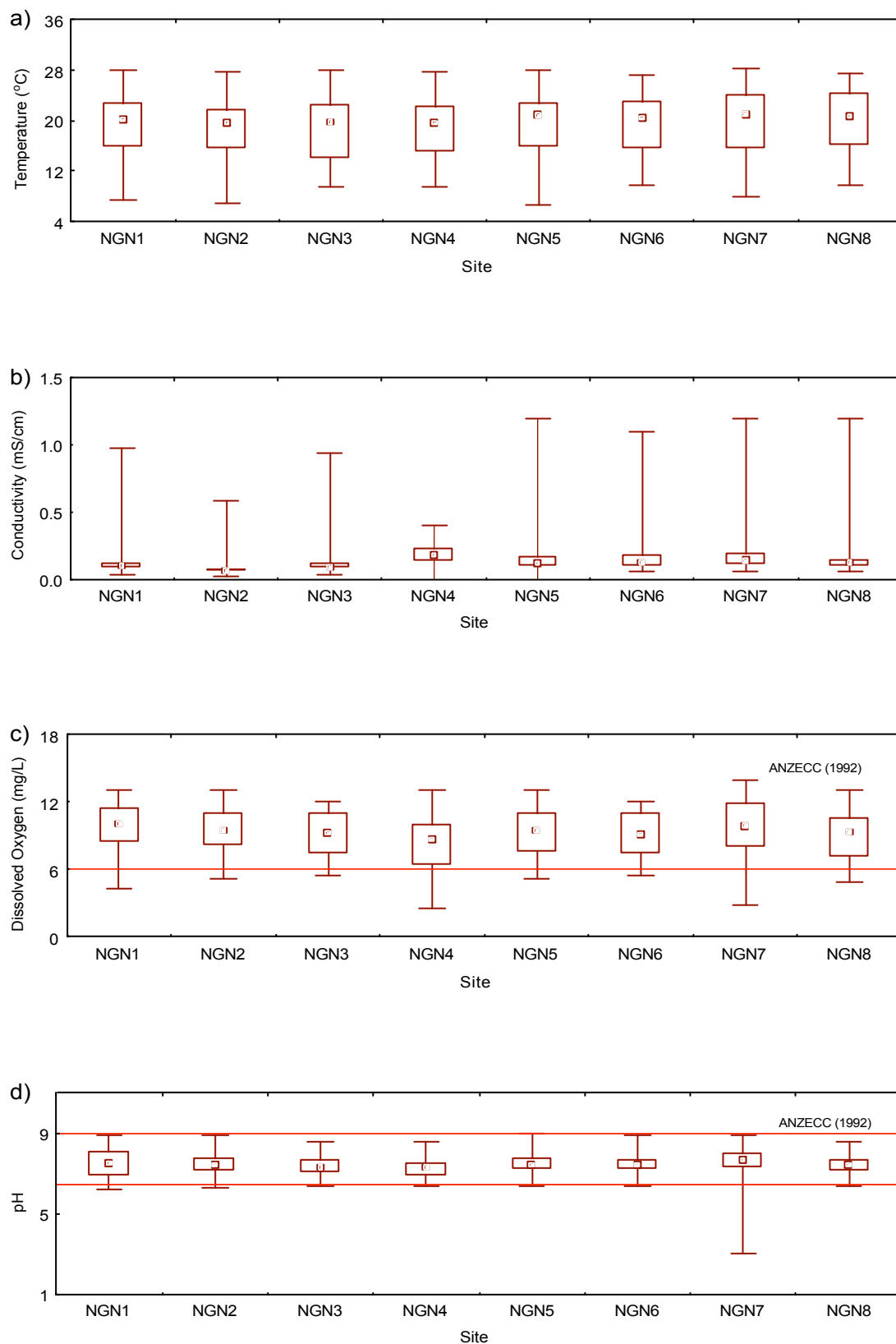
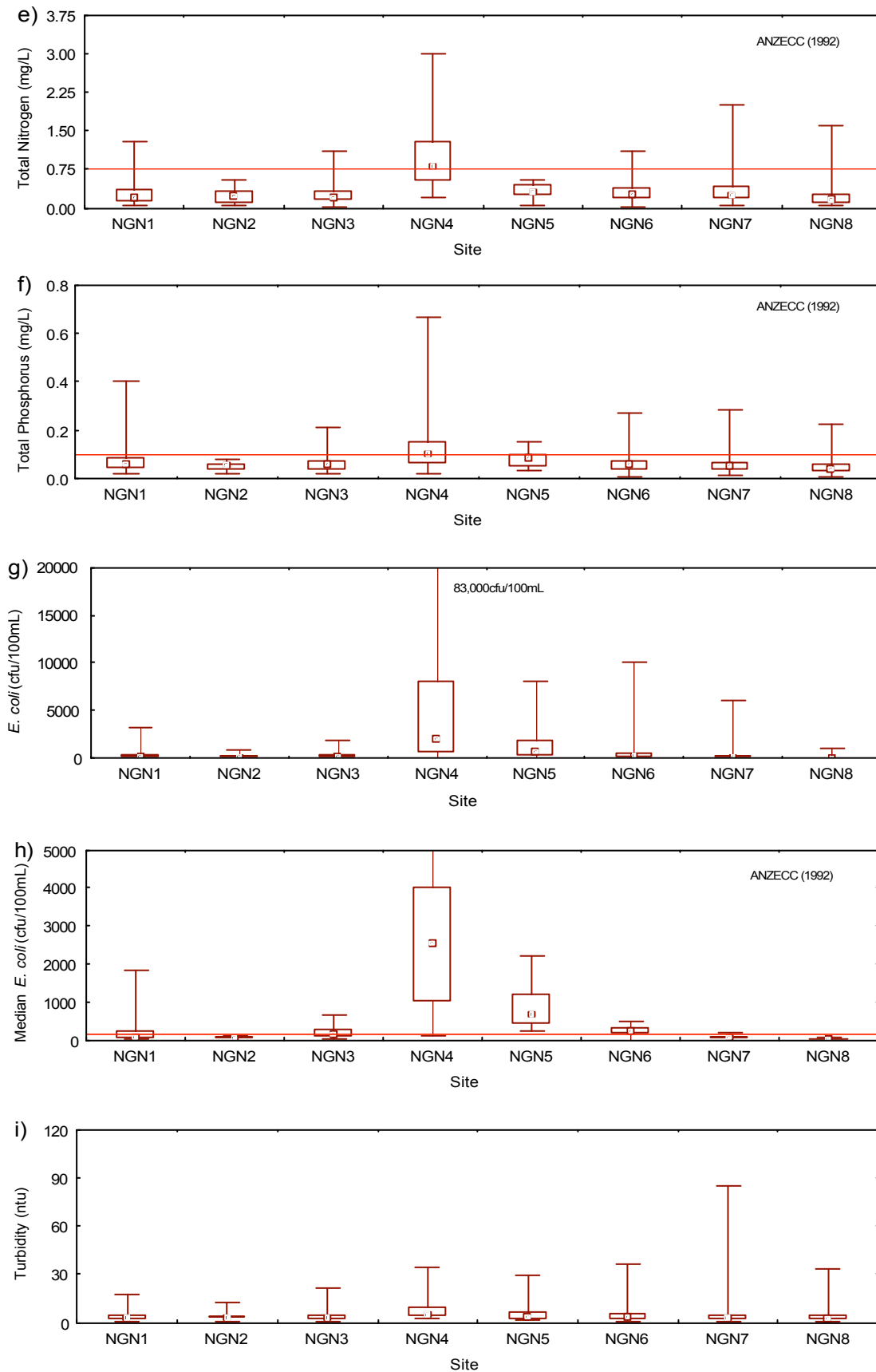


Figure 3.13.1 Water quality sites located in the Nerang River Upstream of Hinze Dam.





**Figure 3.13.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen, and (d) pH recorded at sites within the Nerang River upstream of Hinze Dam. ANZECC (1992) compliance guidelines for the protection of aquatic ecosystems have been included for dissolved oxygen and pH.



**Figure 3.13.2 (cont)** (e) total nitrogen, (f) total phosphorus, (g) raw data for *E. coli* concentrations, (h) rolling median *E. coli* and (i) turbidity recorded at sites within the Nerang River upstream of Hinze Dam. ANZECC (1992) compliance guidelines for both nutrients have been included for comparison with the protection of aquatic ecosystems. Recreational guidelines for primary contact waters have been included for comparison with median *E. coli* concentrations.

### 3.13.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Water temperature ranged between 7°C and 28°C within this region of the Nerang River over the monitoring period (Figure 3.13.2a). This range in water temperature could be influenced by seasonal conditions, depth, flow rates, time of day when measurements were taken or the presence and density/state of riparian vegetation. Water temperatures did not vary significantly amongst sites (KW :  $p = 0.46$ ).

#### CONDUCTIVITY

Conductivity ranged between 0.02mS/cm and 1.6mS/cm within this region of the Nerang River over the monitoring period (Figure 3.13.2b). Conductivity varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher conductivity at NGN 4 than at NGN 1 - NGN 3. Site NGN 2 recorded significantly lower conductivity than at NGN 5 - NGN 8. Site NGN 3 recorded significantly lower conductivity than at NGN 6 and NGN 7.

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.13.2c). Reductions below the guidelines were recorded at all monitoring sites. Concentrations varied significantly amongst sites (KW :  $p < 0.002$ ), with significantly lower concentrations at NGN 4 than at NGN 1 and NGN 7, with intermediate concentrations at all other sites.

#### pH

pH regularly complied with the ANZECC (1992) guidelines (Figure 3.13.2c). Reductions in pH, below the lower guidelines limit, have been recorded at all sites, with reductions at NGN 7 below 3.5. pH varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher pH at NGN 7 than at NGN 3 and NGN 4. Site NGN 4 recorded lower pH than at NGN 1 and NGN 5.

#### TOTAL NITROGEN

Total nitrogen concentrations regularly complied with the ANZECC (1992) guidelines, except at NGN 4 where the median exceeded the guidelines (Figure 3.13.2e). Elevated concentrations above the guidelines have been recorded at all sites, except at NGN 2 and NGN 5 where recordings consistently complied with the guidelines over the monitoring period. Concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations recorded at NGN 4 than at all other sites. Site NGN 8 recorded significantly lower concentrations than at NGN 6 and NGN 7.

#### TOTAL PHOSPHORUS

Total phosphorus concentrations regularly complied with the ANZECC (1992) guidelines, except at NGN 4 where the median exceeded the guidelines (Figure 3.13.2f). Elevated concentrations above the guidelines have been recorded at all monitoring sites, except at NGN 2 where recordings consistently complied with the guidelines. Concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations recorded at NGN 4 than at all other sites, except NGN 5. Significantly lower concentrations were recorded at NGN 8 than at NGN 1, NGN 3, NGN 5 and NGN 6. Site NGN 7 recorded significantly lower concentrations than at NGN 5.

#### E. COLI

*E. coli* concentrations, calculated as a rolling median, generally complied with the ANZECC (1992) guidelines for primary contact recreational waters, except at NGN 4 - NGN 6 where the rolling median *E. coli* concentration exceeded the primary contact recreational guidelines (Figure 3.13.2g). *E. coli* concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher *E. coli* concentrations recorded at NGN 4 and NGN 5 than at all other sites. Site NGN 6 had significantly higher *E. coli* concentrations than at NGN 2 and NGN 5, while significantly lower concentrations were recorded at NGN 7 and NGN 8 than all other sites.

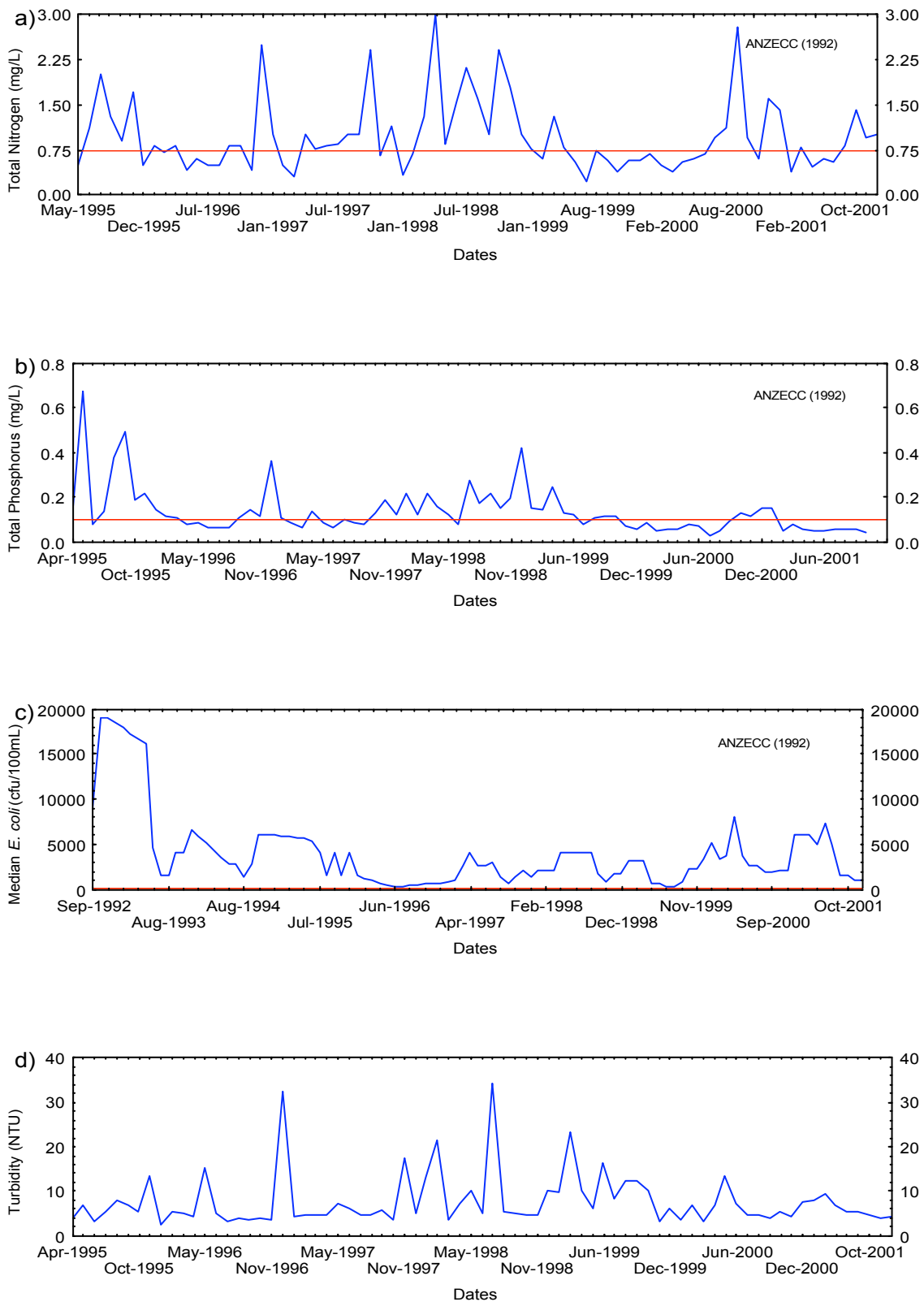
## **TURBIDITY**

Turbidity generally remained below 10ntu at all sites over the monitoring period (Figure 3.13.2i). Turbidity varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher turbidity recorded at NGN 4 than at all other sites.

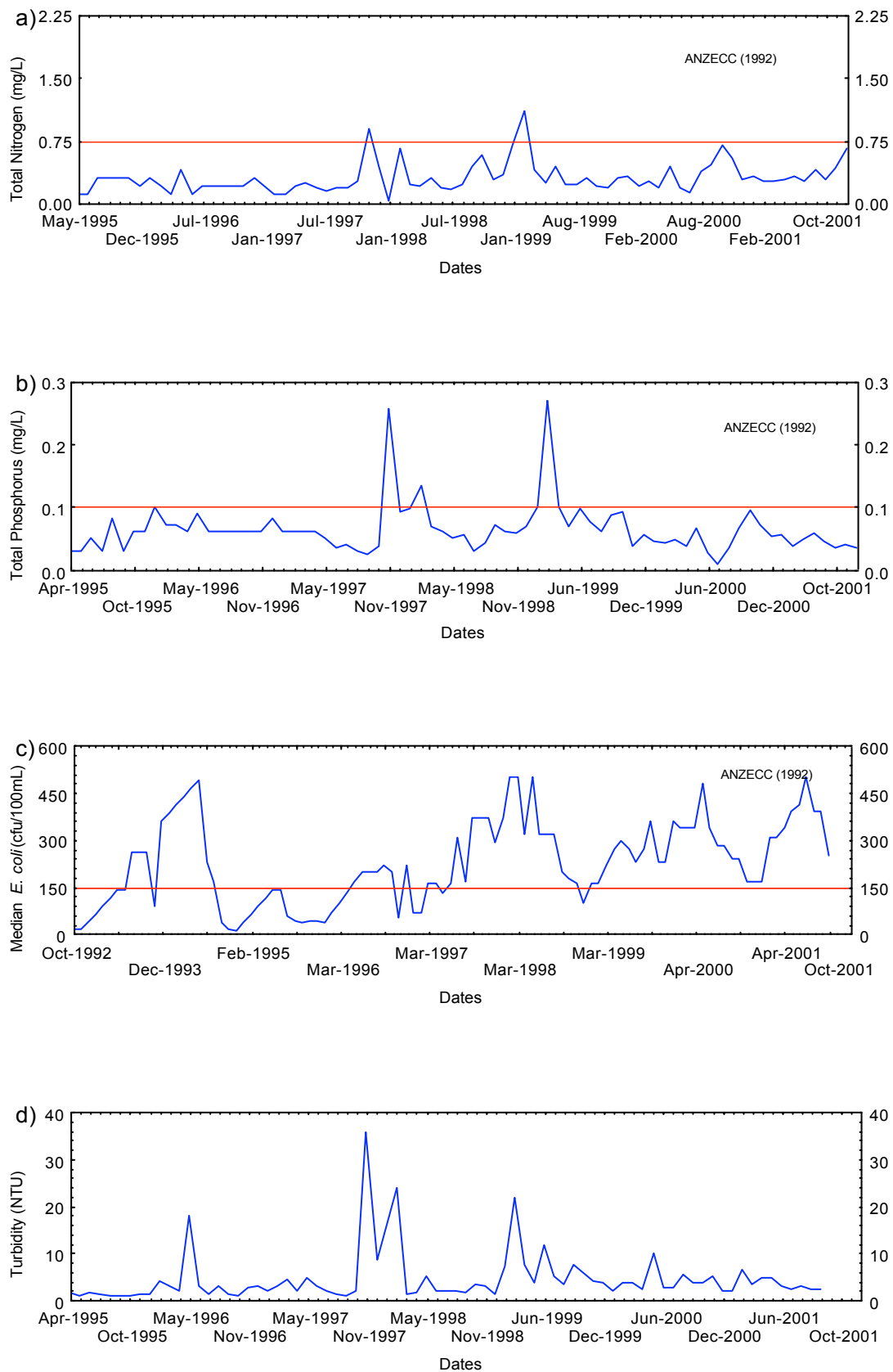
### **3.13.3 WATER QUALITY TRENDS**

Nutrients and *E. coli* concentrations recorded at NGN 4 regularly exceeded the ANZECC (1992) guidelines (Figure 3.13.3). Nutrient concentrations following June 1997 consistently exceeded the guidelines, however, reduced below the guidelines following July 1999. Concentrations increased again above the guidelines following August 2000. Median *E. coli* concentrations frequently exceeded the guidelines for primary contact recreational waters during the initial years of monitoring and while concentrations have improved following this initial period, concentrations still remain above the guidelines. Turbidity at this site has fluctuated over the monitoring period. Several peaks have been recorded up to 35ntu, which are probably related to rainfall.

Nutrient concentrations recorded at NGN 6 regularly complied with the guidelines over the monitoring period. Several peaks above the guidelines in nutrient concentrations have been recorded during November 1997 and February 1999. Median *E. coli* concentrations generally remained above the primary contact recreational guidelines, particularly after March 1997. Turbidity has fluctuated over the monitoring period, with several peaks consistent with both nutrient parameters. These peaks are probably related to rain.



**Figure 3.13.3** Trends in (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at NGN 4 to assess changes in water quality over the monitoring period.



**Figure 3.13.4** Trends in (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at NGN 6 to assess changes in water quality over the monitoring period.

### 3.13.4 DISCUSSION

Water quality conditions in Numinbah Valley generally complied with the ANZECC (1992) guidelines. Minimal land use changes, associated with rural development and a small number of cattle farms within this area of the Nerang River catchment, is probably significant in order for this area to continue maintaining water quality conditions suitable for the protection of aquatic ecosystems.

Nutrient and *E. coli* concentrations recorded at NGN 4 regularly exceeded the guidelines and was found to be significantly poorer for most water quality parameters in comparison with all other sites. Importantly, *E. coli* concentrations have improved following the initial years of monitoring, despite concentrations still regularly exceeding the primary contact recreational guidelines. Nutrient concentrations have fluctuated over the monitoring period at this site, with concentrations regularly exceeding the guidelines. This poorer water quality appears not to be related to rain events (as shown with consistent peaks amongst other sites) and as such, probably indicates a point source of pollution within this section of the catchment. This area will require further investigation.

Water quality at sites within lower Numinbah Valley have generally complied with the guidelines, however, NGN 6 has shown a general increase in *E. coli* concentrations following March 1997. The high *E. coli* concentrations recorded at this site cannot be simply explained and needs to be investigated in more detail.

Turbidity recorded within the upper Nerang River catchment has generally remained below 10ntu at all sites. This is somewhat less varied than turbidity experienced in the lower Nerang River. This distinction is probably associated with differences in land use (*ie* rural compared to urban development). It is therefore important that monitoring and assessment of the upper Nerang River continues in the future to assist with maintaining good water quality conditions, particularly as this area provides the main source of water supply for Gold Coast City.

### 3.13.5 CONCLUSIONS AND RECOMMENDATIONS

The protection and management of this region of the Nerang River catchment is important to ensure the supply of good water to Hinze Dam. Gold Coast Water has prepared a catchment management plan for this region of the Nerang River catchment. This management plan aims to ensure the long-term protection of Numinbah Valley, through the development and implementation of land use, water and riverine management strategies. A Landcare community group exists within this area of the Nerang catchment that has implemented various environmental programs (*eg.* Camphor laurel (*Cinnamomum camphora*) eradication program).

### 3.14 NERANG RIVER - SPRINGBROOK PLATEAU

#### 3.14.1 INTRODUCTION

The Springbrook Plateau rises from the coastal townships of Mudgeeraba and Nerang to approximately 1,000m above sea level in the southern region of the plateau. Runoff from the plateau flows via several small tributaries (Table 3.14.1) and over the Springbrook eastern escarpment via several waterfalls, which form the eastern and western arm of Little Nerang Creek, which then flow into Little Nerang Dam (Figure 3.14.1).

Annual rainfall across the Springbrook Plateau is strongly influenced by the elevation of this area. This area regularly records the highest rainfall in south-east Queensland averaging approximately 3,060mm of rain per year (GCCC, 1997). The lower region of this plateau receives less rainfall averaging approximately 1,600mm per year (GCCC, 1997).

Land use practices within this region consist primarily of small farms and guesthouse accommodation towards the middle to upper plateau region. The middle to lower plateau region has been developed as part of the Springbrook village. This area consists of residential housing, tourist facilities, guesthouses and a horticulture venture.

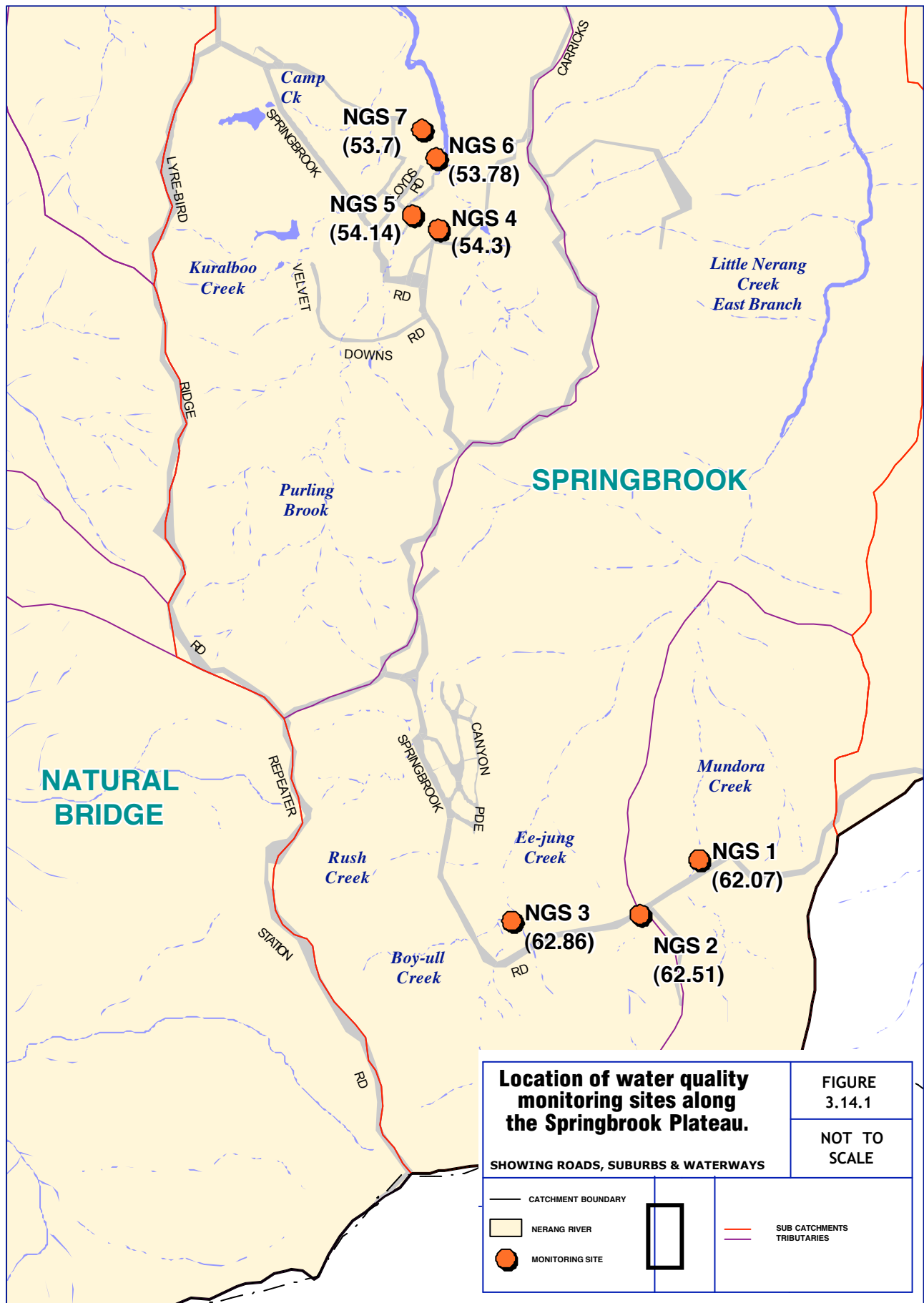
The upper region of the plateau is predominantly National Park and is relatively undisturbed by human impact, with large areas of native subtropical rainforest species (GCCC, 1996).

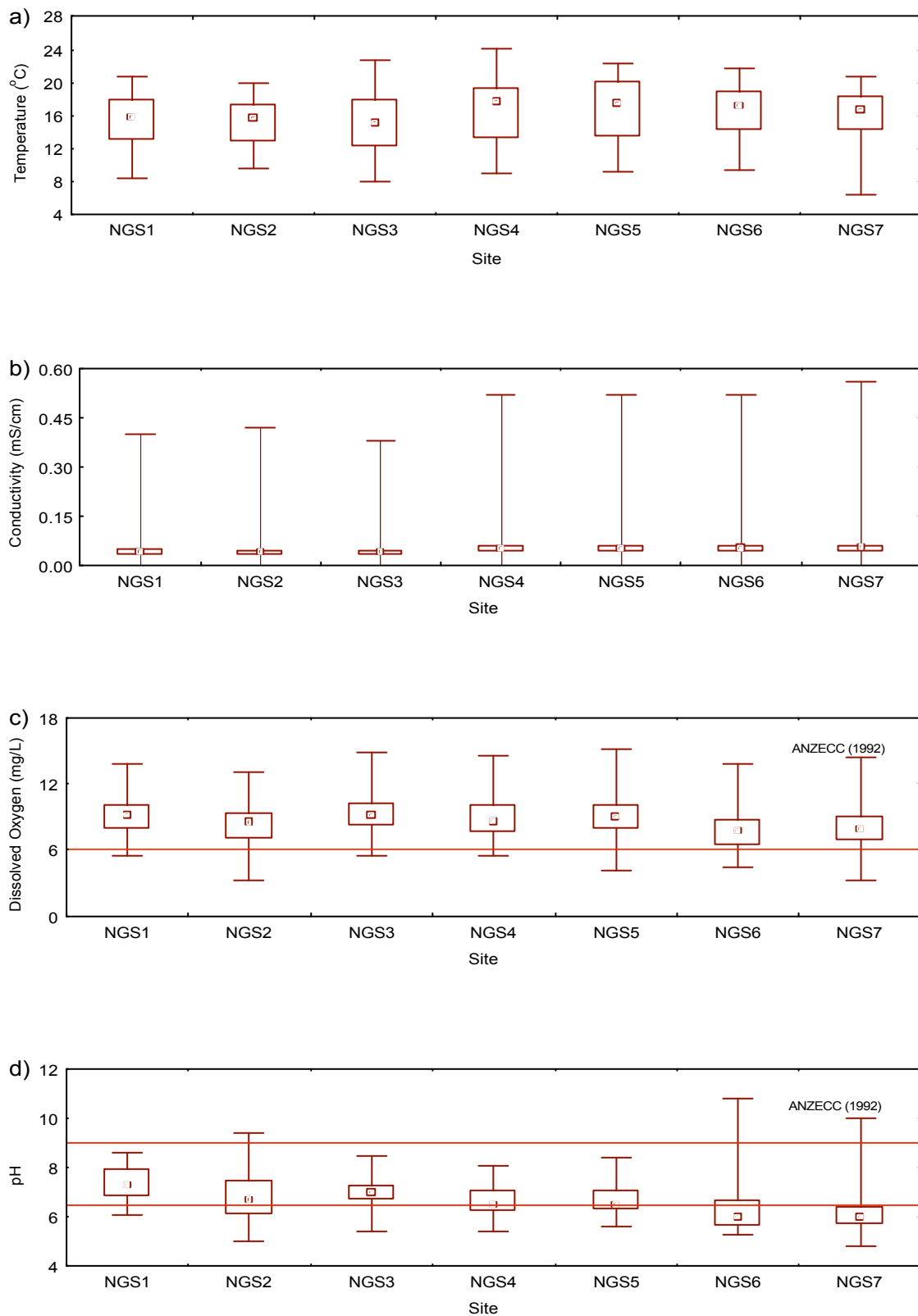
Table 3.14.1 Water quality site codes and distance details for each monitoring site.

Creek Name	Distance #km	Site
Mundora Creek	62.07	NGS 1
EE Jung Creek	62.51	NGS 2
Boy-Ull Creek	62.86	NGS 3
Carrick Creek	54.30	NGS 4
Purlingbrook Creek	54.14	NGS 5
Kuralboo Creek	53.78	NGS 6
Camp Creek	53.70	NGS 7

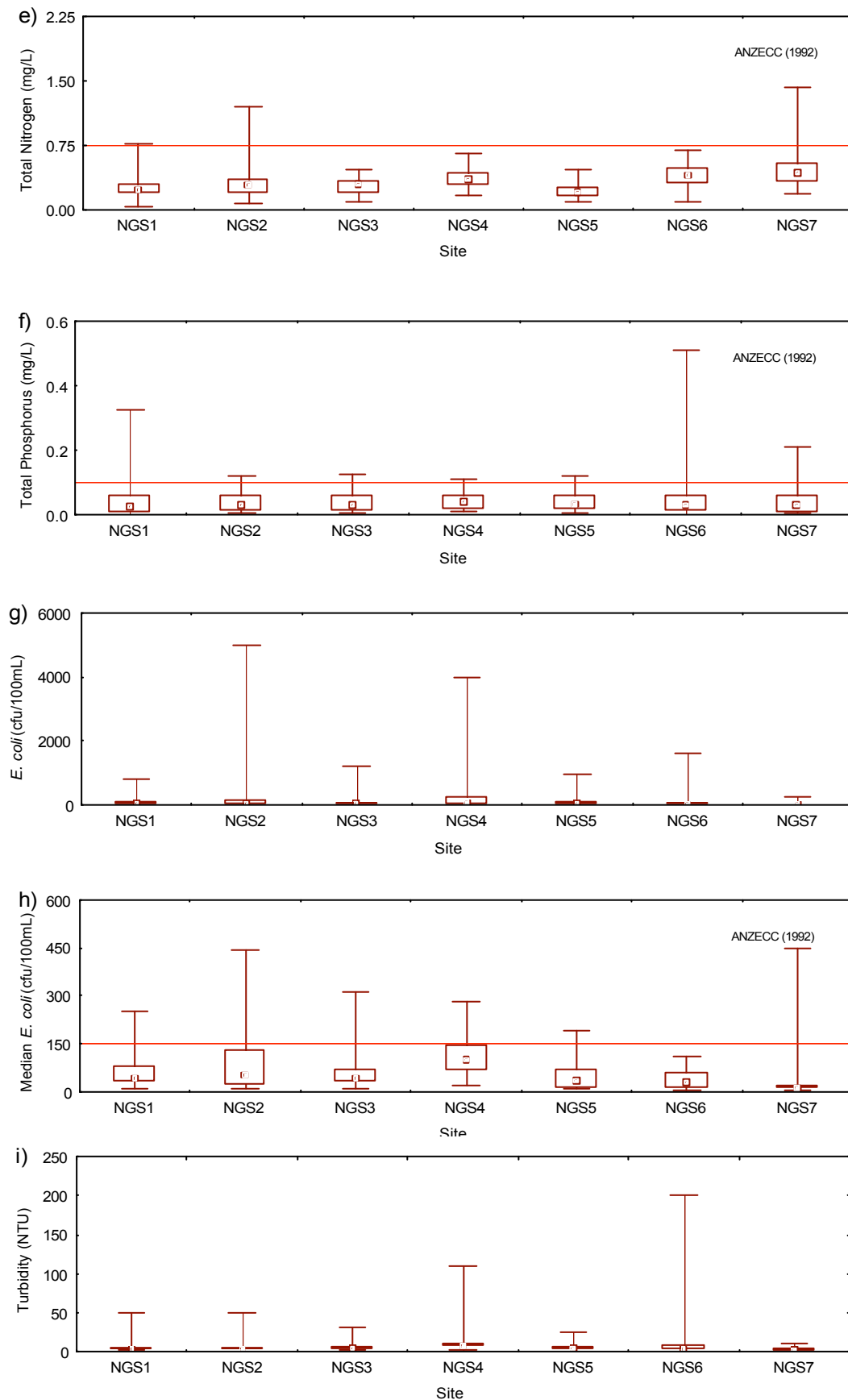
# Measured as distance in kilometres from the Nerang River mouth (Gold Coast Highway bridge, Southport)







**Figure 3.13.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen and (d) pH recorded at sites in the Nerang River (Springbrook). ANZECC (1992) compliance guidelines for the protection of aquatic ecosystems have been included for dissolved oxygen and pH.



**Figure 3.14.2 (cont)** (e) total nitrogen, (f) total phosphorus, (g) raw data for *E. coli* concentrations, (h) rolling median *E. coli* concentrations and (i) turbidity recorded at each site within the Nerang River (Springbrook). ANZECC (1992) compliance guidelines for both nutrients have been included for comparison with the protection of aquatic ecosystems. Recreational guidelines for primary contact waters have been included for comparison with median *E. coli* concentrations.

### 3.14.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Water temperatures at sites on the Springbrook Plateau have ranged between 6°C and 23°C over the monitoring period (Figure 3.14.2a). This range in water temperature could be influenced by seasonal conditions, depth, flow rates, time of day when measurements were taken or the presence and density/nature of riparian vegetation. Water temperatures varied significantly amongst sites (KW :  $p < 0.01$ ), with significantly higher water temperatures at NGS 5 than at NGS 1 - NGS 3. Significantly lower water temperatures were recorded at NGS 2 and NGS 3 than at NGS 4 and NGS 6.

#### CONDUCTIVITY

Conductivity ranged between 0.001mS/cm and 0.024mS/cm for all sites over the monitoring period within this region of the Nerang River (Figure 3.14.2b). Conductivity varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher conductivity at NGS 7 than at NGS 1 - NGS 3. Significantly higher conductivity conditions have been recorded at NGS 4 - NGS 6 with NGS 1 - NGS 3.

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.14.2c). Several monitoring sites recorded concentrations below 4mg/L. Dissolved oxygen concentrations varied significantly amongst monitoring sites (KW :  $p < 0.001$ ), with significantly lower concentrations at NGS 6 and NGS 7 than at NGS 1 and NGS 3 - NGS 5. Site NGS 3 recorded significantly higher dissolved oxygen than at NGS 2. This variation in dissolved oxygen concentrations could be associated with the location of sites to nearby stream rapids.

#### pH

pH generally complied with the ANZECC (1992) guidelines (Figure 3.14.2d), except at NGS 6 and NGS 7 where the median value did not comply with the lower pH guidelines. All monitoring sites recorded pH below the lower guidelines. NGS 6 - NGS 7 recorded values above the upper limit over the monitoring period. pH varied significantly amongst sites (KW :  $p < 0.001$ ), with sites NGS 6 and NGS 7 recording significantly lower pH than at all other sites and intermediate values at NGS 2, NGS 4 and NGS 5.

Surveys of the soils within the elevated plateau region of Tamborine, Beechmont and Springbrook, found the presence of highly fertile red volcanic soils (Krasnozems derived from the basalt of the Tweed volcano), which are described as acidic (pH 4.5) (GCCC, 1997). The presence of acidic soils may explain reductions in pH recorded at each site across the plateau.

#### TOTAL NITROGEN

Total nitrogen regularly complied with the ANZECC (1992) guidelines (Figure 3.14.2e). Sites NGS 1, NGS 2 and NGS 7 recorded concentrations above the guidelines over the monitoring period. Total nitrogen concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at NGS 4 - NGS 7 than at NGS 1 - NGS 3. Significantly lower total nitrogen concentrations were recorded at NGS 5 than at NGS 4, NGS 6 and NGS 7.

#### TOTAL PHOSPHORUS

Total phosphorus regularly complied with the ANZECC (1992) guidelines (Figure 3.14.2f). Elevated concentrations have been recorded at all monitoring sites above the guidelines. Concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at NGS 4 than at NGS 1 and NGS 2. Site NGS 5 recorded significantly higher concentrations than NGS 1.

### ***E. COLI***

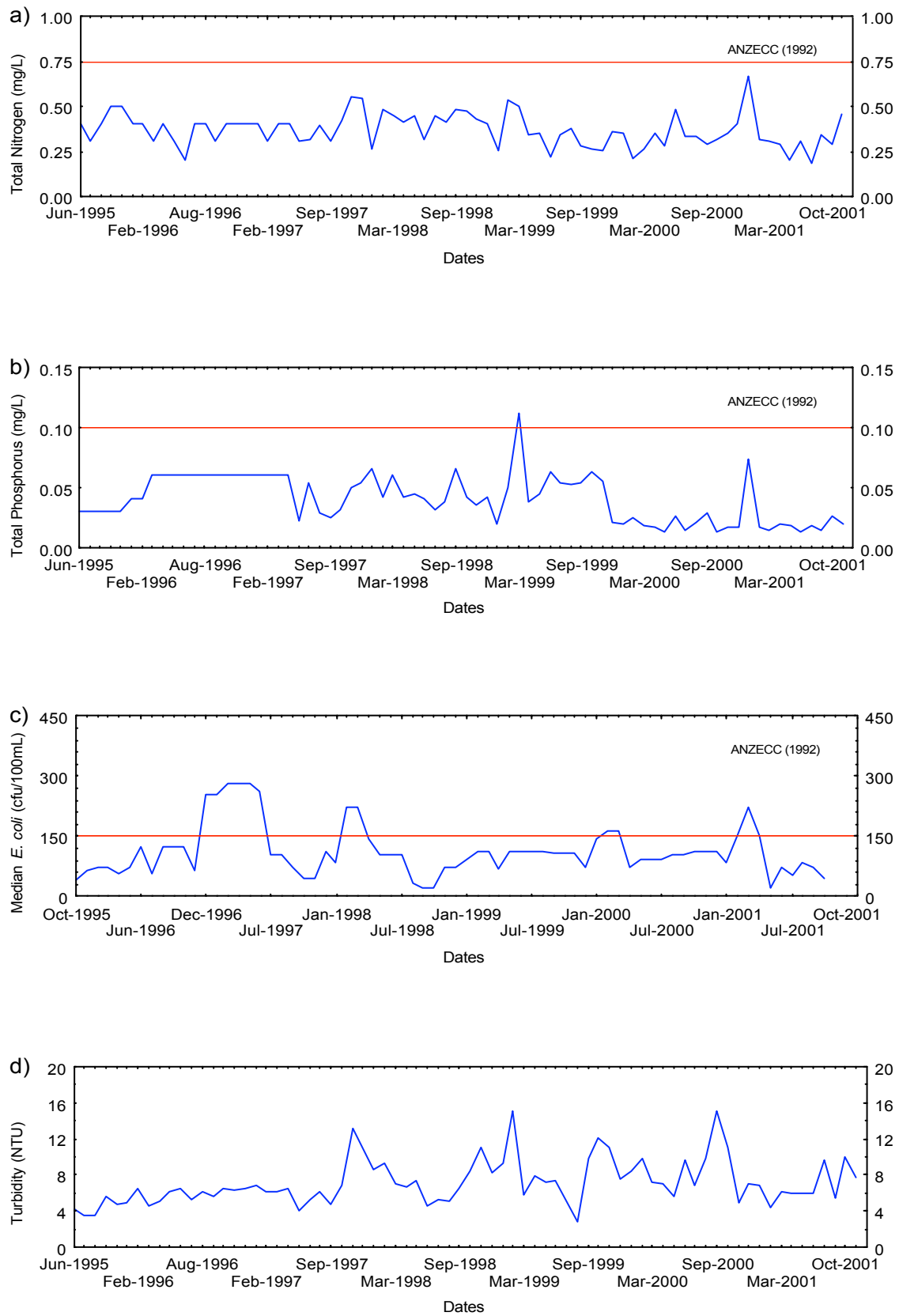
*E. coli* concentrations, calculated as a rolling median, regularly complied with the ANZECC (1992) guidelines for primary contact recreational waters (Figure 3.14.2h). Concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at NGS 4 than at all other monitoring sites. Significantly lower concentrations were recorded at NGS 7 than at all other sites, with intermediate concentrations recorded at NGS 1 - NGS 3 and NGS 5 and NGS 6. Along with the higher *E. coli* concentrations, elevated nutrient parameters were also found at NGS 4. This trend could possibly be related to land use practices, however, conditions appear to generally comply with the ANZECC (1992) guidelines.

### ***TURBIDITY***

Turbidity varied significantly amongst sites (KW :  $p < 0.001$ ) (Figure 3.14.2i), with significantly higher turbidity at NGS 4 than at all other monitoring sites. This trend was found in both nutrient parameters and *E. coli* concentrations. Site NGS 7 recorded significantly lower concentrations than NGS 2, NGS 3, NGS 5 and NGS 6.

### **3.14.3 WATER QUALITY TRENDS**

Water quality trends recorded at Carrick Creek (NGS 4) (Figure 3.14.4) have generally not declined or improved over the monitoring period despite being generally significantly higher for nutrient, *E. coli* and turbidity conditions in comparison to all other sites. Both nutrient parameters regularly complied with the ANZECC (1992) guidelines, excluding March 1999, where a small peak in total phosphorus concentrations above the guidelines was recorded. *E. coli* concentrations regularly complied with the ANZECC (1992) primary contact recreational guidelines, excluding the period between December 1996 and May 1997, where the median concentration exceeded the guidelines. Turbidity has generally remained below 10ntu over the monitoring period.



**Figure 3.14.3** Trends in (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at NGS 4 to assess changes in water quality over the monitoring period.

#### 3.14.4 DISCUSSION

Water quality conditions within the small tributaries on the Springbrook plateau, that flow into Little Nerang Dam, have regularly complied with the ANZECC (1992) guidelines for the protection of aquatic ecosystems and primary contact recreation. It was found that for all sites, the 80<sup>th</sup> percentile for both nutrient parameters and median *E. coli* concentrations, complied with each corresponding guidelines. This would indicate that current land use activities are not adversely impacting on the health and quality of these streams across the plateau.

Water quality conditions appear to not have generally declined over the monitoring, which demonstrates the importance of managing land use activities. Regular monitoring and assessment should continue within this region of the Nerang River catchment to ensure that good water quality conditions are maintained in the future, particularly as this area provides a source of water supply for the City.

#### 3.14.5 CONCLUSIONS AND RECOMMENDATIONS

The protection and management of this region of the Nerang River catchment is important to ensure the supply of good water to Little Nerang Dam and Hinze Dam. Gold Coast Water has prepared a catchment management plan for this region of the Nerang River catchment. This management plan aims to ensure the long-term protection of Springbrook Plateau, through the development and implementation of land use, water and riverine management strategies. A Landcare community group exists within this region of the Nerang catchment that has implemented various environmental programs to rehabilitate riparian areas.

### 3.15 PIMPAMA RIVER

#### 3.15.1 INTRODUCTION

The headwaters of the Pimpama River are located along the eastern edge of the Darlington Ranges. The surrounding foothills within the upper catchment area contain a variety of small farms and rural residential areas. Runoff from the upper catchment funnels into the mainstream course and flows under the Pacific Highway and onto the floodplain area near the township of Pimpama. This system then meanders through the lower floodplain region, which has been modified for a variety of farming practices, particularly sugarcane production. Within the lower region of this catchment the river joins with Hotham Creek, before discharging into southern Moreton Bay approximately 29.3km downstream from its headwaters (Figure 3.15.1).

The upper catchment is primarily rural with a mixture of small farming activities. Land clearing for agricultural purposes has increased catchment erosion and allowed for the invasion of the environmental weed Camphor laurel (*Cinnamomum camphora*). This weed can invade and smother native trees along waterways, degrade soils used for agricultural production and destroy structures (Department of Natural Resources, 2000). Small areas containing native plant species still remain within the upper catchment, however, rural development has placed pressure on these remanent vegetation pockets.

The tidal limit of this system is located at a barrage, approximately 4 km upstream from its confluence with southern Moreton Bay. This structure prevents saltwater movement upstream, where the river has been used as a source of water for farming. The lower course of the Pimpama River has been identified as being impacted by acid sulfate soils. Local land use activities have led to acid production and the leaching of dissolved metals into the lower region of this system (Preda & Cox, 1999).

Table 3.15.1 Site classifications and distance details for each monitoring site.

Region/Site Type	Distance <sup>#</sup> (km)	Site
Upper Freshwater	31.48	PMR 1
	27.45	PMR 2 ( <i>Discontinued</i> )
Upper Freshwater	26.38	PMR 3
	21.78	PMR 4
Discontinued (1996)	19.20	PMR 5
	14.33	PMR 6

<sup>#</sup> Measured as distance in kilometres from the mouth



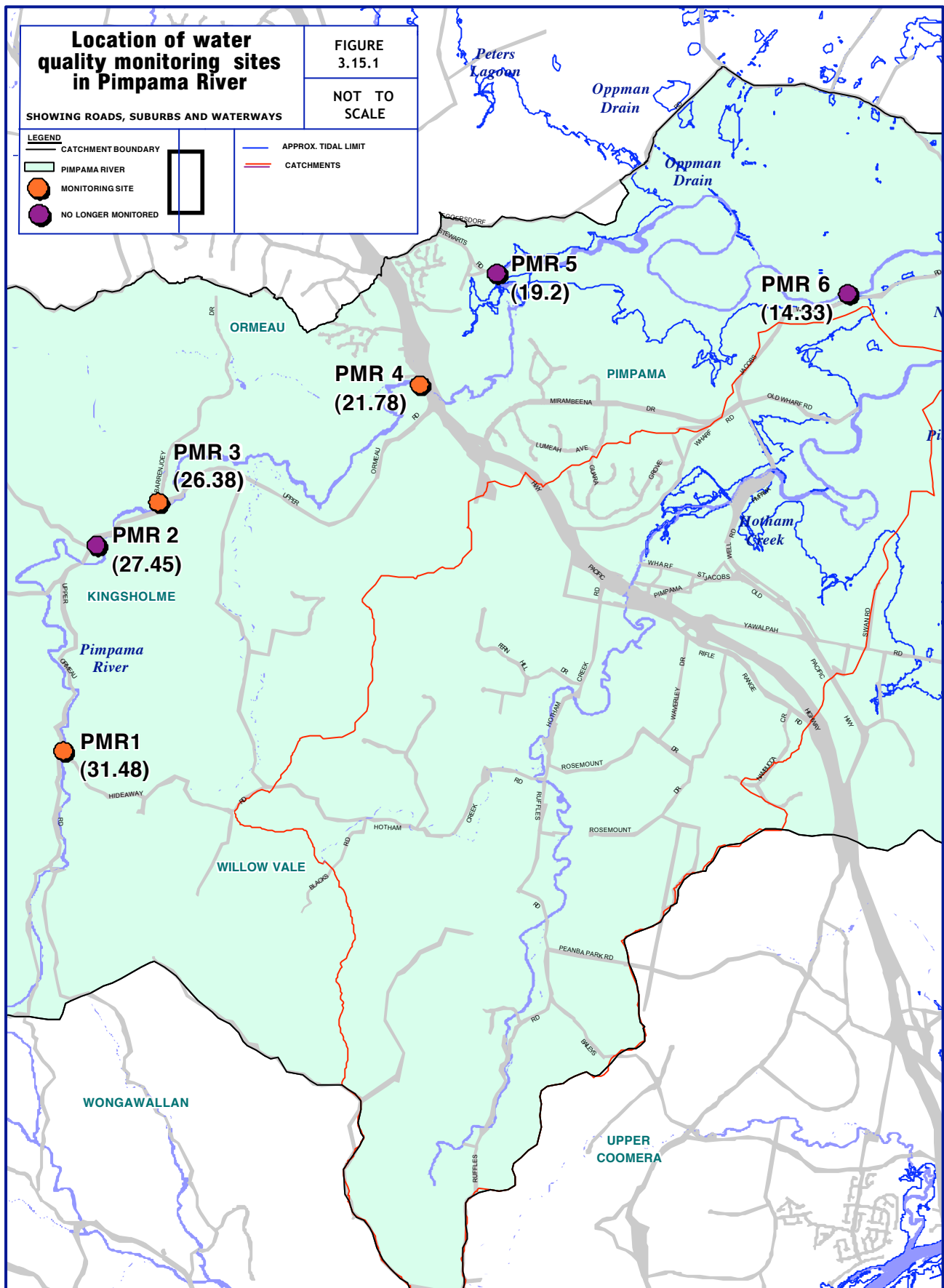
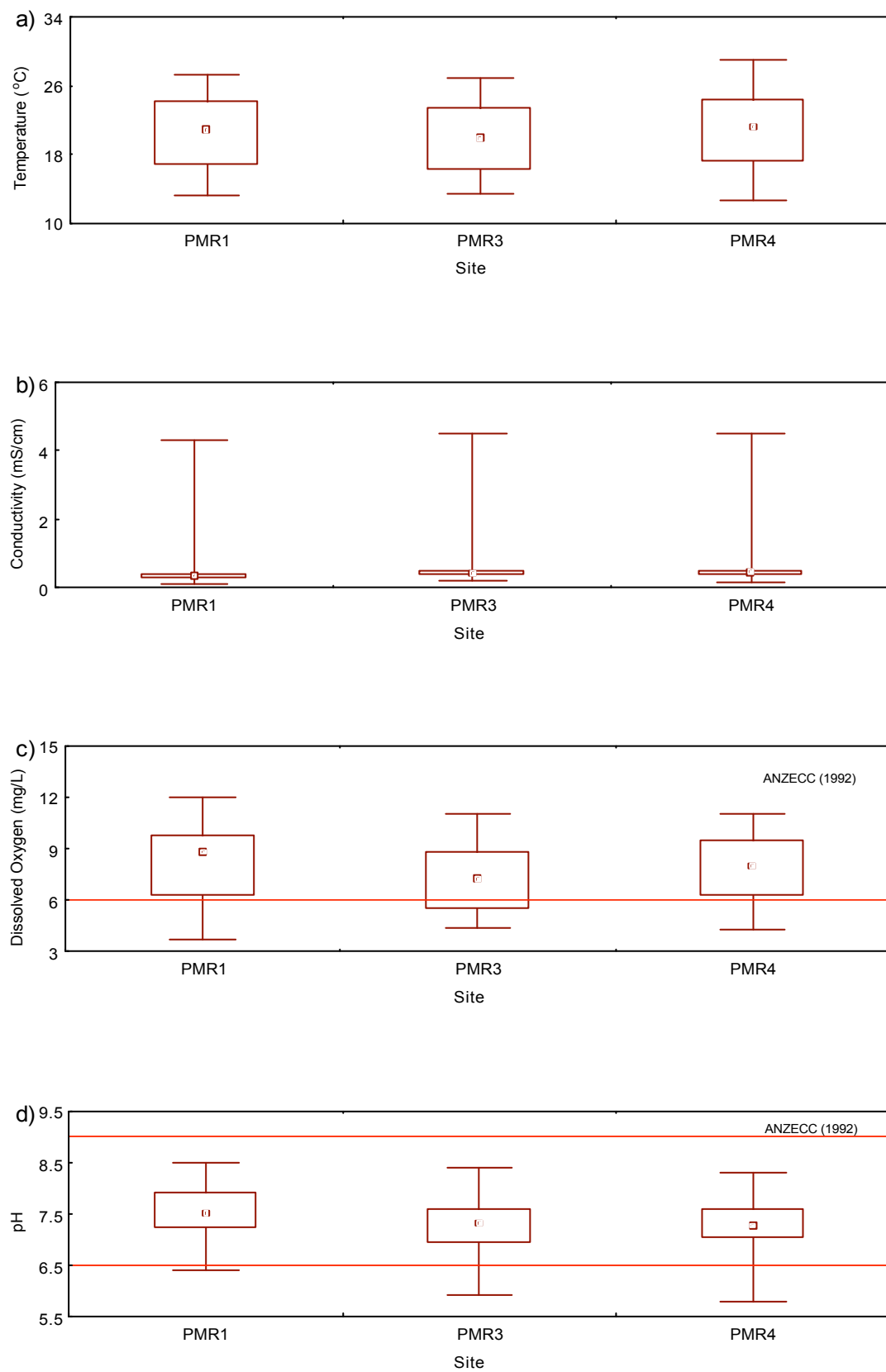
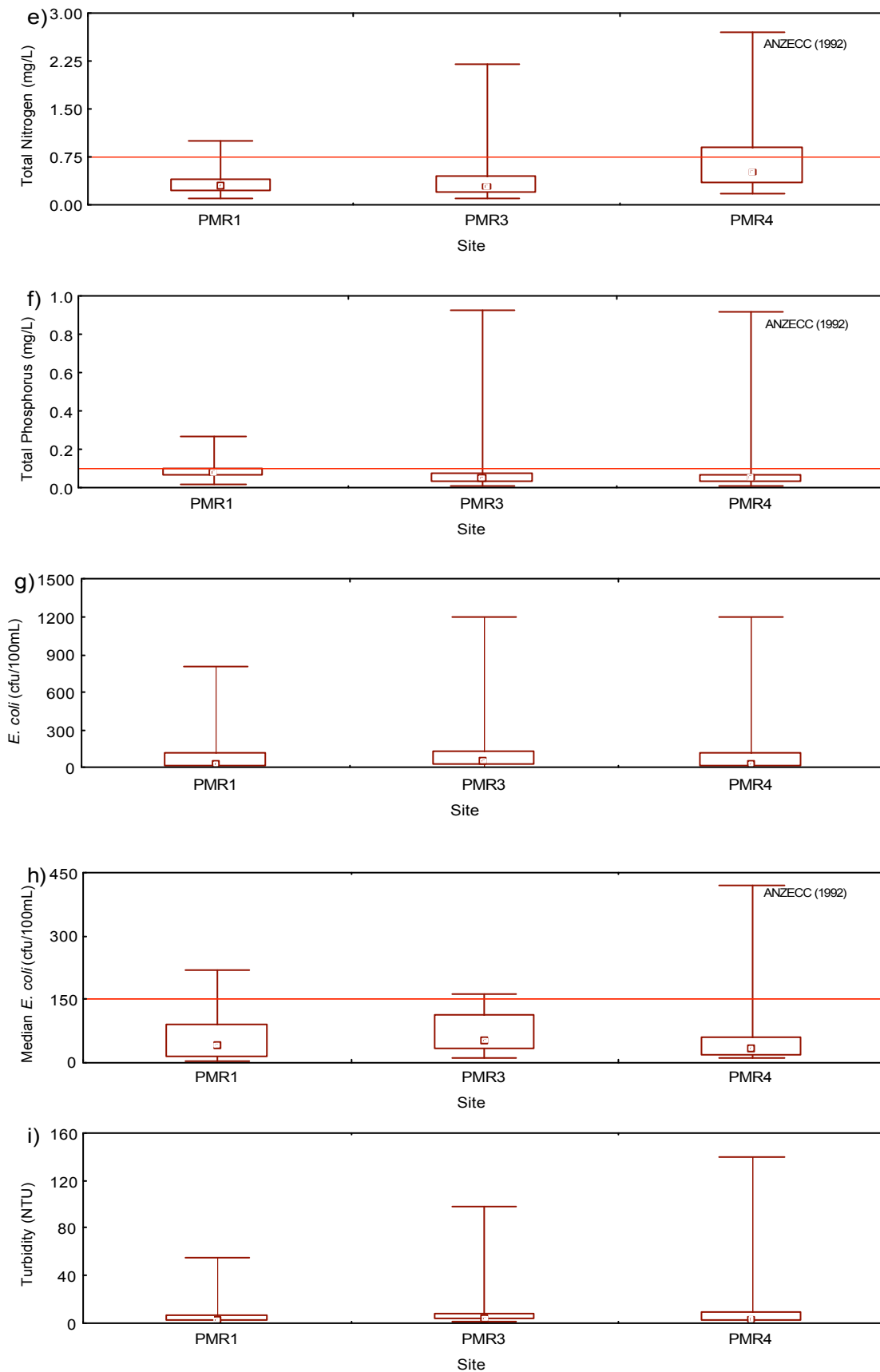


Figure 3.15.1 Water quality monitoring sites located in Pimpama River.



**Figure 3.15.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen, and (d) pH recorded at each site in Pimpama River. ANZECC (1992) compliance guidelines for the protection of aquatic ecosystems have been included for dissolved oxygen and pH.



**Figure 3.15.2 (cont)** (e) total nitrogen, (f) total phosphorus, (g) raw data for *E. coli* concentrations, (h) rolling median *E. coli* and (i) turbidity recorded at each site in Pimpama River. ANZECC (1992) compliance guidelines for both nutrient parameters have been included for the protection of aquatic ecosystems. Recreational guidelines for primary contact waters have been included for comparison with median *E. coli* concentrations.

### 3.15.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Water temperatures ranged between 12°C - 31°C for all sites combined over the monitoring period (Figure 3.15.2a). This range in water temperature could be influenced by seasonal conditions, depth, flow rates, time of day when measurements were taken or the presence and density/nature of riparian vegetation. Water temperatures were not significantly different amongst sites (KW :  $p = 0.41$ ).

#### CONDUCTIVITY

Conductivity ranged between 0.12mS/cm and 4.5mS/cm for all sites combined over the monitoring period (Figure 3.15.2b). Conductivity varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly lower conductivity recorded at PMR 1 than at PMR 3 and PMR 4.

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.15.2c). Reductions in concentrations below 6mg/L were recorded at each site, which was particularly evident at PMR 3. Dissolved oxygen concentrations varied significantly amongst sites (KW :  $p < 0.04$ ), with significantly higher concentrations recorded at PMR 1 than at PMR 3, with intermediate concentrations recorded at PMR 4.

#### pH

pH regularly complied with the ANZECC (1992) guidelines, despite reductions below 6.0 recorded at each site (Figure 3.15.2d). pH varied significantly amongst sites (KW :  $p < 0.002$ ), with significantly higher pH recorded at PMR 1 than at PMR 3 and PMR 4.

#### TOTAL NITROGEN

Total nitrogen concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.15.2e). All sites recorded concentrations above the guidelines, with the 80<sup>th</sup> percentile at PMR 4 exceeding the guidelines. Concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations recorded at PMR 4 than at PMR 1 and PMR 3.

#### TOTAL PHOSPHORUS

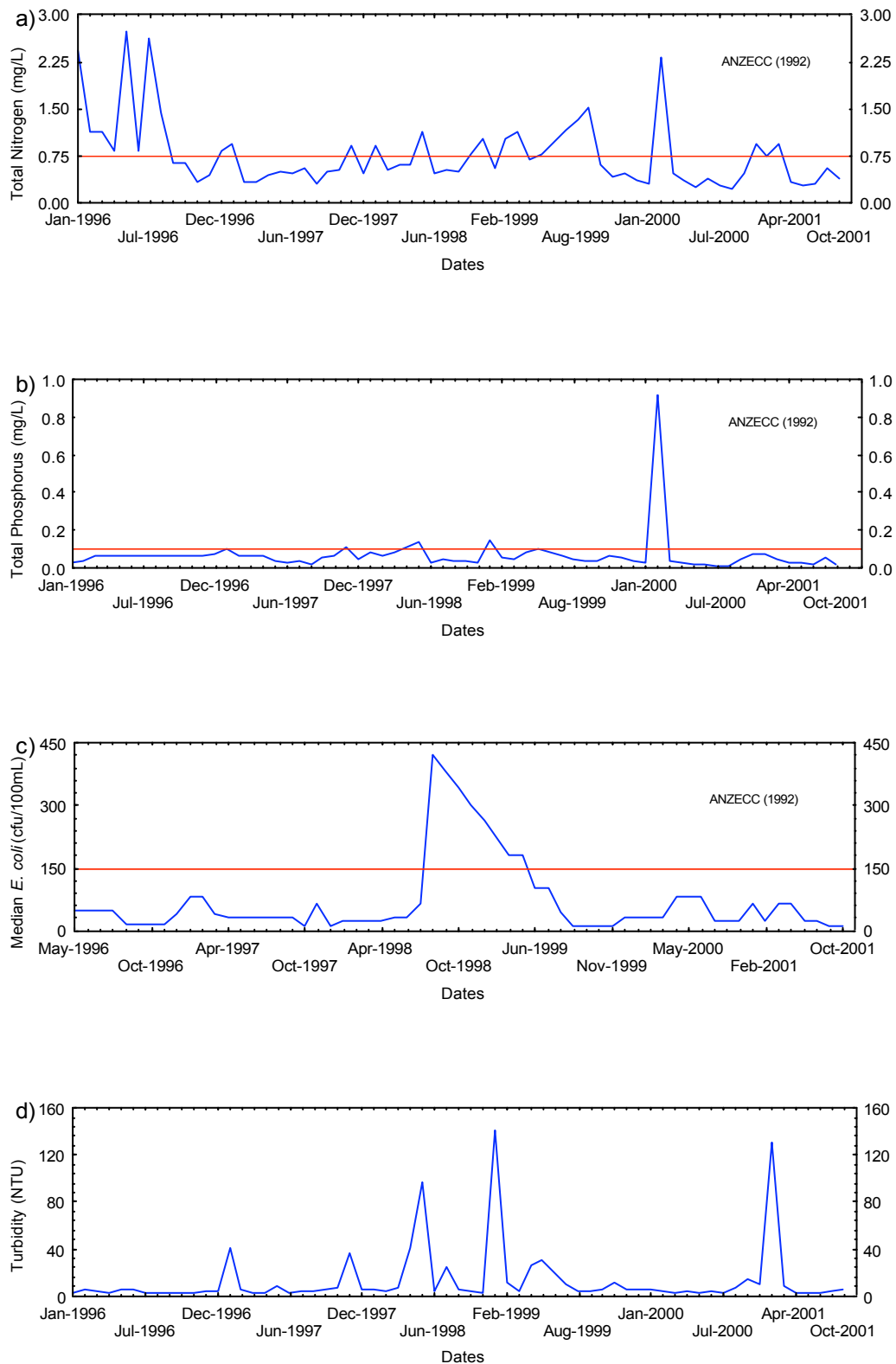
Total phosphorus concentrations regularly complied with the ANZECC (1992) guidelines (Figure 3.15.2f). All sites recorded concentrations above the guidelines. Concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at PMR 1 than at PMR 3 and PMR 4. This apparent improvement in total phosphorus concentrations moving downstream was not similar to trends in total nitrogen concentrations. This trend is unusual in comparison to other catchments and the reasons for this trend is unclear.

#### E. COLI

*E. coli* concentrations, calculated as a rolling median, regularly complied with the ANZECC (1992) guidelines for primary contact recreational waters (Figure 3.15.2h). All sites recorded concentrations above the primary contact recreational guidelines. *E. coli* concentrations varied significantly amongst sites (KW :  $p < 0.004$ ), with significantly higher concentrations at PMR 3 than at PMR 1 and PMR 4.

#### TURBIDITY

Turbidity combined for all sites ranged between 1ntu and 140ntu over the monitoring period (Figure 3.15.2i). Turbidity varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher turbidity at PMR 3 than at PMR 1 and intermediate conditions recorded at PMR 4.



**Figure 3.15.3** Trends in (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at site PMR 4 to assess changes in water quality over the monitoring period.

### 3.15.3 WATER QUALITY TRENDS

Trends in water quality recorded at PMR 4 (Figure 3.15.3) have indicated that each water quality parameter has fluctuated over the monitoring period. These fluctuations are probably related to rainfall and were particularly evident with peaks between April 1998 and March 2000 for both nutrient parameters and turbidity. Total nitrogen concentrations appear to have improved following September 1996. Total phosphorus has also shown no distinct trend in concentrations over the monitoring period.

*E. coli* concentrations generally remained below the primary contact recreational guidelines, excluding the period between September 1998 and May 1999 where concentrations exceeded the guidelines. Turbidity generally remained stable over the monitoring period. Turbidity peaks were consistent with peaks in both nutrient parameters. These peaks in turbidity are therefore likely to be related to rainfall.

### 3.15.4 DISCUSSION

Water quality in the upper catchment area of Pimpama River has generally complied with the ANZECC (1992) guidelines, despite elevated nutrients, turbidity and *E. coli* concentrations recorded on occasions at each site. Peaks in nutrient, turbidity and *E. coli* concentrations are probably related to rainfall events and possibly associated with the loss of catchment vegetation associated with changing land use. Importantly, water quality does not appear to have declined at sites monitored within the upper catchment. Changes in land use associated with farming practices and further rural development however, may result in a future decline of water quality if not managed appropriately.

Water quality in the lower catchment (PMR 5 and PMR 6) occurred between January and December 1996, however, was discontinued following December 1996. This occurred due to the implementation of a water quality program as part of the Logan, Coomera South Moreton Bay Regional Wastewater Management study (see Fearon and Semple, 2001).

### 3.15.5 CONCLUSIONS AND RECOMMENDATIONS

The water quality conditions in the Pimpama River were generally good in comparison with standards for the protection of aquatic ecosystems. The potential impact on water quality in the Pimpama River exists, with proposed rural residential development in areas within the middle to upper catchment. Further, land use disturbances associated with farming activities and residential development in the lower catchment could also impact on the health and quality of Pimpama River, particularly with the oxidation of acid sulfate soils.

The management of catchment runoff through the implementation of best land use management practices for those farming activities in the upper catchment, in conjunction with the management of water harvesting and environmental flows, is considered necessary to ensure that water quality conditions and EVs for this waterway are maintained. GCCC plan to implement a catchment management study for this catchment, in conjunction with Hotham Creek catchment, in the coming years. This study will identify the EVs considered important to the local community. This information will then be used to design a land use specific stormwater management plan to assist in protecting the values of Pimpama River. A community Landcare group in Pimpama River has implemented several rehabilitation projects in riparian areas along the creek. The group has also implemented various educational programs/workshops for local farmers on the various best land use management practices available.

### 3.16 ROBINA LAKES SYSTEM

#### 3.16.1 INTRODUCTION

The Robina Lakes (comprising Robina West and South Lake) are a freshwater lake system, which receive stormwater runoff from the surrounding catchment of approximately 3km<sup>2</sup>. This system is situated within an area that originally formed part of an extensive wetland/floodplain area that existed between the Nerang River and Tallebudgera Creek. The Robina Lakes are linked to Clear Island Waters, which has three tidal weir systems located at Lake Intrepid, Lake Wonderland and Boobegan Creek. These weirs prevent seawater tidal intrusion into Clear Island Waters and the Robina Lakes from the Nerang River (Figure 3.16.1).

The Robina Lakes support a diverse range of native aquatic plants, fish species, crustaceans and bird species. The lake also provides an important visual and recreational amenity for the local community and residents that front the lake (WBM Oceanics Australia, 1998).

The input of nutrient material, associated with urban runoff over time, has led to increased algal and aquatic plant growth within Robina Lakes (WBM Oceanics Australia, 1998). Increased algal production within a waterway, has been shown to have deleterious impacts on aquatic communities, including reductions in dissolved oxygen concentrations during night periods, increased pH and health implications depending on the species of algae (Wetzel, 1983).

The management of Robina Lakes is an intricate and complex process that involves understanding a number of factors including water quality, hydrology, plant and animal communities and maintenance required to ensure a balanced ecology within these lakes.

The two lakes are categorised based on their geographical location in Table 3.16.1. Measurements at the surface and at 0.5m intervals (profile) are recorded for water temperature, conductivity, pH and dissolved oxygen concentrations at each monitoring site. A composite surface water sample is collected from the five sites in Robina South Lake, while a single water sample is collected at RWL 3 for nutrient, turbidity and *E. coli* concentrations for analysis.

Table 3.16.1 Water quality monitoring codes for Robina Lakes.

Region	Site (Code)
Robina South Lake (Manly Drive)	MDL
Robina West Lake	RWL

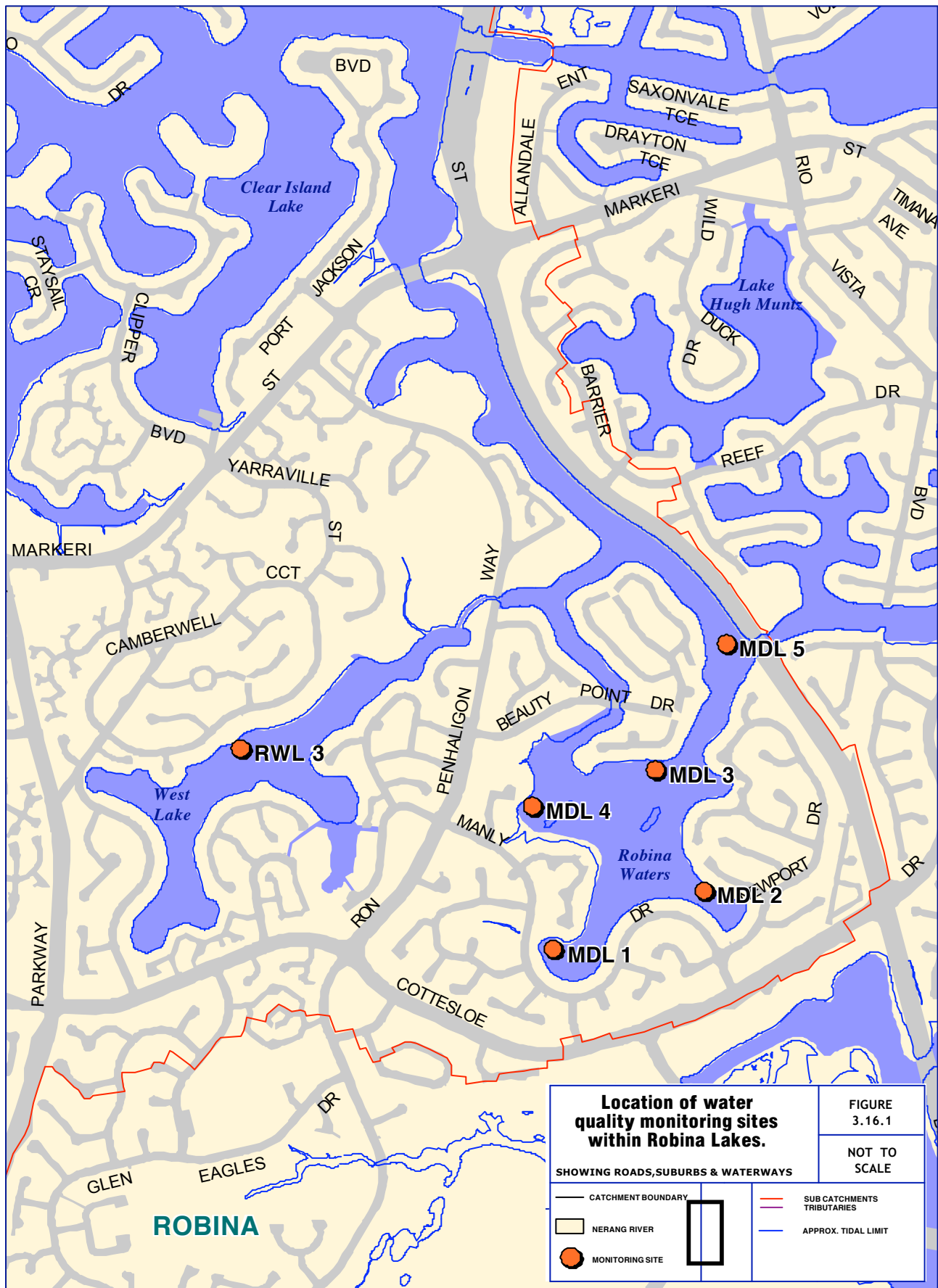
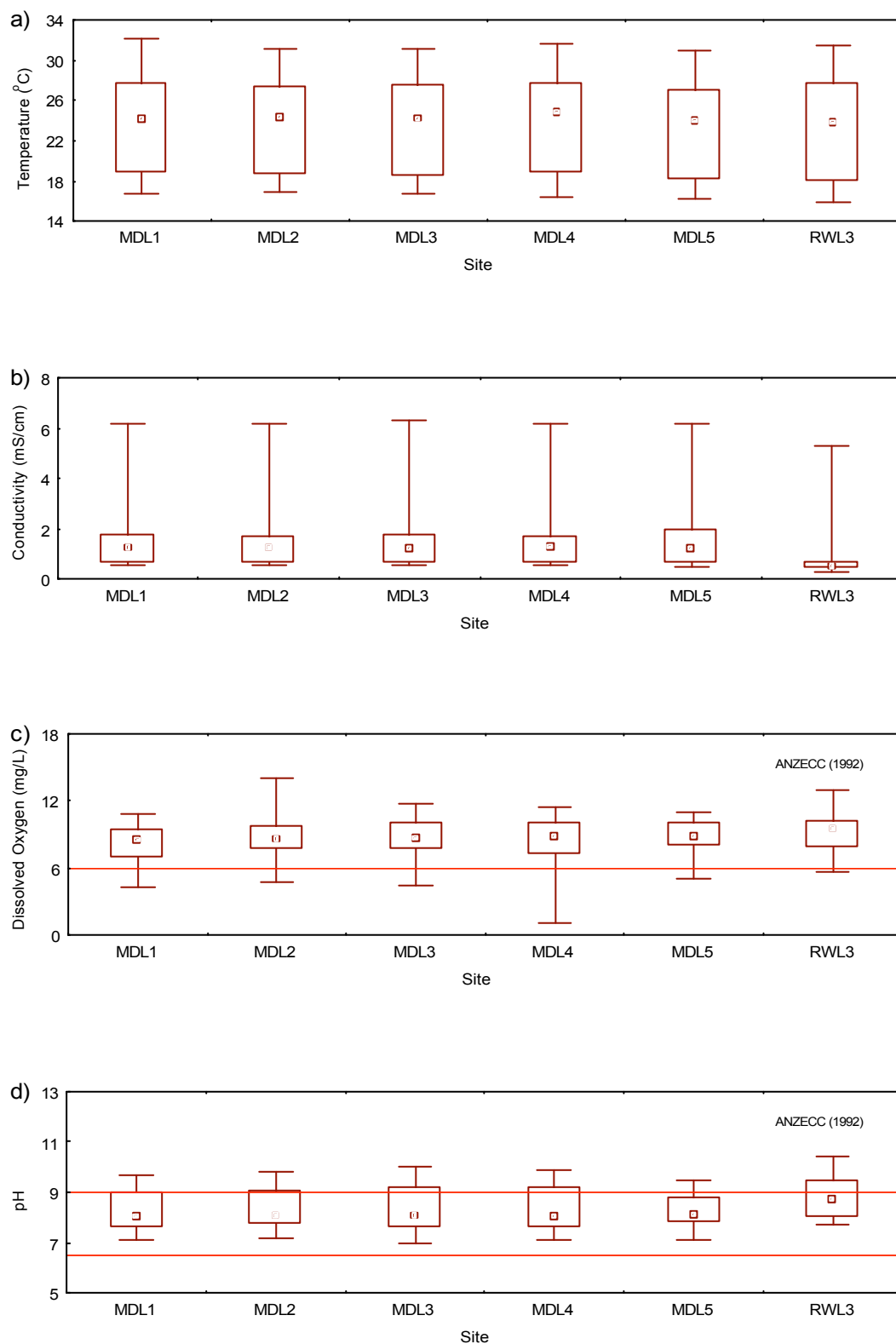
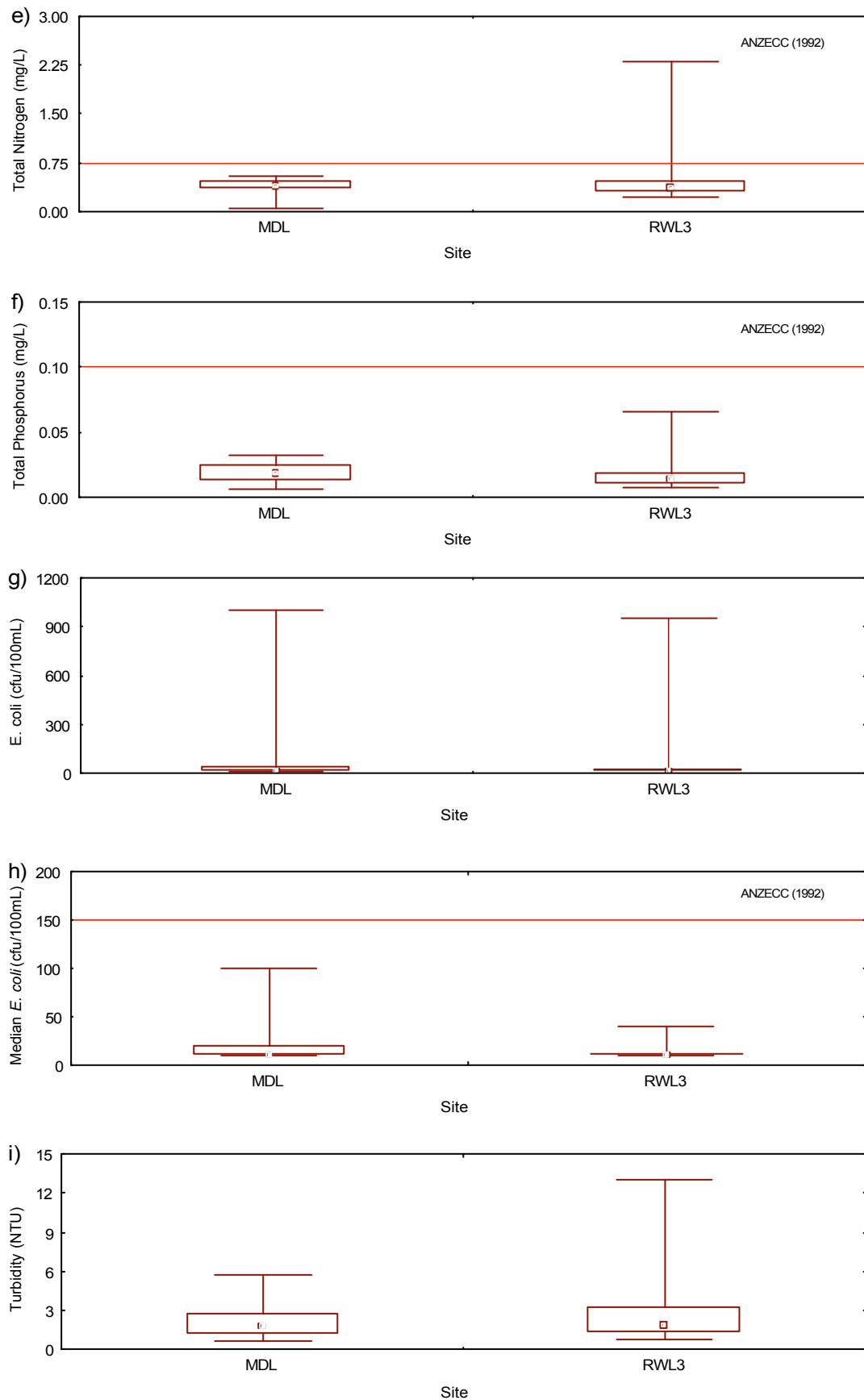


Figure 3.16.1 Location of water quality monitoring sites within Robina Lakes.





**Figure 3.16.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen, and (d) pH recorded in Robina Lakes. ANZECC (1992) compliance guidelines for the protection of aquatic ecosystems have been included for dissolved oxygen and pH.



**Figure 3.16.2 (cont)** (e) total nitrogen, (f) total phosphorus, (g) raw data for *E. coli*, (h) rolling median *E. coli* concentrations and (i) turbidity recorded in Robina Lakes. ANZECC (1992) guidelines have been included for both nutrient parameters and for primary contact recreational waters. Water samples collected in South Lake (MDL) are a composite from five sites.

### 3.16.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Surface water temperatures have varied markedly in each site ranging between 16°C and 32°C (Figure 3.16.2a). This range in water temperature could be influenced by seasonal conditions, flow rates or the time of day when measurements were recorded. Surface water temperatures did not vary amongst sites (KW :  $p = 0.94$ ).

#### CONDUCTIVITY

Conductivity generally remained below 2mS/cm at each site and is typical given the freshwater intension of these lakes (Figure 3.16.2b). Robina West Lake (RWL 3) has recorded conductivity up to 5mS/cm over the monitoring period. It is uncertain as to this higher conductivity at this site. Conductivity varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly lower conductivity in Robina West Lake (RWL3) than in Robina South Lake (MDL).

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations at all sites regularly complied with the ANZECC (1992) guidelines, with the 20<sup>th</sup> percentile above with the guidelines (Figure 3.16.2c). Reductions below the guidelines have been recorded at each site. Dissolved oxygen concentrations varied significantly amongst sites (KW :  $p < 0.03$ ), with significantly higher concentrations recorded in Robina West Lake (RWL 3) than at MDL 1 in Robina South Lake. Intermediate concentrations were recorded at all other Robina South Lake sites (MDL).

#### pH

pH recorded generally complied with the ANZECC (1992) guidelines at all sites (Figure 3.16.2d). pH above the upper guidelines limit has been recorded at all sites, particularly in Robina West Lake (RWL 3) where the 80<sup>th</sup> percentile exceeds the upper guidelines limit. These high pH recordings may be indicative of increased algal and plant productivity. pH varied significantly amongst sites (KW :  $p < 0.02$ ), with significantly higher recordings in Robina West Lake (RWL 3) than at all Robina South Lake sites (MDL).

#### TOTAL NITROGEN

Total nitrogen concentrations regularly complied with the ANZECC (1992) guidelines. This is particularly evident in Robina South Lake (MDL), where all recordings have complied with the guidelines (Figure 3.16.2e). Elevated concentrations above the guidelines however, have been recorded on occasions in Robina West Lake (RWL). Total nitrogen concentration did not vary significantly between each lake (KW :  $p = 0.41$ ).

#### TOTAL PHOSPHORUS

Total phosphorus concentrations have consistently complied with the ANZECC (1992) guidelines in both lakes (Figure 3.16.2f). Total phosphorus concentrations varied significantly between each lake (KW :  $p < 0.03$ ), with significantly higher concentrations recorded in Robina South Lake (MDL) than in Robina West Lake (RWL).

#### E. COLI

*E. coli* concentrations, calculated as a rolling median, have complied with the ANZECC (1992) guidelines for primary contact recreational waters (Figure 3.16.2h). Elevated concentrations in both lakes up to 1,000 cfu/100mL have been recorded. *E. coli* concentrations did not vary between each lake (KW :  $p = 0.06$ ).

#### TURBIDITY

Turbidity has regularly remained below 10ntu in both lakes (Figure 3.16.2.i). These low turbidity recordings are probably indicative of the nature of the surrounding catchment area as fully developed. Turbidity did not vary between each lake (KW :  $p = 0.53$ ).

### **3.16.3 DISCUSSION**

Water quality conditions in Robina Lakes have provided a qualitative assessment of water quality performance in response to land use changes and alterations surrounding this lake. Water quality has generally complied with the relevant ANZECC (1992) guidelines for the protection of aquatic ecosystems. This is important, given that this lake system provides a habitat for many birds and fish species and is also an important recreational and visual amenity for the local community and residents that front the lake.

Urbanisation of the surrounding Robina catchment has been recognised as contributing to the excessive growth of aquatic plants and algal outbreaks (WBM Oceanics, 1998). These aquatic plant species do provide, however, an important habitat for the breeding, feeding and shelter areas against predation, for many fish and wildlife species that inhabit this lake. The present harvesting program implemented by GCCC assists with the control of aquatic plant growth, whilst still allowing for the processing of nutrients washed into Robina lakes. At present the net removal of nutrient is from weed harvesting, with an average of 4,200m<sup>3</sup> of weed removed each year from the Robina and Clear Island Waters lake system. This equates to approximately 152,500kg and 21,200kg of total phosphorus and total nitrogen respectively each year (WBM Oceanics, 18<sup>th</sup> August, 1999).

The quality of water in Robina Lakes is likely to be influenced by land use activities within the surrounding catchment area. Stormwater runoff would contribute greatly to the transportation of nutrients into Robina Lakes. Stormwater management is therefore considered to be an important component in the effective management of Robina Lakes. Activities undertaken within the catchment area including excessive fertiliser use, washing of bins and cars on the street or driveways, incorrect disposal of grass clippings or other garden waste may be major contributors to the excessive growth of aquatic plants and algal blooms during summer. The misuse of pesticide and herbicide chemicals can also lead to water quality and health problems within Robina Lakes.

GCCC is working with other governmental and scientific agencies to develop appropriate water management strategies, catchment management plans and environmental strategies to protect and enhance the environmental quality of Robina Lakes. This information is important for the long-term sustainability of this resource, as an important habitat for aquatic and terrestrial wildlife and also as a recreational asset for the local community.

### **3.16.4 CONCLUSIONS AND RECOMMENDATIONS**

The Robina Lakes has generally recorded good water quality conditions suitable for the protection of aquatic ecosystems. The growth of aquatic plants and algal blooms (including blue green algae species), however, is a common occurrence, particularly during the summer months. This growth of aquatic plants is a direct result of excessive nutrient loads entering Robina Lakes. The management and improvement of stormwater runoff from those residential areas surrounding Robina Lakes, through the development of a detailed stormwater management plan is considered necessary. GCCC is in the process of developing a catchment management plan for the Mudgeeraba/Bonogin/Wyangan and Worongary Creek catchment area. The study will focus on a range of environmental issues specific to this catchment. Of particular importance, will be the management of nutrient loadings entering Clear Island Waters (which is linked to the Robina Lakes). GCCC plan to develop a detailed catchment management study for the Robina Lakes catchment in the coming years. This information could also be used in the development of a specific land use stormwater management plan for the Robina Lakes catchment.

### 3.17 SALTWATER CREEK

#### 3.17.1 INTRODUCTION

Saltwater Creek is a small, approximately 17km in length, tributary of the Coomera River. Its upper catchment is located in the Nerang State Forest, where runoff flows from this area through residential estates within the middle freshwater region of the catchment, under the Pacific Highway, through Helensvale and alongside Hope Island, joining with Coombabah Creek before entering the Coomera River at Paradise Point. A small tributary that channels flow from the Studio Village sub-catchment, traverses through a wetland system near Movie World, before joining with the main creek near the Pacific Highway (Figure 3.17.1).

Residential development planned within the middle to upper freshwater region of the catchment was identified in the Coombabah Creek Catchment Management Study (Sinclair Knight Merz, 1997) as potentially contributing to increased nutrient and suspended sediment loadings in Saltwater Creek. Subsequently, a monitoring program began in 1999 to water quality conditions in Saltwater Creek. The estuarine region of the creek, particularly near the Helensvale and Hope Island region, has experienced pressures associated with stormwater runoff and the loss of riparian vegetation from past development and land use changes (QDoE, 1997). Increased boating traffic within this region has also been identified as contributing to stream bank impacts through erosion (QDoE, 1997).

A formal investigation into the state of Saltwater Creek was undertaken with the Coombabah Creek Catchment Management Study - November 1997. This investigation was completed following community concern with the loss of catchment vegetation and its associated ecological impacts on the aquatic environment. This report highlighted potential water quality pressures associated with urban development, particularly in the middle to upper freshwater region of the catchment and recommended that a more detailed catchment investigation be undertaken (Sinclair Knight Merz, 1997). The Saltwater Creek Environmental Inventory was commissioned in February 2001 to investigate the specific pressures on the health and quality of the creek associated with land use changes. This information will assist GCCC and the local community in developing EVs to protect and where possible enhance the creek.

Table 3.17.1 Site classifications and distance details for each monitoring site.

Region/Site Type	Distance # (km)	Site
Upper Freshwater	14.73	SWC 1
	13.08	SWC 2
Lower Freshwater	11.33	SWC 3
	11.25	SWC 4
Upper Estuary	10.24	SWC 5
Mid Estuary	9.07	SWC 6
Lower Estuary	3.08	SWC 7

# Measured as distance in kilometres from the mouth

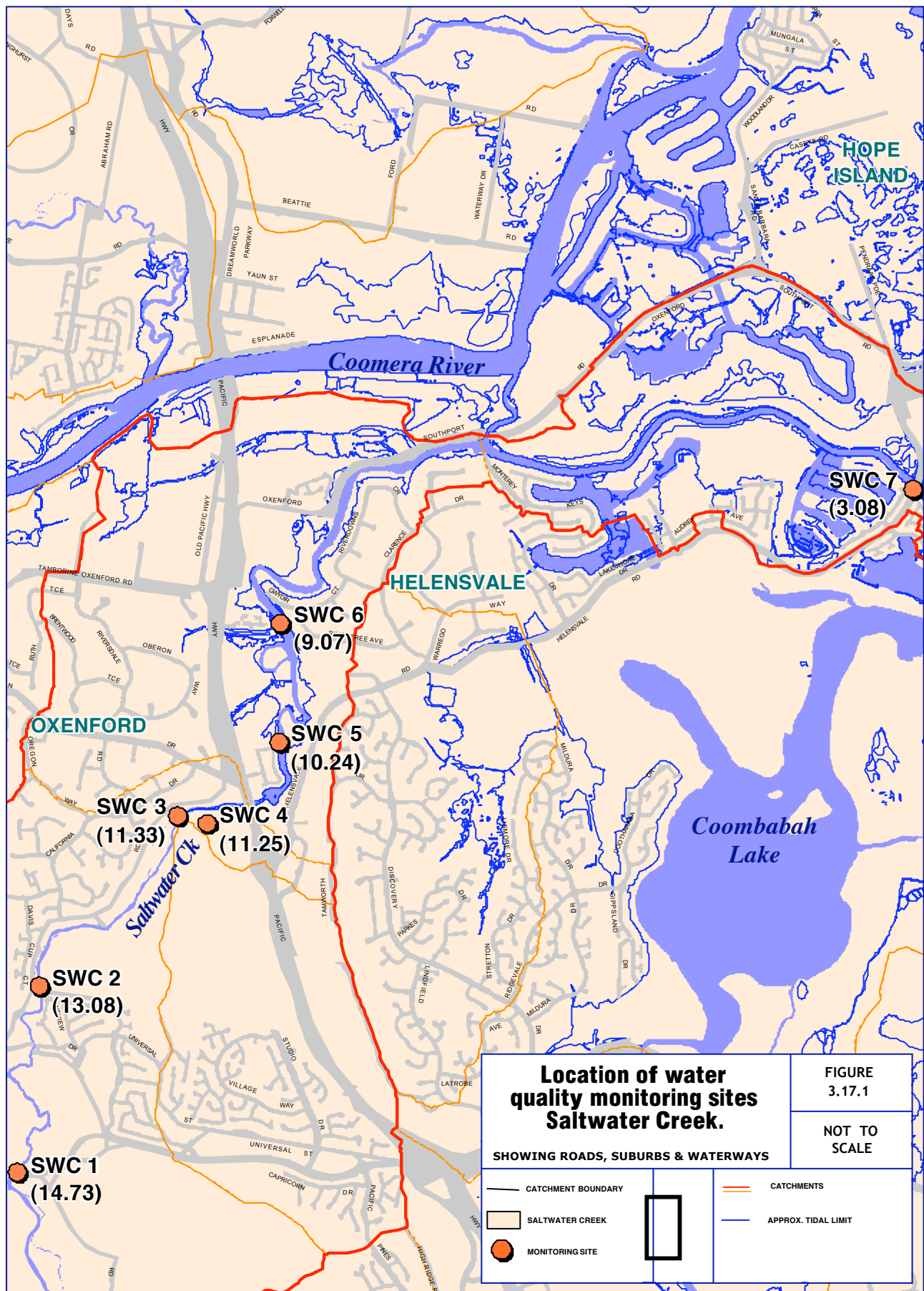
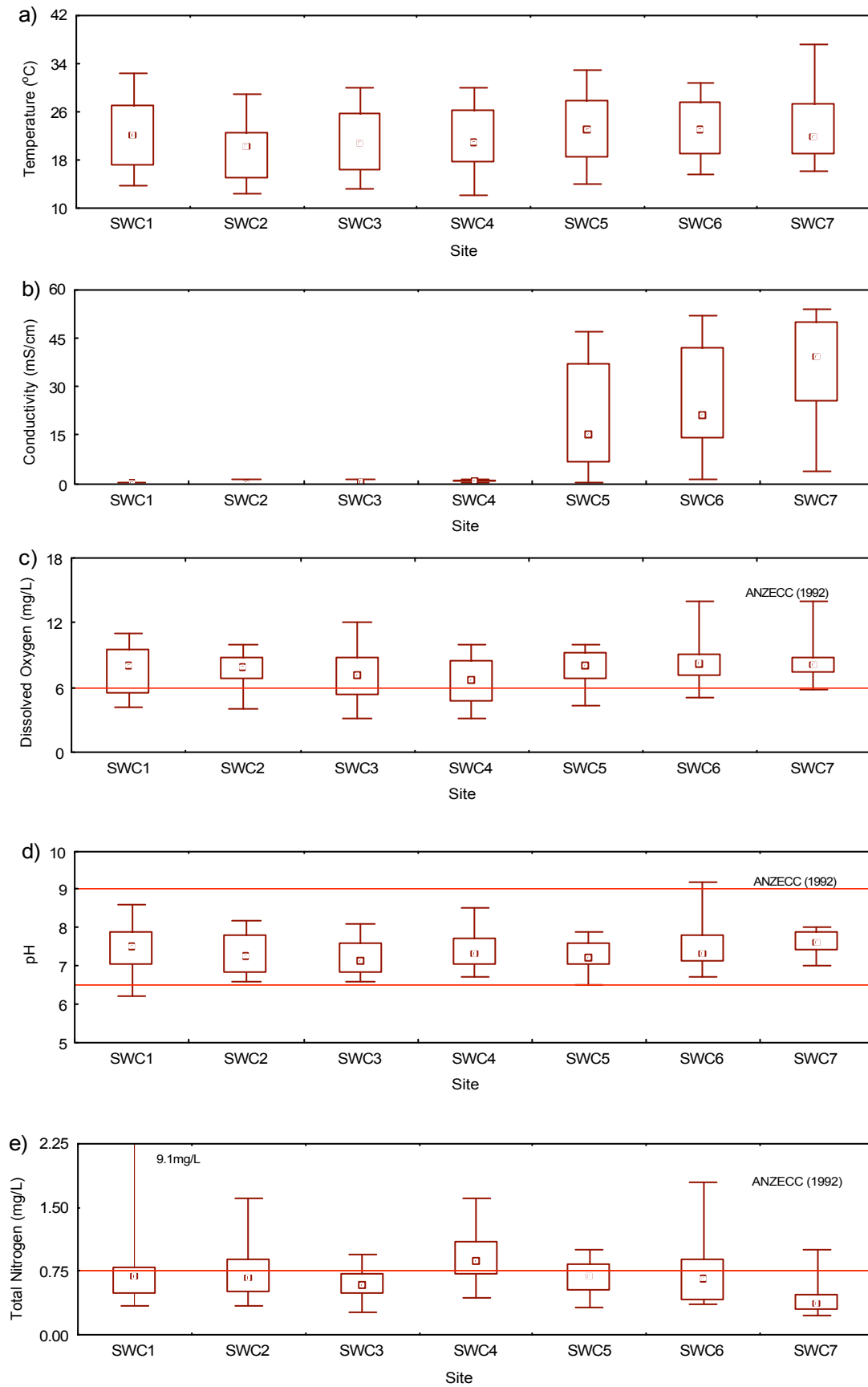
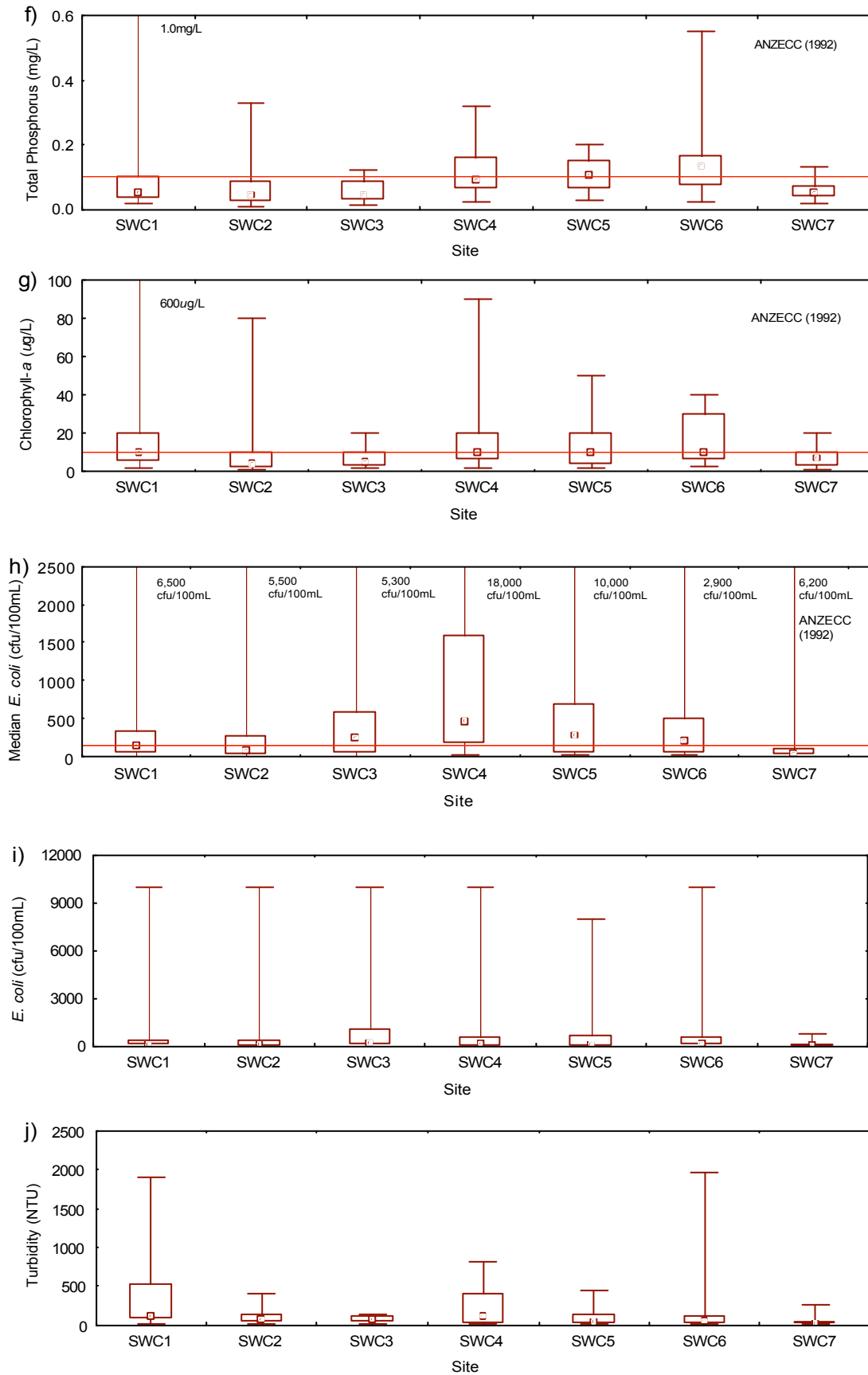


Figure 3.17.1 Location of water quality monitoring sites in Saltwater Creek.



**Figure 3.17.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen, (d) pH and (e) total nitrogen concentrations recorded at each site. ANZECC (1992) compliance guidelines for the protection of aquatic ecosystems have been included for dissolved oxygen, pH and total nitrogen.



**Figure 3.17.2 (cont)** (f) total phosphorus, (g) chlorophyll-*a*, (h) rolling median *E. coli* concentrations, (i) raw data for *E. coli* concentrations and (j) turbidity recorded at each site. ANZECC (1992) guidelines have been included for comparison with total phosphorus and chlorophyll-*a*. Recreational guidelines for primary contact waters have been included for comparison with median *E. coli* concentrations.



### 3.17.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Water temperatures have ranged between 12°C and 37°C in Saltwater Creek (Figure 3.17.2a). This range in water temperature could be influenced by seasonal conditions, depth, flow rates, time of day when measurements were recorded or the presence and density/nature of riparian vegetation. Water temperatures did not vary significantly amongst sites (KW :  $p = 0.15$ ).

#### CONDUCTIVITY

Conductivity varied significantly amongst sites in Saltwater Creek (KW :  $p < 0.001$ ). Sites SWC 5 - SWC 7 are tidally influenced and had consistently higher conductivity than at SWC 1 - SWC 4. At certain times, conductivity decreased below 5mS/cm at each estuarine site, probably due to freshwater runoff from the upper catchment during rainfall periods (Figure 3.17.2b).

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations generally complied with the ANZECC (1992) guidelines (Figure 3.17.2c), although all sites at times recorded concentrations below the guidelines, particularly at SWC 1, SWC 3 and SWC 4. Dissolved oxygen concentrations varied significantly amongst sites (KW :  $p < 0.03$ ), with SWC 1 recording significantly higher concentrations than at SWC 4 and SWC 5.

#### pH

pH complied with the ANZECC (1992) guidelines at each site (Figure 3.17.2d), although pH at SWC 6 was occasionally above the upper guidelines limit. pH varied significantly amongst sites (KW :  $p < 0.002$ ), with significantly higher pH at SWC 7 than at SWC 3 and SWC 5, and intermediate values at other sites. This trend is to be expected, as pH in marine waters is usually higher than pH in freshwater and generally less varied. This, however, was not true for SWC 6 where pH varied more than SWC 5 and SWC 7.

#### TOTAL NITROGEN

Total nitrogen concentrations generally comply with the ANZECC (1992) guidelines, except at SWC 4 where the median concentration exceeded the guidelines (Figure 3.17.2e). Concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher recordings at SWC 4 than at SWC 3 and SWC 6. High total nitrogen recorded at SWC 4 is probably related to the wetland area at this site. Site SWC 7 recorded significantly lower concentrations than all other monitoring sites. Sites SWC 1, SWC 2, SWC 5 and SWC 6 are intermediate between, but significantly different from, SWC 3 and SWC 4.

#### TOTAL PHOSPHORUS

Total phosphorus concentrations regularly complied with the ANZECC (1992) guidelines, except at SWC 5 and SWC 6 where the median concentration was above the guidelines (Figure 3.17.2f). Concentrations varied significantly amongst sites (KW :  $p < 0.001$ ). Site SWC 6 recorded significantly higher concentrations than all other sites, except SWC 4 and SWC 5. SWC 4 and SWC 5 recorded significantly higher concentrations than at SWC 2, SWC 3 and SWC 7.

#### CHLOROPHYLL-A

Chlorophyll-*a* concentrations generally comply with the ANZECC (1992) guidelines (Figure 3.17.2g). Concentrations varied significantly amongst sites (KW :  $p < 0.002$ ), with significantly higher concentrations recorded at SWC 6 than SWC 2 and SWC 7. These higher concentrations at SWC 6 are probably related to high nutrient concentrations. Turbidity did not appear to have influenced chlorophyll-*a* concentrations at this site.

### **E. COLI**

*E. coli* concentrations, calculated as a rolling median, for SWC 1, SWC 2 and SWC 7 generally complied with the primary contact recreational guidelines. All other sites have regularly exceeded the primary contact guidelines, however, comply with the secondary contact recreational guidelines (Figure 3.17.2h). *E. coli* concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations recorded at SWC 4 than at SWC 2 and SWC 7. Significantly lower concentrations were recorded at SWC 7 than at SWC 3, SWC 5 and SWC 6. *E. coli* concentrations were found to be generally highest between the lower freshwater and middle estuarine region of the creek. This is probably due to limited water movement and exchange with the Broadwater. Concentrations improved downstream from this area of Saltwater Creek, with SWC 7 regularly complying with the primary contact recreational guidelines.

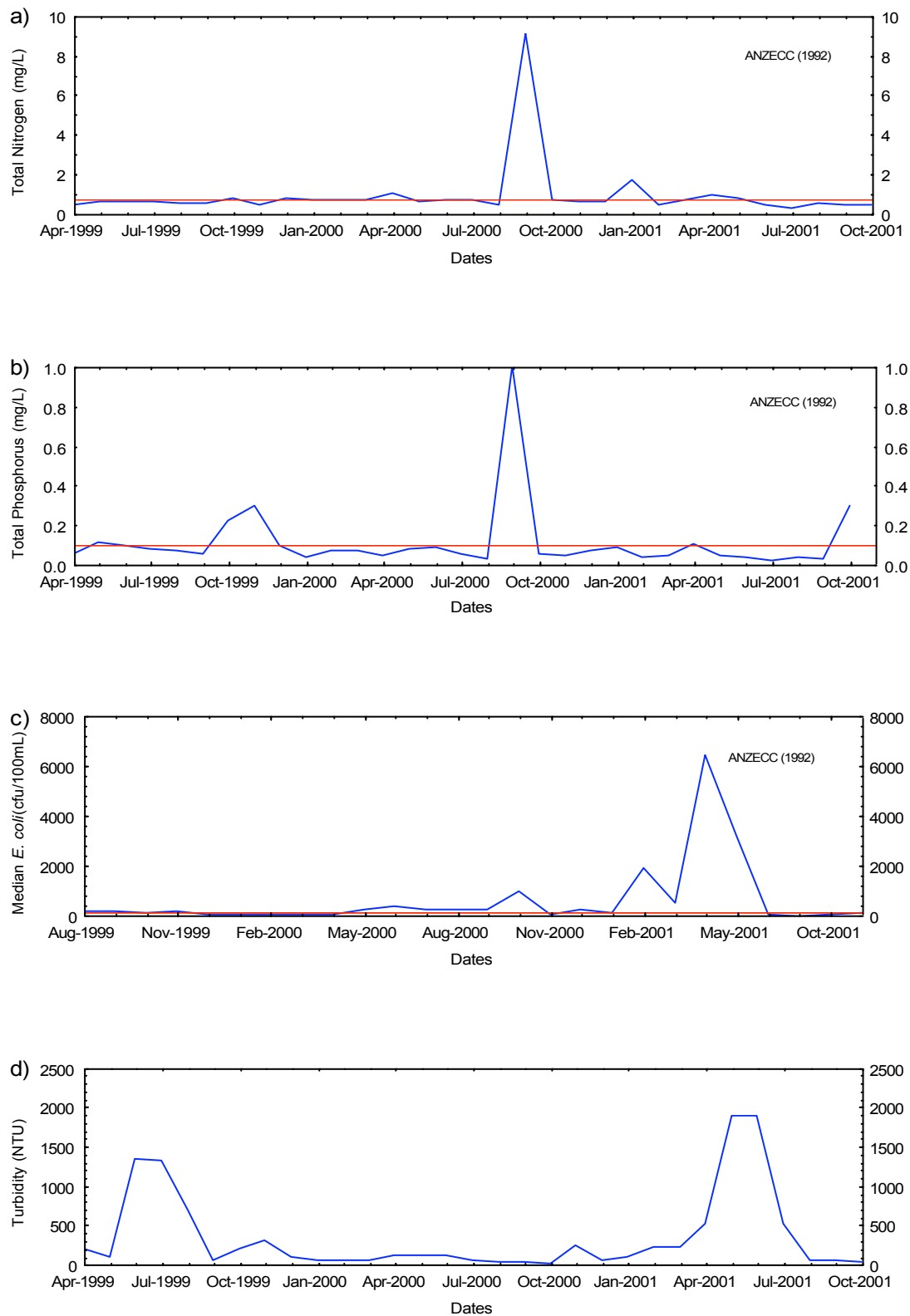
### **TURBIDITY**

Turbidity varied significantly amongst sites (KW :  $p < 0.001$ ) (Figure 3.17.2i), with significantly higher turbidity recorded at SWC 1 than at SWC 5 and SWC 6. Site SWC 7 has recorded significantly lower turbidity than at SWC 1 - SWC 5. High turbidity at freshwater sites and an improvement downstream is unusual in comparison with other waterways. This could be related to land use changes in the upper catchment area.

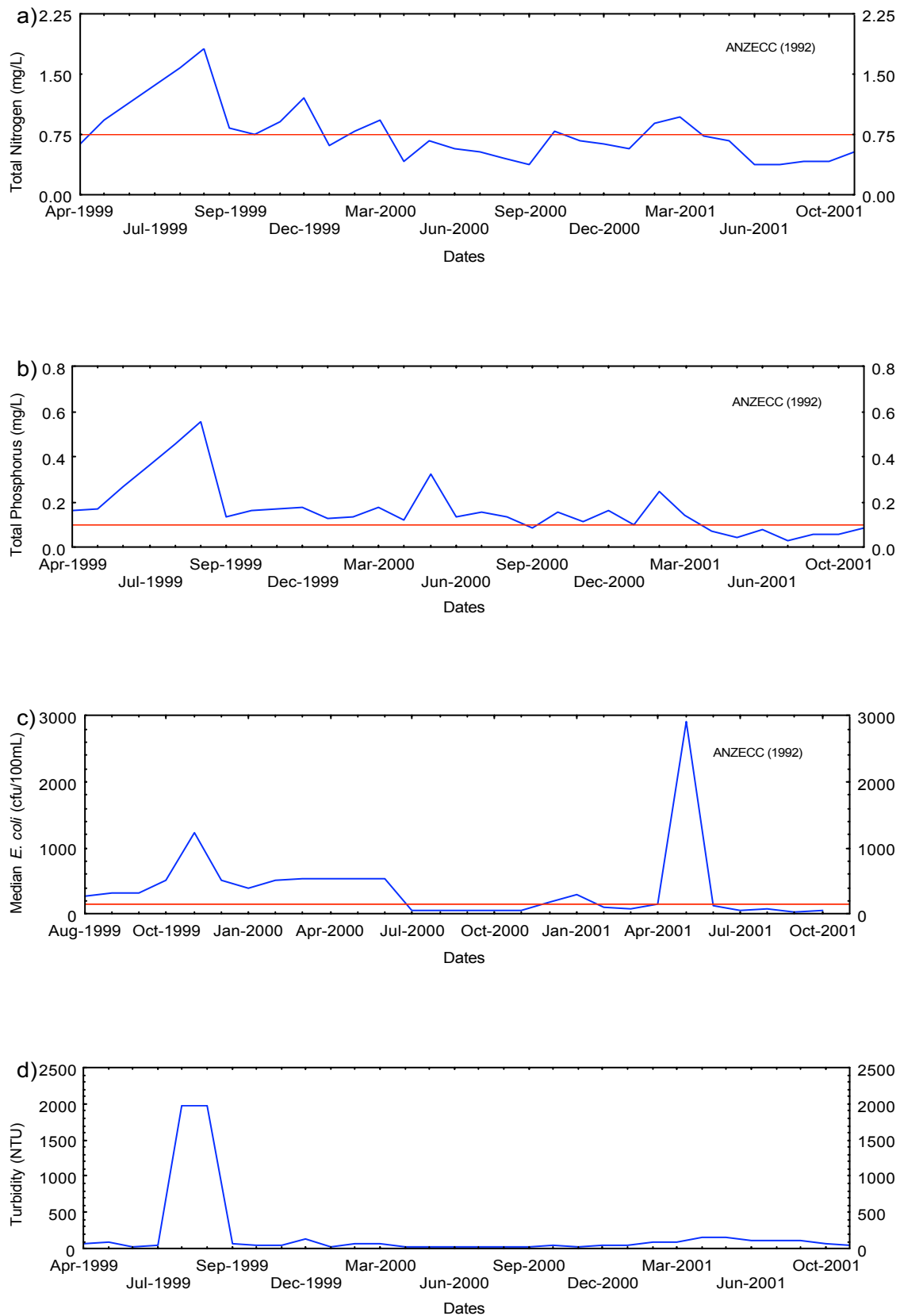
#### **3.17.3 WATER QUALITY TRENDS**

SWC 1 and SWC 6 were chosen to assess water quality trends over the monitoring period (Figures 3.17.3 and 3.17.4). Total nitrogen concentrations generally complied with the guidelines at SWC 1, despite several peaks in concentrations recorded over the monitoring period. Of interest, was the significant peak in total nitrogen recorded in September 2000. Total phosphorus concentrations generally remained below the guidelines at this site, with several elevations recorded over the monitoring period. Similar to total nitrogen, a significant peak was recorded in September 2000. *E. coli* concentrations have regularly exceeded the primary contact recreational guidelines after April 2000. This was particularly evident between February 2001 and June 2001. Concentrations appear to have improved following June 2001, complying with the primary contact recreational guidelines. Turbidity conditions appear to have fluctuated between 100ntu and 2,000ntu over the monitoring period at this site. Turbidity was highest between May 1999 and September 1999 and between January 2001 and October 2001. Despite these peaks, there appears to be no apparent decline or improvement in turbidity at this site.

Total nitrogen and total phosphorus concentrations regularly exceeded the guidelines at SWC 6 prior to March 2000 and May 2001 respectively. Since these dates, nutrient concentrations continually complied with the guidelines at this site. *E. coli* concentrations regularly exceeded the guidelines between April 1999 and July 2000, however, have remained in compliance with the primary contact recreational guidelines following July 2000. A significant peak in *E. coli* concentrations occurred between April 2001 and June 2001, with concentrations then complying with the primary contact recreational guidelines following June 2001. This peak is likely to be associated with a rain event. Turbidity has fluctuated at this site over the monitoring period. However, a significant increase in turbidity was recorded between July 1999 and September 1999, similar to both nutrients and *E. coli* concentrations.



**Figure 3.17.3** Trends in (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at SWC 1 over the monitoring period.



**Figure 3.17.4** Trends in (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at SWC 6 over the monitoring period.

### 3.17.4 DISCUSSION

Water quality monitoring in Saltwater Creek has provided a quantitative assessment of water quality and responses to changing land use over the monitoring period. Water quality appears to be generally poorer within the lower freshwater and middle estuary region of the creek. Recent urban development in the upper and middle catchment area may have contributed to the higher nutrient, turbidity and *E. coli* concentrations recorded in this area of the creek. Chlorophyll-*a* concentrations were also higher at sites in the upper and middle catchment, which is likely associated to high nutrient concentrations. Turbidity was also found to be high in the upper freshwater catchment area, however, improved following September 1999.

The middle and lower estuary area of the catchment has generally recorded better water quality, with nutrient and *E. coli* concentrations regularly complying with the guidelines. Site SWC 6 recorded high nutrient, turbidity and *E. coli* concentrations, however, there appears to be an improving trend in water quality conditions at this site. Nutrients, *E. coli* and turbidity in the lower estuary were lower than other monitoring sites in Saltwater Creek. Greater flushing of the middle to lower estuary may be contributing to this good water quality. However, while this may be the case, management of land use, public education, erosion and sediment control and stormwater management programs should continue to focus on the upper catchment. This would reduce the reliance on tidal flushing of the lower estuary, which is not sustainable in the long-term.

### 3.17.5 CONCLUSIONS AND RECOMMENDATIONS

Water quality in Saltwater Creek appears to be varied, with several sites in the upper and lower catchment generally complying with the ANZECC (1992) guidelines. Sites in Saltwater Creek between the lower freshwater and upper estuary area, however, are shown to regularly record elevated nutrient, *E. coli* and chlorophyll-*a* concentrations.

To examine the pressures associated with residential development in this catchment, in particular the impacts of sedimentation, eutrophication and the loss of stream bank/riparian vegetation through erosion of the lower estuary area, GCCC implemented a catchment management study of the Saltwater Creek in 2001 (Saltwater Creek Environmental Inventory). The study examined the pressures of current and proposed future residential development of the catchment, in combination with biotic condition assessments (*ie* fish, plankton, plant species), to establish the EVs of the creek. GCCC in the coming years will begin implementing the action plan from this catchment study. For example, event monitoring of storm periods is recommended to assess nutrient and sediment export loadings associated with catchment land use changes. A community catchment management group has implemented rehabilitation works in riparian areas along Saltwater Creek. The group has also begun a program to educate the local community on the values of Saltwater Creek.

### 3.18 TALLEBUDGERA CREEK

#### 3.18.1 INTRODUCTION

Tallebudgera Creek flows approximately 29km, from its headwaters of Springbrook National Park on the McPherson Ranges and discharging into the Pacific Ocean, south of Burleigh Headland (Figure 3.18.1).

Land use practices in the catchment are varied and include farming, urban development, golf courses, plant nurseries, tourism, industrial areas and several reserves and National Parks. Agricultural practices dominate land use within the upper catchment including banana, dairy and beef farming. Large areas of the upper catchment have been cleared for the supply of timber or farming activities. This area of the catchment is currently at various stages of regeneration depending on the extent of clearing and weed invasion (Gutteridge Haskins & Davey, 1998). The upper freshwater area of the creek has been found to support platypus populations (Muscat and Luxmoore, 1998).

The middle region of the catchment is primarily used for various grazing and cultivation activities. The loss of vegetation in this area has impacted on water quality within Tallebudgera Creek. The loss of vegetation has also led to weed invasion, in particular, Camphor laurel (*Cinnamomum camphora*), increased stream bank erosion, reduced linkages to wildlife corridors and generally reduced the visual amenity of this area (Gutteridge Haskins & Davey, 1998).

The lower region of the catchment has been mostly developed, with large areas of the riparian vegetation lost to allow access to the creek for the purposes of recreation, tourism and aesthetics. A residential canal system has been built upstream from the mouth of this creek. The canal system acts as an interception/storage area for drainage following rainfall events. The canal area is therefore more susceptible to contamination, as pollutants are transported from the surrounding area via runoff, into the canal and finally into the creek.

The Elanora Wastewater Treatment Plant, prior to June 1992, was licensed to discharge treated effluent into Tallebudgera Creek upstream of the Pacific Highway. Since its decommissioning in 1992, the discharge of treated effluent into Tallebudgera Creek has ceased and is discharged via diffusers at the Gold Coast Seaway on an ebbing tide.

**Table 3.18.1** Site classification and distance details for each monitoring site.

Region/Site Type	Distance <sup>#</sup> (km)	Site
Freshwater	16.89	TBC 0
	10.49	TBC 1
Upper Estuary	7.32	TBC 1A
	6.05	TBC 1B
Middle Estuary	4.58	TBC 2
	3.05	TBC 4
Canal system	3.58	TBC 4C
	2.13	TBC 4D
Lower Estuary	1.33	TBC 6A
	1.54	TBC 8A
	1.26	TBC 10
	0.78	TBC 11

(<sup>#</sup>) Measured as distance in kilometres from the mouth

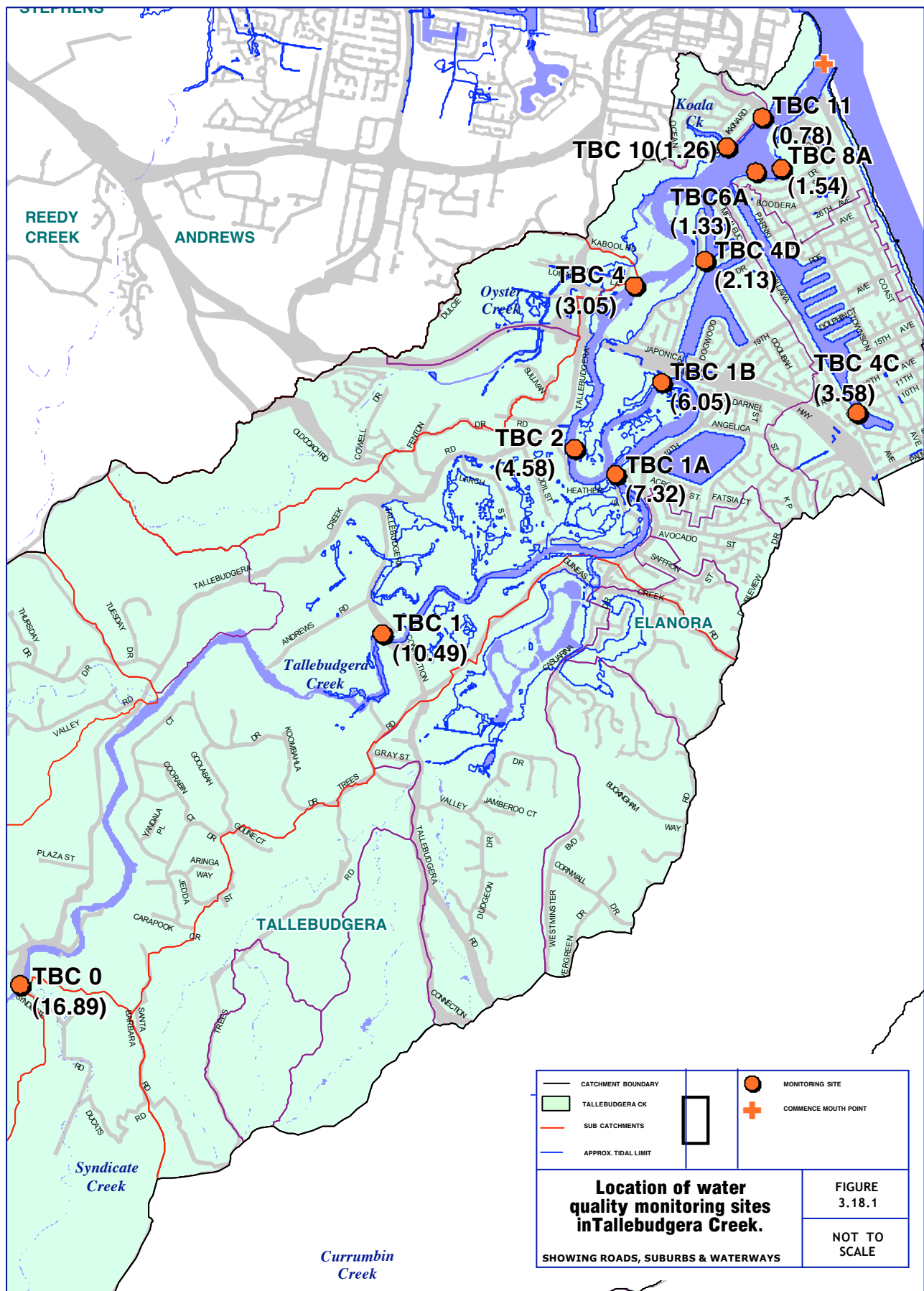
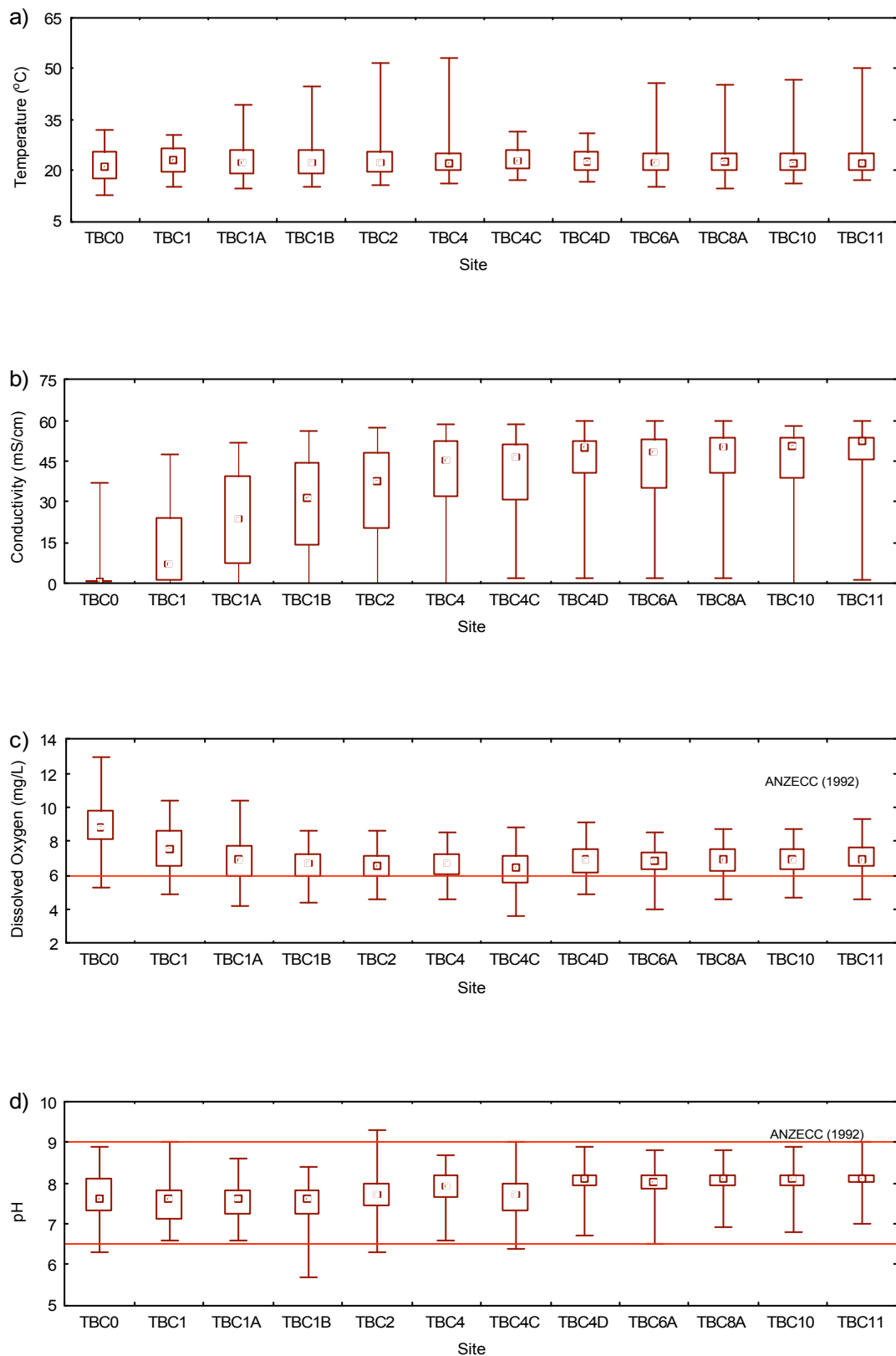
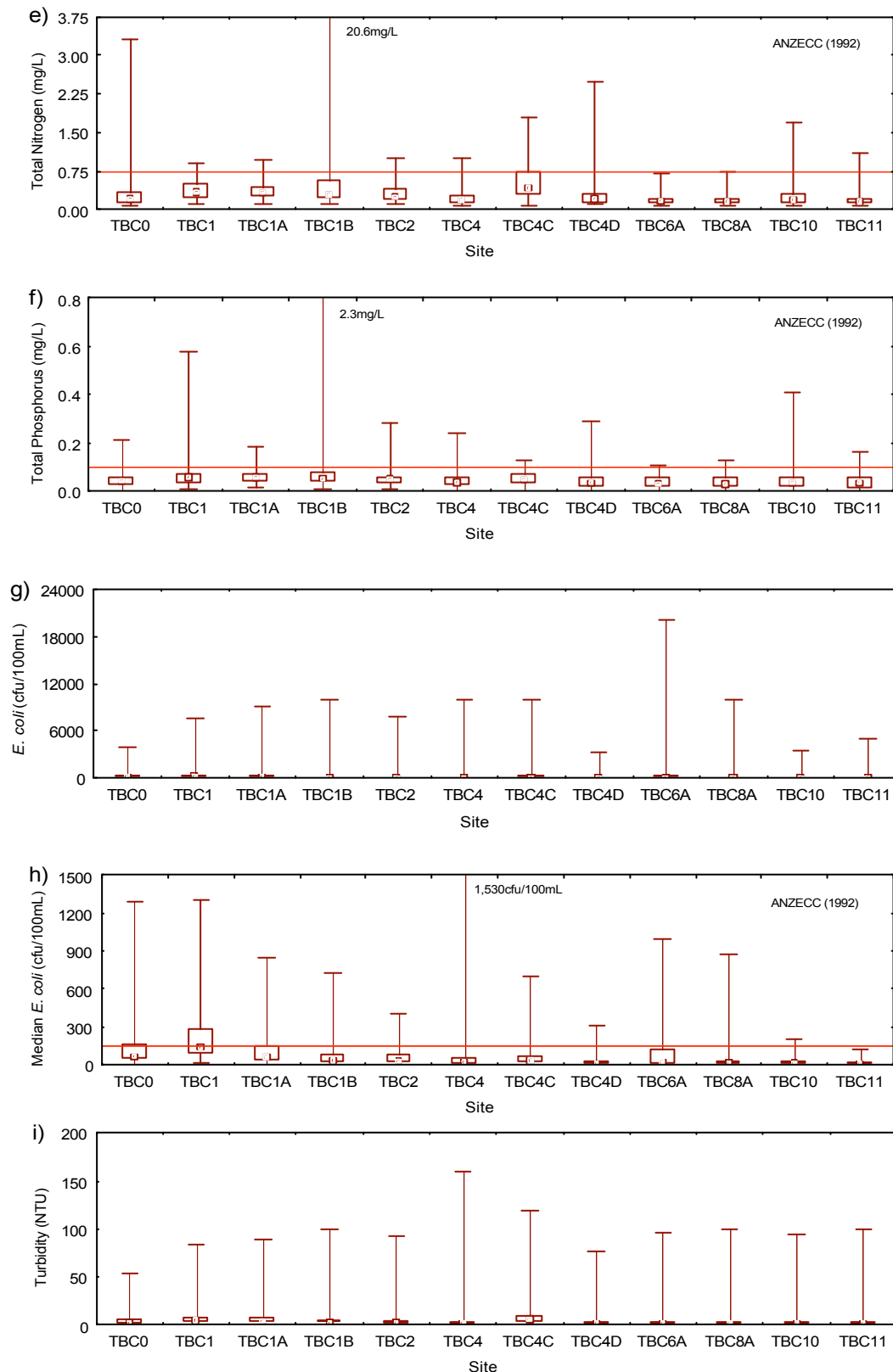


Figure 3.18.1 Location of the monitoring sites within Tallebudgera Creek.



**Figure 3.18.2** Box plots for (a) temperature, (b) conductivity, (c) dissolved oxygen and (d) pH recorded at each monitoring site. ANZECC (1992) compliance guidelines for the protection of aquatic ecosystems have been included for dissolved oxygen and pH.





**Figure 3.18.2 (cont)** (e) total nitrogen, (f) total phosphorus, (g) raw data for *E. coli* concentrations (h) rolling median *E. coli* concentrations and (i) turbidity recorded at each site. ANZECC (1992) compliance guidelines for both nutrients have been included for the protection of aquatic ecosystems. Recreational guidelines for primary contact recreational waters have been included for comparison with median *E. coli* concentrations.

### 3.18.2 COMPLIANCE AND ASSESSMENT OF WATER QUALITY

#### TEMPERATURE

Water temperatures have ranged between 12°C - 53°C in Tallebudgera Creek (Figure 3.18.2a). The range in water temperatures could be influenced by seasonal conditions, depth, flow rates, time of day when measurements were recorded or the presence and density/nature of riparian vegetation. Water temperatures recorded at several sites have exceeded 50°C over the monitoring period. While these conditions are possible, it is considered more likely that these values are data outliers and are a sampling or data entry error. Water temperatures did not vary significantly amongst sites (KW :  $p = 0.35$ ).

#### CONDUCTIVITY

Conductivity varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly lower conductivity at freshwater sites than at all other sites. Upper and middle estuary sites recorded significantly lower conductivity than at canal and lower estuary sites. This conductivity gradient is to be expected as tidal exchange with the Pacific Ocean increases towards the mouth of this creek. At certain times, conductivity decreased below 5mS/cm at all estuarine sites, which is likely to be related to freshwater runoff from the upper catchment area during rainfall (Figure 3.18.2b).

#### DISSOLVED OXYGEN

Dissolved oxygen concentrations regularly complied with the ANZECC (1992) guidelines with the 20<sup>th</sup> percentile at all sites, except TBC 1A, TBC 1B, TBC 2, TBC 4 and TBC 4C (canal site), complying with the guidelines (Figure 3.18.2c). Dissolved oxygen concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations recorded at both freshwater sites than at all estuary sites.

#### pH

pH regularly complied with the ANZECC (1992) guidelines (Figure 3.18.2d). pH varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly lower pH at freshwater and upper estuary sites than at all middle, canal and lower estuary sites, except TBC 4. Middle estuary sites recorded significantly lower pH than at lower estuary sites and TBC 4D. Site TBC 4C recorded significantly lower pH than other canal and lower estuary sites. This trend in pH is to be expected, as pH in areas influenced by marine water usually has higher pH and will experience less variation. At TBC 4C, the influence of freshwater from rainfall runoff from the surrounding urban area appears to have reduced pH to conditions similar to upper estuary and freshwater sites.

#### TOTAL NITROGEN

Total nitrogen concentrations regularly complied with the ANZECC (1992) guidelines, with the 80<sup>th</sup> percentile complying with the guidelines at all sites (Figure 3.18.2e). Elevated concentrations above the guidelines were recorded at each site, except at TBC 6A and TBC 8A. Total nitrogen concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations at all upper and middle estuary sites and TBC 4C than at all other sites. Site TBC 11 recorded significantly lower concentrations than at both freshwater sites. High total nitrogen concentrations recorded at TBC 1, TBC 4C and all upper and middle estuary sites is likely to be related to urban stormwater runoff, upper catchment activities or the Elanora Wastewater Treatment Plant, prior to its decommission in 1992. Sites in the lower estuary had lower total nitrogen concentrations, which is likely to be related to improved tidal exchange with the Pacific Ocean.

## **TOTAL PHOSPHORUS**

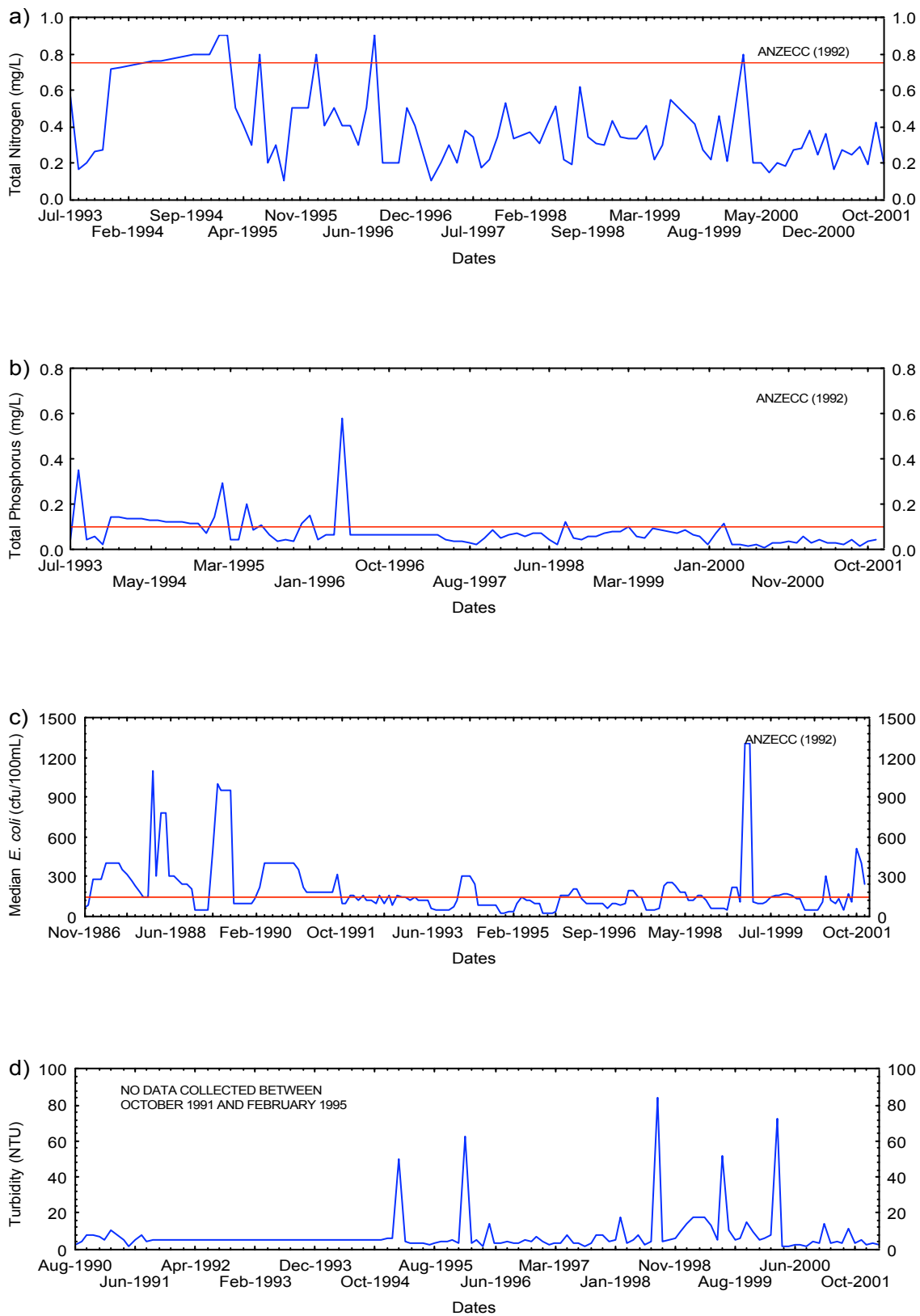
Total phosphorus concentrations regularly complied with the ANZECC (1992) guidelines, with the 80<sup>th</sup> percentile also complying with the guidelines at all sites (Figure 3.18.2f). Concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations recorded at TBC 1, TBC 4C and all upper and middle estuary sites than all other sites. This trend for total phosphorus is similar to total nitrogen concentrations recorded in Tallebudgera Creek. This is probably related to the influence of urban stormwater runoff, upper catchment activities or the Elanora Wastewater Treatment Plant, prior to decommissioning in 1992.

## **E. COLI**

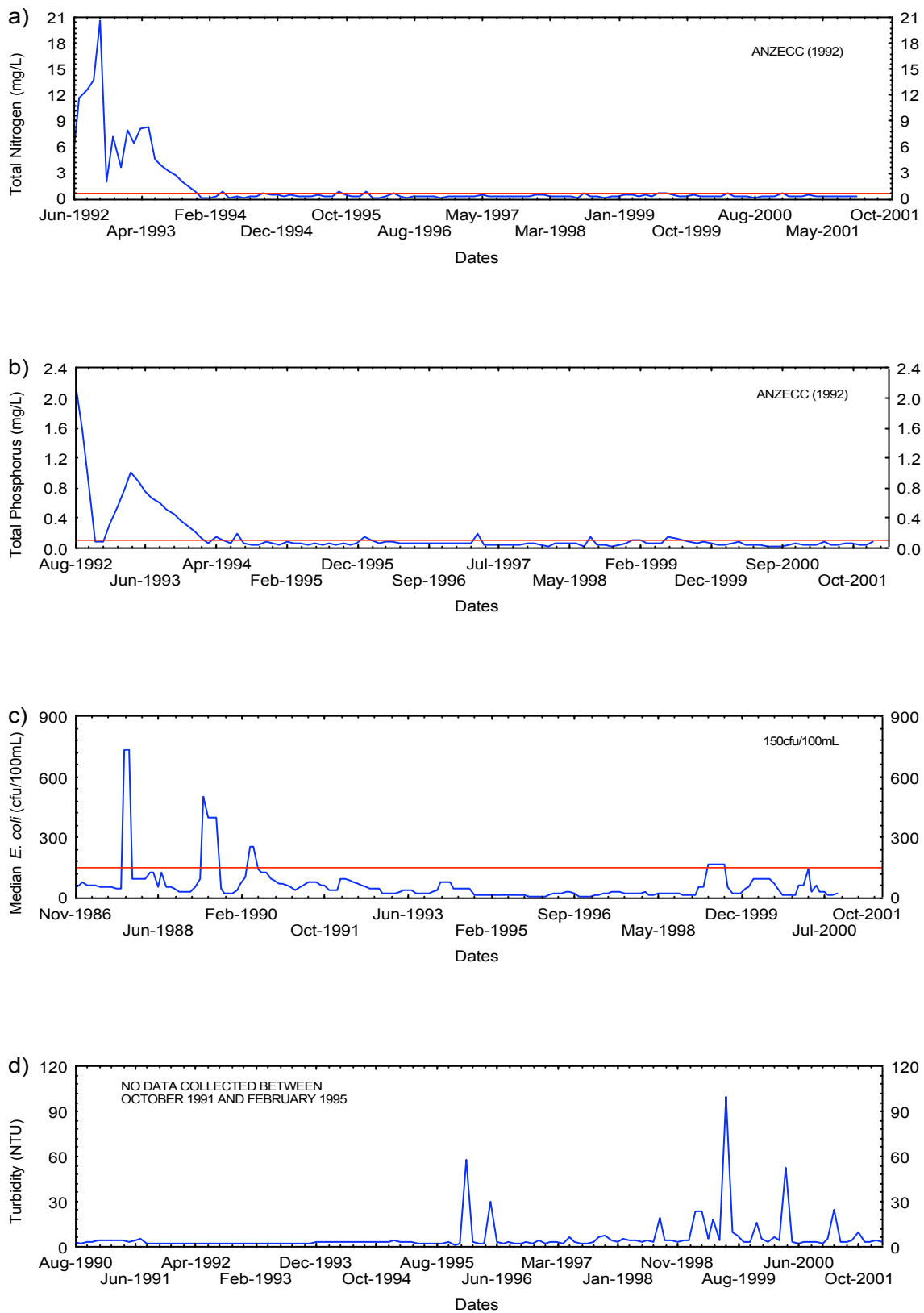
*E. coli* concentrations, calculated as a rolling median, have regularly complied with the ANZECC (1992) guidelines for primary contact recreational waters (Figure 3.18.2h). Elevated median concentrations above the primary contact recreational guidelines were recorded at all sites, except TBC 10 and TBC 11. *E. coli* concentrations varied significantly amongst sites (KW :  $p < 0.001$ ), with significantly higher concentrations recorded at freshwater sites and TBC 1A than all other sites. Significantly lower *E. coli* concentrations were at TBC 4D, TBC 10 and TBC 11 than at all other estuary sites. Site TBC 8A recorded significantly lower concentrations than at TBC 1B, TBC 2 and TBC 4C. The trend in *E. coli* concentrations has shown that concentrations were generally highest at freshwater and upper estuary sites and gradually improved (declined) downstream towards the lower estuary. Site TBC 4C and TBC 6A recorded elevated *E. coli* concentrations, which may be related to their geographical location in close proximity to stormwater drainage outlets. Sites TBC 10 and TBC 11 regularly complied with the primary contact recreational guidelines, which is likely to be related to increased tidal exchange with the Pacific Ocean.

## **TURBIDITY**

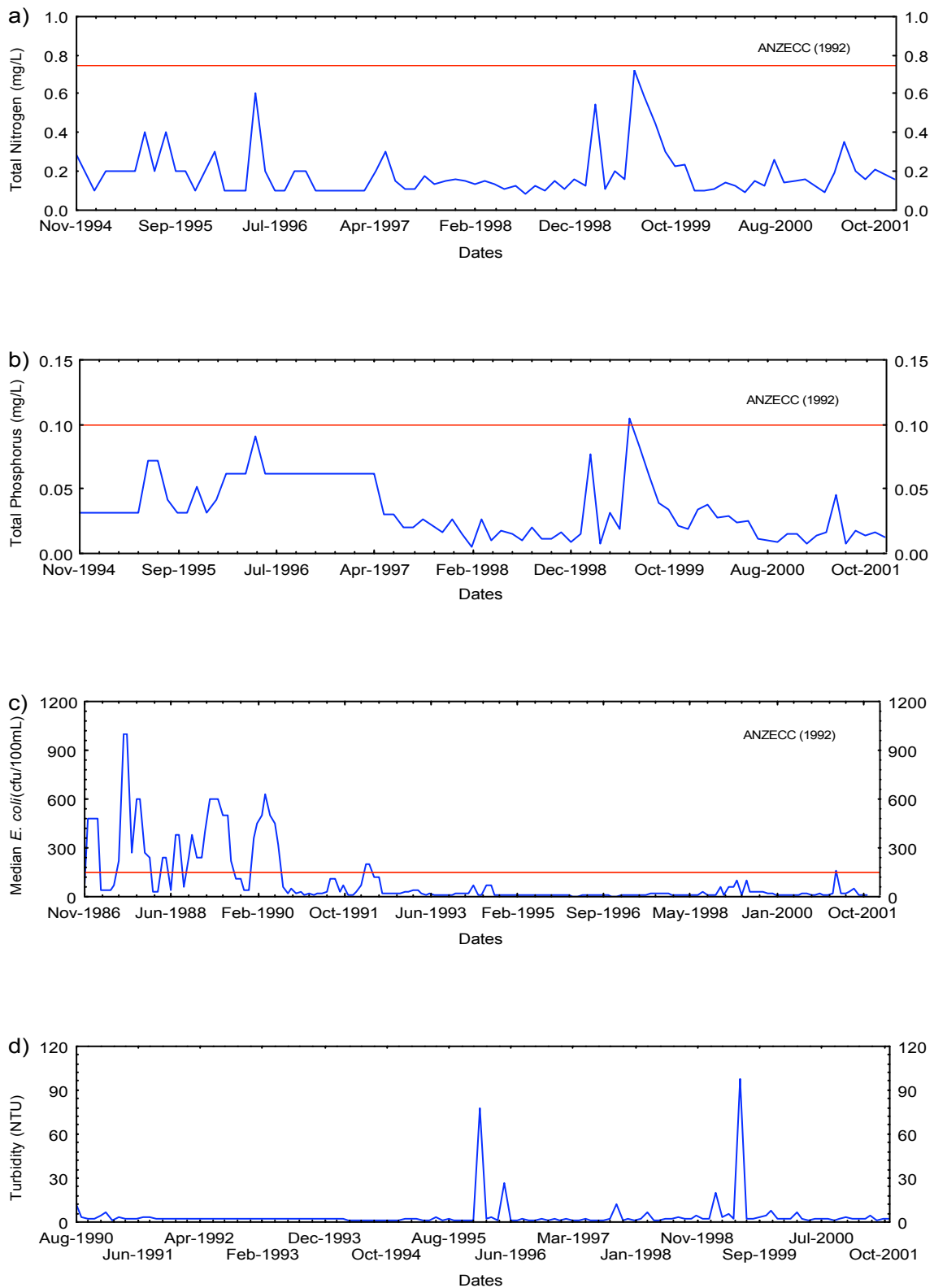
Turbidity varied significantly amongst sites (KW :  $p < 0.001$ ) with significantly higher turbidity at freshwater, upper estuary sites and TBC 2 than at all canal and lower estuary sites (Figure 3.18.2i). Site TBC 4C recorded significantly higher turbidity than at TBC 4D and both canal sites have recorded significantly higher turbidity than at TBC 11.



**Figure 3.18.3** Trends in (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at TBC 1 over the monitoring period.



**Figure 3.18.4** Trends in (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at TBC 1B over the monitoring period.



**Figure 3.18.5** Trends in (a) total nitrogen, (b) total phosphorus, (c) median *E. coli* and (d) turbidity recorded at TBC 6A over the monitoring period.

### 3.18.3 WATER QUALITY TRENDS

Water quality conditions at TBC 1, TBC 1B and TBC 6A has been presented to assess trends over the monitoring period (Figures 3.18.3, 3.18.4 and 3.18.5). All sites have shown that water quality trends have fluctuated over the monitoring period. Nutrient concentrations regularly complied with the guidelines at TBC 1 and TBC 6A, whereas concentrations recorded at TBC 1B significantly exceeded the guidelines during the initial year of monitoring. These high nutrient concentrations recorded at TBC 1B, are likely to be associated with the licensed discharge of treated effluent from the Elanora Wastewater Treatment Plant. Nutrient concentrations improved significantly following the decommissioning of the treatment plant, with concentrations regularly complying with the guidelines. Median *E. coli* concentrations regularly exceeded the primary contact recreational guidelines during the initial years of monitoring at each site. Peaks in concentrations during the initial years of monitoring, appear to be similar between sites, indicating the influence of rainfall. Following February 1990, at all sites, concentrations were less variable and regularly complied with the primary contact recreational guidelines. Periodic increases in *E. coli* concentrations above the primary contact recreational guidelines have been recorded at TBC 1 since June 1993. It is unclear as to the reason for these increases recorded TBC 1. Turbidity at each site has fluctuated over the monitoring period. Turbidity peaks were generally consistent amongst sites examined, and is likely to be related to rain events within this catchment. Turbidity appears to have been stable over the monitoring period.

### 3.18.4 DISCUSSION

Water quality conditions in Tallebudgera Creek have generally complied with the ANZECC (1992) guidelines. The freshwater region of this creek has generally shown better water quality conditions than other downstream regions, particularly in comparison with upper and middle estuary sites. Most water quality parameters have regularly complied with the guidelines. However, TBC 1 has more regularly recorded higher *E. coli* and turbidity than at TBC 0. This site also has recorded higher conductivity, which indicates that during extended dry periods and spring high tides, saltwater intrusion along Tallebudgera Creek reaches this area of the creek.

The upper and middle estuary region of the creek also recorded water quality conditions that complied with the ANZECC (1992) guidelines. However, it was found that conditions are generally poorer in this section of the creek than at sites in the freshwater and lower estuary. Only TBC 4C recorded similar conditions within the lower region of this creek. This upper to middle estuary region of the catchment has experienced major land use changes, with the establishment of various rural and urban land use practices. Gutteridge Haskins & Davey (1998) reported that the middle region of the catchment had the potential to degrade water quality in the lower estuarine section of Tallebudgera Creek. The water quality results over the monitoring period in this report support conclusions in Gutteridge Haskins & Davey (1998).

Water quality at sites Tallebudgera Creek canals, has generally complied with the guidelines, despite higher total nitrogen concentrations than freshwater and other estuarine sites. These higher nitrogen concentrations are likely to be related to the influence of urban stormwater and limited tidal exchange with Tallebudgera Creek. Water quality appeared, however, to improve towards the confluence of the canal and Tallebudgera Creek.

The lower estuary has regularly recorded better water quality conditions than other sections within the creek and is likely to be associated with improved tidal exchange with the Pacific Ocean. However, the results have shown that at certain times, conductivity decreases below 5mS/cm. This suggests that stormwater runoff from the catchment delivers significant volumes of freshwater from the surrounding catchment area to the creek. This freshwater flow can potentially transport nutrients, suspended solids and various other contaminants into the creek, which can impact on the health and quality of Tallebudgera Creek. Therefore, it is important to manage the entire catchment, rather than rely on tidal exchange to flush and dilute any contaminant entering this waterway in order to maintain good water quality conditions.

### **3.18.5 CONCLUSIONS AND RECOMMENDATIONS**

Tallebudgera Creek is generally considered to be in good condition considering this catchment has undergone significant land use changes over the years. Nutrient concentrations appear to have regularly complied with the (ANZECC, 1992) guidelines for the protection of aquatic ecosystems, with only slightly higher nutrient conditions recorded within the canal in the lower estuary. A catchment study was undertaken in 1997 and concluded that land use practices in the catchment were considered to have the greatest influence water quality in Tallebudgera Creek. A strategic action plan was developed as part of this study that identified areas to manage to protect the creek and catchment area. A community catchment management group was formed in this catchment in 2000 and has already begun implementing several rehabilitation works in identified degraded riparian areas along the creek.



### 3.19 CONCLUSIONS TO RESULTS AND DISCUSSION

The water quality information presented in this chapter, has shown that water quality conditions has generally remained within the national guidelines for the protection aquatic ecosystems. The health and quality of Gold Coast waterways is important, given the high degree of value placed on these waterways for tourism, the economy, industry, water supply and the recreational opportunities it provides local residents.

This chapter of the report has highlighted waterway areas, or sites in each waterway, that are performing below acceptable national guidelines or that are generally poorer than other monitoring sites. In most cases nutrients, turbidity and *E. coli* concentrations appear to be the contributing water quality variable to these poorer conditions. Land use changes in catchment areas would appear to be the likely reason for increases in nutrients, turbidity and *E. coli* concentrations. While it was found that these poorer water quality conditions were generally confined to one or two sites within each waterway, Saltwater and Coombabah Creek had most sites regularly not complying with the national guidelines for the protection of aquatic ecosystems. As indicated for both Saltwater and Coombabah Creeks, GCCC has undertaken detailed catchment management investigations to determine the impacts poor water quality conditions have had on the ecological health of each waterway. This information will be used in the formation of land use specific stormwater quality management plans that will identify areas contributing to poor water quality conditions in both Coombabah and Saltwater Creeks. The development of catchment management plans other waterways in the Gold Coast is planned in the future, and will assist in the protection and where necessary, enhancement of the City's waterways.

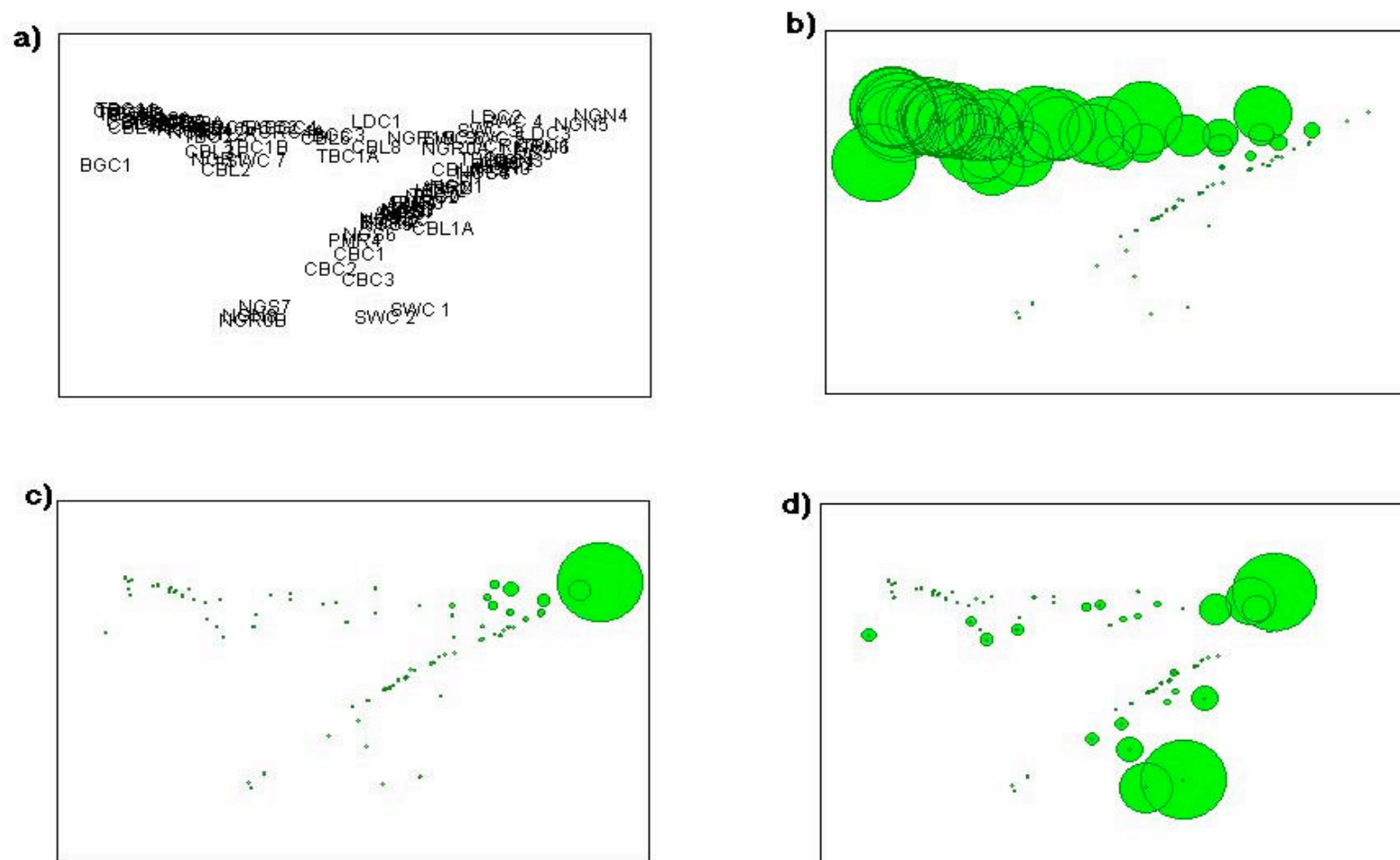
## CHAPTER 4 MULTIVARIATE ANALYSIS OF WATER QUALITY

### 4.1 ALL YEAR DATA SET

The most prominent pattern in the two-dimensional MDS (multidimensional scaling) ordination of the 83 selected monitoring sites, was the separation of sites into two distinct groups, spread along lines at an angle to each other (Figure 4.1.1 a). SIMPER analysis showed that the variable most important in separating the two groups was conductivity, with one group consisting of sites with lower conductivity (*ie* freshwater) and the other group with sites recording higher conductivity (*ie* marine and brackish sites) (Figure 4.1.1b). Within both groups, sites lay along a gradient based on *E. coli* concentrations (Figure 4.1.1c, Table 4.1.1). *E. coli* concentrations increased towards the right of the gradient in each group, with NGN4, at the far right, having the highest mean *E. coli* concentration of both marine and freshwater groups. Whilst the position of most sites, in the ordination plots, is explained by conductivity and *E. coli* concentrations, a small number of sites appear to lie outside the gradient lines. SIMPER analysis showed that these sites stood apart because of higher turbidity in comparison with other sites (Figure 4.1.1d).

**Table 4.1.1** Spearman rho correlation coefficient from BioEnv analysis illustrating the strength of relationship of each variable and a combination of variables from the all year data set. (-) represents no combination of variables were analysed.

Variable	Conductivity	Median <i>E. coli</i>	Turbidity	Dissolved Oxygen	pH	Total Nitrogen	Total Phosphorus	Temperature
Single Variable	0.686	0.581	0.112	0.253	0.408	0.097	0.028	0.415
Turbidity	0.787	0.903	-	-	-	-	-	-
Median <i>E. coli</i>	0.958	-	-	-	-	-	-	-



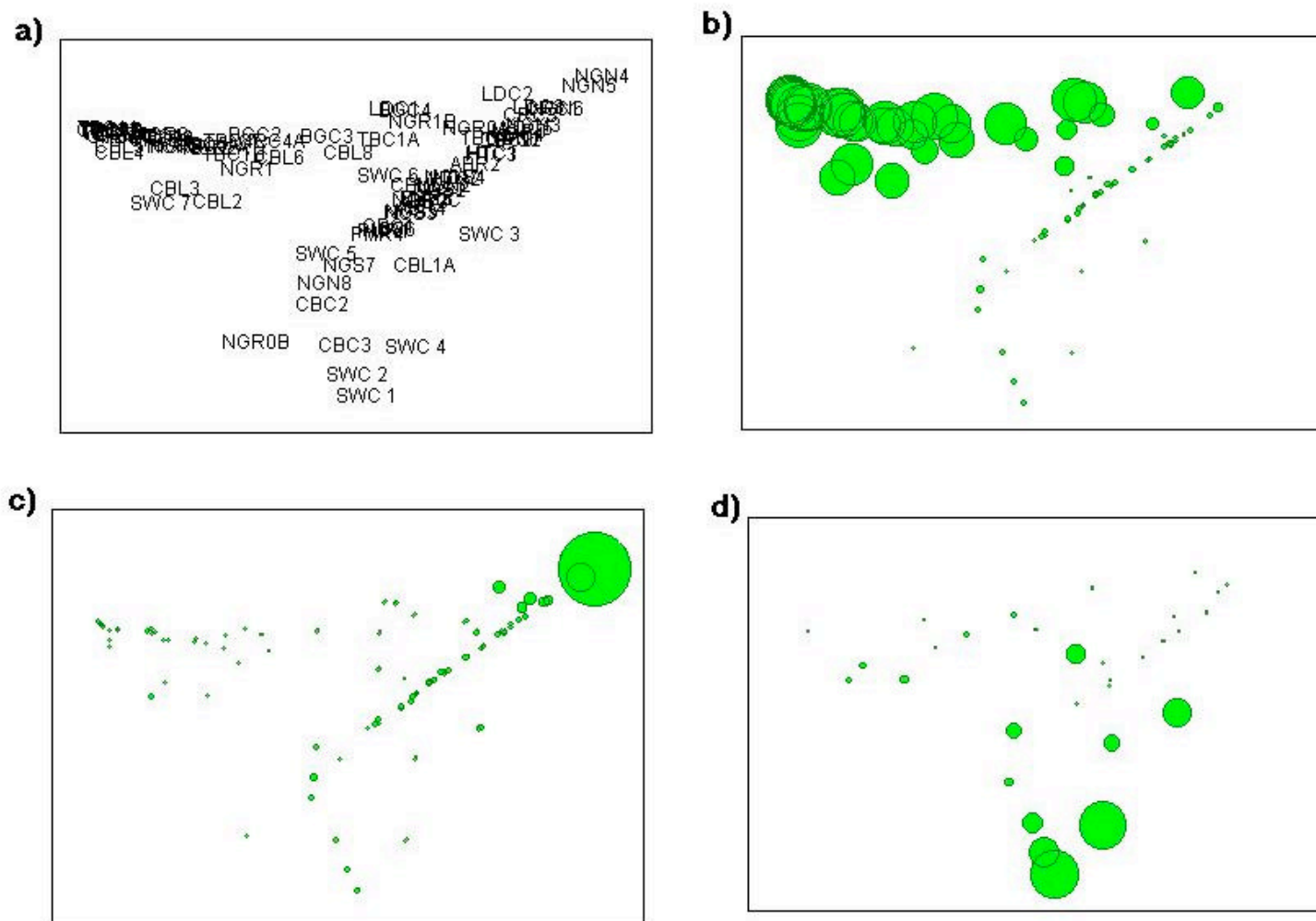
**Figure 4.1.1** Two-dimensional MDS plots for the all year data set and overlay of single variable with a strong correlation. (a) all monitoring sites, (b) conductivity, (c) median *E. coli* and (d) turbidity. Diameter of circles is proportional to the performance of each water quality variable. Stress = 0.07.

## 4.2 FIVE YEAR DATA SET

The two-dimensional MDS ordination using the 5 year data, between October 1997 and October 2001, was found to have two distinct groups spread along lines at an angle to each other, similar to the all year data plot (Figure 4.2.1 a). As for the all year data set, SIMPER analysis showed that conductivity was the most important variable in separating the two groups (i.e. freshwater and marine/brackish) (Figure 4.2.1b). Both groups were also found to lie along a gradient based on *E. coli* concentrations (Figure 4.2.1c, Table 4.2.1). Site NGN4 again recorded the highest mean *E. coli* concentration of both marine and freshwater groups. The position of most sites in the ordination was again explained by conductivity and *E. coli* concentrations. Where sites lay outside the gradient lines, most notably SWC 1 and SWC 4 (Figure 4.2.1a), SIMPER analysis showed that these sites stood apart because of higher turbidity in comparison with other sites (Figure 4.2.1d).

**Table 4.2.1** Spearman rho correlation coefficient from BioEnv analysis illustrating the strength of relationship of each variable and a combination of variables from the five year data set. (-) represents no combination of variables were analysis.

Variable	Conductivity	Median <i>E. coli</i>	Turbidity	Dissolved Oxygen	pH	Total Nitrogen	Total Phosphorus	Temperature
Single Variable	0.642	0.494	0.122	0.159	0.322	0.192	0.105	0.103
Turbidity	0.649	0.392	-	-	-	-	-	-
Median <i>E. coli</i>	0.74	-	-	-	-	-	-	-



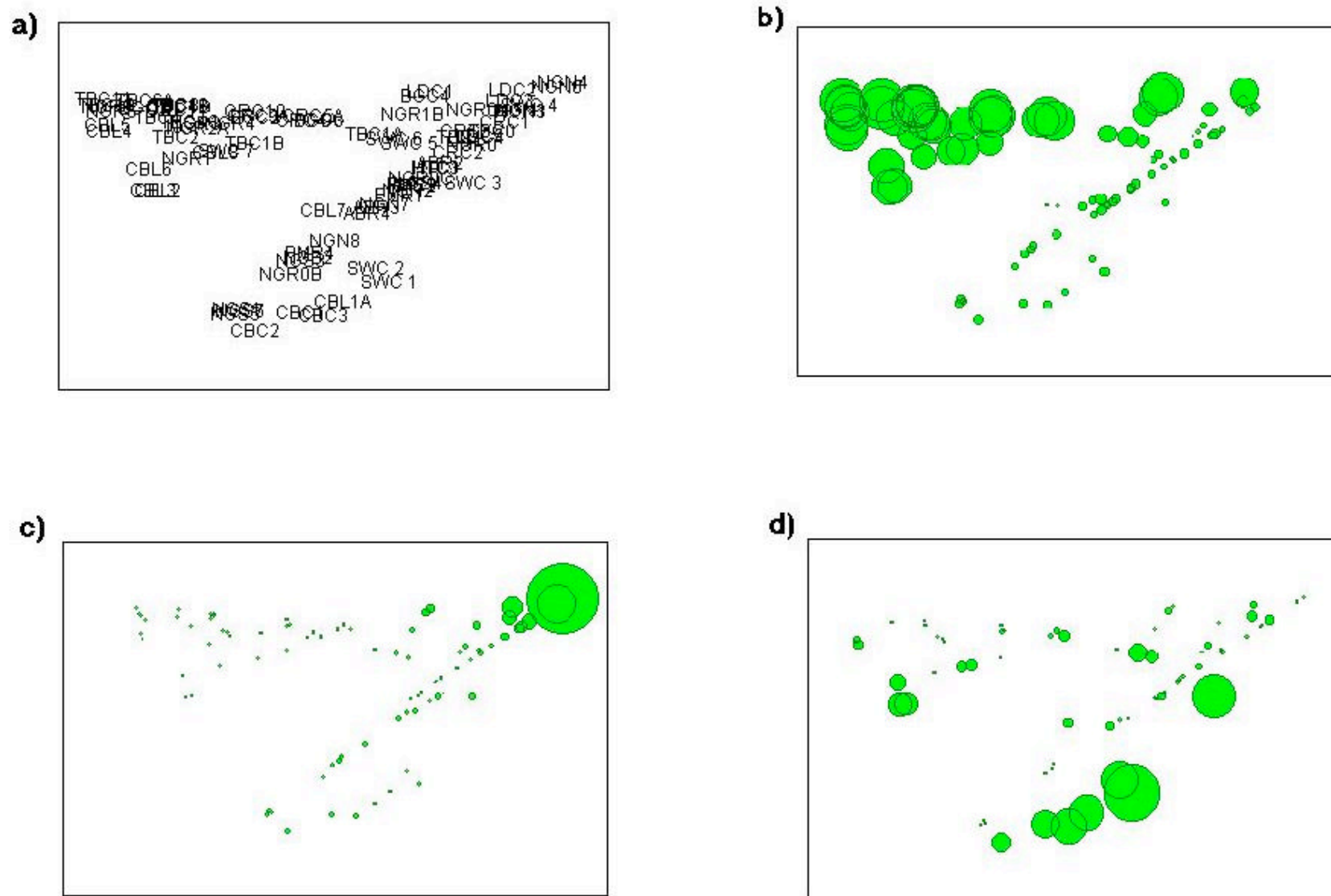
**Figure 4.2.1** Two-dimensional MDS plots for 5 year data set and overlay of single variables with a strong correlation. (a) all monitoring sites, (b) conductivity, (c) median *E. coli* and (d) turbidity. Diameter of circles is proportional to the performance of each water quality variable. Stress = 0.07.

### 4.3 TWO YEAR DATA SET

The two-dimensional MDS ordination using the 2 year data, between October 1999 and October 2001, again revealed two distinct groups, spread along lines at an angle to each other (Figure 4.3.1a). Similar SIMPER results to the all year and 5 year data sets were found. Conductivity was the most important variable separating the two groups (Figure 4.3.1b). Both groups were also found to lie along a gradient based on *E. coli* concentrations (Figure 4.3.1c, Table 4.2.1). Site NGN4 again recorded the highest median *E. coli* concentration of both marine and freshwater groups. This was similar to the ordination of the all year and 5 year data sets where NGN 4 had the highest mean *E. coli* concentration. As with both other data sets, the positions of most sites in the ordination plot were explained by conductivity and *E. coli* concentrations (Table 4.2.1). Sites that lay outside the conductivity/*E. coli* concentration gradient lines, most notably CBL 1a, CBL 2, CBL 3 and CCL 6, stood apart because of higher turbidity in comparison with other sites (Figure 4.3.1d).

**Table 4.3.1** Spearman rho correlation coefficient from BioEnv analysis illustrating the strength of relationship of each variable and a combination of variables from the two year data set. (-) represents no combination of variables were analysed.

Variable	Conductivity	Median <i>E. coli</i>	Turbidity	Dissolved Oxygen	pH	Total Nitrogen	Total Phosphorus	Temperature
Single Variable	0.485	0.479	0.079	0.163	0.247	0.162	0.052	0.143
Turbidity	0.448	0.311	-	-	-	-	-	-
Median <i>E. coli</i>	0.619	-	-	-	-	-	-	-



**Figure 4.3.1** Two-dimensional MDS plots for 2 year data set and overlay of single variables with a strong correlation. (a) all monitoring sites, (b) conductivity, (c) median *E. coli* and (d) turbidity. Diameter of circles is proportional to the performance of each water quality variable. Stress = 0.07.

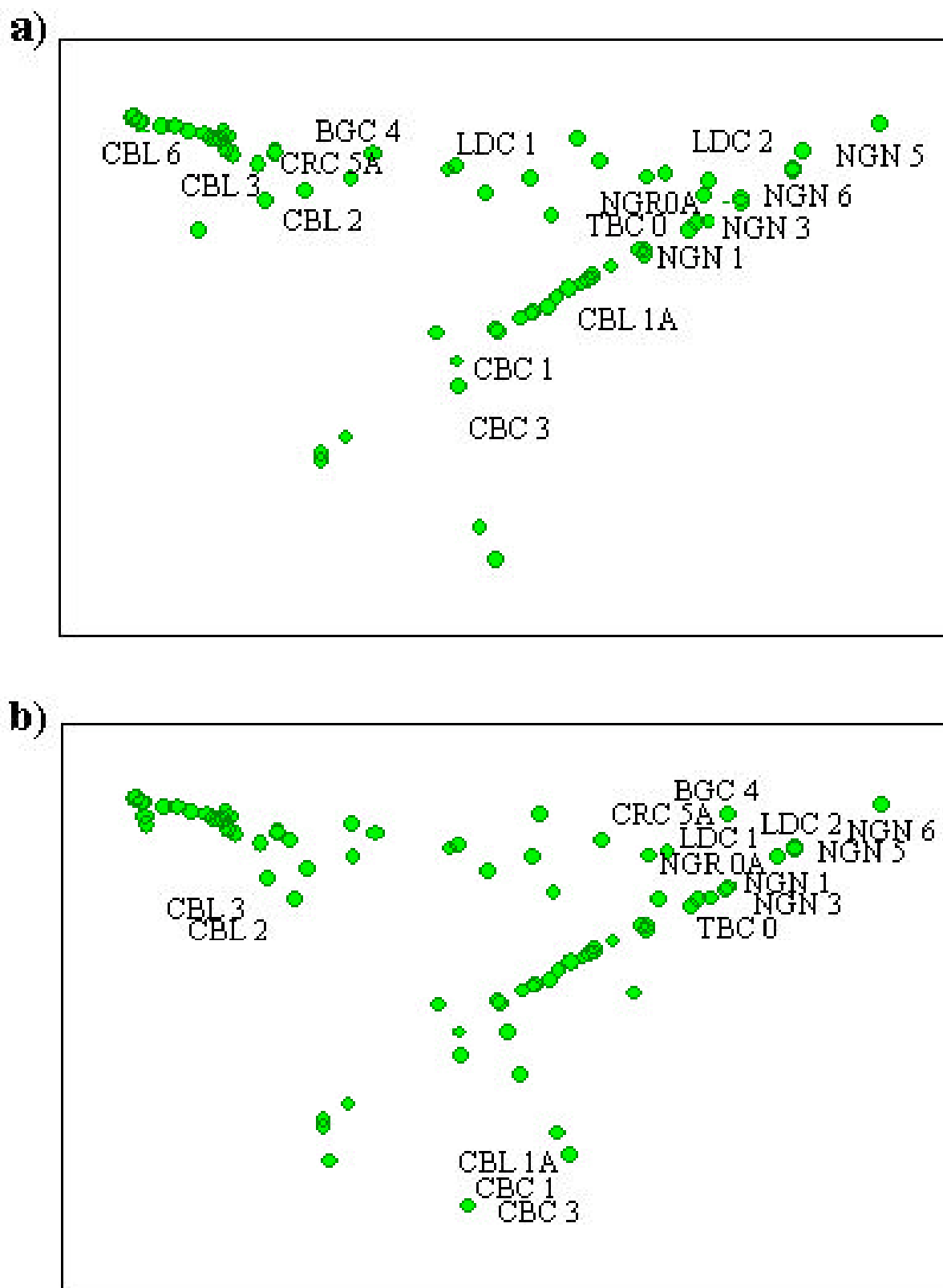
#### 4.4 COMPARISON AMONG DATA SETS

Changes in water quality at sites in recent years should be detectable as shifts in the position of sites on the ordination plots from the different data sets. All sites remained in the same conductivity group in each of the different ordinations, meaning that the average salinity values did not change markedly over time at any site. The most notable change in water quality is reflected by the movement of sites on the ordination plots between the all year data set and the two year data set (Figure 4.4.1). The sites that had the greatest change in position based on *E. coli* and turbidity between the two data sets are shown in Table 4.4.1. Sites NGN 6, NGN 5 and CBC 1, CBL 3 had the greatest change in *E. coli* and turbidity respectively in recent years relative to all years (Table 4.4.1). Site NGN 5 and NGN 6 had a major shift between ordinations, due to a prominent increase in *E. coli* concentrations (Table 4.4.1). Site NGN 4 remains at the far right side of the *E. coli* gradient between the two ordination plots. This is despite a general improvement in water quality conditions, particularly *E. coli* concentrations, over the time (refer to section 3.13). Sites within Coombabah Creek, particularly within the upper freshwater and upper estuarine region, had the greatest change in position, based on turbidity, between the 2 data sets. This would indicate that freshwater and upper estuary sites of this creek have declined considerably over time.

**Table 4.4.1** Comparison of mean water quality results between all year data set and 2 year data set for those sites that showed the greatest change in position, based on *E. coli* and turbidity conditions, between both ordination plots.

Site	<i>E. coli</i> (cfu/100mL)		Site	Turbidity (ntu)	
	All data	2 year		All data	2 year
NGN6	230	1100	CBC1	19	31
NGN5	660	1100	CBL3	15	27
LDC2	300	560	CBL2	18	26
NGN1	78	310	CBL6	12	19
BGC 4	60	230	CBL1A	35	41
NGN3	150	280	CBC3	35	40
LDC1	120	240			
NGR0A	123	235			
TBC0	62	160			
CRC5A	35	90			





**Figure 4.4.2** Two-dimensional MDS plots for a) all years data set and b) the 2 year data set. Sites that showed the greatest change in position from Table 4.4.1 have been labelled (site code has replaced the position of the circle). Stress = 0.07.

## CHAPTER 5 OVERALL DISCUSSION AND RECOMMENDATIONS

### 5.1 WATERWAY DISCUSSION

The water quality information, collected from 18 waterways, shows that the majority of the City's waterways are generally complying with the ANZECC (1992) guidelines for the protection of aquatic ecosystems and the primary contact recreational guidelines (*ie* swimming).

From the presentation of water quality data in this report, several water quality variables, namely nutrients, *E. coli* and turbidity, have shown that concentrations fluctuate between waterways and also amongst sites within each waterway. Large areas in most middle to lower catchments within the City have undergone extensive land use changes to accommodate the growing Gold Coast population. The change in land use is considered to be the major contributing factor relating to water quality within waterway and between waterways in the City.

The perception that upper waterway regions generally experience better water quality conditions, with a subsequent gradual deterioration downstream in response to land use changes, was not apparent for a number of waterways (*eg* Saltwater Creek). In catchments where this was observed, a significant land use change within the upper catchment has taken place in recent years. In these waterways, it is considered that upper catchment management plans should be a high priority for GCCC.

Seasonal variation in water quality conditions was observed at a number of sites, with most recording generally poorer conditions during summer months (whilst in most cases still complying with the acceptable guidelines). Elevated nutrient, turbidity and *E. coli* concentrations have also been recorded across the City at other times of the year and it is thought that these elevations may be related to unseasonal rain events. During significant rain events, dramatic increases in nutrient, turbidity and *E. coli* concentrations were observed and were generally consistent amongst sites within waterways.

The overall water quality trend in Gold Coast City shows that there has not been a decline in conditions over the past decade. Moreover, water quality has generally remained at a similar standard to recent years. Several sites, however, have shown a significant decline in performance, in particularly, within the past 5 years. At these sites, more detailed investigations are required to ensure that these local problems do not become a whole of catchment issue. In the case of Coombabah and Saltwater Creeks, where water quality has shown signs of deterioration in terms of nutrients, turbidity and *E. coli*, detailed catchment studies have been initiated to provide more comprehensive ecological data/information on each waterways response to land use changes. This information is important in developing a specific action plan for each waterway. Detailed catchment management investigations are planned for other waterways in the coming years.

### 5.2 BROADWATER AND BEACHES

The Gold Coast beaches have consistently complied with the ANZECC (1992) guidelines for primary contact recreational waters (*ie* swimming). This is important given the significance of Gold Coast beaches to the local community and tourists that visit the City. The enclosed swimming lagoons within the Broadwater, Tallebudgera and Currumbin Creeks have also regularly complied with the primary contact recreational guidelines. However, at times elevated concentrations above the guidelines have been recorded. These elevations are probably influenced by stormwater runoff from surrounding urban areas.

Monitoring the discharge of treated wastewater at the Gold Coast Seaway by EPA, in conjunction with GCCC, has indicated that this activity does not influence water quality within the Broadwater (Moss and Cox, 1999). Moss and Cox (1999) concluded that runoff from the tributaries surrounding the Broadwater, particularly following rain periods, would have a greater influence on water quality in the Broadwater, than the release of treated wastewater at the Seaway.

Results of analysis contained within this report support Moss and Cox's (1999) conclusions. It was suggested in this report, that the management of those catchments that flow into the Broadwater is important to ensure that the Broadwater is protected.

### 5.3 FRESHWATER AND TIDAL LAKES

Water quality conditions within each lake regularly complied with the ANZECC (1992) guidelines for the protection of aquatic ecosystems. For several water quality variables, however, conditions were found to fluctuate at sites. Several reasons could explain these fluctuations including restricted tidal exchange with larger (primary) waterways, seasonal and climatic changes or urban contaminants. These fluctuations have the potential to affect the health and quality of each lake. In particular, fluctuating dissolved oxygen concentrations can have deleterious impacts on aquatic communities inhabiting these lakes.

The Robina Lakes and Clear Island Waters have experienced problems associated with aquatic plant growth and algal blooms. These aquatic vegetative problems are considered the result of excessive nutrient loads entering each lake. The current water quality monitoring program has not identified problems associated with excessive nutrients in comparison with the national guidelines. However, excessive aquatic plant growth and regular algae blooms are indicative of nutrient enrichment in the Robina Lakes and Clear Island Waters.

The tidal lakes monitored within the City appear to regularly comply with the ANZECC (1992) guidelines for the protection of aquatic ecosystems. While this maybe the case, it is considered that activities undertaken within each catchment (eg. over application of fertilisers to gardens), may potentially impact on these lakes, if not managed correctly.

The management of stormwater quality appears to be the controlling factor in maintaining suitable water quality conditions within each freshwater and tidal lake system. CMU and GCCC's Engineering Services Directorate are investigating and in some cases installed Stormwater Quality Improvement Devices (SQIDS) in areas within the City. It is anticipated that this work will target priority areas, with the view of improving stormwater quality and begin to work towards suitable environmental conditions to protect aquatic wildlife that inhabit the City's constructed lakes.

### 5.4 RECOMMENDATIONS FOR MANAGING GOLD COAST WATERWAYS

The management of Gold Coast waterways, for the protection of EVs and achievement of water quality objectives, requires catchment specific investigations. Such investigations should target areas identified in this report that are performing below the national guidelines and more importantly, are performing at a standard below other sites within and amongst waterways.

While this report has presented a statistical review of water quality data recorded in constructed and natural waterways across the Gold Coast, it is considered that this level of waterway monitoring provides a limited understanding of ecosystem health and waterway processes. Other forms of waterway monitoring, namely aquatic biota investigations, can considerably improve the understanding of waterway health, processes and responses to catchment landscape changes (Norris and Norris, 1995). Sediment, storm events and riparian assessment studies, in combination with water quality and biological monitoring, would further assist in the development of waterway and catchment management plans. This information could also be utilised in catchment management models that predict the effects that future land use changes may have on a receiving waterway. Some recommended project areas are discussed in the following subsection.

## 5.4.1 FUTURE MONITORING ACTIVITIES

### 5.4.1.1 Event Monitoring

Event monitoring represents a means by which water quality (quality and quantity) information can be quickly and efficiently gathered. An event monitoring program currently exists within the City. This project has been designed to assess the relationship between water quality and storm events in three specific land use areas (*ie* urban, mixed residential, forested-pristine). This information will be used to develop specific export loading rates for each land use scenario, which can be used in water quality modelling of other catchments within the City.

It is anticipated that additional event based monitoring programs will be established to target smaller catchments and those waterways identified in this report that are exhibiting poor water quality conditions (*eg* Biggera and Loders Creeks). Such programs would potentially capture the affects of land use changes, pollution events or those more regular minor rain events that the current program does not assess.

It is recognised that while significant storm events are infrequent, they could in fact have a major impact on water quality within waterways (*ie* sediment loadings). The design of a specific event monitoring program could also assist GCCC, along with community catchment management groups, in facilitating remedial strategies designed to prevent erosion and the discharge of pollutants from point sources into our waterways.

### 5.4.1.2 Sediment Monitoring

The rate and quality of sediment deposition in the Gold Coast may have changed over time in response to land uses and the loss of catchment and riparian vegetation (*eg* Coombabah Creek). A sediment program focusing on deposition rates, morphology sourcing and sediment chemistry, in combination with biological monitoring programs, will assist ongoing efforts in both catchment and stormwater management.

Sediment monitoring provides an opportunity to examine waterway conditions over longer periods of time. Sediment monitoring also assists with understanding the potential health and diversity of benthic biota. These organisms live within this environment and are affected by various contaminants. The ANZECC (2000) guidelines recognise the importance of sediment monitoring, and have provided a guide for sediment monitoring.

There has not been a regular sediment monitoring program within the City, however, several smaller specific sediment quality programs have been undertaken in selected waterways.

### 5.4.1.3 Biological Monitoring

Water quality monitoring elucidates the physico-chemical interaction between terrestrial and aquatic environments. However, its capacity to determine the impact of such interactions on the environment is limited. Biological monitoring represents a means of documenting change in ecological health. It also provides resource managers an opportunity to monitor species abundance and diversity over extended periods of time.

While periodic monitoring of water quality parameters may not record brief but environmentally significant changes in waterway health, such changes are captured and recorded by the fluctuating state of aquatic communities. Biological monitoring holds a significant place in the environmental management strategies of waterway managers. By this, biological monitoring has been recognised in the ANZECC (2000) guidelines as an effective means of measuring and monitoring waterway health. To date, biological assessments have been limited to a freshwater fish study within the City (refer to Aquatic Riparian Ecological Assessment reports), several postgraduate research projects and a small number of programs associated with catchment management studies (*eg* Coombabah Creek Environmental Inventory and Saltwater Creek Environmental Inventory).

In the near future, GCCC, in conjunction with other stakeholders, will consider the implementation of an Estuarine Ecosystem Health Monitoring Program. In estuarine areas, this program will monitor waterway health indicators such as seagrass distribution, nutrient processing, phytoplankton bioassays, occurrence of nuisance algae, and sediment nutrient influxes. In freshwater streams, it is proposed to use additional indicators such as fish abundance, invertebrate populations, and nutrient cycling to assess and monitor ecosystem health.

#### **5.4.1.4 Vegetation Surveys**

The health and distribution of aquatic and riparian plant communities plays an integral part in the maintenance of biodiversity. In the freshwater environment, aquatic plants and riparian vegetation provide habitats for aquatic animals, strip contaminants from the water as the flow passes through, helps prevent erosion and stabilise stream banks and provides shading to decrease temperatures and limit the growth of aquatic plants and algae (Karssies and Prosser, 1999).

The distribution of these habitats can be easily assessed by periodic examination of aerial photographs combined with rapid ground truthing methods. Riparian surveys have been commissioned by CMU within several major catchments and sub-catchments of the City to assess the state of riparian and in-stream vegetation (refer to Aquatic and Riparian Ecological Assessment reports). These reports present information for GCCC to consider when allocating resources that will improve the state of riparian and in-stream vegetation in the City. This program should continue on a periodic basis and could be monitored by community catchment management groups, in conjunction with CMU officers.

### **5.4.2 ENVIRONMENTAL EDUCATION PROGRAMS**

#### **5.4.2.1 Community Catchment Management Groups**

Encouraging community participation is a key objective in the ICM process and is important in linking the local community with Government resource management officers. ICM is being implemented within Gold Coast City through the establishment of community catchment management and Landcare groups. These community groups provide a forum for community discussion and input into the catchment management process. These groups have been involved in the identification of local environmental issues including, but not limited to, stream bank stabilisation, weed control, water quality, wildlife management, stormwater management and community awareness. These groups are also actively participating in the preparation and implementation of catchment management strategies.

Tree planting programs to rehabilitate riparian corridors have, in the past, played a key roll in promoting community interest in environmental management. By promoting participation, these groups encourage ownership of and responsibility for their local land and waterway resources.

A Catchment Liaison Officer has been appointed, through a joint venture between the Natural Heritage Trust and GCCC, to establish and support community catchment groups and to form a City wide Gold Coast Catchment Association. This project has been designed to increase public awareness of environmental and waterway related issues through the formation and coordination of community catchment management and Landcare groups. It is anticipated that further community catchment management groups will be established (eg Currumbin Creek and Coomera River) within the City.

#### **5.4.2.2 Waterwatch Program**

Waterwatch is a nationally recognised program that aims to improve water quality and raise environmental awareness by involving the community in the monitoring of the local waterways (Department of Primary Industries, 1995). Gold Coast school and community groups are actively working in a cooperative manner with GCCC to monitor their local waterways.

The Waterwatch program aims to formalise these activities by encouraging schools and community groups to undertake basic water quality testing of their local waterway. This improves community and student awareness of local catchment issues and the importance of resource management.

The Gold Coast Waterwatch program presents an opportunity to increase community awareness and promote environmental strategies within the City. It is anticipated that this program will in turn have a positive impact on the quality of the Gold Coast's waterways.

#### **5.4.3 ENVIRONMENTAL VALUES AND CATCHMENT STUDIES**

The value placed on a waterway is fundamental in determining the direction management strategies should occur for a waterway. Selecting or determining EVs for a particular waterway is recognised in state legislation in Queensland [Environmental Protection Policy (Water), 1997]. The development of EVs for a waterway, involves joint input from a collective number of stakeholders including community and indigenous groups, industry, local and state government and research institutions. The desired outcome from this working group is to develop agreed values and goals, for a waterway, that are considered important by all local catchment stakeholders.

A community consultation process is being undertaken to determine EVs for Gold Coast waterways. Community catchment groups have already been involved in workshops facilitated by officers from CMU and the South-East Queensland Regional Water Quality Management Strategy team. The aim of these workshops is to determine the values for a particular waterway. To ensure wider community participation in this process, community catchment management groups have also been encouraged to disseminate the information throughout their various networks.

Detailed catchment management investigations have been undertaken in several catchments across the City to assist with first developing EVs for waterways and secondly to determine the water quality objectives that are necessary to protect the EVs. Catchment studies undertaken within the City include Tallebudgera Creek, Flat Rock Creek, Coombabah Creek and Saltwater Creek.

With community members becoming increasingly aware of the range of issues affecting waterways, their input is essential to ensure that the EVs of all waterways are determined. This will assist to develop appropriate management actions. In the coming years, CMU will continue to develop catchment management plans for other waterways within the City. This will generally be on a priority basis, and recommendations from this report, in conjunction with GCCC's Total Management Plan, will assist with the prioritisation of future waterway studies. An important outcome of these studies is the action plans that assist GCCC in directing resources to protect and if necessary enhance degraded areas of a waterway. The further integration of issues such as stormwater management and land use planning will greatly improve the value and scope of catchment management plans and investigations. A comprehensive and coordinated total catchment approach to catchment planning will be pursued in future.

#### **5.4.4 REVIEW OF THE WATER MONITORING PROGRAM**

Following the analysis of water quality data presented in this report, a review of the current water quality monitoring program by CMU is planned. This review will assess all monitoring surveys in order to determine the most representative sample regime within each waterway. It will also ensure consistency of water quality parameters across catchment areas. This review is likely to include upgrades of the current composite sample regime as part of tidal and freshwater lake survey, inclusion of monitoring sites in canal areas and the overall rationalisation of site locations in each catchment. Importantly, this planned review of the current program will ensure that the City wide program remains consistent with the new ANZECC water quality guidelines (2000). This will provide a more comprehensive framework for the monitoring of waterway health within Gold Coast City.

## **5.5 CONCLUSIONS**

The Gold Coast waterways are recognised as an important asset to the City, given the high degree of value they have to tourism, economy and the recreational opportunities and visual amenity for local residents. The overall findings in this report suggest that water quality conditions within the City are generally maintaining a level suitable for the protection of aquatic ecosystems. Designated recreational swimming areas and monitoring sites along the beaches have also regularly complied with the primary contact recreational guidelines.

GCCC recognises the potential ramifications associated with the degradation of Gold Coast waterways. In order to maintain the current acceptable water quality conditions experienced within most waterways, it is important that the Gold Coast community, GCCC and the state government, work together to protect the City's aquatic environment. This can be achieved through ensuring that various human derived pollutants are not allowed to enter the stormwater system and that specific catchment management plans, addressing issues pertaining to landscape changes/uses and stormwater management, are prepared by GCCC and other agencies.

It is therefore considered vital, that the continuation of water quality monitoring, in combination with more detailed ecological investigations outlined within this report, is maintained. This form of ecosystem health monitoring will provide a greater level of ecosystem understanding of Gold Coast waterways, so that appropriate water quality standards can be maintained that will protect and enhance the waterways within the City.

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## CHAPTER 7 GLOSSARY of TERMS

TERM	DEFINITION
AESTHETIC	Are those aspects of water that are perceivable by the senses.
ALLUVIAL	A level or gently sloping surface formed of sediments laid down by streams, generally during flooding.
ANZECC	Australian and New Zealand Environment Conservation Council water quality guidelines.
ASSIMILATE	The ability of the natural environment to absorb or deal with external pressures, such as emissions produced as a result of human activities, without leading to permanent and/or significant change.
BACTERIA	One celled spherical, spiral, filament or rod-shaped organisms. They have beneficial, harmful and indifferent effects on other organisms.
BASALT	Dark coloured rocks of volcanic origin.
BASELINE INFORMATION	Information relating to a specific time or defined area of land or water, from which trends or changes can be assessed.
BENTHIC INVERTEBRATES	Are invertebrates that are associated with (attached or buried) the sea or river floor.
BIODIVERSITY	The variety of all life forms: the different plants, animals and micro-organisms, the genes they contain and the ecosystems they form.
BIOLOGICAL MONITORING	Routine counting, testing or measuring of biota to determine their condition, or that of their surrounding habitats.
BIOTA	Are the living organisms present in a specific region or area, ranging in size from a small puddle to a biome or larger.
BRACKISH SYSTEM	An aquatic environment where water is saline, but less so than sea water.
CAMBA	China-Australia Migratory Birds Agreement
CATCHMENT	The area determined by topographic features within which rainfall will contribute to runoff at a particular point under consideration.
CONTAMINANT	To make impure or unsuitable by contact or mixture with an unclean substance.

TERM	DEFINITION
EBBING TIDE	A reduction in the volume of water from high tide to low tide.
ECOSYSTEM	An ecological community together with the physical environment with which its members interact.
ENVIRONMENTAL VALUES	Are particular values or uses of the environment that are conducive to public benefit, welfare, safety or health and that require protection from effects of pollution, waste discharges and deposits. Several environmental values may be designated for a specific water body.
EPIDEMIC	Spreading rapidly for a period through the community.
EPIPHYTE	A plant that grows on another plant for support, but is not a parasitic.
EPISODIC	An episode or event occurring sporadically or incidentally.
ESTUARY OR ESTUARINE	Area of an inlet or river mouth that is influenced by the tides and also by freshwater from the land and where fresh and salt waters mix.
FRESHWATER	Is water with a salinity less than 1.5mS/cm.
HABITAT	The place where an animal or plant normally lives and reproduces.
HEAVY METAL	Metallic element with relatively high atomic mass, such as lead, cadmium, and mercury; generally toxic in relatively low concentrations to plants and animal life.
IN-SITU	Water quality test conducted in the field and not at a laboratory.
JAMBA	Japan-Australia Migratory Birds Agreement
MACROINVERTEBRATE	Small animal without a backbone eg insects, worms, snails, mussels, prawns and cuttlefish.
MEDIAN	The middle number in a sequence of numbers.
MONITORING	Routine counting, testing or measuring of environmental factors or biota to determine their status or condition.
NUTRIENTS	Material that organisms take in and assimilate for growth and maintenance.

TERM	DEFINITION
PARAMETER	Is a variable which may be kept constant while the effect of other variables is investigated. For this report, parameters are the variables being monitored.
PHOTOSYNTHESIS	The conversion of carbon dioxide to carbohydrates, in the presence of chlorophyll, using light energy.
PHYTOPLANKTON	Microscopic plant plankton that require sunlight for photosynthesis.
POLLUTANT	The addition of a material to the air, soil or water that adversely affects the environment.
POTABLE WATER	Is water suitable, on the basis of both health and aesthetic considerations, for drinking or culinary purposes.
RAMSAR	Is an international treaty that seeks to prevent the worldwide loss of wetlands, and to conserve them through wise use and management.
RIPARIAN VEGETATION	Is the vegetation which inhabits the banks of waterways.
RURAL	Pertaining to country life.
SOLUBILITY	Is the amount of a substance that will dissolve in a given amount of another substance.
STORMWATER	Surface runoff or drainage of rainfall following a storm event.
STRATIFICATION	Of a water body can occur when different layers of water form as a result of varying parameter levels, (e temperature and conductivity).
SQIDS	Stormwater Quality Improvement Devices - the installation of treatment devices to improve stormwater quality to a predetermined standard/level.
THALWEG	The longitudinal outline of a riverbed from source to mouth.
URBAN	Pertaining to a town or city.
WATER QUALITY OBJECTIVES	Are a numerical concentration limit or narrative statement that has been established to support and protect the designated uses of water at a specified site.
ZOOPLANKTON	The animal portion of the plankton.