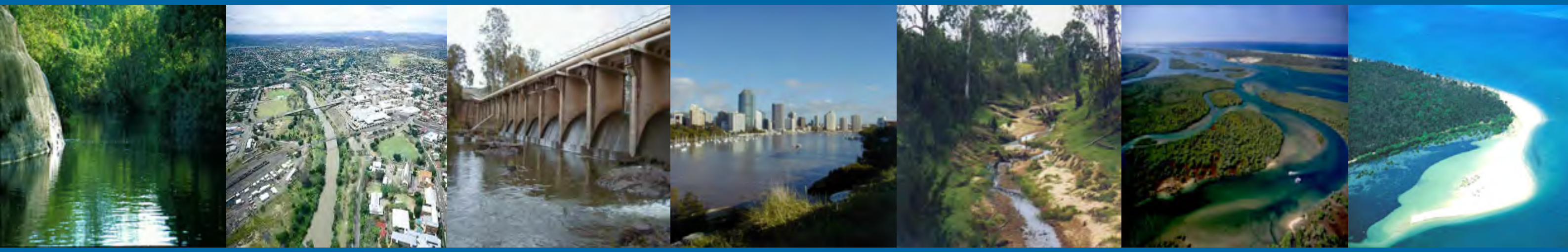
State of South-east Queensland Waterways Report 2001



State of South-east Queensland Waterways Report 2001

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Prepared by the Moreton Bay Waterways and Catchments Partnership

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Contents

Foreword

Welcome to the first *State of South-east Queensland Waterways Report* released by the Moreton Bay Waterways and Catchments Partnership. This Report is significant in that it alerts the community to the current state of the waterways of South-east Queensland and the changes or pressures which are affecting their condition.

As a community, we place a high value on our rivers, Moreton Bay, and associated creeks and tributaries. These waterways are part of the lifestyle and culture of our region; they supply water for urban, agricultural and industrial uses; they are used for recreation, boating and sport; and they support a wide range of natural habitats and species, as well as economic activities such as commercial fishing, port operations and transport.

In the context of a rapidly growing population, we cannot expect our waterways to continue to meet all these needs unless we take a strategic and pro-active approach to their management. The State of South-east Queensland Waterways Report is a valuable tool in this process. The Report examines the current condition of these waterways and provides detailed information which will inform future planning and management activities.

This Report is intended to assist government, community groups and industry in identifying future responses to improve the condition of waterways. It provides information and interpretations of the changes, trends and threats in each of the sub-catchments. The Report also provides technical information and data to inform and assist in the evaluation of the performance of the 1998 Waterways Management Plan and the South-east Queensland Regional Water Quality Management Strategy.

The State of South-east Queensland Waterway Report builds on the information provided in the 1996 State of the Brisbane River, Moreton Bay and Waterways Report. This reporting process also provides a valuable baseline for ongoing monitoring. It will allow us to gauge the success of our collective efforts to protect one of South-east Queensland's precious assets — our waterways.

The Report forms part of the cooperative approach which has been adopted in South-east Queensland to protect and improve the quality of our catchments and waterways and achieve the Healthy Waterways Vision that,

South-east Queensland's catchments and waterways will, by 2020, be healthy ecosystems supporting the livelihoods and lifestyles of people in South-east Queensland, and will be managed through collaboration between community, government and industry.

Diane Tarte
Project Director
Moreton Bay Waterways & Catchments Partnership

Acknowledgments

Many people have contributed to the production of this report. The enthusiastic response and effort of the authors/contributors, sources of information and reviewers from the scientific team, local and state governments as well as community and industry organisations are much appreciated.

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Executive Summary

The *2001 State of South-east Queensland Waterways Report* is a follow-up to the 1996 State of Brisbane River, Moreton Bay and Waterways Report. Like its predecessor, this report is intended to inform and advise community groups, industry and all levels of government and assist in identifying future responses to improve the condition of waterways. The report provides a synthesis of our current understanding of the state of South-east Queensland waterways, extending from Noosa River in the north to the Gold Coast waterways in the south.

The state of each waterway is summarised in the form of a conceptual model, which integrates scientific understanding of the key ecological processes and patterns which best indicate the ecosystem health of the waterways (Fig 1). While this report uses the framework provided in the 1996 State of Waterways Report, it differs from that report in relying more on ecological health measures than on conventional physico-chemical indicators. General trends of the different pressures on our waterways have been summarised (Table 1). South-east Queensland has one of the fastest growing populations in Australia, with just over 2 million people, increasing by 2.9% per annum (Fig 2). These increases in population are expected to result in 75km^2 of bushland, agricultural land and other rural land being converted to housing and other urban purposes each year.

Following the 'state-pressure-response' approach, the report also outlines management responses that are being implemented or planned to deal with the pressures. The future of the south-east Queensland waterways is reliant on appropriate management to ensure that the state of our waterways improves. Water quality management initiatives currently operating in the catchment include various measures involving local government regulations, government and industry policies and practices, catchment management plans, city and shire planning schemes, and community actions.

A key challenge identified during preparation of this report is the need to place the ecosystem health information in its broader social and economic context. This task is particularly important given increasing community and government awareness of the links between the social, environmental and economic dimensions of waterways and catchment management. The need to take account of the interconnected nature

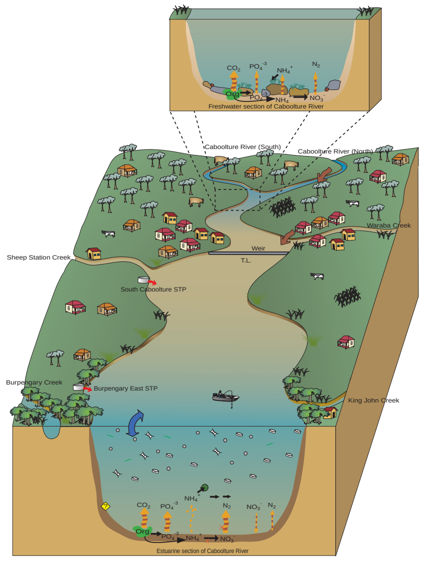


Figure 1: An example of a conceptual model showing key processes and patterns of ecosystem health

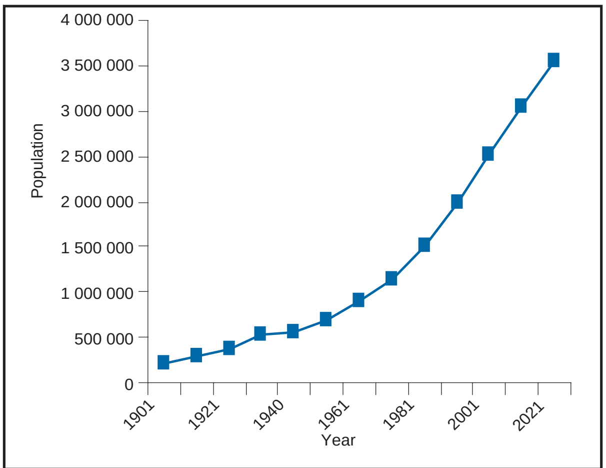


Figure 2: Population growth in South-east Queensland over the past 100 years and into the future

of these issues is given extra impetus by the broad range of stakeholders and interests embraced by the Moreton Bay Waterways and Catchments Partnership. The Healthy Waterways Vision provides the highest order goal for the Moreton Bay Waterways and Catchments Partnership:

> *South-east Queensland's catchments and its waterways will, by 2020, be a healthy ecosystem supporting the livelihoods and lifestyles of people in South-east Queensland, and will be managed through collaboration between community, government and industry.*

Table 1: Trend in pressures since 1996 for each south-east Queensland catchment

	Pressure										
Catchment	**Population**	**Point source**	**Diffuse discharge**	**Urban discharge**	**Rural land development**	**Industrial use use pressures**	**Land clearing**	**Disturbance of riparian vegetation**	**Flow modification**	**Extractive industry**	***Lyngbya* blooms**
Noosa	↑	ID	↑	ID	ID	ID	NA	NA	NA	NA	NA
Maroochy	↑	↑	↔	NA	ID	NA	↑	↑	NA	NA	NA
Mooloolah	↑	↔	↑	NA	NA	NA	NA	↑	NA	NA	NA
Caboolture	↑	↑	↑	NA	NA	NA	↑	↑	ID	↔	NA
Pumicestone	↑	NA	NA	NA	NA	NA	↑	↑	↔	↔	NA
Pine Rivers	↑	↓	↑	NA	↑	NA	↑	NA	↑	↑	NA
Upper Brisbane/ Stanley	↑	NA	NA	NA	NA	NA	↔	NA	↔	NA	NA
Wivenhoe/ Somerset	NA	↑	↑	NA	↑	NA	↑	NA	↑	↑	NA
Lockyer	↑	NA	NA	NA	NA	NA	↔	NA	↑	NA	NA
Bremer	NA	↓	↔	NA	NA	NA	ID	NA	ID	NA	NA
Mid Brisbane	NA	NA	↑	NA	↑	NA	NA	↔	↔	↑	NA
Tidal Brisbane	↑	↔	↑	NA	NA	↑	NA	↓	ID	↓	NA
Logan/Albert Redlands	↑	↔	↔	NA	NA	↑	NA	NA	ID	NA	NA
Gold Coast	↑	↓	NA	↑	NA	NA	NA	NA	ID	NA	NA
Moreton Bay	↑	↔	NA	NA	NA	NA	NA	↓	NA	↑	↑

↑ Increasing trend since 1996

↔ No change in trend since 1996

↓ Decreasing trend since 1996

NA Not applicable

ID Insufficient data

Chapter 1

Introduction

Eva Abal and Kate Moore

About this report

The *2001 State of South-east Queensland Waterways Report* is a follow-up to the 1996 State of Brisbane River, Moreton Bay and Waterways Report. The 2001 report, like its predecessor, is intended to inform and advise community groups, industry and all levels of government and to assist in identifying future responses to improve the condition of waterways. The report provides a synthesis of our current understanding of the state of south-east Queensland waterways.

The report serves as a parallel document to the *South East Queensland Regional Water Quality Management Strategy 2001* and the *Waterways Management Plan*. This report is also supplemented by three publications, *Moreton Bay Study*, *Discover the Waterways of South East Queensland* and the soon to be published *Healthy Catchments and Healthy Waterways: Making the connection in South East Queensland*, all of which provide an information basis for the Healthy Waterways campaign.

This report has been prepared under the auspices of the Moreton Bay Waterways and Catchments Partnership, with input from the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management. The report follows the 'state-pressure-response approach', describing the current state of the waterways, the pressures they face and possible responses of the community and government to deal with these pressures.

The focus of the report is on the ecosystem health of the waterways, examining water quality, biological, physical and chemical attributes of the system, and the pressures that impact on them. Where baseline information is available, from either the 1996 report or other available sources, this report describes the trends and developments that have occurred since 1996 in Moreton Bay and major south-east Queensland waterways.

This report adopts a different style from that used for state of the environment reporting at the state and national level. The approach used is to summarise the state of waterways in the form of conceptual models, which integrate current scientific understanding in terms of key ecological processes and patterns. Hence, while this report uses the framework provided in the 1996 State of Waterways Report, it differs from the former report in relying more on ecological health measures than on conventional physico-chemical indicators.

The development of indicators for assessing the state of our waterways is an ongoing process. The indicators used in this report were evaluated in the design phase of south-east Queensland's Ecological Health Monitoring Program (EHMP). They are based on key processes, relevant anthropogenic impacts and critical habitats, using measures of water quality, sediment features and biological indicators. The EHMP intentionally focused on assessing the ecosystem response to natural and anthropogenic inputs, rather than measuring the inputs (i.e. nutrient and sediment loads). It is envisaged that future state of waterways reporting will use information about the analyses and trends of EHMP indicators.

The EHMP is being implemented for freshwater, marine and estuarine areas of south-east Queensland to comply with the ANZECC monitoring guidelines, which 'essentially means the keeping of a continual record of certain parameters, advising whether they are being maintained within prescribed limits and warning when undesirable changes occur'. These themes are discussed further in Chapter 16, together with a framework for the future development of indicators.

Following the state-pressure-response approach, the report outlines management responses that are being implemented or planned to deal with the pressures. The response mechanisms are those based on current government and community activities, as well as commitments included in the South East Queensland Regional Water Quality Management Strategy and Waterways Management Plan.

The 14 catchment chapters were individually prepared. People involved in the acquisition of data for specific catchments were approached for input and/or authorship. Sources of data for specific catchments have been acknowledged, where appropriate. Each chapter focuses on a specific catchment within the south-east Queensland region including Moreton Bay. The report relies heavily on interpretation of the currently available data, which have been collected by a range of people/organisations, and have not necessarily been consistently collected or assimilated for the whole study area. As a result, references to the actual works and/or information sources are made at the end of each chapter. Readers who require more detailed information are strongly encouraged to read these reports.

South-east Queensland region

The south-east Queensland region is a diverse and contrasting environment, its waterways varying from trickling streams to the open waters of Moreton Bay. The total area of the catchment is 22 672km^2, and the area of the Bay adds 1523km^2. There are several river catchments in the region: the Caboolture, Pine, Stanley, Brisbane, Lockyer and Bremer Rivers, which drain into Moreton Bay. In addition there are northern rivers, the Noosa, Maroochy and Mooloolah, and southern rivers including the Logan and Albert Rivers and various rivers and creeks within the Gold Coast waterways. Many of the waterways in the region form part of the Moreton Bay Marine Park, which stretches from Caloundra to Southport, encompassing some tidal rivers and extending east to three nautical miles offshore.

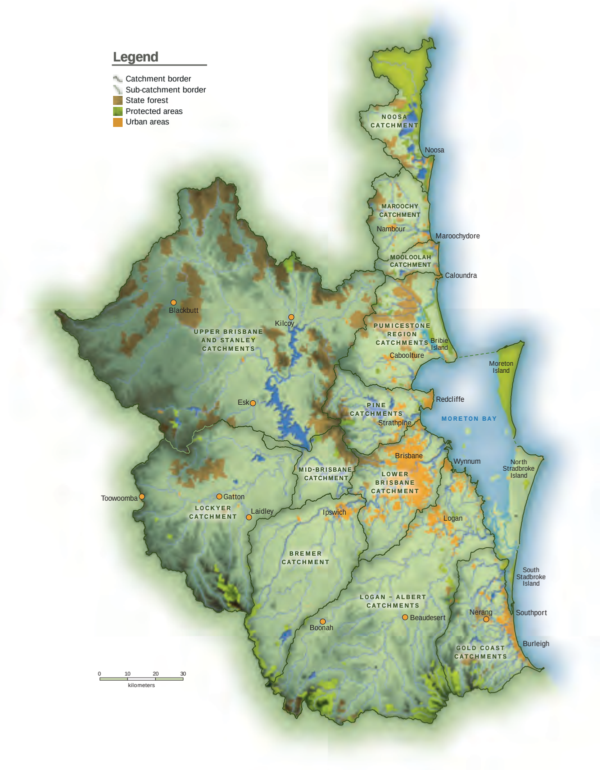


Figure 1.1: South-east Queensland catchments

Twenty local governments are present in the south-east Queensland area. Figure 1.2 shows relative land use areas within the entire south-east Queensland area.

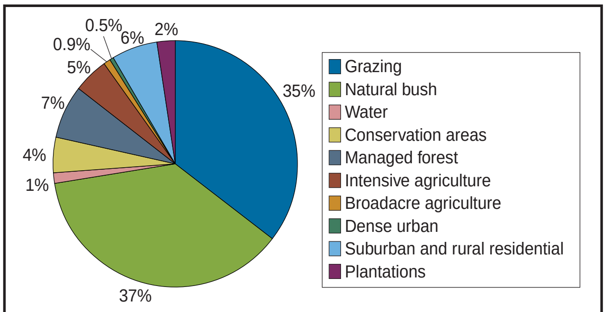


Figure 1.2: Land use in the SEQ region

South-east Queensland has one of the fastest growing populations in Australia, with just over 2 million people, increasing by 2.9% per annum. These increases in population are expected to result in 75km^2 of bushland, agricultural land and other rural land being converted to housing and other urban purposes each year.

The clearing of vegetation for these various land uses can have negative impacts on the catchment. For example, increases in sediment yield up to 30 times the load before clearance have been recorded. Land clearing and urban development can lead to accelerated stormwater runoff and reduced diversity of aquatic organisms. Further, tidal properties may be altered, with increased exchange, range and velocity. There is also an increased risk of solid and liquid waste reaching the waterways.

History of the area

Aboriginal occupation of the south-east Queensland area dates back at least 22 000 years. The current coastal areas formed 6000 years ago following rises in sea level and the most intensive Aboriginal occupation occurred around 4000 years ago. The main forces of disturbance in the region were from major flood and cyclone events, wild fires and Aboriginal 'firestick farming' practices. These managed fires altered the vegetation growth, favouring open eucalypt forests and grasslands over closed forest types. Aboriginal groups living in the coastal region enjoyed productive fishing grounds on the western side of Moreton Bay, in part due to the release of fertile sediments from increased erosion in the upper catchment resulting from the 'firestick farming' activities.

The start of European settlement in 1823 marked the beginning of intensive clearing of vegetation in the region, and pastoral development began in the 1840s. Since European settlement, 6700km^2, or two-thirds of the original 9800km^2 of woody vegetation in south-east Queensland, has been cleared. Figure 1.3 shows the amount of clearing since 1840. Clearing of vegetation continues today but less for agricultural activities and more for urban development.

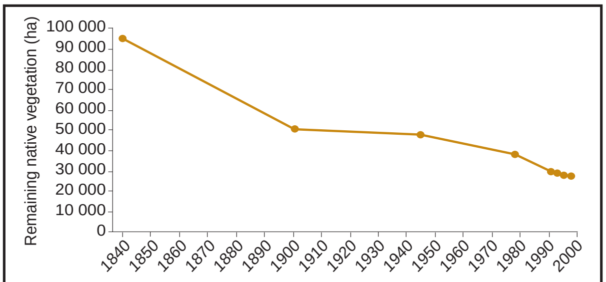


Figure 1.3: Amount of clearing from 1840 to today in south-east Queensland

Sections of the catchment

Catchments can be divided into four sections: riverine, tidal estuary, seasonal estuary and marine.

Riverine

The riverine section is non-tidal and includes freshwater streams and rivers. Natural systems have diffuse sources of suspended sediments and nutrients, and a reduction in available light because of riparian and floating vegetation. Nutrients and light are considered the limiting factors for aquatic primary productivity.

Tidal estuary

The tidal estuary occurs further downstream and is the start of the salinity gradient. Stratification of the water column is reduced and sediments are resuspended due to the action of the tide. There are elevated levels of nutrients from both point and non-point sources, and light may become the limiting factor for aquatic primary productivity due to high turbidity.

Environmental Protection Agency

The Brisbane River at the City is an example of a tidal estuary.

Seasonal estuary

The seasonal estuary is the variable portion of coastal waters affected by river discharges. There is sufficient light penetration for the growth of phytoplankton but turbidity may reduce seagrass distribution.

Marine section

This section of the catchment includes the marine portion of Moreton Bay and is affected by tidal flushing and open coastal waters. The marine portion of the Bay contains extensive seagrass beds grazed by dugongs and turtles. Nitrogen is the limiting factor in this environment as turbidity is minimal. Open coastal waters are generally characterised by good water quality as Pacific Ocean currents and other coastal processes disperse suspended sediments and contaminants.

Environmental Protection Agency

Jumpinpin Bar is considered marine due to high tidal flushing.

State of the waterways

The south-east Queensland region has a subtropical climate, the majority of the annual rainfall occurring in summer and early autumn. The area is characterised by relatively low runoff, with occasional large volume floods and severe droughts. In dry weather there is minimal exchange to Moreton Bay and there are no significant freshwater flows in most river systems. During dry weather conditions, point source wastewater discharges form a significant proportion of flow. With increased rainfall, flows from the upper portions of the catchment dominate, with comparatively high loads of sediment and nutrients being transported to the Bay and open coastal areas.

The Bay appears to recover rapidly from small flood events but the cumulative impacts over many years may be significant. The western portion of the Bay suffers from the effects of an increasing human population. The water quality is degraded and important habitats such as seagrass beds are lost. Towards the east, however, the tidal influence increases and water quality is better, with good light penetration, extensive seagrass beds and an abundant faunal community. Recently blooms of the marine cyanobacteria *Lyngbya majuscula* have been documented in Deception Bay and Eastern Moreton Bay. In 2000, the *Lyngbya* blooms in Moreton Bay were the largest recorded. *Lyngbya* poses a threat to the healthy seagrass beds in these areas.

Pressures on the waterways

The waterways of south-east Queensland are facing many pressures that may further degrade the system. Population growth with subsequent urbanisation and land development are major issues in the area.

Development of marinas and canal estates in the coastal zone potentially impacts on littoral vegetation, and results in increased sediment loads and contamination by nutrients, heavy metals, hydrocarbons and pesticides. Agricultural activities in the upper catchment areas contribute significantly to sediment loads entering the Bay and coastal waters. Commercial and recreational fishing have the potential to exceed sustainable levels and threaten fish populations. Sand extraction, mining and dredge-spoil dumping impact on aquatic fauna through increased turbidity. Recreational activities such as camping, fishing and four-wheel driving within the catchment increase erosion and may contribute to contamination of the water by nutrients, metals, hydrocarbons and pesticides. Impoundment of creeks and rivers greatly alters the hydrology and flow of river systems and changes floral and faunal communities. Dams currently supplying water to the south-east Queensland population may not be sufficient beyond 2035; additional resources will need to be found in the future if demand continues to increase.

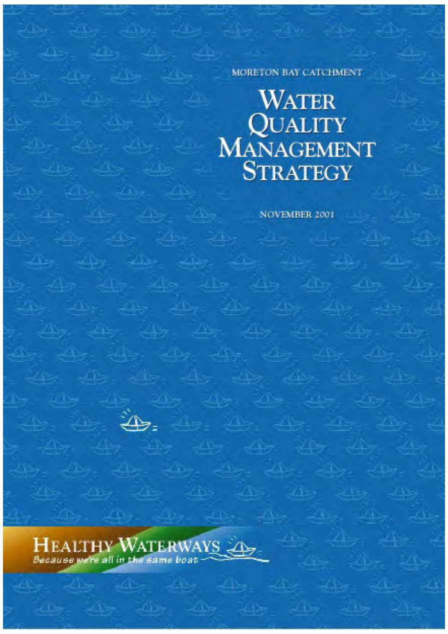
Responses to the pressures on the waterways

The future of the south-east Queensland waterways is reliant on appropriate management to ensure that the waterways improve rather than deteriorate further. Water quality management initiatives currently operating in the catchment include various measures in local government regulations, policies, practices, catchment management plans, city and shire planning schemes, community action, and political and social commitments.

Healthy Waterways Library

Various community groups work within their catchments to help care for the waterways.

Coordination of these actions is necessary, as well as coordination of further scientific research and monitoring. The Moreton Bay Waterways and Catchments Partnership is a joint federal, state, local government, industry and community initiative which aims to coordinate existing actions and develop further actions to manage impacts on water quality in the region.



The South East Queensland Regional Water Quality Management Strategy document

The Partnership's programs assist in providing scientific and modelling information on which to base management decisions; identifying gaps in management actions and scientific knowledge; identifying short- and long-term management options and priorities; coordinating and auditing program implementation; and conducting performance monitoring and review.

The Healthy Waterways Campaign is the education and awareness arm of the Moreton Bay Waterways and Catchments Partnership. It has been developed as a cooperative identity with its own distinct logo.

The logos for the Healthy Waterways Campaign

This logo can be used by stakeholders to show that they understand the issues facing the area, are aware of what needs to be done and will work in a cooperative manner to achieve 'Healthy Waterways'.

The aim of the campaign is to inspire and remind everyone to take action to protect and enhance the waterways and catchments of south-east Queensland.

Healthy Waterways Library

We must all work together to ensure the future health of our waterways.

Chapter 2

Noosa River

Adrian Jones and Thomas Schlacher

Description of the waterways

The headwaters and much of the upper Noosa River catchment are within Cooloola National Park. It is a largely intact coastal lagoon system, containing a diversity of bed and bank habitats, and is valuable habitat for a range of fish species.

The Noosa River catchment covers a total area of approximately 950km^2. The headwaters originate in the Womalah escarpment, together with the first major tributary, Teewah Creek. The Upper Noosa River flows south through the low-lying Noosa Plain into Lake Cootharaba, where Kin Kin Creek enters. The Noosa River continues into Lake Cooroibah and enters the ocean at Noosa Heads. Lakes Weyba and Doonella are in tributaries of the lower reaches of the river (Fig 2.1). There has been extensive clearing in the lower section of the river around the populated areas of Tewantin, Noosaville and Noosa Heads. The majority of the Noosa River catchment is contained within Noosa Shire, but a significant part of the northern area is within the Cooloola Shire.

Figure 2.1: Map of Noosa River catchment

The dominant land uses are conservation areas, natural bush, rural and forested. Urban areas constitute less than 3% of the total catchment area (Fig 2.2). The catchment includes 6km^2 of sugar cane (0.63% of total area) and 37.8km^2 of mangroves (3.98% of total area). Since 1996, 6.33km^2 of council reserve has been purchased under Noosa Shire Council's policy, 'Purchase of Environmentally Significant Land with Conservation Levy Funds'.

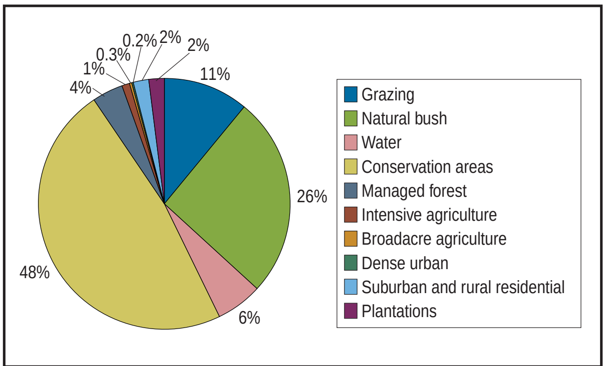


Figure 2.2: Land use in the Noosa River catchment

Historical (1958) photo of the Noosa River mouth

Department of Natural Resources and Mines

Recent (1996) photo of the Noosa River mouth

Department of Natural Resources and Mines

State of the waterways

Water sediment quality

Water quality parameters

Water quality in the Noosa River catchment is relatively good. Table 2.1 provides a summary of water quality parameters in the catchment under base flow conditions.

Table 2.1: Water quality parameters for several sites in the Noosa River catchment. Secchi depth is lowest at Lake Cootharaba because sediments in the shallow lake are easily resuspended by the wind and waves.

Site (km upstream)	Secchi depth(m)	Salinity (g/l)	DO (%)	Turbidity (NTU)
0.3	1.4	23.5	102.7	1
2.3	1.3	22.2	95.2	2
3.9	1.2	19.1	87.4	2
5.3	1.1	17.9	86.0	4
6.9	1.0	16.3	81.1	3
8.5	1.2	16.7	82.7	3
10.3	0.9	15.0	91.0	8
16.0	1.5	13.9	77.9	3
16.0	1.5	13.9	77.9	3
21.5	0.6	12.5	79.8	15
26.0	1.4	14.1	85.2	1

Turbidity and chlorophyll a

Turbidity and chlorophyll *a* levels in the Noosa River are low compared to those in other rivers in south-east Queensland. Turbidity within the Noosa River increases upstream to Lake Cootharaba, but decreases again in the reaches above the lake. In contrast, chlorophyll *a* is fairly constant along the length of the river, except at the mouth of the river and Lake Cootharaba, which show lower levels (Fig 2.3).

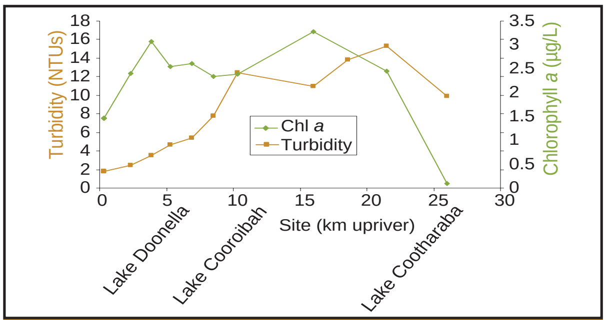


Figure 2.3: Turbidity and chlorophyll *a* measurements in the Noosa River

Nutrients

Dissolved inorganic nutrient concentrations in the Noosa River (Fig 2.4) are one to two orders of magnitude lower than those in many other south-east Queensland rivers. Inorganic nutrients make up a small fraction of the total nutrient concentration in the Noosa River, indicating that particulate and/or dissolved organic nutrients are the major nutrient form (Fig 2.5). Given the relatively low turbidity in the Noosa River, it is more likely that dissolved organic nutrients dominate the system (Table 2.2). These nutrient characteristics of the Noosa system are consistent with those of a healthy, natural waterway.

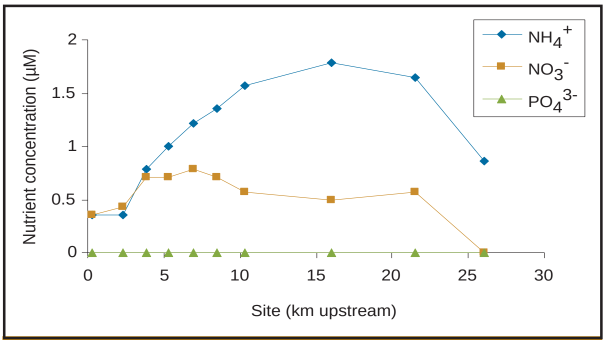


Figure 2.4: Dissolved water column inorganic nutrients in the Noosa River under base flow conditions

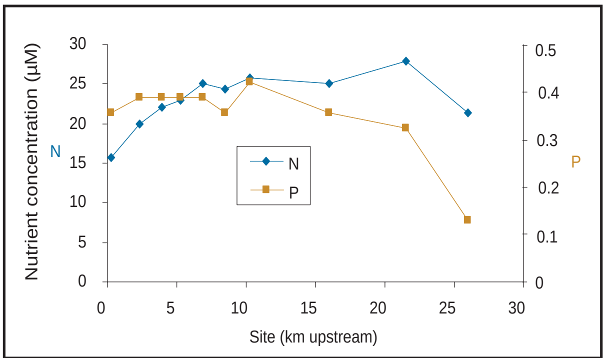


Figure 2.5: Total water column nitrogen and phosphorus concentrations in the Noosa River

Table 2.2: Catchment loads for the Noosa River

Subcatchment	TN (kg/year)	TP (kg/year)	TSS (kg/year)
Ringtail Creek	13 000	2 000	720 000
Teewah Creek	4 400	700	290 000
Upper Noosa River	13 000	2 100	860 000
Kin Kin Creek	31 000	4 600	1 800 000
Lake Cootharaba	18 379	6 779	895 379
Cooloothin Creek	3 100	440	220 000
Lake Cooroibah	9 300	1 600	690 000
Lake Weyba	14 000	2 300	1 000 000
Lower Noosa River	22 000	4 200	1 700 000
Total catchment load	**128 179**	**24 719**	**8 175 379**

The Noosa River catchment has a low $\delta^{15}N$ signature, which indicates a low input of nitrogen derived from sewage. Fish and oysters from the Noosa estuary have markedly lower $\delta^{15}N$ values than those from other estuaries in south-east Queensland.

Biological indicators

Phytoplankton bioassays

Phytoplankton communities in the upper reaches of the Noosa River and in Lake Weyba respond to additions of urea, suggesting an adaptation to organic forms of nitrogen. At all other sites, bioassay experiments indicate that the phytoplankton community is co-limited by nitrogen and phosphorus. The greatest potential for phytoplankton blooms is at the mid-river sites (5.3km (Fig 2.6) to 20km AMTD) which correspond to the most urbanised parts of the river and regions of higher sediment (Fig 2.7) and water column nutrients (Figs 2.4 and 2.5).

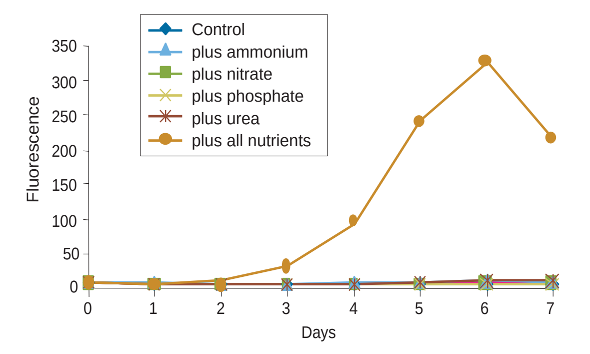


Figure 2.6: Phytoplankton response for the site 5.3km upstream from the mouth, showing a high potential for phtyoplankton blooms following addition of N and P

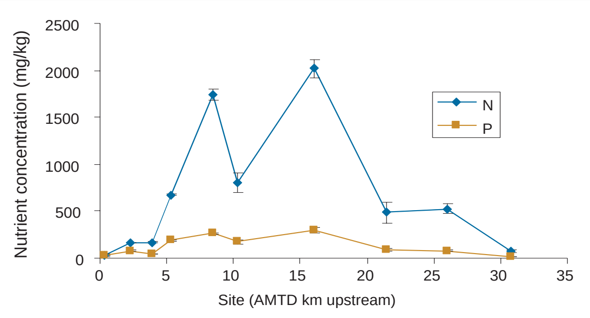


Figure 2.7: Sediment nutrients in the Noosa River

Seagrass

There are extensive seagrass beds in the Noosa River estuary, including large beds in Lake Cooroibah and near Tewantin. The depth range at Lake Cooroibah is less than at Tewantin and correlates with higher turbidity and lower light availability (Fig 2.8). These depth ranges are considered good for an estuarine river.

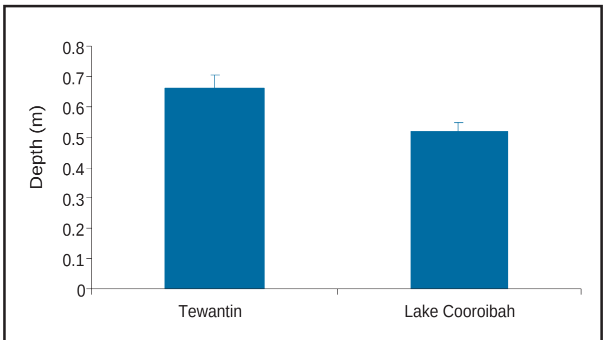


Figure 2.8: Seagrass depth range in Lake Cooroibah and Tewantin sites in the Noosa River catchment

Fauna

Sampling of the Noosa River estuary (Table 2.3) during March 2001 recorded 40 fish species and 4 species of prawns; these are numbers similar to those found in the Maroochy and Mooloolah Rivers. The Noosa River Habitat Area includes land below the high water mark and all waters of Lakes Como, Cootharaba, Cooroibah, Weyba and Doonella, and Weyba Creek and parts of the Noosa River.

Table 2.3: Fish and prawn species present in the Noosa River estuary

Species name	Common Name
Fish	
Acanthopagrus australis	Yellowfin bream
Alectis ciliaris	Pennant fish
Ambassis jacksoniensis	Port Jackson glassfish
Ambassis marianus	Yellow perchlet
Arrhamphus sclerolepis	Snub-nosed garfish
Atherinomorus ogilbyi	Common hardyhead
Carangoides humerosis	Epaulette trevally
Centropogon marmoratus	Bullrout
Favonigobius exquisites	Exquisite sand goby
Gerres subfasciatus	Silver biddy
Herklotsichthys castelnaui	Southern herring
Hyporhamphus regularis ardelio	River garfish
Lethrinus sp.	Emperor
Liza argentea	Tiger mullet
Liza dussumieri	Flat tail mullet
Lutjanus russelli	Moses perch
Monocanthus chinensis	Fan bellied leatherjacket
Monodactylus argenteus	Butter bream
Mugil cephalus	Sea mullet
Mugil georgii	Fantail mullet
Myxus elongatus	Sand mullet
Pantolabus parasiticus	Round finned trevally
Pelates sexlineatus	Trumpeter
Petioscirtes lupus	Sabre tooth blenny
Platycephalus fuscus	Dusky flathead
Pseudomugil signifer	Blue eye
Pseudorhombus arsius	Large toothed flounder
Pseudorhombus jenynsii	Small toothed flounder
Rhabdosargus sarba	Tarwhine
Scomberoides lysan	Queenfish
Selenotoca multifasciata	Striped butterfish
Siganus margaritiferus	Pearly spotted rabbitfish
Sillago ciliata	Sand whiting
Sillago maculata maculata	Winter whiting
Sphyraena obtusata	Striped sea pike
Terapon jarbua	Crescent perch
Tetractenos hamiltoni	Common toadfish
Torquigener pleurogramma	Weeping toado
Tripodichthys angustifrons	Yellowfin tripod fish
Vanacampus margaritifer	Mother of pearl pipefish
Prawns	
Macrobrachium novaehollandiae	New Holland river prawn
Palaemon serrifer	Barred estuarine shrimp
Penaeus esculentus	Brown tiger prawn
Metapenaeus macleayi	School prawn

Catchment condition

Overall, the majority of the riparian vegetation within the catchment is in moderate to very good condition (Fig 2.9). Exceptions include urban areas and sub-catchments developed for agricultural use and exotic pine plantations (Kin Kin, Ringtail and Cooloothin Creeks). In rural areas, some exotics such as camphor laurel (*Cinnamomum camphora*) , Chinese elm (*Celtis sinensis*), small leaved privet (*Ligustrum sinense*) and lantana (*Lantana montevidensis*) dominate, restricting riparian vegetation to a narrow fringe. Areas of native hardwood forest generally have very good riparian zones, while areas dominated by exotic pine plantations typically have riparian vegetation in very poor condition with a narrow remnant width.

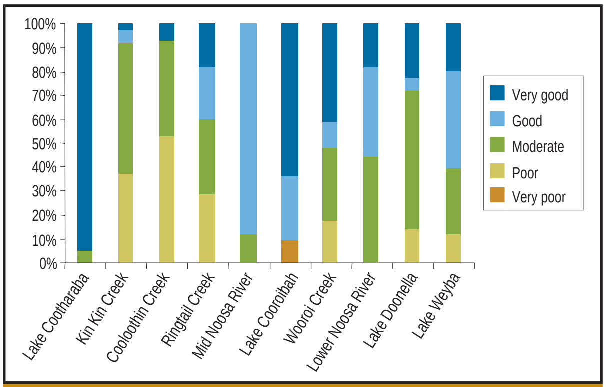


Figure 2.9: Overall condition of riparian lands in the Noosa River catchment

Typically the foreshores of the lakes are in good to very good condition. Although Lake Doonella has a large riparian buffer zone, it has a higher level of surrounding development which may impact on the lake. Creeks within national park or native state forest were in the best condition.

Pressures on the waterways

Historical photographs, anecdotal evidence, newspaper reports and various scientific studies have indicated extensive impacts from land reclamation in the lower Noosa River, and river mouth alterations such as rock walls. These cumulative impacts have resulted in changed hydrology and ecosystem health from the lower Noosa River to the national park north of Lake Cootharaba.

Point source discharges

In contrast to most other rivers in south-east Queensland, the Noosa River does not receive any sewage inputs. The Noosa STP discharges south of Noosa into Burgess Creek, which flows directly into the Pacific Ocean. Many houseboats are moored in the Noosa River and sewage discharge from these craft is considered a significant local concern.
Since 1996: insufficient data

Diffuse discharges

The main pollutant inputs to Noosa River are derived from stormwater and catchment runoff. Possible non-point sources include acid sulfate soil runoff, land disposal of sewage effluent, industrial runoff (Eenie Creek catchment), agricultural runoff (Kin Kin catchment), stormwater runoff (urban areas), canal development runoff, boat waste (oils, grease, sewage) and general litter. Cane farms in the catchment apply 938kg of the herbicide Diuron every year.
Since 1996: increased

Population

Currently the catchment has a permanent and rapidly expanding population of over 36 000, which doubles during the peak tourist season.
Since 1996: increased

Urban development

Urban development is concentrated in the southern sub-catchments and has considerable impact on the riparian vegetation within the creeks. Mass clearing for housing estates is widespread in these areas, resulting in greatly increased inputs of sediments and nutrients to the creeks and river. In some urban areas, exotic weed invasion is significant: weeds include para grass (*Brachiaria mutica*) and Singapore daisy (*Wedelia trilobata*), which can dominate the waterways, out-competing the native species.
Since 1996: insufficient data

Rural land use

The majority of rural land use activities (grazing, sugar cane, small cropping, and fruit and nut orchards) occur within the Kin Kin Creek, Ringtail Creek and Cooloothin Creek sub-catchments. Vegetation (much of it rainforest) is susceptible to disturbance from grazing, fire and weed invasion. In most grazed areas, animals frequent the creek banks, resulting in trampling and consumption of vegetation (reducing potential regeneration of rainforest species) and the introduction of weeds and development of tracks that destabilise and erode river banks.
Since 1996: insufficient data

Recreational use

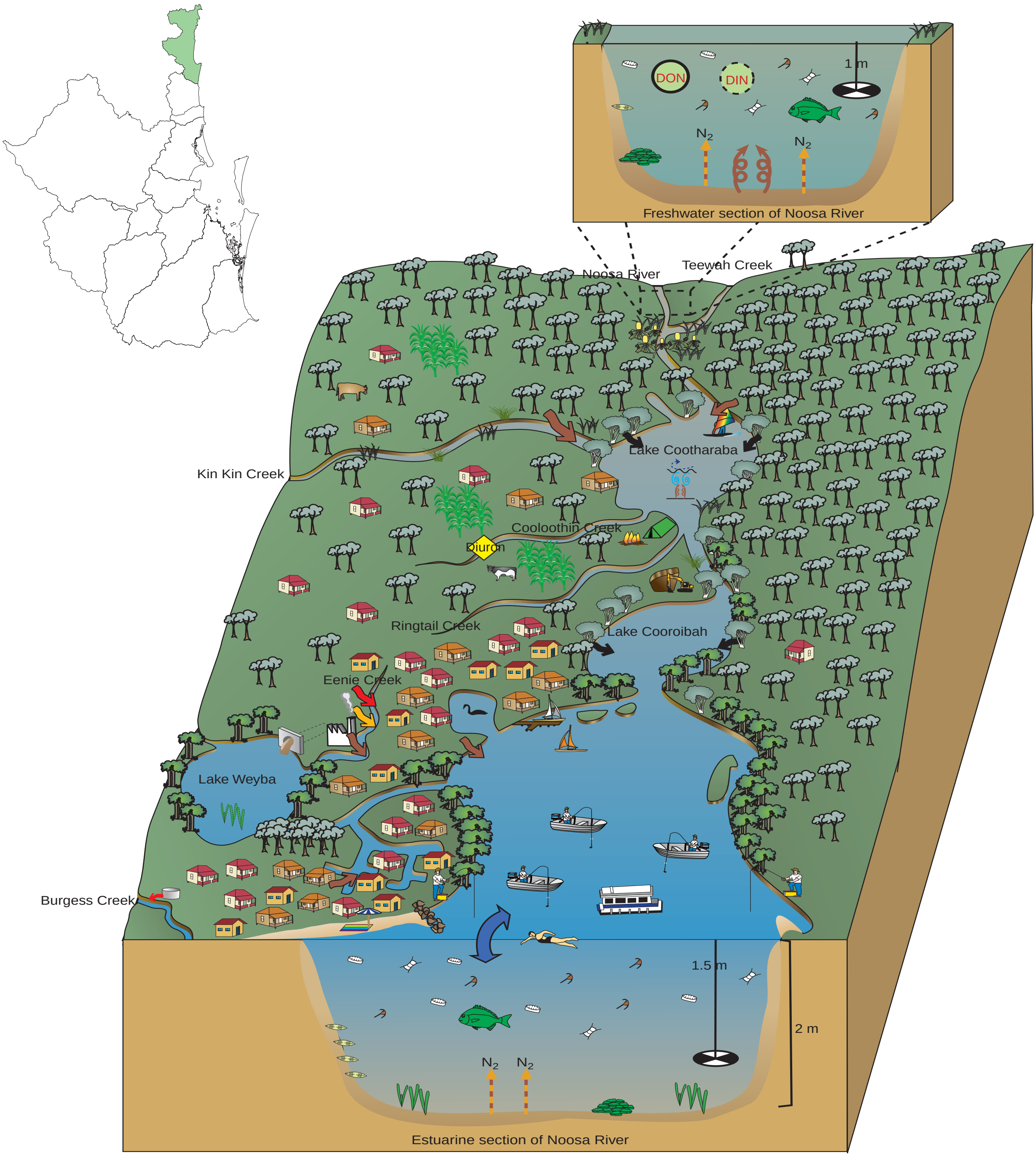
The effects of boat wash are the most likely cause of accelerated bank erosion which is evident along the Noosa River between Lake Cootharaba and Lake Cooroibah. Riparian vegetation around popular swimming holes also suffers from the effects of animals, humans and vehicles. The use of fertilisers, herbicides and insecticides on golf courses also can impact on the waterways.
Since 1996: increased

Industrial use

The quarry at the north -west corner of Lake Cooroibah and the industrial area adjacent to Eenie Creek are the major industrial pressures on the catchment. Acid sulfate soils appear exposed near the quarry and may result in acidic water entering the lake during rain events. Stormwater from the industrial area has been connected with petrochemical pollution in Eenie Creek. Development of a business centre and a major arterial road planned for the Eenie Creek area may affect water quality in the future.
Since 1996: insufficient data

Responses to the pressures on the waterways

Issues	Local initiatives	Responses
Point source discharges		• Evaluation of wastewater discharges to Burgess Creek completed • Future management actions may be developed following discussion between Noosa Shire Council and the EPA.
Diffuse discharges	• Noosa River Catchment Strategy projects • Voluntary Code of Practice by Queensland Farmers Federation • Australian Macadamia Society projects • Noosa Shire Council to develop and implement urban stormwater quality management plans • Stormwater infrastructure being put in place • Sunshine Beach Clean Ocean Project • Transport Infrastructure (Sunshine Coast Waterways) Management Plan 2000 requires live-aboard vessels to be fitted with a holding tank for sewage and grey water	• Range of local programs and plans outlining management actions to deal with this issue. • An Environmental Management Support System allows predictions to be made in relation to changes to water quality as a result of different land use and development practices, enabling stakeholders to develop future actions to deal with this issue. • In 2002, stakeholders of the Partnership will begin to identify priority areas for riparian and stormwater management and set targets for on-ground works. This process will focus on implementing on-ground works to deal with this issue. • Additional vessel sewage requirements that will apply to all coastal waters will be introduced through amendments to the *Transport Operations (Marine Pollution) Act 1995.*
Population		• The SEQ Regional Framework for Growth Management is the basis for planning for the projected increases in the regional population. All member organisations are using the framework to guide sustainable growth in the region through a range of implementation mechanisms including planning schemes, corporate plans and a range of service delivery programs.
Urban development	• Noosa River Catchment Strategy • Noosa and District Landcare projects and demonstration sites • Queensland Biodiversity Network • Save Today Our Parkland • Noosa Parks Association • Noosa River Ranger projects • Catchment Strategic Plan by NICA including the NRCMS and a communication strategy and the NICA group development plan • Noosa and District Landcare Riparian Revegetation Grants Scheme • Noosa Parks Association and Greening Noosa revegetation projects • Noosa Shire Council initiatives including Strategic Plan, draft Vegetation Management Local Law, and support for Land and Wildlife • DNRM's Queensland Acid Sulfate Soil Investigation Team • Noosa Catchment Strategy to identify and map areas of acid sulfate soils	• An Environmental Management Support System allows predictions to be made in relation to changes to water quality as a result of different land use and development practices, enabling stakeholders to develop future actions to deal with this issue.
Rural land use		• In 2002, stakeholders of the Partnership will begin to identify priority areas for riparian and stormwater management and set targets for on-ground works. This process will focus on implementing on-ground works to deal with this issue.
Recreational use	• Studies to identify required environmental flows • Water Resource Plan combined with Maroochy and Mary Rivers plans	• Management actions to deal with riverbank erosion issues will be developed based on the outcomes of the current scientific investigations.
Industrial use	• Licensing of environmentally relevant activities under the *Environmental Protection Act 1994* • Investigations into riverbank erosion, erosion monitoring techniques, boatwash erosion, the effect of different craft types and vessel speeds	• A review of the regulatory regime for extractive industry is currently under way. Future management actions to address extractive industry issues will be developed, based on the outcomes of this review.



Conceptual model for the Noosa River

Sources of information

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Chapter 3

Maroochy River

Thomas Schlacher and Tim Carruthers

Description of the waterways

The catchment of the Maroochy River is diverse, encompassing several major population centres and extensive agricultural areas as well as large forested areas. The catchment area is 642km^2, lying between the Blackall Range and the coast. Population centres in the catchment include Eumundi, Nambour, Eudlo and Coolum, as well as Maroochydore at the river mouth.

Cooloolabin and Wappa Dams drain into the South Maroochy River, which joins the North Maroochy River just south of Yandina. This junction is approximately 24km upstream from the ocean and represents the tidal limit of the estuary. There are three other main tributaries, Coolum Creek, Petrie Creek and Eudlo Creek. Stumers Creek is a significant stream to the Coolum area and flows directly into the ocean (Fig 3.1). The majority of the catchment is contained within the Maroochy Shire Council local government area. Most of the catchment is largely cleared for agricultural and urban uses (Fig 3.2).

Figure 3.1: Map of Maroochy River catchment

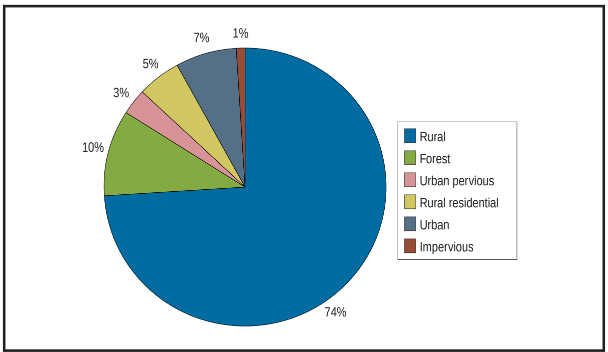


Figure 3.2: Land use in the Maroochy River catchment

The mouth of the river is untrained and moves its full amplitude from north to south and back every 20–25 years.

Aerial photos of the Maroochy River estuary showing extensive movement of the mouth

State of the waterways

The state of the Maroochy River catchment is varied: approximately one-third is in good condition, one-third is in moderate condition and one-third is in poor or highly degraded condition. Eudlo Creek is the most degraded stream in the catchment.

Water quality

Physical and chemical indicators

The Maroochy River is highly affected by both point source loads (STP discharges) and catchment runoff, and this is reflected in a water body that is clearly enriched with all routinely measured forms of nitrogen and phosphorus (Figs 3.3 and 3.4).

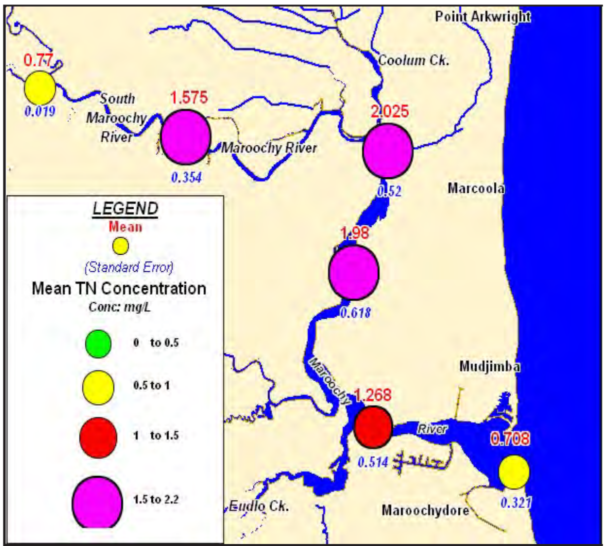


Figure 3.3: Total nitrogen distribution in the Maroochy estuary (Feb. 2001)

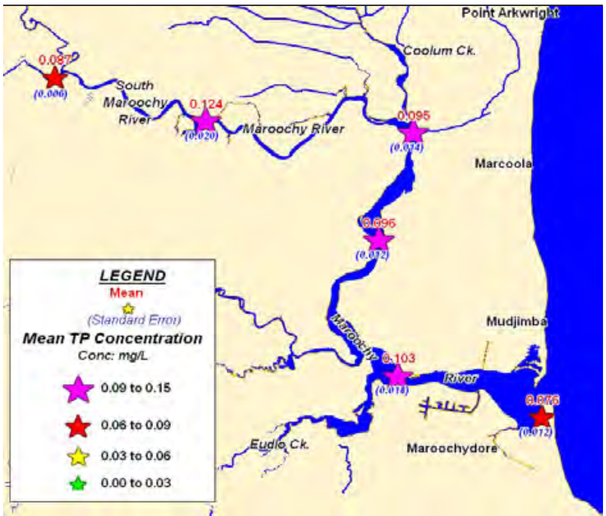


Figure 3.4: Total phosphorus distribution in the Maroochy estuary (Feb. 2001)

Dissolved oxygen (DO) levels are substantially depressed in some freshwater sections, possibly as a result of organic loads originating from diffuse, but as yet untraced, sources. While turbidity records indicate that mean values broadly match those of other estuaries in south-east Queensland, rainfall events produce exceptionally turbid conditions forming prominent sediment plumes in nearshore waters (Table 3.1).

Table 3.1: Summary of water quality status in the Maroochy River

Indicator	Estuarine Lower	Estuarine Mid	Estuarine Upper	Riverine	Comments
Dissolved oxygen	✓	marginal compliance	✓	✗	Substantial reduction in DO in the freshwater reaches. Also, slight reduction in the middle estuarine reaches. Both linked to STP discharges and/or catchment runoff, particularly during storm events.
pH	✓	✓	✓	✓	pH values typical of estuarine and fresh waters.
Turbidity	✓	marginal compliance	marginal compliance	marginal exceedance	Generally within reference ranges but rainfall events produce exceptionally turbid conditions in the estuary and large plumes export sediment to nearshore marine waters. Evidence of elevated turbidity in freshwater tributaries.
Chlorophyll *a*	✓	✗	✗	marginal compliance	Phytoplankton biomass is consistently elevated in the middle and upper estuary as a result of high nutrient loads in these areas.
Dissolved phosphorus	marginal exceedance	✗	✗	✗	Highly elevated phosphorus levels throughout most of the system with pronounced spikes coinciding with STP discharge locations.
Dissolved nitrogen	marginal exceedance	✗	✗	✗	Severe nitrogen enrichment indicated at most locations.

✓ compliance with guidelines; marginal compliance
✗ exceeding water quality guidelines and/or reference ranges
marginal exceedance

Biological indicators

Phytoplankton bioassays

Growth of phytoplankton in the lower reaches of Maroochy River (river mouth to Coolum Creek) is nitrogen-limited. The mid- to upper estuarine reaches near Lake Dunethin exhibited no or very slow nutrient stimulation of the phytoplankton community, suggesting that this region is nutrient-saturated. The upper reaches near the junction of the North Maroochy and South Maroochy Rivers responded only to additions of both nitrogen and phosphorus, suggesting co-limitation of these phytoplankton communities.

Riparian vegetation, mangroves and seagrass

Riparian vegetation along 83% of stream length is in poor to very poor condition and is in very good condition along only 8%. The mean riparian zone width is 14m. Riparian vegetation in the upper catchment consists mostly of camphor laurel and other weeds. Although these weeds reduce erosion, their presence causes stream shallowing and reduces in-stream and terrestrial biodiversity. Approximately 3.5km^2 of mangrove habitat remains in the Maroochy catchment. Seagrass is highly restricted in the Maroochy River: one small remnant *Zostera capricorni* meadow is found at the junction of Eudlo Creek. The depth range of this meadow is small (0.13m) and the seagrass is intermittently covered with a large abundance of microalgae (the cyanobacteria *Phormidium, Oscillatoria* and *Spirulina*). Historically there were more seagrass beds in and around the Maroochy River.

Phytoplankton

The lower estuary of the Maroochy River has abundant large diatoms (e.g. *Coscinodiscus* sp., Fig 3.5a), but also contains *Dinophysis* sp., which is a dinoflagellate associated with diarrhetic shellfish poisoning (DSP). Upriver from Coolum Creek, the phytoplankton community is very diverse, including chain-forming diatoms (e.g. *Chaetoceros* sp., Fig 3.5b) and dinoflagellates. The mouth of Eudlo Creek is characterised by low species diversity but has an abundant community of centric diatoms. In both Petrie and Eudlo Creeks occasional phytoplankton blooms occur, such as a bloom of the non-toxic cyanobacteria *Phormidium*, and small amounts of *Oscillatoria*.

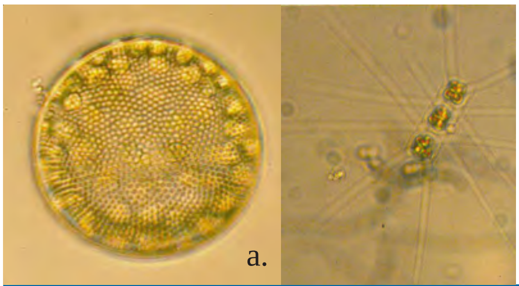


Figure 3.5: Phytoplankton of Maroochy River
a. *Coscinodiscus* sp. and **b.** *Chaetoceros* sp.

Wastewater signals in fauna

While the effects of wastewater discharges into the estuary are readily manifested in high concentrations of nutrients and stimulation of phytoplankton growth, these loads have more far-reaching effects that extend through the entire estuarine food web. Nitrogen that is derived from sewage can be readily traced to the tissues of oysters, benthic invertebrates (marine yabbies, soldier crabs, mangrove crabs etc.) and fish. Essentially all fauna in the lower and middle sections of the Maroochy estuary carry a distinct sewage signal in their tissues. This signal may be derived from STP discharges and from septic effluents.

Mapping of nitrogen signatures in oysters produces a clear pattern of the distribution of sewage-derived nitrogen in the system (Fig 3.6). Oysters growing in the middle estuarine reaches, where wastewater loads from STPs are concentrated, derive a higher fraction of their body nitrogen from wastewater sources. The likely uptake route is via feeding on phytoplankton that have incorporated inorganic nutrients discharged by the STPs. Oysters are abundant, sessile and readily available, and integrate 'nitrogen histories' in their body tissue, and are therefore a good bio-indicator for mapping sewage plumes.

All benthic invertebrates in the Maroochy River estuary have distinctly higher nitrogen ratios ($\delta^{15}N$) than those in the Mooloolah River estuary. Sewage-derived nitrogen in the Maroochy River estuary can be traced to higher trophic levels, such as fish, all of which have muscle $\delta^{15}N$ values indicating a wastewater signal entering at the base of the estuarine food web (Fig 3.7).

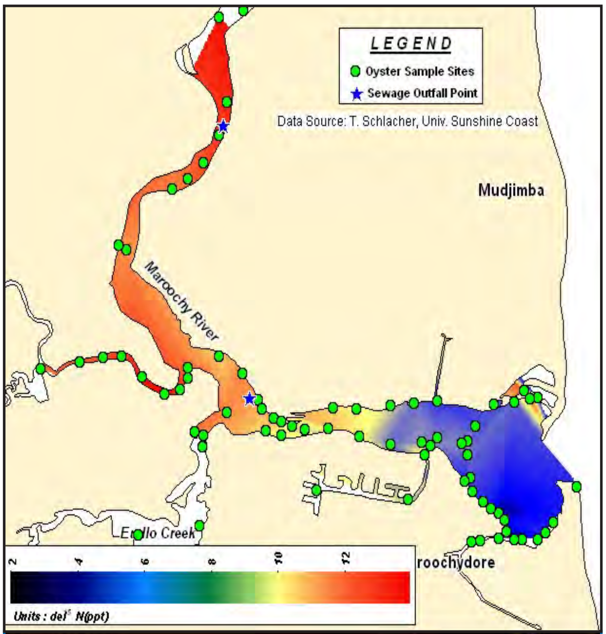


Figure 3.6: Nitrogen isotope ratios ($\delta^{15}N$) in oysters from the Maroochy estuary (Sept. 2000)

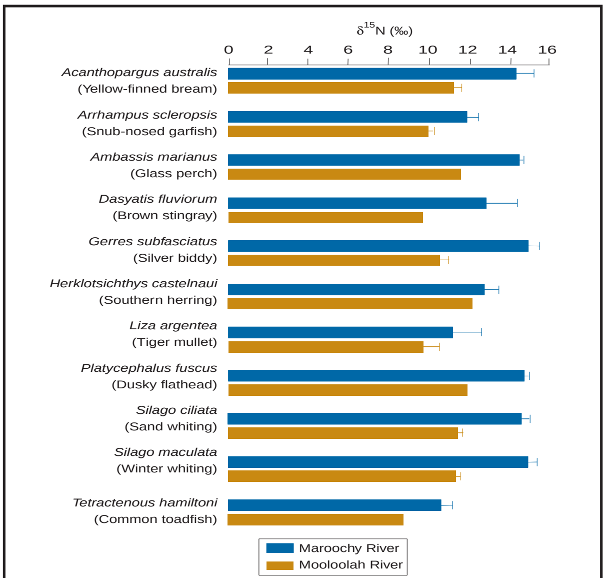


Figure 3.7: Comparison of nitrogen ratios ($\delta^{15}N$) in fish from the Maroochy and Mooloolah estuaries

Toxicants

Large quantities of pesticides are applied in the Maroochy River catchment, mostly in the intensive farming areas on the floodplain (9614kg/yr of the herbicide Diuron is added to cane farms alone), and fish kills have been linked to the pesticide endosulfan. Fish kills in Petrie and Paynter Creeks in 1993 and 1994 prompted toxicant monitoring in which concentrations of a suite of pesticides and heavy metals were measured in mud crabs and sediments. Mud crabs were deemed safe for human consumption, their levels of potentially toxic substances complying with national standards for residues in food. However, concentrations of dieldrin (a pesticide related to DDT that has been banned in Australia since 1994) in water were consistently above guideline values for the protection of aquatic ecosystems. Pesticides of this chemical type persist in the environment, and therefore reported residues are likely to be a legacy from past agricultural practices in the catchment.

Concentrations of metals in sediments are generally low and comply with national guidelines. A recent (September 2000) detailed mapping of trace metal concentrations in oysters growing in the lower and middle Maroochy estuary showed higher levels of cadmium, mercury and zinc than in oysters from the adjacent Mooloolah estuary, but overall these levels are not significantly elevated.

Fish

Major fish kills in two tributaries (Paynter and Petrie Creeks) of the Maroochy River in 1993 and 1994 have been linked to the pesticide endosulfan. The estuary was stocked with sand whiting and dusky flathead following the fish kills. Reared fish survived well after release and contributed significantly to the fisheries catch, but whether an actual increase in total fish abundance has occurred as a direct result of the stocking program is unclear. Hypoxic conditions which developed after an overflow of aquatic weeds from Wappa Dam caused a fish kill in 1998. The Maroochy River Fish Habitat Area (Zones A and B) extends from the high water mark and covers waters of the Maroochy River and Coolum, Petrie and Eudlo Creeks.

Acid sulfate soils

Acid sulfate soils are a major environmental consideration in this catchment. Cases of red spot in fish in the area are regularly reported.

Pressures on the waterways

Population centres and urban inputs

The population within the Maroochy catchment is currently estimated to be 96 300 and growing at a rate of 3.3% per year. There is also a large seasonal component, maximum numbers recorded being during the peak summer holiday season. Increasing urbanisation throughout the catchment results in increased stormwater runoff into the waterways. Urban stormwater contains hydrocarbons, fertilisers, detergents and garbage and is often concentrated in canal estates. Stumers Creek has been modified for flood mitigation and only flushes into the ocean during high rainfall events. As a result, polluted urban stormwater builds up behind the dune and does not appear to receive any significant natural treatment until it is flushed.
Since 1996: increased

Rural areas

The upper catchment is steep, with mostly dirt roads. Colloidal road base flows directly into streams after rain events. Much of the soil in this area is clay and therefore not appropriate for absorption trenches for on site sewerage systems. Black and grey waters from these systems often find their way to streams during high rainfall events.
Since 1996: insufficient data

Point source discharges

There are six STPs in the catchment, with the three largest (Maroochy, Nambour and Coolum) having upgraded to biological nutrient removal in 1998. The bulk of the treated wastewater discharge occurs at the combined outfall of the Nambour and Maroochydore treatment plants, located about 5km from the tidal inlet near the David Low Bridge (Table 3.2). The old Woombye and Nambour landfills on Petrie Creek may contribute toxic loads to the creek.
Since 1996: plant upgrades in 1998

Table 3.2: Contributions to total nitrogen and total phosphorus loads in the Maroochy estuary

Source	TN loads	TP loads
Freshwater catchment	53%	36%
Estuarine catchment	16%	11%
STPs	31%	53%

Diffuse discharges

Rural catchment land uses including sugar cane farming, beef and dairy cattle, forestry, and market gardening all result in diffuse nutrient and sediment inputs to the Maroochy River. There is 60km^2 of sugar cane in the Maroochy catchment, covering approximately 10% of the total catchment area. Cane drains are designed for rapid flow and thus localise the impact of nutrient and sediment inputs from this otherwise diffuse source.
Since 1996: no change

Land clearing

While the catchment of the North Maroochy River is largely cleared for agriculture, the South Maroochy River is mostly forested. The upper reaches of Petrie Creek are forested, but the lower reaches flow through Nambour and sugar cane areas. Paynter Creek is forested in its upper reaches, but flows through urban areas in the mid reaches and is cleared in the lower reaches. Eudlo Creek is forested in its upper reaches and has little development along its lower reaches, while the central region is either cleared or cropped. The catchments of Coolum and Yandina Creeks are almost entirely used for sugar cane crops. Ginger is also an important crop, contributing high sediment loads in wet times.
Since 1996: increased

Disturbance of riparian vegetation

The south bank of the Maroochy River from the estuarine mouth to Eudlo Creek is cleared, with road verges and retaining walls extending to the water's edge, while the north bank along this section is still largely vegetated. From Eudlo Creek to Coolum Creek, and also up into Coolum Creek, banks are well vegetated with mangroves. Between Coolum Creek and the junction of the North and South Maroochy Rivers, either there is a narrow band of riparian vegetation or the vegetation has been totally cleared, and many invasive grass species are evident in this section. In the Maroochy catchment, 70% of riparian vegetation has been rated to be in 'very poor' and 13% in 'poor' condition.
Since 1996: increased

Boating

The main seagrass meadow in the Maroochy River is adjacent to a boat ramp, just downstream from the junction of Eudlo Creek. This is an intertidal mud flat and is highly susceptible to disturbance from boating traffic. In 1998, 5190 boats were registered in the Maroochy Shire, increasing by approximately 7% annually. Boating traffic associated with fishing and water skiing can also contribute towards bank erosion, especially in narrow channels.

Since 1996: increased

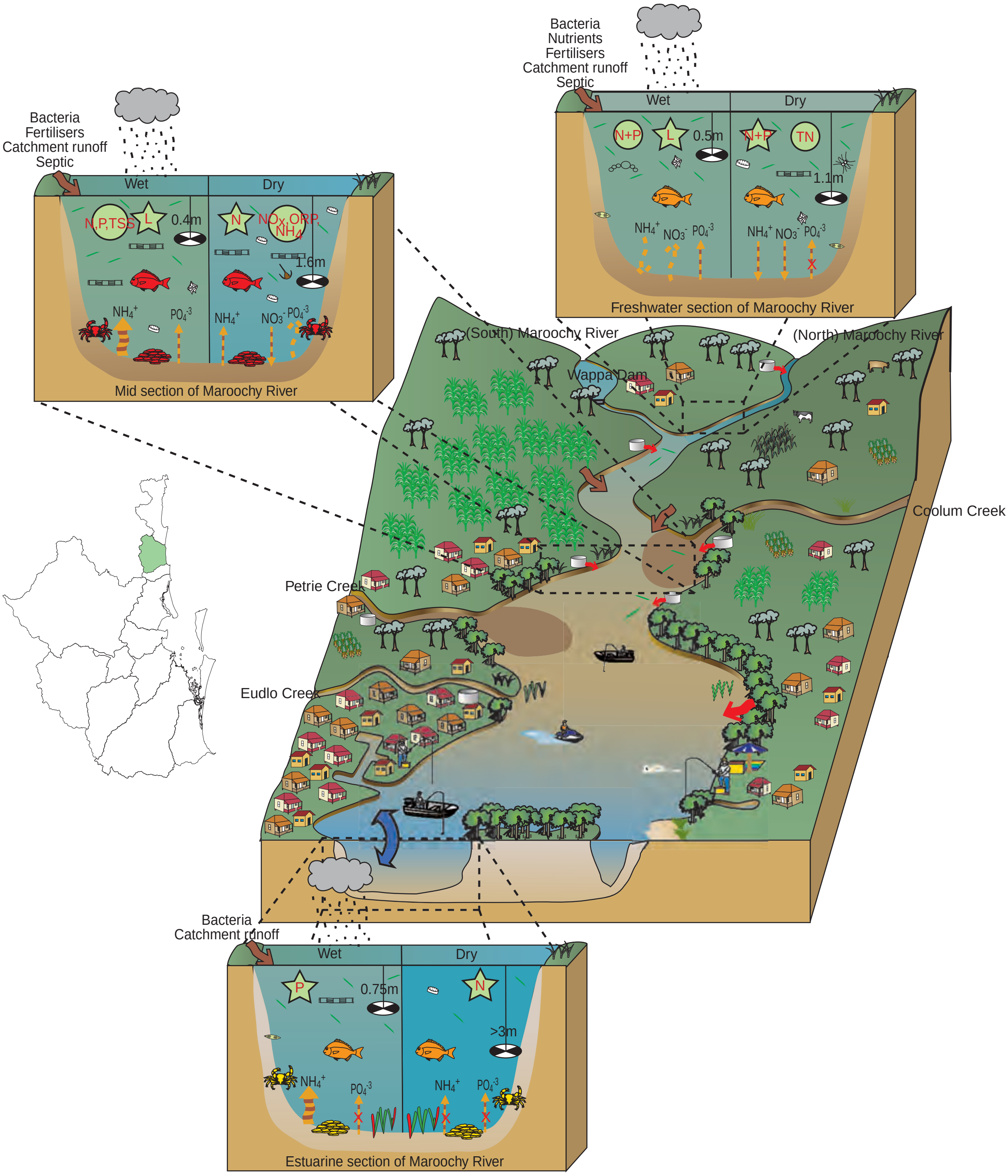
Fishing

Fishing, both recreational and commercial, is substantial in the Maroochy estuary: 28 000 angler visits are recorded per annum, and 12 commercial boats operate in the estuary. The commercial catch of yellowfin bream declined by 60% in the period 1988 to 1998, but no definitive trend is evident for catches of dusky flathead and summer whiting. Fishing pressure is high on stocks of dusky flathead, where total mortality is greater than twice the natural mortality. Up to 50% of natural fisheries habitat is altered mainly as a result of encroachment by urban and agricultural land uses.

Since 1996: increased

Responses to the pressures on the waterways

Issues	Local initiatives	Responses
Population centres and urban impacts	• Maroochy Shire Council is developing an Urban Stormwater Management Strategy. • Maroochy-Mooloolah-Noosa Water Quality Management Strategy	• The SEQ Regional Framework for Growth Management is the basis for planning for the projected increases in the regional population. All member organisations are using the framework to guide sustainable growth in the region through a range of implementation mechanisms including planning schemes, corporate plans and a range of service delivery programs.
Rural areas	• Maroochy Mooloolah Catchment Management Strategy • Petrie Creek Catchment Care Group • Stumers Creek Catchment Care Group • Namba, Maroochy, Eudlo and Ilkley Landcare and Maroochy Waterwatch • Maroochy Wetland Support Group • Adopt a Park program	• Range of local programs and plans outlining management actions to deal with this issue. • In 2002, commencement of a regional scientific investigation to assess the impact of on-site sewage treatment systems. Future management actions will be based on the outcomes of the investigation.
Point source discharges	• Maroochy Shire Council has put in funds for biological nutrient removal upgrades at several STPs, relocation of outfalls from small creeks and the reuse of 11% of effluent. • Maroochy Strategic Wastewater Management Study • Coolum and Suncoast STP effluent is reused on golf courses.	• A water quality modelling project currently under way will investigate a range of STP upgrade scenarios. Future management actions and STP upgrades will be developed based on the outcomes of the modelling project.
Diffuse discharges	• Catchment Association has collected land use information and distributed water quality information. • Maroochy Council's stormwater study • Sunshine Coast Environment Council's study on litter entering the waterways • Voluntary Code of Practice by Queensland Farmers Federation • Maroochy Shire to produce an Urban Stormwater Management Strategy	• Range of local programs and plans outlining management actions to deal with this issue. • An Environmental Management Support System allows predictions to be made in relation to changes to water quality as a result of different land use and development practices, enabling stakeholders to develop future actions to deal with this issue.
Land clearing		• An Environmental Management Support System allows predictions to be made in relation to changes to water quality as a result of different land use and development practices, enabling stakeholders to develop future actions to deal with this issue.
Disturbance of riparian vegetation	• Maroochy Mooloolah Catchment Management Strategy • Restoration projects by community groups • Petrie Creek Nambour Reach Management Plan • Natural Heritage Trust rehabilitation projects • Maroochy Mooloolah Seedling Grant Scheme • Weed harvester in Wappa Dam • Bushcare's Land for Wildlife Program • Maroochy Shire Council's Bushland Management Program, Vegetation Protection Local Law and Conservation Assessment and Management Plans for Remnant Vegetation in the Maroochy Shire • State of Maroochy River Report • Biomap project to map flora and fauna • SEQ Biodiversity Strategy, Habitat 2000 project and Queensland Biodiversity Network	• In 2002, stakeholders of the Partnership will begin to identify priority areas for riparian and stormwater management and set targets for on- ground works. This process will focus on implementing on-ground works to deal with this issue.
Boating		• Transport Infrastructure (Sunshine Coast Waterways) Management Plan 2000



Conceptual model for the Maroochy River

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Healthy Waterways Library

Sugar cane is an important crop in the Maroochy River catchment.

Chapter 4

Mooloolah River

Thomas Schlacher and Tim Carruthers

Description of the waterways

The Mooloolah River system drains a relatively small catchment with an area of 194km^2 that extends 25km inland from the coast. It is situated between a series of coastal ranges of moderate elevation (~400m) in the west and the Pacific Ocean in the east. The river is formed by many spring-fed rivulets in the Blackall Range upstream of the Mooloolah township. The two main rivulets are one in Maleny farmlands and one next to Montville Road that join to form the North Mooloolah River. The south and north branches of the river flow together in the upper reaches east of Mooloolah township. All flow from one headwater tributary (Addlington Creek) is impounded in Ewen Maddock Dam, and three unimpounded small creeks (Sippy Creek, Mountain Creek and University Creek) join the main channel in the middle and lower sections of the catchment. The total length of the river from source to sea is 41km. The river varies greatly in width, some areas being less than 5m wide. The mouth is a relatively wide (~100m) and deep (>5m) entrance that is artificially stabilised for both commercial shipping and recreational boating. The estuarine reaches are short (13km). Currimundi Lake, Tooway Creek, Bunbubah and Coondibah Creeks are located within the Mooloolah catchment area; they flow directly into the sea under normal weather conditions, but do form part of the Mooloolah breakout during flood events (Fig 4.1).

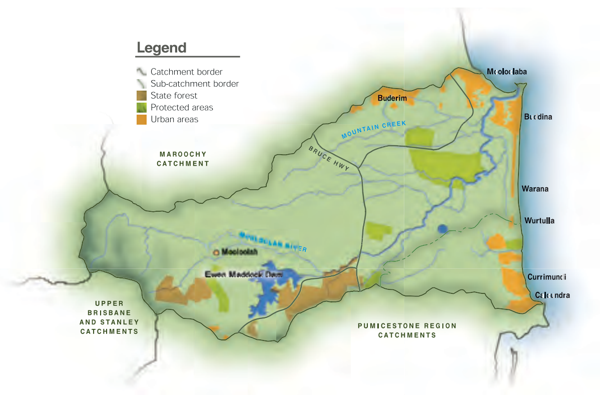

Figure 4.1: Map of Mooloolah River catchment

The majority of grazing is practised towards the upper catchment areas and sugar cane farming is concentrated on the floodplains around the tidal limit. Much of the upper freshwater catchment still contains substantial areas of native vegetation, including rainforests with rare and endangered plants such as king ferns and orchids. By contrast, the lower coastal areas abutting the estuary have largely been cleared and transformed into urban areas, particularly canal estates (Fig 4.2). Large-scale landscape modifications have radically altered the nature of the lower Mooloolah estuary, changing a relatively small estuary that drained coastal wetlands into a system that is today completely dominated by residential canal estates, marinas, harbours and artificially stabilised banks. The catchment is contained within the Maroochy Shire Council and Caloundra City Council local government areas.

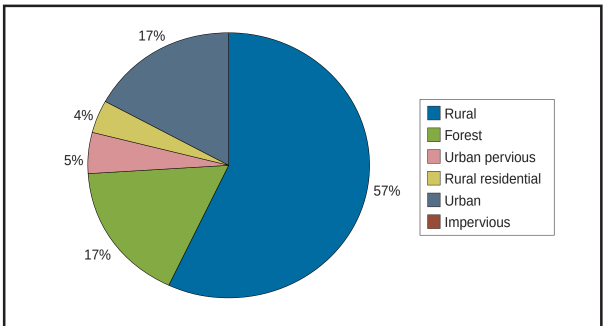

Figure 4.2: Land use in the Mooloolah River catchment

Although there has been historical development in the area (Charle's Park, 1864, and the wharf at Ballinger's selection, 1870), development has accelerated sharply in the past three decades. Canal estates have transformed the coastal plain since 1966, and development continues in Kawana Waters. Marinas provided for pleasure craft and harbour and shipyard facilities have been developed since the late 1960s. In the middle and upper sections of the estuary (upstream from McKenzie's Bridge) native vegetation remains on the western shore in the Mooloolah National Park and the river has riparian strips along both banks. There are, however, clear signs of increasing encroachment by urban development between the estuarine channel and the ocean.

Department of Natural Resources and Mines

Historical (1958) photo of the Mooloolah River mouth

Department of Natural Resources and Mines

Current (1997) photo of the Mooloolah River mouth

State of the waterways

Most indicators have a spatially disjunct distribution in the Mooloolah River, with a division between the coastal and upper catchment areas. The coastal areas have good water quality when measured against traditional parameters, although the area is highly modified by human activities and dominated by urban land uses. The upper reaches of the North Mooloolah River are in very good condition with healthy vegetation. The South Mooloolah River suffers poor water quality due to cattle and grey water entering the river.

Water quality

Physical and chemical indicators

Different processes occur in the lower and upper tidal estuarine reaches of the river. Strong tidal exchange facilitates significant flushing by marine waters in the lower estuarine reaches, which helps maintain relatively good water quality. Water clarity is generally high, except after rainfall when stormwater discharges import large amounts of suspended material. Total nutrient concentrations and phytoplankton biomass are moderate when compared with those in other south-east Queensland estuaries (Figs 4.3 and 4.4). Oxygen levels in the lower estuary comply with ANZECC guidelines but comply only marginally in the mid estuary. The upper estuarine and freshwater sections have significantly lower oxygen levels and show signs of nutrient pollution (Table 4.1).

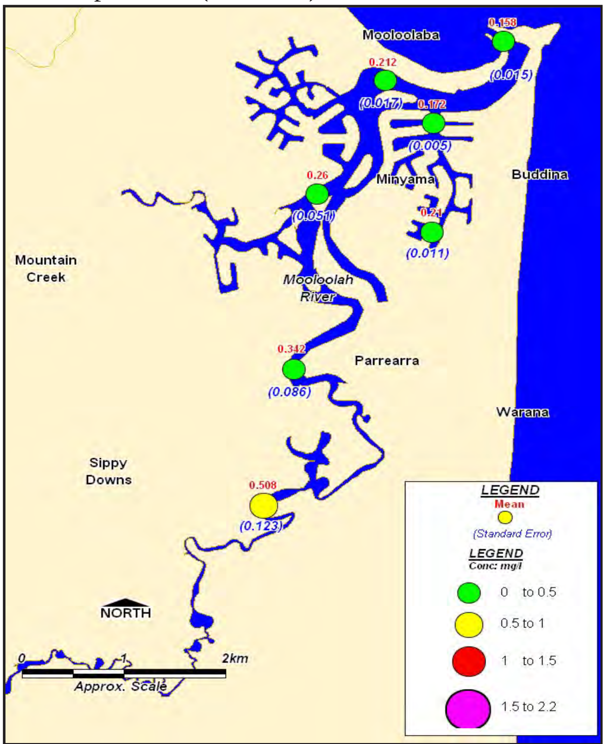

Figure 4.3: Total nitrogen distribution in the Mooloolah estuary (mg/L) (Feb. 2001)

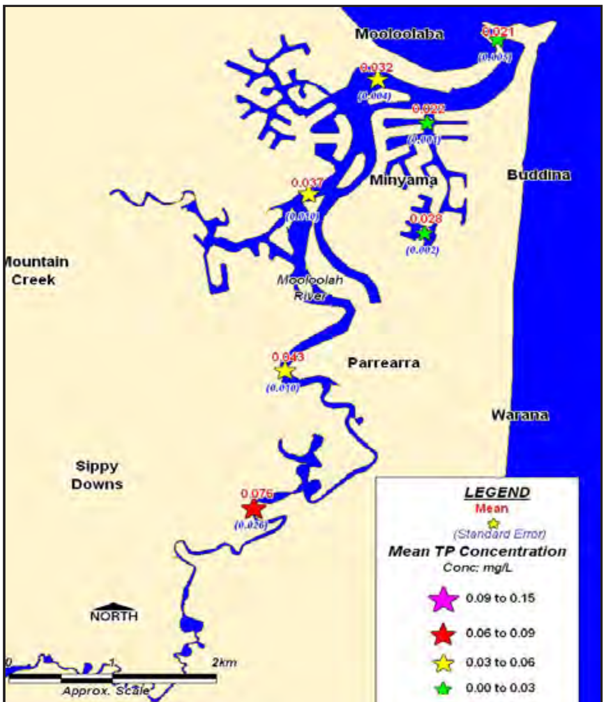

Figure 4.4: Total phosphorus distribution in the Mooloolah estuary (mg/L) (Feb. 2001)

Table 4.1: Summary of water quality status in the Mooloolah River

Indicator	Estuarine Lower	Estuarine Mid	Estuarine Upper	Riverine	Comments
Dissolved oxygen	✓	marginal compliance	✗	✗	Gradient of decreasing oxygen saturation towards the freshwater reaches,with substantially low DO levels recorded in the upper estuary and riverine sections. Low oxygen levels are possibly the result of unidentified sources of organic input into the upper/middle catchment.
pH	✓	✓	marginal compliance	✓	pH values typical of estuarine and fresh waters (marginally lower pH levels in upper estuary).
Turbidity	✓	✓	✓	✓	Generally clear water column with good light penetration, but highly turbid conditions develop after rainfall events.
Chlorophyll *a*	✓	✓	✓	✓	Generally no evidence of consistent and widespread eutrophication.
Phosphorus	✓	✓	✓	✗	Nutrient enrichment indicated in the freshwater sections but source(s) unknown.
Nitrogen	✓	✗	✗	✗	Gradient of higher nitrogen levels in an upstream direction from the tidal inlet towards the freshwater section; likely linked to catchment inputs, but these are neither quantified or traced.

✓ compliance with guidelines; marginal compliance
✗ exceeding water quality guidelines and/or reference ranges
marginal exceedance

Biological indicators

Phytoplankton bioassays

Growth of phytoplankton in the Mooloolah estuary is nitrogen- and phosphorus-limited. Phytoplankton in the upper estuary respond more strongly to nutrient additions, suggesting that nutrient loading in these areas is more likely to stimulate phytoplankton blooms than at sites near the estuarine inlet and that phytoplankton are better adapted to take advantage of nutrient pulses.

Mangroves and seagrass

No mangroves or other wetland vegetation remain downstream of Mooloolah Island. The banks have been completely cleared of vegetation to make way for road verges, stabilised shores, harbours, canal estates and marinas. Further upstream healthy stands of mangroves and dry eucalypt woodland remain, particularly in Mooloolah National Park, but in other places the band of fringing vegetation is very narrow and threatened by suburban sprawl. Seagrass used to thrive in the estuarine sections, but today no seagrass remains.

Phytoplankton

The Mooloolah estuary has a diverse phytoplankton community of diatoms and dinoflagellates. *Dinophysis* sp. (associated with diarrhetic shellfish poisoning) was recorded throughout the estuarine reaches, and was abundant near the estuarine mouth (Fig 4.5).

Fauna

The upper reaches of the Mooloolah River in the Diamond Valley area boast a diverse range of macroinvertebrates and fish.

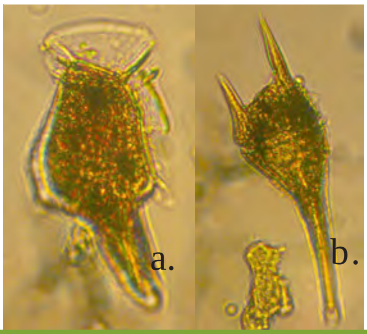

Figure 4.5: Phytoplankton of Mooloolah River
a. *Dinophysis* sp. and **b.** *Ceratium* sp.

Wastewater signals in fauna

In situations where large loads of sewage-derived nitrogen impact on an estuary the sewage signal may be traced through the entire estuarine food web. Resident organisms can be used to measure the extent of sewage plumes if discharges are spatially distinct and concentrated. In the nearby Maroochy River, oysters clearly reflect how nitrogen from wastewater discharges is distributed throughout the system. Applying this rationale and methodology to the Mooloolah estuary, where no distinct point source of sewage is known to discharge, the emerging $\delta^{15}N$ signatures are reduced.

Nitrogen isotope ratios ($\delta^{15}N$) indicate that Mooloolah oysters, benthic invertebrates and fish have generally much lower contributions of sewage-derived nitrogen in their tissues than those in the Maroochy estuary (Fig 4.6). However, $\delta^{15}N$ values in oysters are slightly elevated in marinas and canal estates compared with the main channel. This suggests some eutrophication by sewage from boats, stormwater drains or both (Fig 4.7). $\delta^{15}N$ patterns in the benthic fauna might also indicate isolated sewage-derived nitrogen sources in some locations (Fig 4.8). Finally, fish tissues reflect differences in wastewater loads between estuaries. Individuals caught in the Mooloolah estuary have significantly lower $\delta^{15}N$ incorporated into their muscle, which demonstrates that wastewater inputs are lower but also implies that fish movement between estuaries is small (Fig 4.9).

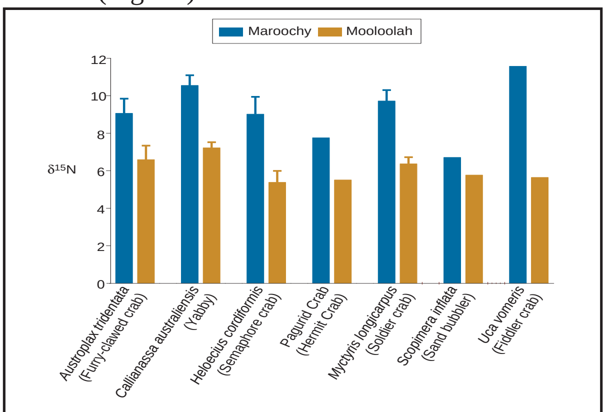

Figure 4.6: Comparison of nitrogen isotope ratios, $\delta^{15}N$ (ppt), in benthic invertebrates from the Maroochy and Mooloolah estuaries (Sept. 2000)

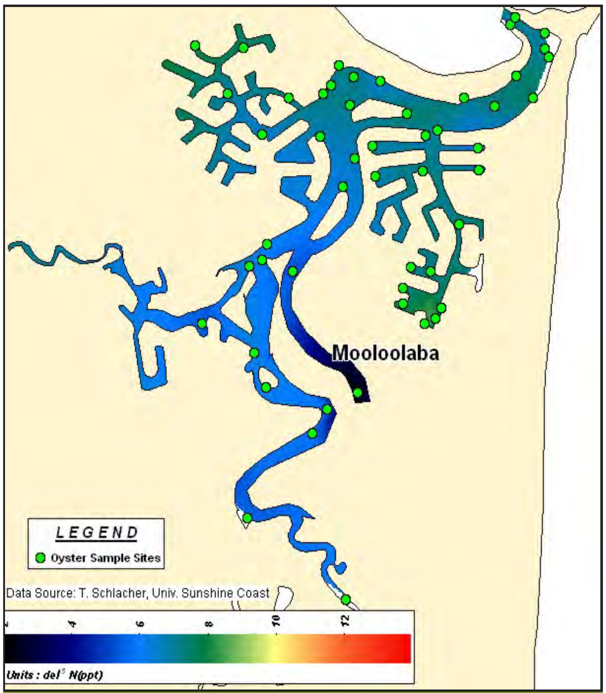

Figure 4.7: Nitrogen isotope ratios, δ^{15}N (ppt), in oysters from the Mooloolah estuary (Sept. 2000)

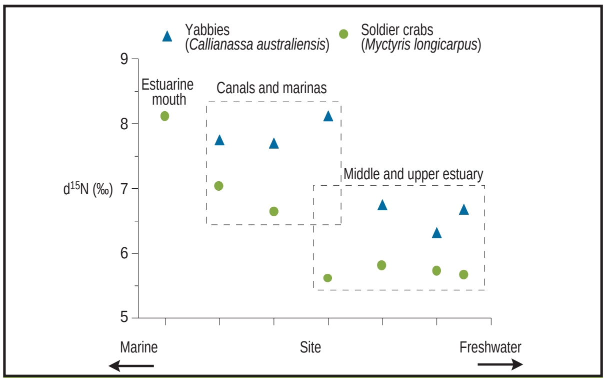

Figure 4.8: Variation in nitrogen isotope ratios, δ^{15}N (ppt), of yabbies and soldier crabs in the Mooloolah estuary

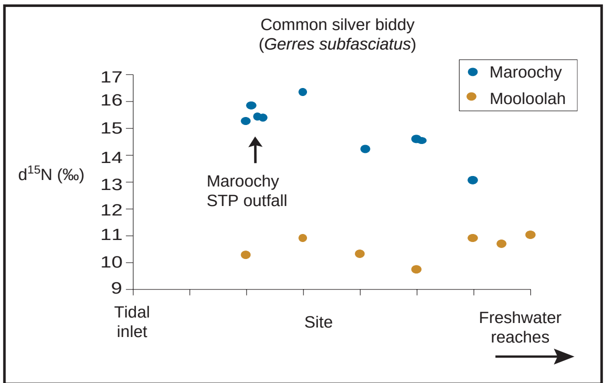

Figure 4.9: Example of difference between nitrogen isotope ratios, δ^{15}N (ppt), in fish in estuaries and variation within a system

Toxicants

Oysters from the Mooloolah estuary have highly elevated concentrations of copper in their tissues. These copper levels are at the upper end of values reported from other locations worldwide. Although copper is present in high concentrations in oysters from most sites in the lower reaches of the Mooloolah estuary, 'hot spots' of potential copper contamination appear to exist in one marina/yacht basin that also abuts a boatyard. This spatial pattern of copper concentration suggests a link to ship-based pollution and/or land-based activities related to boat maintenance (Fig 4.10). Lead concentrations in oysters are higher than in the adjacent Maroochy estuary.

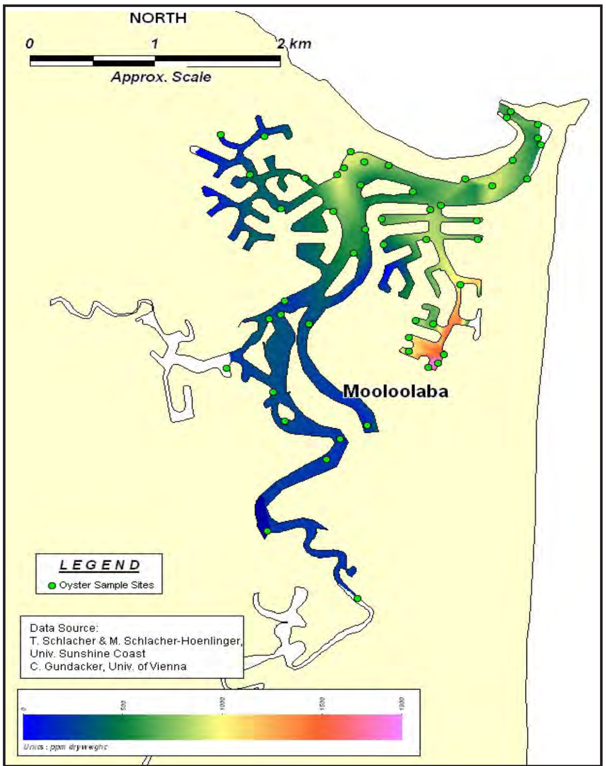

Figure 4.10: Concentrations of copper in oysters from the Mooloolah estuary (Sept. 2000)

Currimundi Lake

The entrance of Currimundi Lake naturally closes through the movement of sand by tidal and wave-induced currents. Closure can be rapid and requires strong flushing to reopen the lagoon to the sea. Active management and removal of the sand plug are an issue of long-standing community concern and discussion. Water quality in the lagoon is highly variable spatially and temporally, with acceptable phosphorus levels but elevated nitrogen concentrations. Faecal contamination levels exceed guideline levels following rainfall events. Oxygen depletion can at times be a problem in the deeper sections. Partial removal of the sand plug and artificial opening of the lagoon are management actions currently taken by Council when closure is deemed to continue for too long.

Pressures on the waterways

Population centres and urban inputs

The Sunshine Coast is one of the most rapidly growing regions in Australia. The population grows at an average annual rate of 2.9% (or 6500 to 7200 residents), and is predicted to reach 287 000 by 2006 and 383 000 by 2016. This growth is driven primarily by immigration. Ironically, the prime motivation for people moving to the region is 'the environment', but the very growth in population and its effects on the environment may be at odds with people's aspirations. The coastal areas are hosting the majority (70%) of the growth, and the proportion of coastal versus hinterland development is increasing slightly. Overall, the coastal areas of Maroochy and Caloundra City (the Mooloolah catchment straddles both shires) have the potential to accommodate an additional 30 300 dwellings (Figs 4.11 and 4.12).

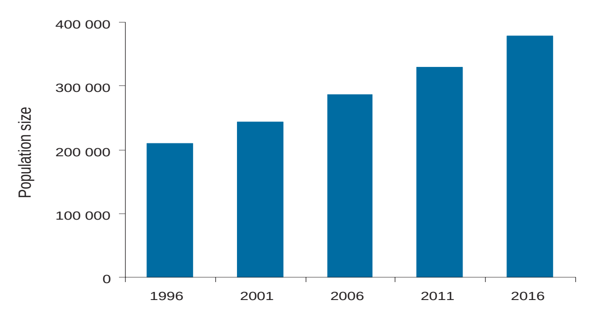

Figure 4.11: Sunshine Coast population growth forecast

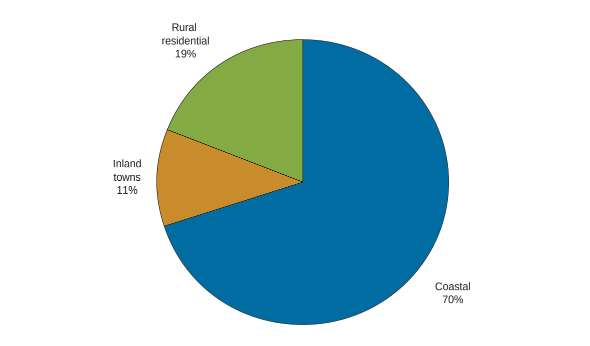

Figure 4.12: Patterns in land use of new dwellings (1991–98)

The lower estuary of the Mooloolah River exemplifies the consequences of this population growth. Canal estates and other residential areas have already engulfed the lower floodplain. On the last remaining coastal strip of land bordering the estuary, the area between the mid/upper estuary and Nicklin Way, a further 'master-planned community' (Kawana Waters) is currently under construction. This canal estate is projected to provide 14 000 residential dwellings.

Since 1996: increased

Point source discharges

There are only two licensed activities that are permitted to discharge into the Mooloolah estuary: a secondary (emergency) outfall of the Kawana STP in the upper estuarine reaches, and a seafood processing plant near the estuarine inlet. Neither of these licensed point sources is, however, considered significant, because discharges are very infrequent and/or quantities are very small. The possibility remains that other activities and developments could at times be considered as possible point sources. These include the boat harbour, yacht club, marinas and canal estates in the lower estuary, as well as land disposal of treated sewage in the upper catchment. These are not confirmed as point sources because load estimates are not available for these possible contributors, and their potential impacts on the environment are untested. Activities and structures associated with boating and shipping may contribute towards loading with heavy metals, and some quantities of faecal pollution may originate from marinas and/or stormwater drains in canal estates and on-site sewage treatment system in upper reaches.

Since 1996: no change

Diffuse discharges

A multitude of diffuse sources is present throughout the catchment but these are poorly quantified. A hallmark of the Mooloolah estuary is the almost complete conversion of the lower estuary into a system of canal estates, marinas and boat harbours. Essentially, the 'catchment' of the lower estuary is now urban. In the canal estates, numerous stormwater drains—often at a high spatial concentration and flow capacity—discharge substantial quantities of runoff to the estuary during rain events. Stormwater carries high loads of inorganic nutrients, numerous toxicants, organic detritus and bacteria. A plainly visible sign of stormwater effects are the prominent turbidity plumes originating from large drains in the canals during rainfall events. Siltation is an issue in the upper catchment because of increasing development. Land slips occur on Maleny hillsides during heavy rains due to the clearing of vegetation.

Since 1996: increased

Riparian condition

Encroachment of residential areas into riparian buffer zones appears the most significant pressure on riparian vegetation. Land clearing for agriculture in the middle and upper estuary is an additional pressure. The condition of riparian vegetation along half of the stream length in the Mooloolah catchment is very poor (Table 4.2).

Table 4.2: Riparian vegetation condition

Condition rating	% of stream length
Very good	4
Good	13
Moderate	20
Poor	15
Very poor	48

Areas in which riparian vegetation has been significantly altered are mainly concentrated around the urban developments of Mooloolah in the freshwater reaches, and the coastal strip around Mooloolaba, Buddina and

Warana. Most riparian zones within the catchment are narrower than the width of the upper bank, indicating that clearing has extended to within the river banks. Numerous alterations to the habitats of the lower estuary have occurred as a consequence of harbour and canal construction, potentially having a significant effect on fish habitats. While it has not been adequately demonstrated what effect canal estates have on fish, a reduction in structural diversity appears clear. Furthermore, critical estuarine habitat functions such as nursery and feeding areas will have diminished following the loss of mangroves and seagrass. Near the Mooloolah National Park exists 'Hidden Lakes' which are also vital fish habitat areas and need urgent protection.
Since 1996: further degradation

Boating and shipping

The Mooloolah estuary is the home port of a sizeable commercial fishing fleet, and has a major yacht basin (the Mooloolaba Yacht Club), and two marinas. Moreover, numerous recreational and some commercial fishing vessels are moored in those canal estates that have deepwater access. Only a few true 'houseboats' are anchored outside the marinas (which have populations of both semi-permanent and migratory residents), but yachts also anchor in the main channel of the estuary, sometimes for extended periods of time. Marinas have land-based facilities for human waste disposal, but the disposal practices of yacht crews are likely to be varied (anecdotal evidence also points to breaches of disposal practices *within* marinas). Thus there exists the very real potential for faecal ship-based contamination, indicated by elevated nitrogen concentrations and $\delta^{15}N$ values. Other potential pollutants include hydrocarbons (fuel, grease etc.) and a combination of chemicals used for anti-fouling protection of hulls. High copper residues (an element frequently used on boat hulls) in oysters coincide very broadly with areas of high vessel densities, but assessments need to be broadened to include more chemicals. Recreational boating activity is also extensive in the estuary and boat-based fishing is concentrated in the upper estuary. In the middle estuarine reaches, the narrow channel morphology amplifies the effects of boat wakes which often break the unconsolidated, muddy intertidal banks and may increase shore erosion and turbidity.
Since 1996: increased

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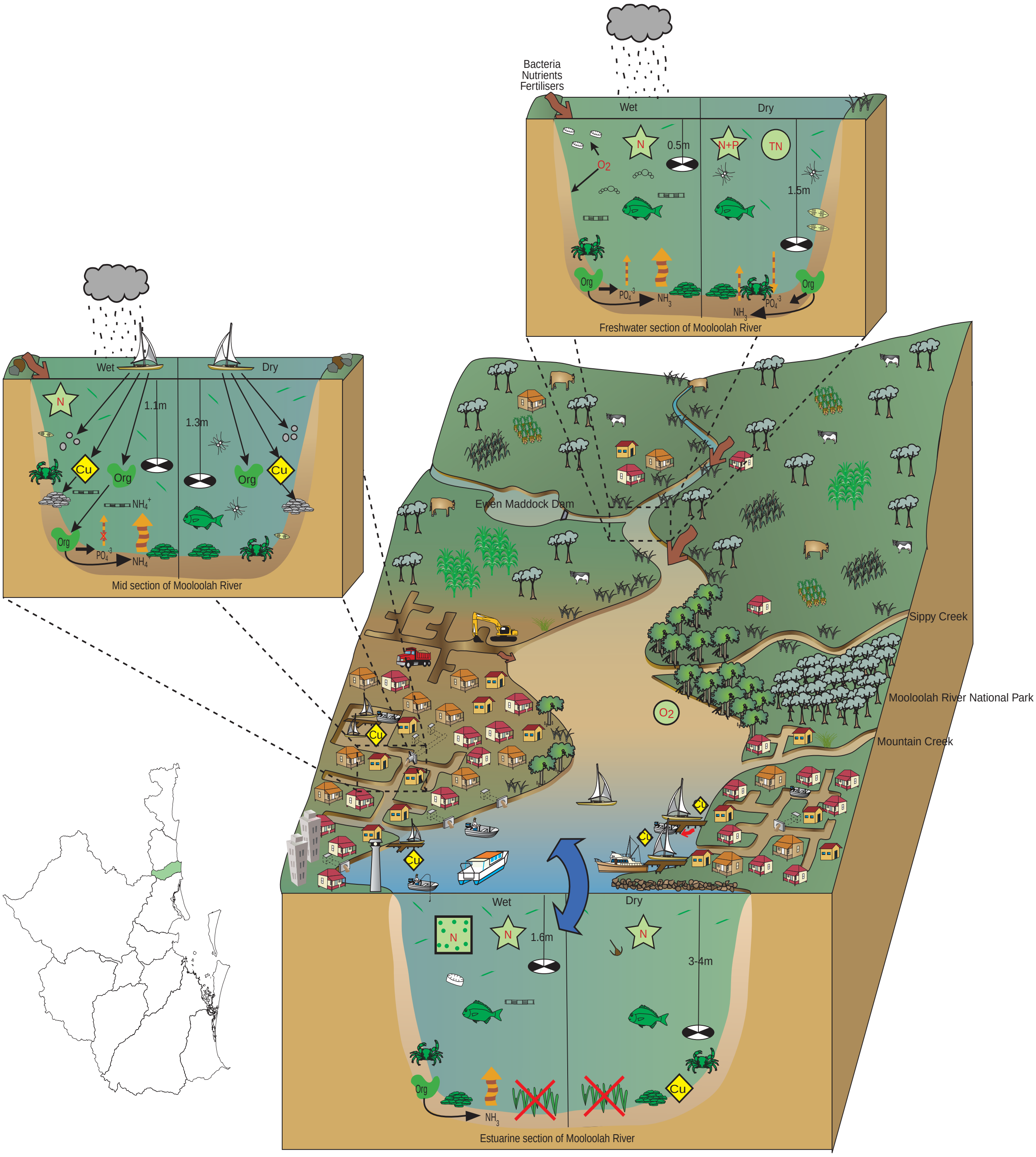
Responses to the pressures on the waterways

Issues	Local initiatives	Responses
Population centres and urban impacts	• Maroochy Shire Council is developing an Urban Stormwater Management Strategy. • Maroochy Mooloolah Catchment Management Strategy 2000 • Catchment Care Groups in Stumers Creek and Mountain Creek • Mooloolah Waterwatch • Friends of Currumundi Lake and Friends of Currumundi Lake—Northwest • Tooway Lake Catchment Care Group • Maroochy's Adopt a Park program • Maroochy-Mooloolah-Noosa Water Quality Management Strategy	• The SEQ Regional Framework for Growth Management is the basis for planning for the projected increases in the regional population. All member organisations are using the framework to guide sustainable growth in the region through a range of implementation mechanisms including planning schemes, corporate plans and a range of service delivery programs. • Range of local programs and plans outlining management actions to deal with this issue.
Point source discharges	• Caloundra City Council discharges effluent from the Kawana Ocean outfall.	
Diffuse discharges	• Catchment Association has collected land use information and distributed water quality information. • Sunshine Coast Environment Council's study on litter entering the waterways • Voluntary Code of Practice by Queensland Farmers Federation • Caloundra City Council's draft Urban Stormwater Management Strategy • Transport Infrastructure (Sunshine Coast Waterways) Management Plan 2000 prohibits living aboard vessels on the Mooloolah River except in private marinas and the Crown Boat Harbour.	• Range of local programs and plans outlining management actions to deal with this issue. • An Environmental Management Support System allows predictions to be made in relation to changes to water quality as a result of different land use and development practices, enabling stakeholders to develop future actions to deal with this issue. • Additional vessel sewage requirements that will apply to all coastal waters will be introduced through amendments to the *Transport Operations (Marine Pollution) Act 1995.*
Riparian condition	• Maroochy Mooloolah Catchment Management Strategy • Restoration projects by community groups • Natural Heritage Trust rehabilitation projects • Maroochy Mooloolah Seedling Grant Scheme • Development and application of local laws, vegetation mapping, planning scheme and development assessment, management plans, conservation agreement program, Open Space Plan and the Mooloolah River Trail Project • Bushcare's Land for Wildlife Program • State of the Mooloolah and Major Tributaries Report • Biomap project to map flora and fauna • SEQ Biodiversity Strategy, Habitat 2000 project and Queensland Biodiversity Network	• In 2002, stakeholders of the Partnership will begin to identify priority areas for riparian and stormwater management and set targets for on the ground works. This process will focus on implementing on-ground works to deal with this issue.
Boating and shipping		• Transport Infrastructure (Sunshine Coast Waterways) Management Plan 2000



Conceptual model for the Mooloolah River

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Chapter 5

Caboolture River and Pumicestone Passage

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Joanne Clapcott, Mark Kennard and Dieter Tracey

As the Caboolture River and Pumicestone Passage are separate systems, this chapter has been split to cover each individually.

Caboolture River

Description of the waterways

The coastal catchment of the Caboolture River is relatively small, covering 589km^2. The river rises in the D'Aguilar Ranges and meanders through agricultural and rural residential land in its upper section, with urban development increasing in the lower catchment. Deception Bay and the lower reaches of the Caboolture River are within a Habitat Zone of Moreton Bay Marine Park and part of the Moreton Bay Ramsar Site.

The Caboolture River flows into Deception Bay and is the main estuarine waterway in the catchment. The tidal limit of the river is at the Caboolture Weir, approximately 19km from the mouth. Burpengary Creek is the only other major estuarine waterway in the catchment. Caboolture River and Wararba Creek are the major freshwater streams in the catchment (Fig 5.1).

Figure 5.1: Map of Caboolture River and Pumicestone Passage catchment

The Caboolture River catchment has a rapidly expanding population that currently stands at 115 000, predominantly residing in the centres of Caboolture, Morayfield and Beachmere. The catchment is located within the Caboolture Shire Council and Caloundra City Council local government areas.

Major land uses within the Caboolture River and Pumicestone Passage catchment include grazing, natural bush and plantations (Fig 5.2). Seventy-seven percent of the stream length in the catchment is considered in moderate condition.

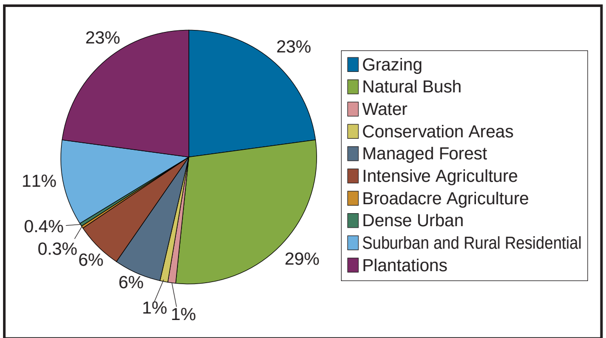

Figure 5.2: Land use in the Pumicestone Region

Department of Natural Resources and Mines

Historical (1949) photo of the Caboolture River at Caboolture

Department of Natural Resources and Mines

Current (1997) photo of the Caboolture River at Caboolture

State of the waterways

Freshwater

Water quality

Nutrients

High concentrations of nitrogen oxides and other inorganic nutrients are evident in the freshwater reaches of the river. The sustained high concentrations of nitrogen oxides in these waterways suggest that aquatic plants are saturated with nitrogen.

Wararba Creek, a major tributary of the Caboolture River, has predominantly low levels of nutrients. The majority of nitrogen in Wararba Creek is derived from diffuse sources which fluctuate temporally and at times give rise to elevated phytoplankton biomass.

Dissolved oxygen

Dissolved oxygen concentrations in the upper Caboolture catchment tend to be relatively low at night and supersaturated during the day, ranging from 23% to 116% saturation. This is demonstrative of high rates of oxygen production during the day and a high biological demand for oxygen at night, suggesting poor stream health in freshwater reaches.

Temperature

Stream temperatures are low, ranging from a minimum of 13°C during winter to 20°C in summer. These temperatures are indicative of adequate riparian shading in the upper reaches of the Caboolture River.

Riparian zones

The upper catchment of the Caboolture River includes undisturbed streams in the D'Aguilar National Park. In the middle of the catchment streams are impacted by the clearing of the riparian zone for agriculture and rural residential land uses. The riparian zones in the upper parts of the catchment are generally in good condition but have been extensively cleared in the middle catchment. Approximately 6km of riparian zone along both Burpengary and Lagoon Creeks has been restored. Mean riparian width across the catchment is 14.3m.

Aquatic vegetation

The condition rating of aquatic vegetation is considered very poor across the catchment. This indicates a low abundance of aquatic vegetation within streams, but low levels may be a natural feature of the catchment.

Biodiversity

Limited information is available on biodiversity in the Caboolture River catchment.

Estuarine

The estuarine reaches of the Caboolture River are moderately eutrophied, but overall are still in fair condition. Water quality in the Caboolture River is characterised by relatively low levels of suspended sediment and point source nutrient discharges. The high concentrations of phytoplankton are able to rapidly assimilate these nutrients, causing persistent algal blooms proximate to nutrient sources. There is evidence of biological processing of nutrients occurring in the Caboolture River during summer. Phytoplankton, mangroves and bacteria all possibly contribute to the processing of nutrients in this river estuary. The nitrogen sewage plume in the Caboolture River is highest at the STP outfalls but also extends upstream and downstream of the STP outfalls. Average residence time in the Caboolture River under base flow conditions is 53–57 days, which is the lowest of the major river estuaries entering Moreton Bay.

Healthy Waterways Library

The Caboolture River estuary flows into Deception Bay.

Water quality

Nutrients

Nutrient concentrations in the Caboolture River estuary are relatively low compared with these in the other major river estuaries flowing into Moreton Bay. The Caboolture South STP discharges 19km from the mouth. Nutrient concentrations are greatest in the middle section of the estuary, proximate to the STP discharge, and consistently exceed both ANZECC and QWQ guidelines in this area. The upper section of the Caboolture River estuary is subject to diffuse nutrient sources such as agricultural ruoff but concentrations in this section seldom exceed ANZECC and/or QWQ guidelines. The mouth of the Caboolture River is well flushed and consequently the nutrients from the Caboolture Regional STP, 1.2km upriver, are rapidly diffused. Nutrient concentrations in the lower section of the Caboolture River generally comply with ANZECC and QWQ guidelines (Table 5.1).

Table 5.1: Water quality in the Caboolture River is better than in the other river estuaries flowing into Moreton Bay (May 2000–May 2001).

Parameter	Median	Range
Dissolved oxygen (%)	82	35–120
Turbidity (NTU)	8	0–74
Secchi depth(m)	0.9	0.4–3.6
Total nitrogen (µM N)	36	11–107
Ammonia (µM N)	1.6	0.1–14
Nitrogen oxides (µM N)	4	0.1–48
Total phosphorus (µM P)	1	0.3–6
Filterable reactive phosphorus (µM P)	0.4	0.1–2

Sewage plumes

The plume of sewage nitrogen mapped using $\delta^{15}N$ signatures is highest at the Caboolture South STP discharge and gradually dissipates towards the river mouth. The Caboolture South STP uses biological nutrient removal technology, which, along with its placement upstream, promotes in-stream processing of sewage nitrogen to reduce downstream impacts (Fig 5.3).

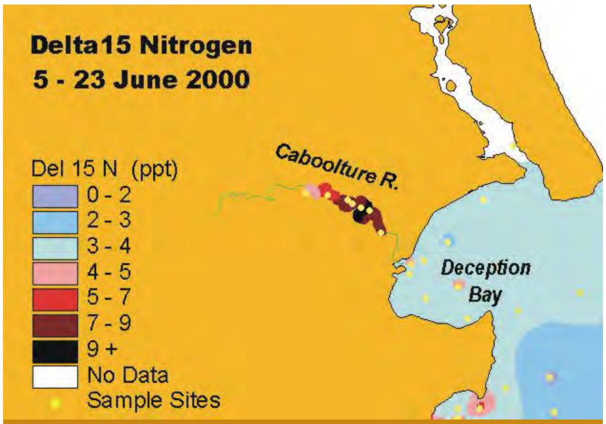

Figure 5.3: The sewage plume in the Caboolture River is greatest near the Caboolture South STP.

Biological processing of nutrients

There is a distinct seasonal variation in the capacity of the Caboolture River to process nutrients, despite the relatively low and consistent ambient nutrient concentrations. There is a high level of biological processing of inorganic nitrogen by plants and/or bacteria in summer, while in winter the magnitude of biological processing is considerably reduced and inorganic nitrogen passes unprocessed into Deception Bay (Fig 5.4). There is little evidence of denitrification occurring in the Caboolture River. The total phosphorus concentrations in the Caboolture River are comparatively low and are predominantly deposited before reaching the bay.

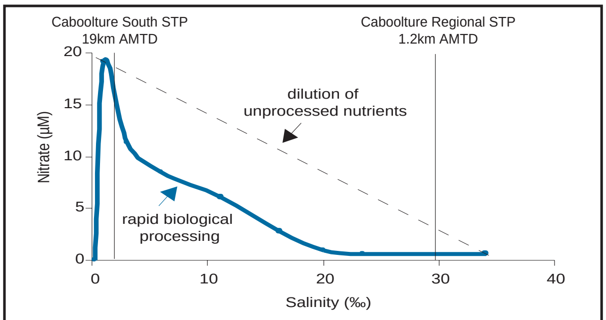

Figure 5.4: A high level of biological processing by plants and/or bacteria occurs in the Caboolture River.

Turbidity

Secchi depth in the Caboolture River does not comply with guidelines during summer except at the well-flushed mouth. Turbidity is greatest in the middle section of the river between 5 and 15km upstream. During summer turbidity in the middle section exceeds guidelines, reaching values up to 70NTU.

During winter secchi depths in the Caboolture River are far greater, ranging between 1.0 and 2.5m and occasionally exceeding 3.0m at the mouth (Fig 5.5). Turbidity in the Caboolture River is generally higher than in the western embayments of Moreton Bay.

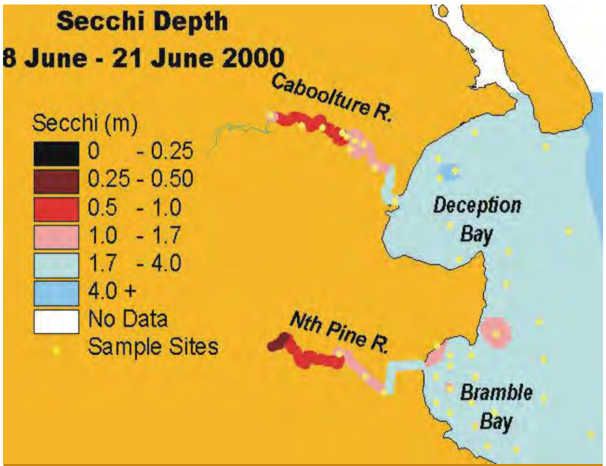

Figure 5.5: Turbidity in the Caboolture River is low compared with the other river estuaries flowing into Moreton Bay.

Phytoplankton

The Caboolture River estuary is characterised by high levels of phytoplankton biomass. The relatively high ambient phytoplankton populations coupled with relatively low turbidity contribute to a high algal bloom potential in the Caboolture River. Phytoplankton growth is at a maximum during summer, chlorophyll *a* concentrations regularly exceeding ANZECC and QWQ guidelines. Algal blooms in the estuary frequently occur proximate to nutrient point sources such as STPs. The middle reaches of the river, downstream of Caboolture South STP, have the highest concentrations of chlorophyll *a*, frequently exceeding 25µg/L. The upgrade of the Caboolture South STP and the decommissioning of the Caboolture North STP, in late 1997 and early 1999 respectively, have resulted in reduced and stabilised DO concentrations and a reduction in the frequency and intensity of algal blooms (Fig 6). Phytoplankton concentrations decrease towards the river mouth in association with increased flushing.

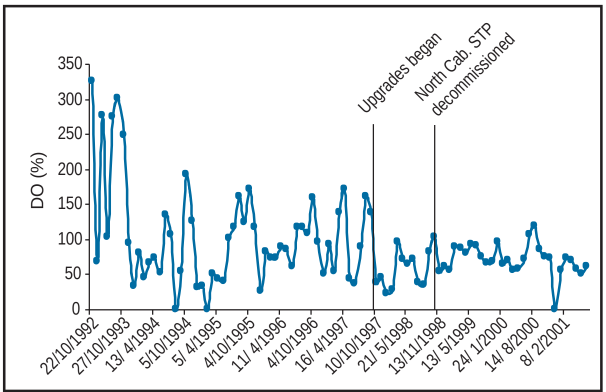

Figure 5.6: Stabilised DO concentrations due to STP upgrades have been accompanied by a reduction in the frequency and intensity of algal blooms in the upper tidal reaches of the Caboolture River.

Riparian zones

The riparian zones in the estuarine reaches of the Caboolture River have been extensively cleared to make way for existing and expanding urban, rural residential and forestry areas. The shorelines of the Caboolture River and Burpengary Creek comprise mangrove woodlands dominated by *Avicennia* with sandy-mud foreshores adjacent to tidal flats. Samphire flats occur around the mouth of both the Caboolture River and Burpengary Creek. *Avicennia* and *Aegiceras* grow in the estuarine creek beds. Mangrove cover in the Caboolture catchment was approximately 17.96km^2 in 1998. This represents a net increase of 1.18km^2 in mangrove distribution in this region since 1974.

Biodiversity

The Caboolture River estuary provides habitat for many fish species including Australian bass, bream, blue salmon, estuary cod, flathead, garfish, jewfish, luderick, mangrove jack, sea mullet, tailor and whiting. The estuary is also home to juvenile finfish and many crustaceans such as mud crabs, sand crabs, banana prawns, school prawns, greasyback prawns and bay prawns. Lands below high water mark and waters of the Caboolture River, Burpengary Creek and to the southern alignment of Emerald Avenue, Deception Bay, are included in the Deception Bay Fish Habitat Area.


Marine Botany, UQ

The waters of the Caboolture River and Deception Bay are included in the Deception Bay Fish Habitat Area.

Pressures on the waterways

Population

The population of the Caboolture River catchment has increased 16% to about 115 000 since 1996 and is predicted to increase further to 145 000 over the next five years. The majority of people are resident in Caboolture and the smaller centres of Morayfield and Beachmere. Attendant to the rapid increases in urban population are urban runoff and waste production. Increased human traffic in and around the river catchment is also projected with the growth in population. Water use per head of population has decreased by 20% in the past 7 years. There are 7000 on-site sewage treatment systems in the Caboolture Shire, of which only 42% meet Shire requirements.
Since 1996: increased

Tourism and recreation

Tourism is a major focus of the Caboolture region and continues to increase. Between October 1998 and September 1999, $1.62 million was spent on tourist facilities. Current occupancy rates of tourist facilities range between 35% and 51% and are 45% on average.

The Caboolture catchment also supports a vast array of recreational activities, the most popular being dog exercising, birdwatching, bushwalking and canoeing. Many recreational pursuits in the region occur in and around the waterways; these include boating, swimming, skiing, sailing and fishing. In 1999 there was a maximum of 10 commercial vessels operating in the Caboolture River, taking 16.2 tonnes of fish.
Since 1996: increased

Catchment loads

Major point source discharges

There are two major point source discharges into the Caboolture River. The Caboolture South STP has a total capacity of 40 000 population equivalent and discharges into the estuary near Caboolture Weir. This STP was upgraded in late 1997. The Caboolture Regional STP has a total estimated capacity of 37 500 persons and discharges into the mouth of the river. Although the Caboolture North STP was decommissioned in April 1999. There has been a 9–15% increase in the volume of sewage effluent over the last three years, with only 2% of this effluent reused.
Since 1996: increased

Non-point source discharges

Approximately 53% of the pollutant load in stormwater runoff is attributed to urban areas. About 23% of these pollutants are derived from industrial areas, the bulk of which occur around Caboolture and the lower section of the river catchment area. The remainder of the pollutant loads are derived from agriculture (12%), rural areas (5.3%) and forestry (6.7%).
Since 1996: increased

Flow modification

In-stream structures and water extraction impact on the natural processes of the Caboolture River. There are eight licensed in-stream structures within the Caboolture River catchment area, which reduce water flow and hinder the movement of aquatic fauna. The Caboolture Weir has a storage capacity of 1300ML and is the main urban water storage for Caboolture Shire.

There are approximately 237 licensed water extraction sites within the river catchment area; the volumes and impact of these extractions are unknown, however.
Since 1996: insufficient data

Land clearing

The Caboolture River catchment experienced the highest amount of clearing in south-east Queensland from 1988 to 1997 (3% per year), excluding areas of state forests. The clearing of woody vegetation in the Caboolture Shire has made way for land uses such as pasture production (2.75km^2) and new settlements (1.46km^2).

Since 1996: increased

Healthy Waterways Library

Caboolture River catchment had the highest amount of clearing in south-east Queensland from 1988 to 1997.

Removal and degradation of riparian vegetation

Extensive land clearing for agricultural use has resulted in a reduction of native riparian vegetation. This leads to reduced uptake of nutrients by the catchment area prior to inclusion into the river system. Recent development pressure in the region has increased the stormwater runoff load and has decreased riparian vegetation, resulting in a decline in water quality and affecting fish habitats and wetland areas in the river catchment. Riparian vegetation zones are narrowest in areas of intense land use, especially in the lower reaches of the river catchment.

Since 1996: increased

Extractive industries

There are only 2 extractive industries proximate to waterways in the Caboolture Shire: a hard rock plant near Burpengary Creek and a sand plant near King Johns Creek.

Since 1996: no change

Pumicestone Passage

Description of the waterways

Pumicestone Passage is a narrow, shallow (80% <2m deep) coastal plain or passage estuary bordered by Bribie Island in the east and the low-lying salt flats and wallum of the coastal plain in the west. The estuary is influenced primarily by tidal flushing of the southern passage from Deception Bay in northern Moreton Bay, and there is a net northern movement of water through the passage. In flood conditions, runoff from the catchment dominates the waters of the passage and outflow from the Caboolture River moves north towards the passage. Extensive areas of melaleuca forest, heathland, saltmarsh, and mangroves, as well as large areas of intertidal mudflats and channels, surround the estuary and seagrass meadows within the estuary. The passage is of great ecological and economic significance, providing habitat, feeding and spawning areas for numerous species, and is listed as a Ramsar site. Most of Pumicestone Passage and its associated tidal creeks are within a conservation zone of Moreton Bay Marine Park, recognising the area's high amenity, cultural and ecological values. The Tripcony Bight Protection Zone, located in the central part of the passage, has high ecological value and is protected from all forms of collecting. The Pumicestone Channel Fish Habitat Area extends from Toorbul Point to Bells Creek and includes tributaries and the foreshore of Bribie Island.

The total catchment area is 728km^2, incorporating the drainage areas of numerous freshwater creeks. The Pumicestone sub-catchment extends from the coastal salt flats west to the Glass House Mountains, with the estuary receiving terrigenous inputs from Bribie Island and the Caboolture River. Population centres in the Pumicestone catchment are Caloundra in the north, and the smaller townships of Beerburrum, Beerwah and Landsborough in the hinterland. The catchment falls within the Caloundra City Council and Caboolture Shire Council local government areas.

Environmental Protection Agency

Pumicestone Passage with the Glasshouse Mountains in the background

State of the waterways

Water quality

Water quality in Pumicestone Passage and its in-flowing creeks is highly variable. Unlike the river estuaries of the region, base flows are relatively low and are sustained by groundwater seepage. During periods of low flow, water quality in the passage is relatively good and is sustained by a net northward tidal movement of water from Moreton Bay. For much of the time, nutrient values in the creeks draining the catchment generally fall within guideline levels but loads of nutrients and suspended solids from these creeks can be very high during runoff events. Periods of high flow also deliver catchment loads from the Caboolture River. Human activities in the catchment deliver nutrients, sediment, organic loads and faecal coliforms as well as toxicants such as metals and pesticides. Water quality in the passage has generally deteriorated since the early 1980s.

Riparian zone

Coastal and riparian vegetation of the passage is in poor to moderate condition. Extensive areas of coastal heathland and native forest have been cleared to make way for agriculture and pine plantations, which occupy 39% of the catchment area. Between 1974 and 1991, 130km^2 of vegetation was cleared. Melaleuca forest remnants are fragmented and coastal heathland communities are poorly represented. Only one significant remnant of banksia woodland remains on Bribie Island.

The riparian zones in the northern section of Pumicestone Passage are dominated by *Avicennia*, *Ceriops*, *Aegiceras* and *Rhizophora* mangroves, while the southern section comprises low open *Avicennia* shrubland with scattered sand and samphire flats.

Biodiversity

Although still in moderate to good condition, tidal wetlands are decreasing due to development pressures and fragmentation. Pumicestone Passage has 20% of the saltmarsh-claypan area in south-east Queensland (~10km^2) and 14% of the mangrove area (21.7km^2). Pumicestone Passage is one of only two areas in southern Queensland with substantial growths of orange mangrove *(Bruguiera gymnorrhiza*). Mangrove and melaleuca communities support large numbers of birds.

Over 16km^2 of seagrass is present in Pumicestone Passage, supporting significant dugong and turtle populations. Pumicestone Passage provides habitat for many juvenile fish and adult fish species including Australian bass, bream, blue salmon, estuary cod, flathead, garfish, jewfish, luderick, mangrove jack, sea mullet, tailor and whiting. The estuary is also home to many crustaceans such as mud crabs, sand crabs, banana prawns, school prawns, greasyback prawns, eastern king prawns and bay prawns.

Pressures on the waterways

Population

Pumicestone Passage is situated in the heart of a rapidly developing region, including increasing numbers of weekend and day visitors from Brisbane. The population of the Pumicestone sub-catchment was 28 300 in 1991 and was predicted to increase to over 90 000 by 2001. The SEQ2001 project predicts that demand for rural and urban land will generally exceed suitable and available land by 2011. Urban development is likely to be associated with increased discharges of wastes, resulting in increasing nutrient and other catchment loads.
Since 1996: increased

Urban development is increasing in the Pumicestone Region.

Fishing and boating

Although all commercial fishing stopped in Pumicestone Passage in 1995, the passage is an important area for recreational fishing and boating. Recreational angler catches are known to be substantial, though numbers are not certain.
Since 1996: insufficient data

Catchment loads

Some dredging for sand and gravel extraction occurs in the catchment. Three large quarries at Sunrock, Glass House Mountains and Bald Knob removed 1 188 000 tonnes of sand and gravel in 1989–90 and intermittent extraction has occurred from Toorbul, Elimbah Creek, Coonowrin Creek and Coochin Creek.
Since 1996: no change

Flow modification

Coastal areas have been modified for canal estate developments on Bribie Island, and the construction of training walls. The passage is dominated by tidal flow (annual flow from creeks contributes only 1.5% of the tidal flow) and there are no major water storage facilities in the catchment. Overall, no substantial changes in flow have resulted from human activity.
Since 1996: no change in flow

Land use

At present, the majority of the catchment area is used for forestry, pine plantations and intensive agriculture, predominantly pineapple growing. During flood events high sediment and nutrient loads result from catchment activities. The catchment has been and continues to be subject to extensive clearing of coastal heathland and melaleuca communities for farming, plantations, urban development and grazing. Intertidal areas are also decreasing, with 1.21km^2 of mangroves and 0.50km^2 of saltmarsh-claypan cleared between 1984 and 1987.
Since 1996: increased clearing

Responses to the pressures on the waterways

Issues	Local initiatives	Responses
Population		• The SEQ Regional Framework for Growth Management is the basis for planning for the projected increases in the regional population. All member organisations are using the framework to guide sustainable growth in the region through a range of implementation mechanisms including planning schemes, corporate plans and a range of service delivery programs. • Range of local programs and plans outlining management actions to deal with this issue.
Catchment loads —Major point source discharges	• Upgrades of the South Caboolture STP in 1997 and 1999 • Upgrade of the Burpengary East STP in 1998 • Decommissioning of the North Caboolture STP in 1998 • Upgrade of the Bribie Island STP and calls for tenders for a further upgrade • All STPs have been upgraded to 5mg/L total nitrogen • South Caboolture Water Reclamation Project • Caboolture Council is investigating wastewater reuse options. • All solids are transported directly to Swanbank for disposal. • Caboolture Council has instigated a study in wastewater from rural residential areas and is investigating the provision of sewage to Toorbul and Donnybrook.	
—Non-point source discharges	• Pumicestone Region Catchment Management Strategy • Stormwater Management Systems to Improve Pumicestone Waterways • Pumicestone Erosion Hazard Identification Project • Voluntary Agricultural Code of Practice by the Queensland Farmers Federation • Catchment Association and Pineapple Cannery and Growers Groups are investigating use of a mulching machine. • Urban Stormwater Quality Management Plan	
Flow modification		• Range of local programs and plans outlining management actions to deal with this issue. • An Environmental Management Support System allows predictions to be made in relation to changes to water quality as a result of different land use and development practices, enabling stakeholders to develop future actions to deal with this issue.
Land use and clearing	• Pumicestone Region Catchment Management Strategy • Caboolture Region Integrated Catchment Management Group • Friends of Lagoon Creek • Caboolture Shire Council has employed a Catchment Management Officer. • Pumicestone Region Catchment Coordination Association • Caloundra Council supports Pumicestone Water and Ecosystem Monitoring Coordinator and the Integrated Catchment Management Manual for the Pumicestone Region.	• In 2002, stakeholders of the Partnership will begin to identify priority areas for riparian and stormwater management and set targets for on-ground works. This process will focus on implementing on-ground works to deal with this issue.

Responses to the pressures on the waterways cont'd

Issues	Local initiatives	Responses
Land use and clearing —Removal and degradation of riparian vegetation	• Pumicestone Region Catchment Management Strategy actions • Projects by Friends of Lagoon Creek, Caboolture Region Integrated Catchment Management Group (CRICM) and Caboolture Region Environmental Education Centre (CREEC) • Burpengary Creek Rehabilitation Program • Caboolture River Gold project, Burpengary Continuation project • Caboolture Shire Council's 'Adopt a Waterway Program' • Caloundra City Council's Tree Protection Local Law, Pest Management Plan, Vegetation Mosaic of Lands within the Boundaries of Caloundra City Council, Conservation Agreement Program and Open Space Plan • Bushcare's Land for Wildlife Program • Weed eradication programs • Catchment Association's State of Rivers Survey	
Boating and shipping		• Transport Infrastructure (Sunshine Coast Waterways) Management Plan 2000

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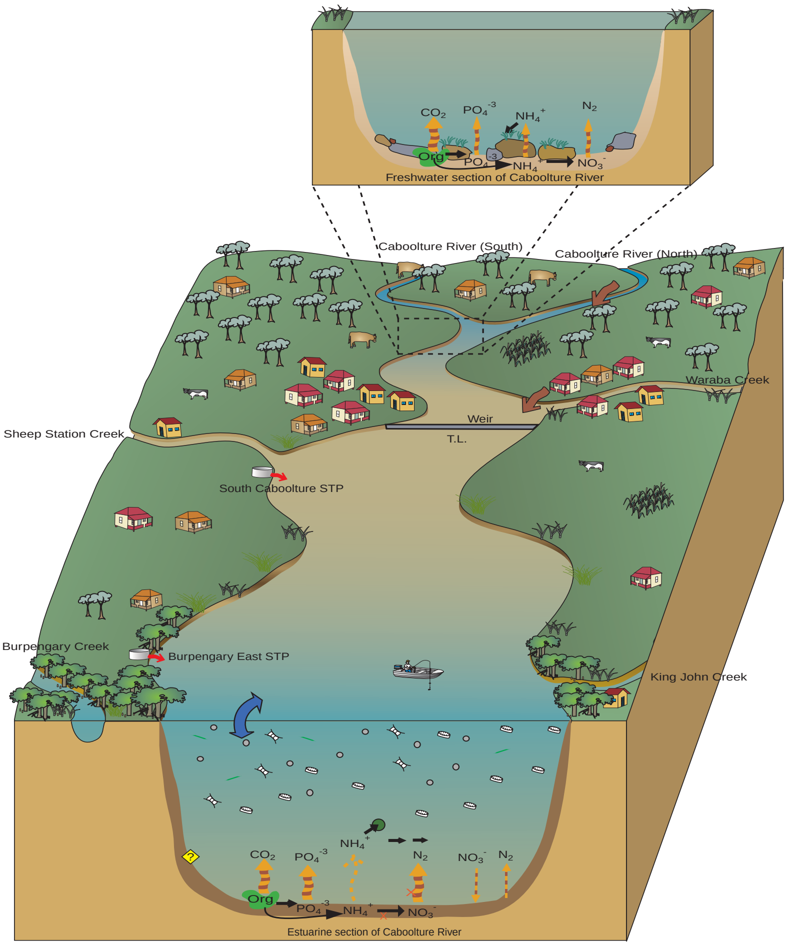
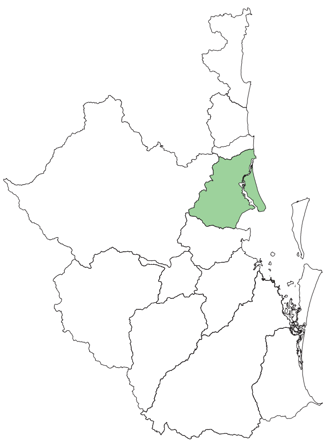
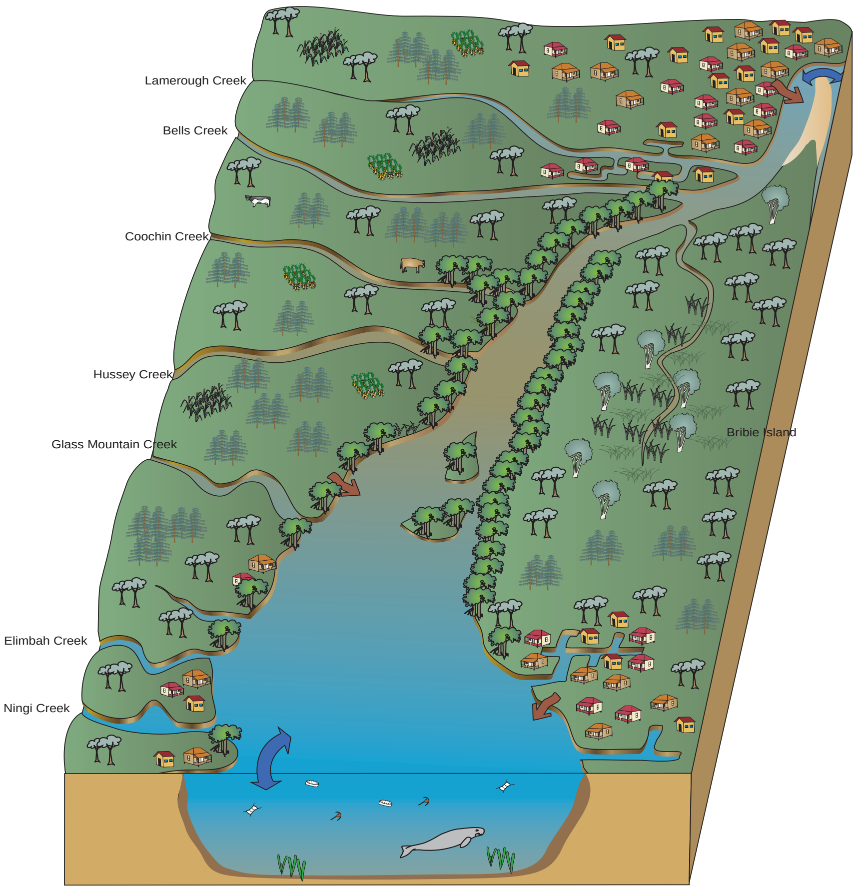


Conceptual model for the Caboolture River catchment





Conceptual model for the Pumicestone Passage catchment

Chapter 6
Pine Rivers

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Description of the waterways

The Pine Rivers catchment covers an area of 695km^2. It rises in the D'Aguilar Ranges in the undeveloped areas of Brisbane Forest Park and Bunyaville State Forest. The river flows through rural residential areas before entering the urbanised lower catchment where Petrie, Strathpine and Kallangur comprise the major urban centres. The North and South Pine Rivers form the major waterways of this catchment. There are two dams in the catchment, Lake Samsonvale on the North Pine River and Lake Kurwongbah on Sideling Creek, while the South Pine River remains relatively unregulated, having only one weir. The tidal limit for the North Pine River occurs 17km from the river mouth at Youngs Crossing, and on the South Pine River at 14.4km at Strathpine. The two rivers converge just before entering Bramble Bay, south of the Redcliffe Peninsula (Fig 6.1). The majority of the catchment falls within the Pine Rivers Shire local government area, but small portions are located within Caboolture, Redcliffe and Brisbane City Council areas. Parts of the Pine River east of the Bruce Highway Bridge are within a habitat zone of Moreton Bay Marine Park, and part of the Moreton Bay Ramsar site.

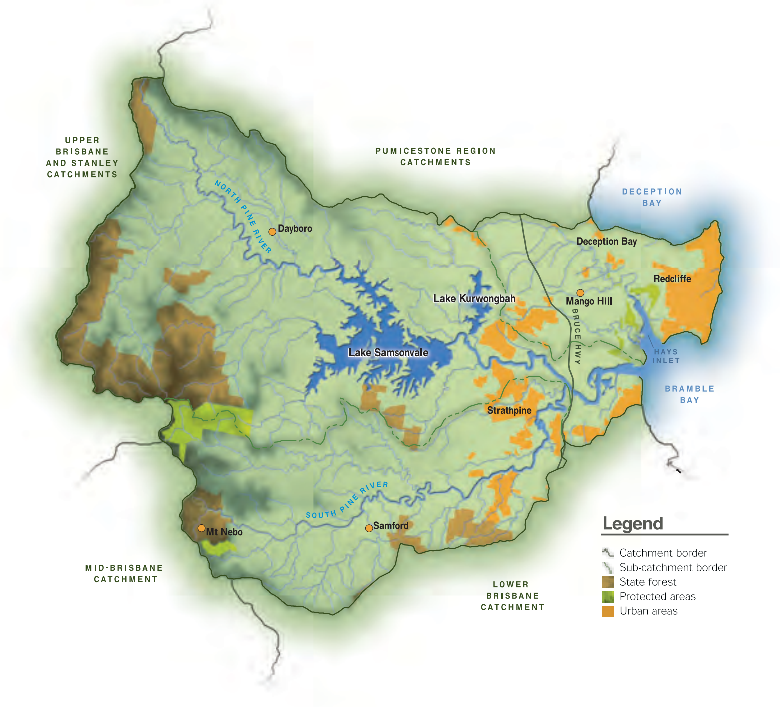


Figure 1: Map of the Pine Rivers catchment

The major land uses in the catchment include grazing and natural bush; the rest of the catchment is made up of various other land uses (Fig 6.2).

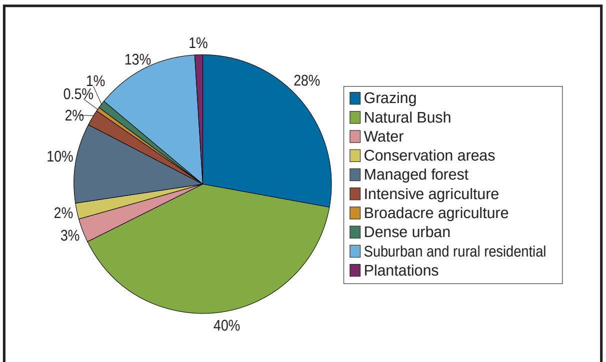


Figure 6.2: Land use in the Pine Rivers catchment

Lake Samsonvale (North Pine Dam) impounds the North Pine River approximately 30km to the north-west of Brisbane City. Construction of the dam began in 1968 and was completed in 1976. At full supply level, Lake Samsonvale has a storage capacity of 215 000ML, and inundates an area of 22km^2, with a total shoreline of 125km. The dam is a water supply dam only, and thus has no provision for the temporary storage of floodwaters. Water is drawn directly from the lake to the nearby Brisbane City Council treatment plant and is also released periodically into the Pine Rivers Shire Council offtake pool.

The total catchment area of Lake Samsonvale is 347km^2. Major streams feeding intothe lake are the North Pine River, Rush Creek, Kobble Creek, Terrors Creek, Laceys Creek and Mount Samson Creek. Dayboro is the major settlement in the Lake Samsonvale catchment. In addition, there are numerous rural residential allotments scattered throughout some of the catchment.

This chapter is divided into sections covering freshwater reaches of the river, Lake Samsonvale and the estuarine section.

Department of Natural Resources and Mines

Historical (1949) photo of Albany Creek area

Department of Natural Resources and Mines

Current (1997) photo of the Albany Creek area

State of the waterways

Freshwater

The freshwater region of the Pine Rivers catchment includes undisturbed streams in Brisbane Forest Park and the D'Aguilar National Park. Clear Mountain, Bunya and Mount Mee State Forests also lie in the catchment. Many of the creeks in the catchment carry only intermittent flows and can remain dry for long periods. Streams in the mid catchment are impacted by the clearing of the riparian zone for grazing and rural residential land uses, while the lower catchment is highly disturbed due to urban development. The hydrology of the North Pine River is also significantly altered by Lake Samsonvale and Lake Kurwongbah.

Water quality

Nutrients

Nutrient concentrations were found to be relatively low in streams in the Pine Rivers catchment during periods of low flow (Table 6.1). This suggests that incorporation of nutrients by aquatic plants is sufficient to remove any nutrients that enter the stream as base flow.

Table 6.1: Water quality parameter ranges

Ammonia	0.07–5.7µM
Nitrate	0.14–4.2µM
Total nitrogen	18–19µM
Phosphate	0.16–0.96µM
Total phosphorus	0.32–3.2µM

Dissolved oxygen

Dissolved oxygen concentrations in the South Pine River and Cabbage Tree Creek ranged from 38% to 122% saturation. This suggests that oxygen production may be high during the day, while biological demand for oxygen is correspondingly high at night, which is typical of poor stream condition. Low oxygen concentrations are a problem in this catchment, particularly during summer when oxygen solubility is reduced and oxygen consumption increases.

Temperature

Stream temperatures during the day vary by 2–6°C . Maximum temperatures in February reach 26 °C in Cedar Creek and 31 °C in Cabbage Tree Creek, which is high enough to detrimentally affect some animal communities. These high stream temperatures are probably due to inadequate riparian shading.

Riparian zones

Some of the riparian zones in the upper parts of the catchment are generally intact and in good condition. Others, however, others have been extensively cleared for agricultural and rural purposes. In the mid and lower catchment, much of the remaining riparian vegetation is introduced weed species. Riparian zones in several protected reserves remain in good condition.

In-stream processes

Gross primary production

Rates of gross primary production (GPP) in the upper and mid Pine Rivers catchment range from low (42 mgC/m/d) to moderate (170 mgC/m/d); the mean rate of GPP is below the maximum guideline value for upland streams. This suggests that excessive algal growth is not a problem in the catchment.

Benthic respiration

In contrast to GPP, benthic respiration rates (R_{24}) in the South Pine River and Cabbage Tree Creek are high. Benthic respiration is above the maximum guideline values for healthy streams, suggesting that large inputs of organic carbon are causing these large demands for oxygen.

Denitrification

Denitrification in the South Pine River is below that expected for a healthy stream, indicating very low denitrification efficiency. Rates of denitrification are higher in Cabbage Tree Creek but are still low relative to the available nutrients. Overall, in-stream processes are unhealthy in the agricultural and urban sections of the catchment.

Fish

Habitat degradation from clearing of riparian vegetation, and flow regulation leads to poor stream condition which alters natural fish populations. At least 29 native fish species are likely to have occurred in the Pine River prior to human settlement. Three exotic fish species, Gambusia (*Gambusia holbrooki*), swordtail (*Xiphophorus helleri*) and Tilapia (*Oreochromis mossambicus*) currently dominate the fish communities. Gambusia are extremely abundant, particularly in urban tributaries of the South Pine River. Tilapia are abundant in Lake Samsonvale and occur downstream. It is possible that at least three native species no longer occur in the freshwater reaches; these include the endangered Oxleyan pygmy perch (*Nannopera oxleyana*), the ornate sunfish (*Rhadinocentrus ornatus*) and the freshwater mullet (*Myxus petardi*).

Lake Samsonvale

Water quality

Dissolved oxygen levels in Kobble Creek do not meet ANZECC guidelines, and pH is relatively low (< 6.5). Overall, Kobble Creek is of relatively high ecological health. Mt Samson Creek has moderate levels of pollution.

Lake Samsonvale impounds the North Pine River.

Flora and fauna

Fish

Several fish species have been released into Lake Samsonvale for recreational purposes: silver perch (*Bidyanus bidyanus*), golden perch (*Macquaria ambigua*), Mary River cod (*Maccullochella peelii mariensis*), Australian bass (*Macquaria novemaculeata*), saratoga (*Scleropages leichardti*), snub-nosed garfish (*Arrhampus sclerolepis*), bony bream (*Nematalosa erebi*) and lungfish (*Neoceratodus forsteri*), as well as red-claw crayfish (*Cherax quardicarinatus*). All these animals are of recreational fishing importance. Fish are unable to migrate between the lower North Pine River and Lake Samsonvale due to the dam wall.

Macrophagic carnivores dominate the fish population in Lake Samsonvale (71% of total catch). Eleven fish species are found in the North Pine River arm of the lake, while six are found in the Kobble Creek arm. The presence of one exotic fish species, Tilapia (*Oreochromis mossambicus*), has been documented.

Aquatic weeds

Salvinia *(Salvinia molesta)* is the major aquatic weed species present in Lake Samsonvale. However, water hyacinth (*Eichhornia crassipes*) and water lettuce *(Pistia stratiotes)* are also present in the lake.

Algae

Lake Samsonvale typically stratifies in summer with a resultant increase in numbers of cyanobacteria, in particular the species *Cylindrospermopsis raciborskii*. Nutrients may also be carried into the storage from the catchment during high rainfall events, which may lead to increased growths of bloom-forming algae.

A destratification system was installed in Lake Samsonvale in 1996 with the aim of improving water quality. As a result of the operation of this destratification unit, maximum numbers of cyanobacteria (in particular the toxic *Cylindrospermopsis raciborskii*) appear to have been reduced, and these algae now start to develop in early spring instead of midsummer.

Birds

The lake is a major habitat for waterbirds, for example cormorants, swans and pelicans. No studies have been undertaken to determine numbers of bird colonies, nesting patterns, or the contribution of bird droppings to nutrient inputs into the lake.

Coastal and estuarine

Water quality

Water quality in the estuarine reaches of the Pine Rivers is poor. Consistently high concentrations of nutrients, in conjunction with an average residence time of 55 to 62 days, trigger phytoplankton blooms near point source discharges as well as in the upper estuarine reach of the North Pine River (Table 6.2). The nitrogen sewage plume is greatest near the Murrumba Downs STP and cartonboard factory discharge and extends both upstream and downstream. The Pine Rivers have consistently high turbidity and limited biological processing allowing nutrients to pass unchanged into Bramble Bay.

Table 6.2: Summary of water quality conditions of the estuarine reaches of North Pine River between May 2000 and May 2001

Water quality parameter	Median	Range
Dissolved oxygen (%)	92	36–150
Turbidity (NTU)	8	1–43
Secchi depth(m)	1.0	0.3–5
Total nitrogen (µM N)	26	10–152
Ammonia (µM N)	0.8	0.1–34
Nitrogen oxides (µM N)	1	0.1–100
Total phosphorus (µM P)	3	0.4–34
Filterable reactive phosphorus (µM P)	2	0.1–30

Nutrients

Nutrient concentrations in the Pine Rivers are lower than in the larger river estuaries of the Brisbane and Logan Rivers, but greater than in the Caboolture River. Nutrients in the middle reaches of the Pine Rivers result predominantly from point source discharges. Nutrient concentrations are consistently highest at 10.5km upriver proximate to the Murrumba Downs STP and cartonboard factory discharges, exceeding ANZECC and QWQ Guidelines. Ammonium and nitrate concentrations regularly exceed 10µM and 25µM nitrogen, respectively. Recent upgrades to both STPs in Pine Rivers have resulted in a reduction of 175 tonnes per year of nitrogen and 22 tonnes per year of phosphorus entering the waterways. Nutrient loads from Amcor Cartonboard have not changed since 1996.

Nutrient concentrations in the upper reaches of the Pine Rivers are lower than in the middle reaches and are influenced more by diffuse sources. Ammonium concentrations in the upper, freshwater reaches are consistently higher than nitrate concentrations. Urban stormwater inputs are the dominant source of nutrients in the lower Pine Rivers. The well-flushed zone near the mouth of the North Pine River has consistently low nutrient concentrations.

Sewage plume

The North Pine River sewage plume is greatest near the discharges of Murrumba Downs STP and an industrial discharge point. An elevated sewage ($\delta^{15}N$) signature extends both upstream and downstream of the point source discharges (Figure 6.3).

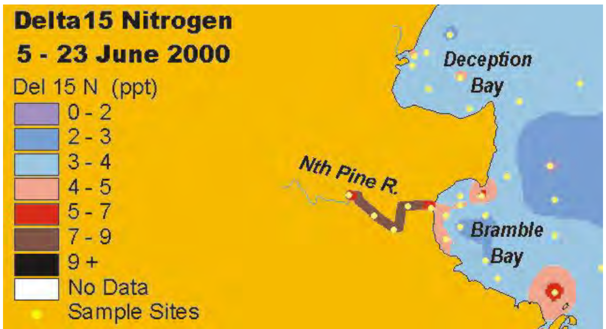


Figure 6.3: The North Pine River sewage plume is greatest near the point source discharges and extends upriver as well as downriver into Bramble Bay.

Phytoplankton

The Pine Rivers are characterised by high phytoplankton biomass. Algal blooms occur at Youngs Crossing on the North Pine River, due to relatively high nutrient concentrations, low dispersion and high light availability. The chlorophyll *a* concentration regularly exceeds 10µg/L downstream of the point source discharges in response to elevated nutrient concentrations, which exceeds ANZECC and QWQ Guidelines (Fig 6.4).

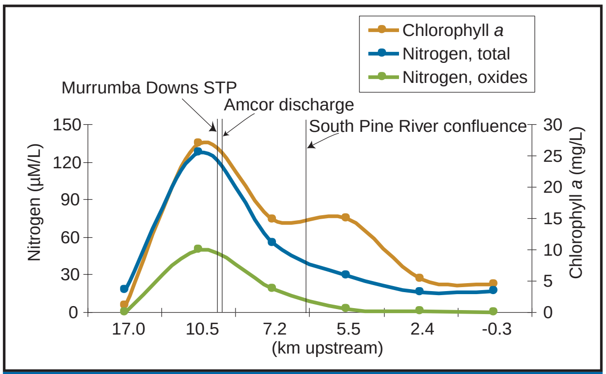


Figure 6.4: Phytoplankton concentrations in the North Pine River are greatest near the nutrient point sources.

Water clarity

Turbidity levels in the Pine Rivers generally range between 1NTU and 20NTU, the highest levels occurring during the summer months. Turbidity is consistently low near the tidal limit at Youngs Crossing; however, values reaching 40NTU occur near the mouth in summer months, contributing to a localised plume into Bramble Bay. The secchi depth sometimes exceeds 1.7m during winter but in summer secchi depths are rarely greater than 1.0m. The confluence of the South Pine River causes elevated levels of turbidity in the North Pine River at just below 7km upstream (Fig 6.5).

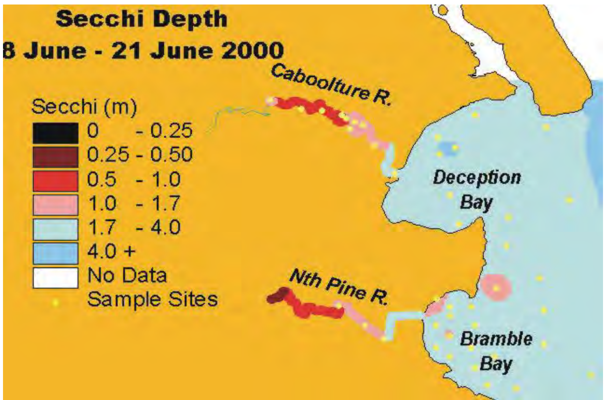


Figure 6.5: The confluence of the South Pine River causes decreased secchi depths in the North Pine River.

Riparian zones

The major habitat of the riparian zone in the estuarine reaches of the Pine Rivers comprises mangrove communities, *Avicennia* being the dominant species. A number of small mangrove islands occur at the mouth of the Pine River. There are approximately 6.92km^2 of mangroves in the Pine Rivers catchment. Information on changes to riparian vegetation over the past five years alone is not currently available; however, a recent study on wetlands distribution has reported a net increase in mangrove coverage of 0.61km^2 since 1974.

Biodiversity

A number of different fish species occur in the Pine Rivers, and part of the North Pine River is protected fish habitat. The fish species present include Australian bass, bream, blue salmon, estuary cod, flathead, garfish, jewfish, luderick, mangrove jack, sea mullet, tailor and whiting. Crustaceans inhabiting this region include mud and sand crabs, as well as banana and eastern king prawns. The declared Hays Inlet Fish Habitat Area covers the tidal land and waters from 10m inshore of the Hornibrook Highway into Hays Inlet and the Pine River, north from its midstream line to 3km downstream.

Cabbage Tree Creek

Water quality is poor in the estuarine section of Cabbage Tree Creek. The major source of nutrients and organic matter in lower Cabbage Tree Creek is the Sandgate STP (operated by Brisbane City Council), which discharges 1.2km upstream. The water quality and ecological health of the river generally improve upstream; however, a fish kill due to Biphenthrin (an anti-termite chemical) was recorded in December 1999 in upper Little Cabbage Tree Creek.

Pine Rivers tributaries

There is little available information on water quality and ecosystem health for the major tributaries of the Pine Rivers, which are Kobble, Terrors, Laceys, Griffin, One Mile and Four Mile Creeks.

Cedar Creek

Cedar Creek is one of the healthiest and least impacted creeks in the Pine Rivers Shire. An extensive fish kill was recorded at Cedar Creek in August 2000, but may be linked with sudden temperature changes. Cedar Creek is affected by nutrient enrichment, which is detectable in the upper reaches increasing downstream, and is mostly derived from diffuse sources such as agricultural practices. Total nitrogen, total phosphorus and faecal coliform concentrations regularly exceed ANZECC guidelines. Poorly maintained on-site wastewater treatment plants (e.g. septic systems) are an important source of diffuse nutrients in Cedar Creek and in the rural and semi-rural areas of the Pine Rivers catchment in general. Monitoring of these septic tanks shows that 90% of these systems do not function in accordance with the Department of Natural Resources and Mines Interim Code.

Mosquito Creek

Mosquito Creek is rich in organic matter originating from forest litter, but has low nutrient concentrations and overall is considered to be healthy. Browns Creek, which joins Mosquito Creek, shows evidence of high nutrient loading and organic pollution, largely from unregulated rural activities and clearing of riparian vegetation.

Pressures on the waterways
Pine Rivers catchment

Population pressures

Increasingly, the major pressure facing the Pine Rivers catchment is residential development, especially moderate to high-density urban development. The current population of the Pine Rivers catchment (excluding creeks flowing directly into Bramble Bay) is approximately 77 000 people. This population is expected to increase to 94 500 over the next 10 years. Only 1% of dwellings in the catchment were built before 1960 and urban development has doubled in the past 20 years. In 1996, urban development was projected to consume 0.80km^2 per year, and this is expected to increase with population growth, especially around the lower reaches of the catchment area. Agricultural land is increasingly being developed for rural residential purposes.

These land use changes increase the pressure on waterways in the catchment by altering the natural process of runoff during storms and increasing pollutant loads.
Since 1996: increased


Healthy Waterways Library

Pine Rivers catchment with development in background

Major point source discharges

There are three major point source discharges into the Pine Rivers. Murrumba STP and Amcor Cartonboard discharge approximately 10km up North Pine River, and Brendale STP discharges 7.5km upstream along the South Pine River. Other point source discharges include the Bracken Ridge STP, which discharges into Bald Hills Creek at the mouth of the Pine Rivers, and the Sandgate treatment works at Cabbage Tree Creek, which discharges into Bramble Bay. Murrumba and Brendale STPs were both upgraded in 2000.
Since 1996: decrease in TN and TP

Dams and weirs

Water supply for Pine Rivers Shire comes from two main sources, Lake Samsonvale (2560ML[5 yr av], supplying 50% of the Shire's population) and Lake Kurwongbah (9168ML [5 yr av], supplying 50% of the population). Approximately 12 500ML of water was extracted from Lake Samsonvale and Lake Kurwongbah in 1996–97 and 12 225ML was extracted in 2000–01. Both Lake Samsonvale and Lake Kurwongbah have reduced the natural flow rates for the upper river catchment.

Water extraction is projected to increase to approximately 26 160ML by 2012, mainly because of increased urban and industrial development in the shire. This is also expected to decrease the flow rate of waterways within the river catchment. There is a proliferation of small farm dams in the rural areas of the catchment, and these will have a large impact under base flow conditions as they tend to trap and store minor flows. There are no dams or weirs on South Pine River.
Since 1996: slight increase in extraction

Riparian vegetation

The degradation of remaining vegetation and loss of riparian zone functions is expected to increase due to urban development and weed invasion. It is estimated that 42% of the original catchment vegetation remains. In 1996, vegetation clearing was a key feature of catchment development but future clearing will not be a significant threat as local laws have restricted further clearing.

Along Browns Creek in the Lake Kurwongbah catchment area, riparian vegetation has largely been cleared for grazing and creek banks are severely disturbed by uncontrolled stock access.
Since 1996: decrease in vegetation clearing, but increased pressures to vegetation condition

Extractive activities

There are three sand and gravel extraction industries, two clay extraction operations and two hardrock industries in the catchment. Sand, gravel and clay resources within the catchment are extensive. Some of these deposits are unlikely to be available for extraction because of competing land uses or environmental constraints. The extent of extraction has not increased, but its distribution has, moving into more marginal areas. Extraction is expected to continue in existing approved and licensed extraction sites, but opportunities for new sites to be opened up in the coastal lowlands area are extremely limited.
Since 1996: distribution and demand has increased, not supply or extent

Introduced species

A total of 37 undesirable plant species, 56 declared weeds and 8 feral animal species are known to have impacted on the catchment prior to 1996. An increase in the invasion and spread of weeds is expected in the future as a result of continued clearing and urban development.
Since 1996: increased

Lake Samsonvale

The major issues of importance to the overall state of the water quality and ecological health of Lake Samsonvale are summarised in Table 6.3.

Table 6.3: Summary of pressures and stresses affecting the North Pine Dam catchment

- Erosion
- Increasing sediment loads
- Sewage inputs
- Unsewered areas
- Stormwater runoff
- Bacteria and parasitic contaminants
- Algal blooms

Inappropriate management of:

- Rural residential subdivisions
- Land clearing, including removal of riparian vegetation
- Cattle grazing and access to streams
- Agricultural activities/cropping

Land clearing

A large proportion of the riparian vegetation in the Lake Samsonvale catchment has been either cleared or modified for grazing, agriculture and rural residential subdivisions, bringing increased sediment and nutrient inputs. The southern shores of Lake Samsonvale at this stage still feature large continuous areas of remnant vegetation.
Since 1996: increased

Environmental Protection Agency

Clearing has increased in the Lake Samsonvale catchment.

Input of catchment sediments

Lake Samsonvale is an effective trap of sediments originating in the catchment from erosion and surface runoff. The bulk of sediment inputs settle in the deeper parts of the lake. Sediment accumulation may be affecting water quality and aquatic habitats within the lake, and may have degraded benthic areas. Water quality is also affected by direct input of sediments from surface runoff (due to degraded riparian zones and cleared land surrounding the lake) and in-stream erosion. SEQWater and Pine Rivers Shire Council are currently undertaking catchment land use, sediment and nutrient load investigations and modelling. SEQWater has installed automatic event sampling stations in the North Pine River and Kobble Creek above Lake Samsonvale's full supply level.
Since 1996: increased

Fishing and boating

Fishing from the shore may be undertaken from any of the designated recreation areas around Lake Samsonvale, no permit being required. Limited boating access is available for fishing from electric or manually powered boats through a trial scheme being operated by the Pine Rivers Fish Management Association (PRFMA). Club-organised sailing activities are permitted via membership of the sailing club, which leases a property adjoining the lake.
Since 1996: stable

Water extraction

Water is being pumped out of the lake for use at Clear Mountain Resort. Furthermore, a number of licensed pumps abstract water for farm use and rural dwellings.
Since 1996: increased

Cattle access and grazing

Cattle have generally unrestricted access to streams flowing into Lake Samsonvale, potentially increasing sediment and nutrient loads in the water. One of the conditions of leases of land adjoining the lake, however, is that the property be fenced, prohibiting cattle access to the shores of the lake in these cases. There are a number of dairies in the catchment, which can potentially contribute to nutrient inputs into streams feeding into the lake.
Since 1996: stable

Agriculture

Inappropriate management of agricultural lands can lead to the contamination of inflowing streams by pesticides, herbicides, fertilisers and sediment. One of the major agricultural land uses in the Lake Samsonvale catchment is pineapple growing.
Since 1996: insufficient data (likely to have decreased)

South East Queensland Water Corporation

Pineapples are a major agricultural crop in the Pine Rivers catchment.

Rural residential development

Numerous areas in the catchment of Lake Samsonvale are being subdivided for rural residential uses and hobby farms. Many of these are not sewered, and wastewater is treated using septic systems. Council monitoring suggests that these areas can potentially be a source of elevated nutrients, in particular nitrate, since wastewater from septic systems can seep into the groundwater. Land clearing for residential development has the potential to increase stormwater runoff and soil erosion into streams feeding into Lake Samsonvale.
Since 1996: increased

Extractive industries

There are two quarries in the Pine Rivers catchment, one each in the catchments of Lake Samsonvale and Lake Kurwongbah. (A decommissioned quarry used to operate in the Mt Samson Creek subcatchment of Lake Samsonvale but is now a rural residential subdivision.)
Since 1996: increased

Sewage treatment plants

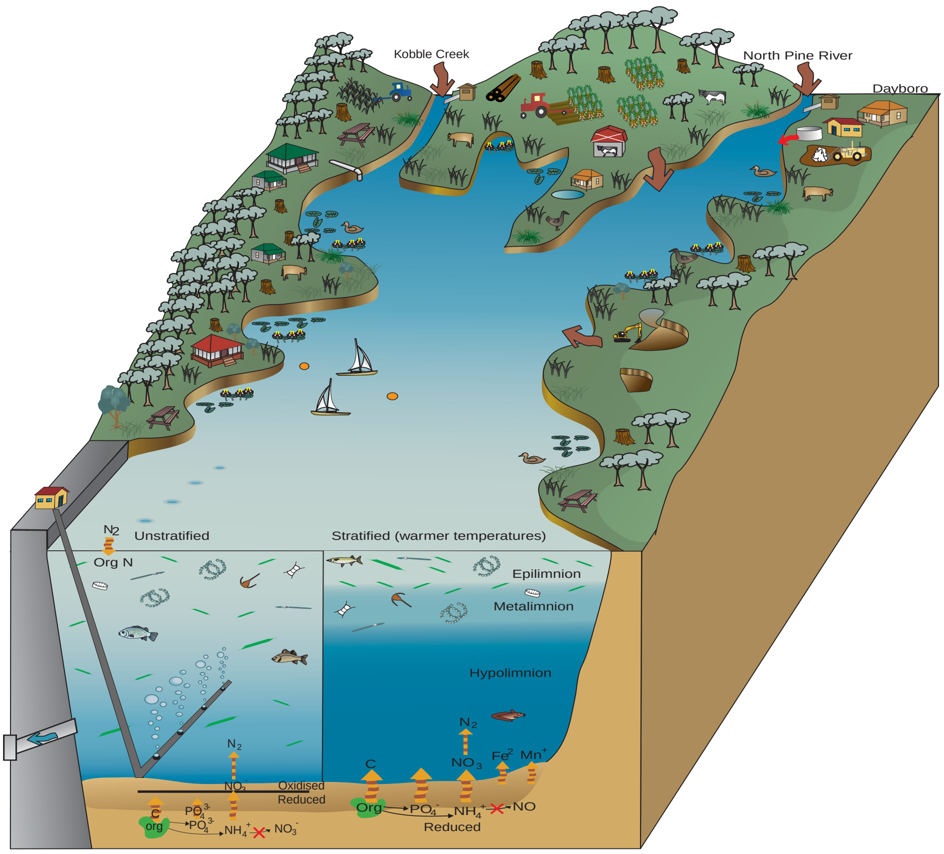
There is one STP located within the catchment near Dayboro, using land irrigation to dispose of wastewater.
Since 1996: STPs stable, septic systems increased

Groundwater recharge

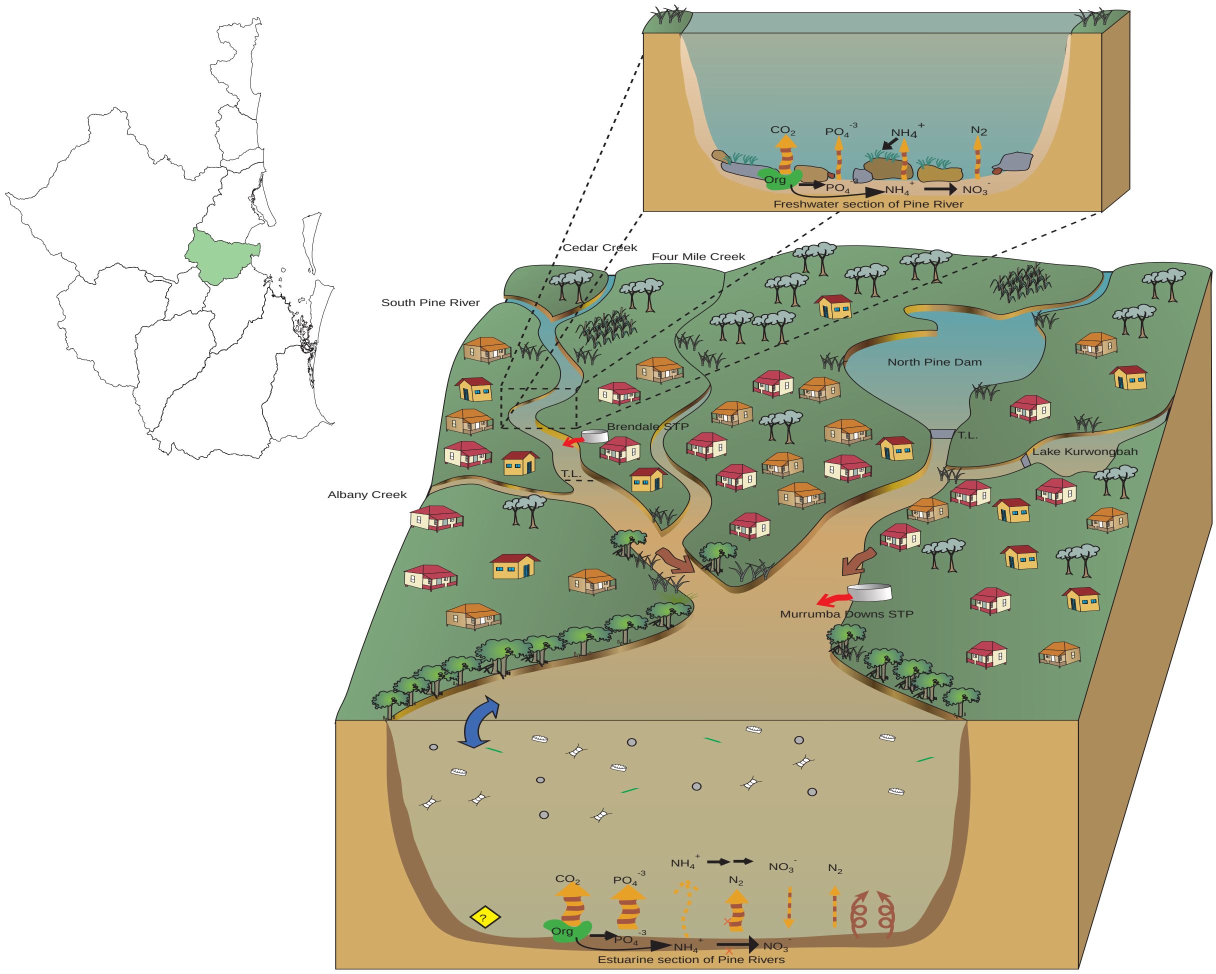
Groundwater seepage back into the lake as water levels drop as a result of water use or drought can carry pollutants with it, such as chemical residues from old cattle dips, nutrients from fertilisers and herbicide or pesticide residues. Groundwater seepage may also be impacted by poorly maintained septic systems.
Since 1996: insufficient data, likely to increase

Responses to the pressures on the waterways

Issues	Local initiatives	Responses
Population pressures		• The SEQ Regional Framework for Growth Management is the basis for planning for the projected increases in the regional population. All member organisations are using the framework to guide sustainable growth in the region through a range of implementation mechanisms including planning schemes, corporate plans and a range of service delivery programs. • Range of local programs and plans outlining management actions to deal with this issue.
Major point source discharges	• Upgrade Brendale and Murrumba Downs STPs to 5mg/L total nitrogen • Developing an Integrated Environmental Management System • Investigating feasibility of closing Bracken Ridge STP and transferring sewage to Sandgate STP (BCC plants) • 100% of Dayboro STP effluent reused • Investigating expansion of the current 10% reuse from the Brendale STP • Established a recycling demonstration plant	• The upgrades to the Pine Rivers Shire Council's wastewater treatment plants have achieved the nominated nitrogen and phosphorus discharge targets outlined in the SEQRWQMS. The Pine Rivers Shire Council will continue to monitor discharges from its wastewater treatment plants to ensure discharge quality is maintained. • An Environmental Management Support System allows predictions to be made in relation to changes to water quality as a result of different land use and development practices, enabling stakeholders to develop future actions to deal with this issue.
Dams and weirs		• Many of these issues will be dealt with during the development of the Moreton Region Water Resource Plan, which includes development of environmental flow management strategies. This Water Resource Plan is scheduled for completion in 2005.
Riparian vegetation	• Pine Rivers Shire's Vegetation Conservation Local Law and Vegetation Management Act • Pine Rivers Catchment Management Plan • Tinchi Tamba Wetlands Natural Area Management Plan • Restoration projects by community groups	• In 2002, stakeholders of the Partnership will begin to identify priority areas for riparian and stormwater management and set targets for on-ground works. This process will focus on implementing on-ground works to deal with this issue.
Extractive activities		• A review of the regulatory regime for extractive industry is currently under way. Future management actions to deal with extractive industry issues will be developed based on the outcomes of this review.
Land clearing	• Pine Rivers Catchment Management Strategy developed by the Pine Rivers Catchment Association • South East Queensland Water Corporation has prepared the initial stage of a Water Quality Strategy Plan for Lake Samsonvale, and developed a 'Manual of Development Guidelines for Water Quality Management'. • Lake Samsonvale Catchment Management Strategy • Draft Lake Kurwongbah Catchment Management Strategy	• Range of local programs and plans outlining management actions to deal with this issue.
Input of catchment sediments	• Voluntary Code of Practice by Queensland Farmers Federation • Pine Rivers Council developed stormwater quality management strategies consisting of individual catchment management plans which aim to manage, through the provision of stormwater management infrastructure and the revegetation of riparian zones, the impacts of projected land use change. Completed plans include: Four Mile Creek, Freshwater Creek, Saltwater Creek, One Mile Creek, Cabbage Tree Creek. • Urban Stormwater Quality Management Plan • Council has a design manual for new developments. • Building Stormwater Management Infrastructure	• An Environmental Management Support System allows predictions to be made in relation to changes to water quality as a result of different land use and development practices, enabling stakeholders to develop future actions to deal with this issue.



Conceptual model for North Pine Dam



Conceptual model for the Pine Rivers freshwater and estuarine sections

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Environmental Protection Agency

Hays Inlet leads into Bramble Bay.

Chapter 7

Upper Brisbane and Stanley Rivers Catchments

James Udy, Joanne Clapcott and Mark Kennard

Description of the waterways

The Upper Brisbane and Stanley Rivers catchments cover a total area of 7010 km^2 (Fig 7.1). Large areas of land in the foothills of the Great Dividing Range and the Conondale Range (47%) remain in a relatively natural state due to their steep topography and inclusion in national parks or state forests. The remainder of the catchments have been cleared, with 45% of the catchments devoted to cattle grazing, beef and dairy herds, and 1% used for intensive agriculture (Fig 7.3). The native vegetation consists of blue gum woodlands, ironbark open forests and softwood scrub. Remnant subtropical rainforest can also be found in protected valleys. The streams in the catchments are relatively unregulated before flowing into the Somerset or Wivenhoe Dams.

Local government jurisdictions included in the Upper Brisbane and Stanley Rivers catchments are Kilcoy Shire, the northern section of Esk Shire and the western section of Caboolture Shire, and Rosalie, Crows Nest, Nanango and Kilkivan Shires. The Stanley River flows into Lake Somerset and then into the Upper Brisbane River, which flows into Lake Wivenhoe.

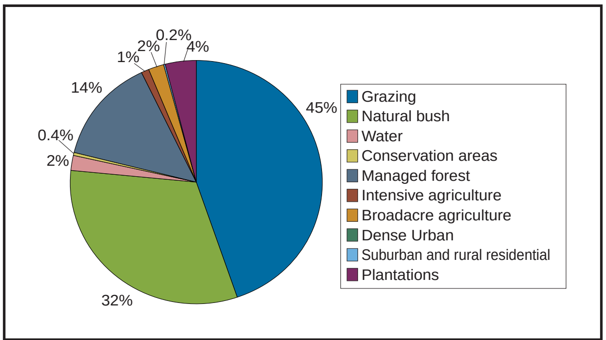


Figure 7.2: Land use in the Upper Brisbane and Stanley River catchments

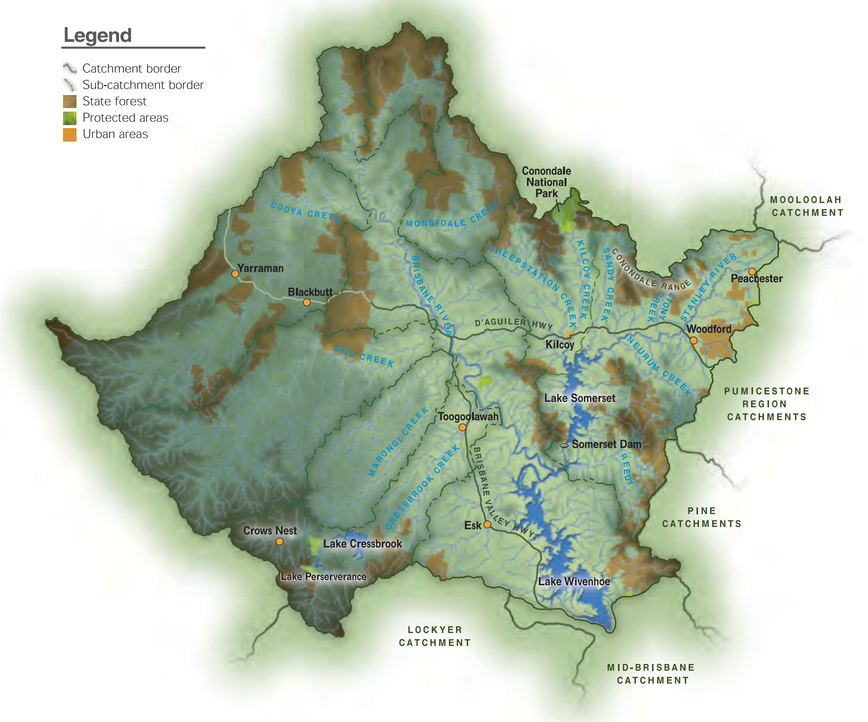
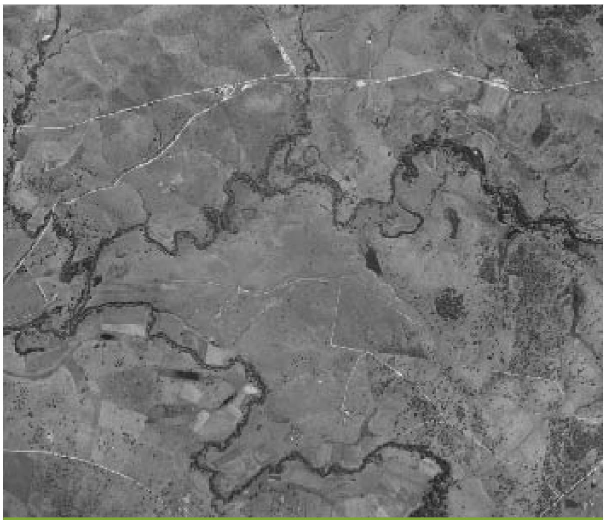


Figure 7.1: Map of Upper Brisbane River and Stanley River catchments



Historical (1958) photo of the Stanley River

Department of Natural Resources and Mines

Current (1997) photo of the Stanley River

Department of Natural Resources and Mines

State of the waterways

Water quality

Dissolved inorganic nutrient concentrations are relatively low and total nutrient concentrations are below ANZECC guidelines at most sites (Table 7.1).

Table 7.1: Ranges in water quality parameters taken from 13 sites in the Upper Brisbane and Stanley Rivers Catchments during dry weather (Sept. 2000)

Ammonium	0.14–1.4µM
Nitrate	0.35–7.8µM
Total nitrogen	7.8–33µM
Phosphate	0.06–0.51µM
Total phosphorus	0.32–3.2µM

In contrast, a site downstream of the Kilcoy STP had extremely high nutrient concentrations (Table 7.2).

Table 7.2: Water quality parameters for site downstream from Kilcoy STP (Sept. 2000)

Ammonium	234.3µM
Nitrate	85.2µM
Total nitrogen	362.1µM
Phosphate	48µM
Total phosphorus	64µM

These nutrient measurements suggest that in the absence of runoff from the catchment or point source inputs, catchment nutrient concentrations are relatively low. This is because nutrients entering the stream during periods of base flow are taken up and incorporated by aquatic plants or microbes. These results are also in agreement with AQUALM model predictions, suggesting that these streams receive most of their nutrients during rain events. While much of the nutrient input during high flow periods is likely to be transported downstream and deposited in the dams, some is expected to remain as nutrient reserves in the stream sediments, contributing to algal and macrophyte growth during periods of low flow.

Dissolved oxygen

Monitoring of DO concentrations over 24 hours reveals considerable variation in stream health throughout the catchments. Low minimum values and high variability in DO concentrations throughout the day in the Upper Brisbane River indicate high rates of oxygen production during the day and a high biological demand for oxygen at night, implying poor stream health. Low DO concentrations are likely to be a problem in summer when high stream temperatures reduce oxygen solubility and increase oxygen consumption. In contrast, many streams, particularly in the Stanley River catchment, exhibited relatively high DO concentrations and a small daily change, characteristic of healthy streams (Fig 7.3).

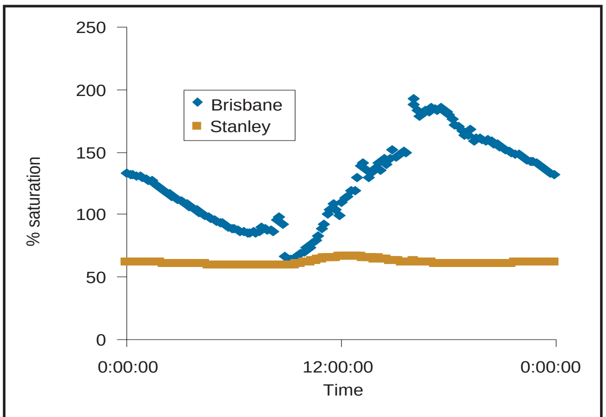
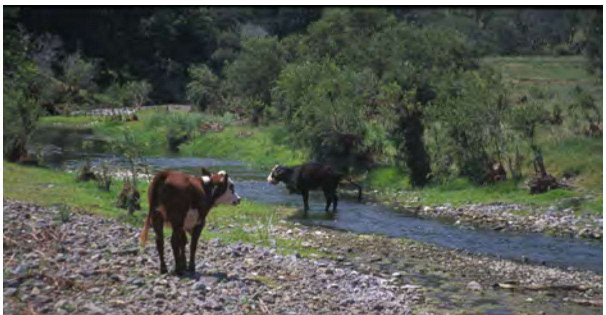


Figure 7.3: Changes in water dissolved oxygen typical of streams in the Upper Brisbane and Stanley Rivers catchment



Healthy Waterways Library

Cows have free access to the Upper Brisbane River and contribute faecal coliforms and increase erosion.

Temperature

A high diurnal variation in temperature was recorded in some streams of the Upper Brisbane River catchment (up to 7°C). This suggests that many of these streams do not have adequate shading and may reach temperatures in summer that are damaging to some animal species. Streams of the Stanley River catchment are considered healthier as the variation in diurnal temperature is lower (Fig 7.4).

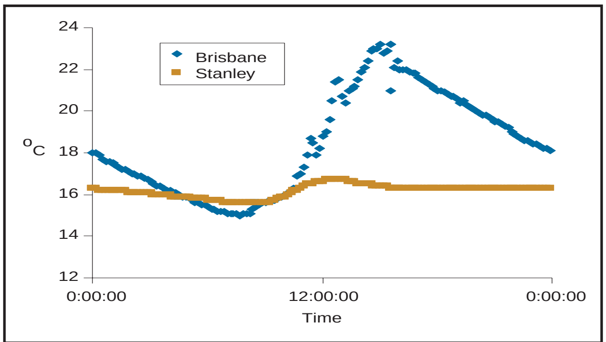


Figure 7.4: Changes in water temperature over 24 hours (sunny day) typical of streams of similar size in the Upper Brisbane and Stanley Rivers catchments (Sept. 2000)

Riparian zones

The riparian zones in the upper parts of the catchment are generally in good condition. In the lower catchment and on the floodplains the riparian zones have been extensively cleared. Riparian degradation is more pronounced in the Upper Brisbane catchment, little or no woody vegetation remaining on many of the stream banks. Thin stands of trees remain along the creeks in the eastern part of the catchment (Kilcoy, Stoney and Stanley Creeks) and provide valuable shade to creeks in this region.

In-stream processes

Gross primary production

Measurement of GPP in the catchment demonstrates that health of streams is highly variable. The mean value for GPP is above the maximum guideline value for lowland rivers and well in excess of the guideline value for upland streams, but large variation in GPP values is evident. Thirty-eight percent of the sites have very high values that are typical of degraded streams, 15% have values close to the maximum guideline value for lowland streams and 46% have low rates of GPP, indicative of healthy streams (Table 7.3).

Benthic respiration

Generally levels of benthic respiration (R_{24}) are above the maximum guideline value for healthy lowland and upland streams. In combination with the diurnal changes in stream DO levels, this suggests that many creeks in the Upper Brisbane and Stanley Rivers catchments have very large oxygen demands (Table 7.3).

Denitrification

Seventy percent of sites in the catchment have denitrification rates in the range expected for healthy streams (0.05–0.10mmolN/m^2/d) and 25% of sites have levels below the rates expected for a healthy stream, suggesting that removal of sediment nitrogen is not efficient at these sites. One site, downstream of the Kilcoy STP, has an elevated denitrification rate of 4.3mmolN/m^2/d, indicating an increased capacity for denitrification in response to higher levels of inputs. This is ultimately beneficial to the catchment, as it helps to remove the excess nitrogen that is contributed by sewage input (Table 7.3).

Table 7.3: Mean values of GPP, R_{24} and denitrification for the catchments compared with maximum ANZECC guideline values

Parameter	Mean	ANZECC guidelines Lowland rivers	Upland streams
GPP (mgC/m^2/d)	740	500	150
R_{24} (mgC/m^2/d)	600	400	100
Denitrification (mmolN/m^2/d)	0.2–4.3		

Fish community

At least 19 native fish species are expected to have occurred in the Upper Brisbane and Stanley Rivers prior to European settlement. Fifteen native species are present in the catchment, dominated numerically by hardyheads (*Craterocephalus* sp.) and firetailed gudgeons (*Hypseleotris galii*) and in biomass by eel-tailed catfish and longfinned eels. The southern purple-spotted gudgeon (*Mogurnda adspersa*) is present in the catchment and is of conservation significance due to declining population sizes throughout southern Australia. At least four exotic fish species (Gambusia, goldfish, tilapia and carp) are thought to occur, with *Gambusia holbrooki* making up 35% of the total fish collected during recent sampling (Table 7.4).

Available evidence suggests that the fish fauna of the Upper Brisbane and Stanley Rivers is in relatively poor condition, probably due to a combination of anthropogenic impacts. These include impacts associated with flow regulation and barriers to fish movement (dams and weirs), poor water quality, degraded in-stream habitat and riparian degradation due to agricultural activities in the catchment. Natural populations of at least three native migratory species (Australian bass, sea mullet and freshwater mullet) are no longer present in the catchment due to the dams.

Table 7.4: Freshwater fish species known or expected to occur in the Upper Brisbane and Stanley Rivers. Also shown is the relative abundance (total 6542 fish) and relative biomass (total 40.4kg) of each species collected during sampling at 21 sites in the catchment. Species expected to occur in the catchment but not collected are denoted by *. Species stocked in dams in the catchment are denoted by (S).

Species	Common name	% abundance	% biomass
Native species			
Craterocephalus stercusmuscarum fulvus	Flyspecked hardyhead	13.19	0.96
Craterocephalus marjoriae	Marjorie's hardyhead	11.83	1.43
Hypseleotris galii	Firetailed gudgeon	8.06	0.52
Retropinna semoni	Australian smelt	6.04	0.52
Ambassis agassizii	Agassiz's glassfish	5.11	0.86
Mogurnda adspersa	Southern purple-spotted gudgeon	4.49	1.82
Hypseleotris klunzingeri	Western carp gudgeon	4.46	0.27
Melanotaenia duboulayi	Duboulay's rainbowfish	3.87	0.92
Tandanus tandanus	Eel-tailed catfish	3.76	34.14
Pseodomugil signifer	Southern blue-eye	1.77	0.08
Phylipnodon spp.	Dwarf flathead gudgeon	1.33	0.09
Leiopotherapon unicolor	Spangled perch	0.52	5.13
Glossamia aprion	Mouth almighty	0.35	0.08
Anguilla reinhardtii	Longfinned eel	0.11	48.85
Phylipnodon grandiceps	Flathead gudgeon	0.11	0.03
Macquaria ambigua	Golden perch (S)	0.02	2.40
Macquaria novemaculeata	Australian bass (S)	*	
Mugil cephalus	Sea mullet	*	
Myxus petardi	Freshwater mullet	*	
Arius graeffei	Fork-tailed catfish	*	
Maccullochella peelii mariensis	Mary River cod (S)		
Bidyanus bidyanus	Silver perch (S)		
Scleropages leichardtii	Saratoga (S)		
Arrhamphus sclerolepis krefftii	Snub-nosed garfish (S)		
Exotic species			
Gambusia holbrooki	Eastern Gambusia	34.94	1.73
Carrasius auratus	Goldfish	0.05	0.16
Cyprinus carpio	European carp	*	
Oreochromis mossambicus	Tilapia	*	

Pressures on the waterways

Clearing

The main pressures on the Upper Brisbane and Stanley Rivers stem from the extensive clearing of land for cattle grazing. Clearing and settlement of this region began in the 1840s, the lower-lying land along the rivers being cleared first. Clearing of woody vegetation in the catchment continues; an average of 11.74 km^2, or 0.2% of the catchment, has been cleared every year since 1988. This has led to gully erosion, especially in sections of the Upper Brisbane catchment. The riparian vegetation along the lower sections of the creeks in the Upper Brisbane and Stanley catchments is either reduced to a thin strip of trees growing on the stream bank or non-existent. Although the few riparian trees provide valuable shade to reduce algal growth and extreme temperatures in summer, they often provide limited bank stability and trees are eventually undercut.

Since 1996: little change

Population pressures

The current population of the Upper Brisbane and Stanley Rivers catchments is estimated to be approximately 17 000, of whom only 38% live in the regional centres of Esk, Kilcoy and Woodford, which have STPs. There is considerable potential for continued population growth both in regional centres and on small rural allotments.

Since 1996: increased mainly due to hobby farming

Water flow regulation

There are several licensed storages in the catchments including Perseverance and Cressbrook Dams, numerous weirs (Kilcoy, Cressbrook, Pukallus and McCauley Weirs) and many other licensed small storages. Water flow regulation has had significant effects on natural drainage patterns in this catchment. There is limited irrigation in this catchment compared to the Lockyer catchment, with only 11km^2 or 0.1%, of the catchment area having irrigation licences. Hence, the impact of irrigation on the hydrology of the catchments is minimal.

Since 1996: relatively unchanged

Responses to the pressures on the waterways

Issues	Local initiatives	Responses
Clearing	• Brisbane Valley-Kilcoy Landcare projects **Upper Brisbane** • North East Downs Landcare Group prepared the Brisbane River Upper Emu Creek Strategy. • Upper Brisbane Catchment Network • Crows Nest Creek Catchment • Rosalie North Landcare **Stanley** • Caboolture Region Integrated Catchment Management • Caboolture Shire Council—Catchment Management Officer • Catchment Coordinator appointed • Caloundra City Council projects • Caboolture Shire Councils 'Adopt a Waterway' • Bushcare's Land for Wildlife Program • Voluntary Code of Practice by Queensland Farmers Federation	• In 2002, stakeholders of the Partnership will begin to identify priority areas for riparian and stormwater management and set targets for on-ground works. This process will focus on implementing on-ground works to deal with this issue. • An Environmental Management Support System allows predictions to be made in relation to changes to water quality as a result of different land use and development practices, enabling stakeholders to develop future actions to deal with this issue
Population pressures	**Upper Brisbane** • Projects by catchment and Landcare groups • Esk, Crows Nest and Kilcoy Councils have responsibility to develop urban stormwater management plans. **Stanley** • Caboolture Shire Council has begun an Urban Stormwater Quality Management Plan. • Caloundra City Council's draft Urban Stormwater Management Strategy • Development of local government planning schemes under the Integrated Planning Act • SEQ Natural Resource Management Strategy • CRICM's *Downstream* newsletter • Rivers and the Range Schools Project • Caboolture Council's 'Adopt a Waterway School Education Program Manual' and 'Caring for Shire Creeks' booklet • Caboolture Region Environment Education Centre • Catchment Wise Officer	• The SEQ Regional Framework for Growth Management is the basis for planning for the projected increases in the regional population. All member organisations are using the framework to guide sustainable growth in the region through a range of implementation mechanisms including planning schemes, corporate plans and a range of service delivery programs. • Range of local programs and plans outlining management actions to deal with this issue
Water flow regulation		• Many of these issues will be dealt with during the development of the Moreton Region Water Resource Plan, which includes the development of environmental flow management strategies. This Water Resource Plan is scheduled for completion in 2005.

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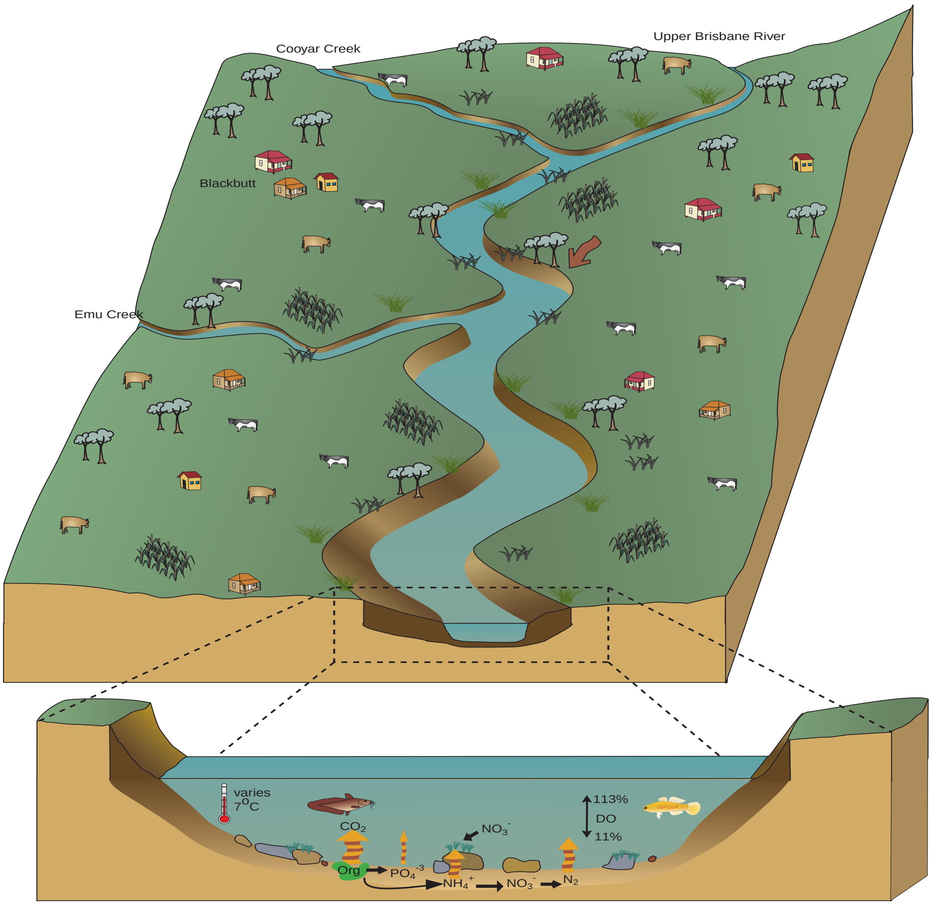
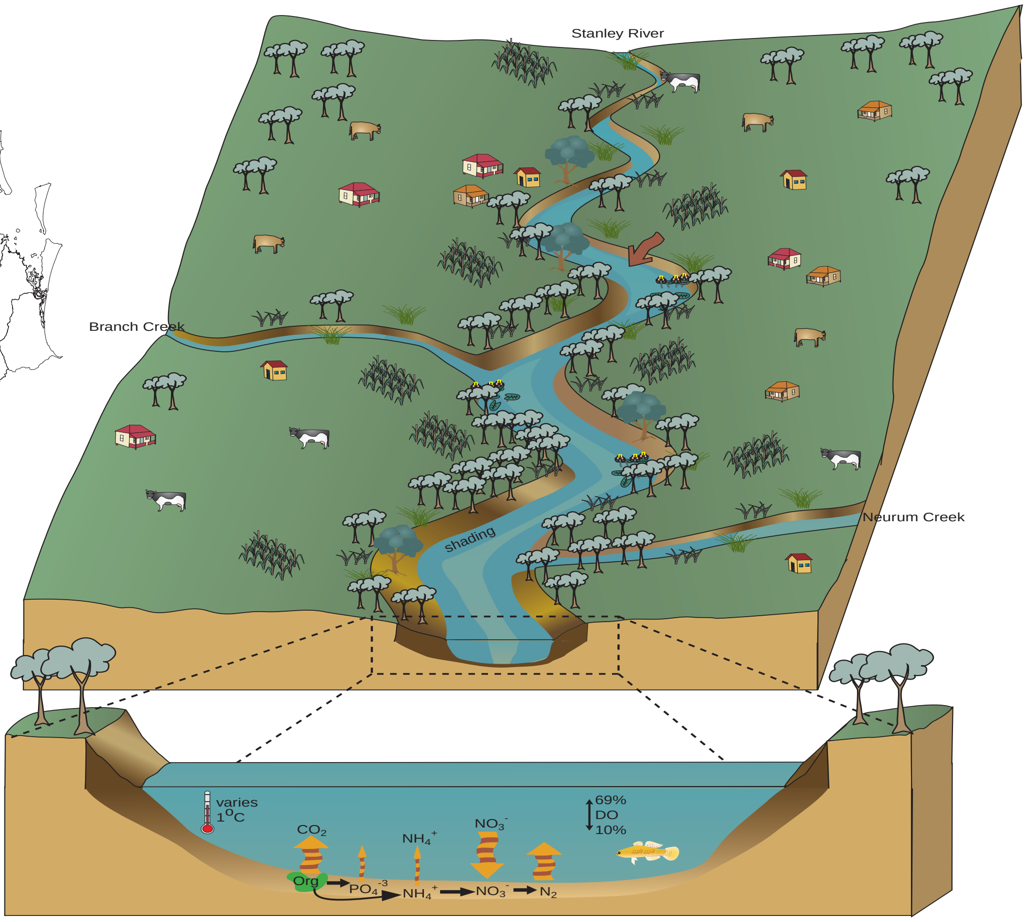


Conceptual model for the Upper Brisbane River



Conceptual model for the Stanley River

Chapter 8

Wivenhoe/Somerset Dams

Thorsten Mosisch

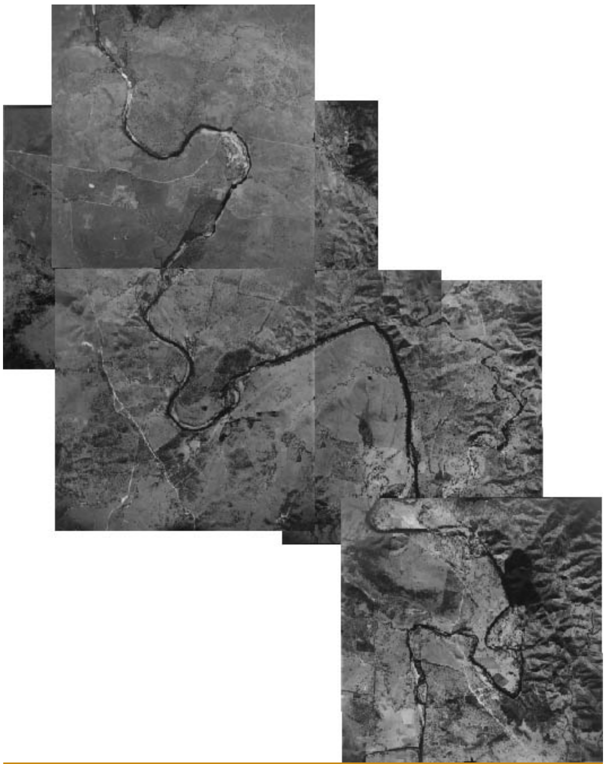
Description of the waterways

Wivenhoe Dam

Wivenhoe Dam, the largest water storage in south-east Queensland, is located in Esk Shire on the Brisbane River, approximately 150km upstream from the river mouth. The total catchment area of Lake Wivenhoe is 5730km^2, most of which drains the Upper Brisbane River catchment. Major streams feeding into the Upper Brisbane River are Cooyar, Emu and Cressbrook Creeks. Other major creeks flowing directly into Lake Wivenhoe include Esk Creek, Sandy Creek and Reedy Creek. Ten small townships are located within the Wivenhoe Dam catchment (see Chapter 7 for map of Wivenhoe Dam area).

Construction of the dam began in 1978. The dam started to store water in 1983, and was completed in 1985. As a result of the dam's construction, approximately 50–60km of river (lotic) habitat has been replaced with lake (lentic) habitat, leading to major changes in ecosystem processes. At full supply level, Lake Wivenhoe has a storage capacity of 1 165 000ML, and inundates an area of 107km^2. At that level, the lake is approximately 60km long, with a total shoreline of 590km.

While the primary function of Wivenhoe Dam is to provide a safe supply of raw drinking water to Brisbane and adjacent local authorities, it also plays an important role in flood mitigation. Consequently, it has been designed to hold an additional 1 450 000ML above its full supply level for the temporary storage of flood waters. Lake Wivenhoe also acts as the lower storage for a 500-megawatt pumped-storage hydro-electricity generating facility (Splityard Creek Dam) that is located near the southern end of the lake. A small hydro-electricity generating plant of approximately 4 megawatts output is currently under construction in the Wivenhoe Dam wall. In addition, Lake Wivenhoe represents an important regional recreational and tourist resource, with several well-established camping and recreational reserves situated at locations around its shoreline.



Department of Natural Resources and Mines

Historical (1949) photo of the Brisbane River before construction of the Wivenhoe Dam

Department of Natural Resources and Mines

Current (1997) photo of Wivenhoe Dam

Somerset Dam

Somerset Dam is located in the Esk and Kilcoy Shires on the Stanley River, at the upstream limit of Lake Wivenhoe. It is the second largest water storage in south-east Queensland. The total catchment area of Lake Somerset is 1340km^2, draining the Stanley River catchment. Approximately 31km of the Stanley River was changed from lotic to lentic habitat after construction of the dam. Apart from the Stanley River, major streams feeding into Lake Somerset are Kilcoy Creek, Sandy Creek, Sheepstation Creek, Oaky Creek, and Neurum Creek. Seven small townships are located within the Somerset Dam catchment (see Chapter 7 for map of Somerset Dam area).

Construction of the dam started in 1935, but was interrupted for six years during World War II and was finally completed in 1959. At full supply level, Lake Somerset has a storage capacity of 380 000ML, inundates an area of 42km^2, and has a total shoreline of 240km. The primary function of Somerset Dam is as a raw drinking water storage, with water releases supplementing Wivenhoe Dam, from which water is released to Mt Crosby Weir. Lake Somerset also plays an important role in flood mitigation. For this reason it has been designed to hold an additional 521 000ML above its full supply level for the temporary storage of flood waters. South East Queensland Water operates a small hydro-electricity generating plant installed in the wall of Somerset Dam. This facility generates 4 megawatts of renewable ('green') power which is fed into the main electricity distribution grid, and plays an important role in supplementing electricity during peak demand in the Kilcoy area. Lake Somerset represents an important regional recreational and tourist resource, having several well-established camping and recreational reserves, and is a major power boating and water skiing location.

Catchment land use

Although natural bush still occupies sizable areas of the catchments of Lakes Wivenhoe and Somerset (32% in both cases), there has been a major shift towards pastoral land use since European settlement. Forty-one percent of the Wivenhoe Dam catchment and 38% of the Somerset Dam catchment are used for pasture/grazing. Plantations, urban and rural settlements, and the reservoirs themselves occupy the remaining catchment area (Fig 8.1).

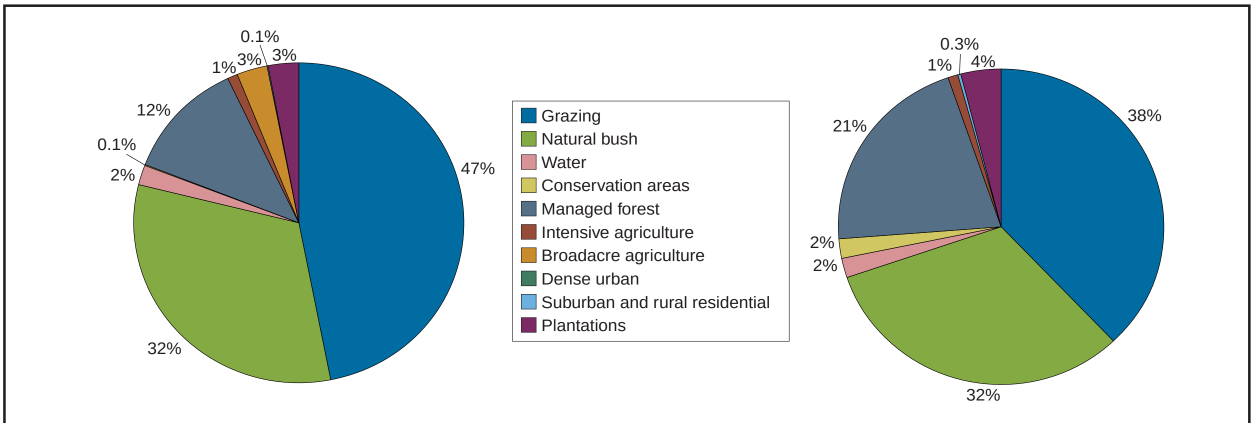


Figure 8.1: Land use in the Wivenhoe Dam (left) and Somerset Dam (right) catchments

South East Queensland Water Corporation

South East Queensland Water owns Wivenhoe, Somerset and North Pine Dams, and is the major supplier of untreated bulk water to local governments in the south-east Queensland region. It is owned by the Queensland Government (20%), Brisbane City Council (45%) and eleven other local governments in south-east Queensland (35%).

State of the waterways

Littoral zone

The water levels in both lakes tend to fluctuate due to regular water releases as part of dam operations, and releases are likely to increase in the future. The variability of water levels may have an effect on littoral habitats, effectively preventing the establishment of a productive littoral zone.

Biota

Fish

Recreational fishing is permitted on both Lake Wivenhoe and Lake Somerset. Australian bass (*Macquaria novemaculeata*) has been stocked in Lake Wivenhoe from the Brisbane River catchment, while golden perch (*Macquaria ambigua*), silver perch (*Bidyanus bidyanus*), saratoga (*Scleropages leichardtii*), and Mary

River cod (*Maccullochella peelii mariensis*) have been translocated from other catchments. Fish are unable to migrate between the Upper Brisbane River and Lake Wivenhoe to Lake Somerset, or between Lake Wivenhoe and the Mid Brisbane River (Table 8.1).

Table 8.1: Fish species present in both dams

Snub-nosed garfish	*Arrhamphus sclerolepis*
Flyspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*
Firetailed gudgeon	*Hypseleotris galii*
Spangled perch	*Leiopotherapon unicolor*
Australian bass	*Macquaria novemaculeata*
Bony bream	*Nematalosa erebi*
Tilapia	*Oreochromis mossambicus*
Flathead gudgeon	*Philypnodon grandiceps*
Australian smelt	*Retropinna semoni*
Lake Wivenhoe only	
Agassiz's glassfish	*Ambassis agassizii*
Fork-tailed catfish	*Arius graeffei*
Mosquitofish	*Gambusia holbrooki*
Mouth almighty	*Glossamia aprion*
Lungfish	*Neoceratodus forsteri*
Glencoe tandan	*Neosilurus hyrtlii*
Eel-tailed catfish	*Tandanus tandanus*
Lake Somerset only	
Barred grunter	*Amniataba percoides*
Golden perch	*Macquaria ambigua*
Mary River cod	*Maccullochella peelii mariensis*

The presence of one exotic fish species, Tilapia (*Oreochromis mossambicus*), has been documented and it is likely to spread. Overall, there is limited information available on the distribution of exotic and native fishes in the lakes. Some of the freshwater exotic fish species present in the Upper Brisbane River may also occur in Lakes Wivenhoe and Somerset.

Aquatic weeds

Major aquatic weed species present in Lake Wivenhoe and Lake Somerset are salvinia (*Salvinia molesta*), water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*). All three species are extremely fast growing, spread easily by fragmentation, and are capable of covering large areas of water in a relatively short time under favourable conditions. Major infestations of aquatic weeds have been known to lower water quality, and have an effect on dam operations.

Mat of *Salvinia molesta* and *Pistia stratiotes* in Lake Wivenhoe

South East Queensland Water Corporation

Another aquatic weed species, *Egeria densa*, forms distinct bands throughout much of the littoral zone of Lake Wivenhoe, causing a major nuisance to recreational users. *E. densa* also provides habitat for aquatic snails, some of which have been shown to be an intermediate host for the larval stage of certain schistosomes. These free-swimming larvae (cercariae) are known to cause 'swimmers itch' in sensitised people.

Algae

Algal blooms, particularly of cyanobacteria, can cause major problems to the water quality in the dams, especially when inflow to the reservoir is low, at high ambient temperatures and when the lake stratifies. Both Lakes Somerset and Wivenhoe typically stratify in summer with a resulting increase in numbers of cyanobacteria, in particular the species *Cylindrospermopsis raciborskii*. Increased growth of bloom-forming algae may also be associated with high rainfall events when, in conjunction with suitable environmental conditions, nutrients are carried into the storages from the catchments. Some bloom-forming species of cyanobacteria have the ability to produce toxins which can have a harmful effect on consumers, and have the potential to be skin irritants. Cyanobacterial blooms can also cause deoxygenation of the water, be the cause of taste and odour problems, and affect aesthetics of water bodies through scum formation.

Cyanobacterial bloom at Silverton Creek, Wivenhoe Dam catchment

South East Queensland Water Corporation

Epiphytic algal communities in the lakes are not abundant, due to the absence of a substantial aquatic littoral zone as a result of fluctuating water levels. While most littoral macrophytes are able to withstand some periods of exposure, the epiphytic algae on these macrophytes are far more susceptible to desiccation. As a result, ecosystem processes in the littoral zone that contribute to the natural functioning of the lake are affected.

Birds

Both Lake Wivenhoe and Lake Somerset are major habitats for waterbirds such as cormorants and swans. No studies have been undertaken to determine numbers of bird colonies, nesting patterns, or the contribution of bird droppings to nutrient inputs into the lakes.

Biological monitoring program

In 1999, the South East Queensland Water Board (now South East Queensland Water Corporation) initiated a five-year biological monitoring program, designed to assess the health of a number of waterways flowing into each of its water storages. General water quality, aquatic macroinvertebrates and fish were used as key indicators of ecological health. To date, three sampling events have been carried out. Macroinvertebrate sampling sites at Lake Wivenhoe are located on Byron Creek, Esk Creek and the Upper Brisbane River, while three fish sampling sites are located in the upper, middle and lower reaches of the lake. Sampling sites at Lake Somerset are located on Kilcoy Creek, Neurum Creek, Sheep Station Creek and Sandy Creek, while two fish sampling sites are situated at the upper and lower reaches of the lake.

Results of the biological monitoring program so far have shown that:

- Water quality at the majority of riverine sites is within the ANZECC (1992) guidelines for the protection of aquatic ecosystems. However, elevated nutrient levels (TN and TP) were detected at the Esk Creek monitoring site, possibly as a result of discharges from the Esk STP and from urban/agricultural runoff (TP and TN values exceeded ANZECC guidelines on one sampling event). Elevated nutrient levels were also detected in Kilcoy Creek and Sheep Station Creek, most likely due to nutrient inputs from surrounding land use and, in the case of Sheepstation Creek, STP effluent.
- The health of Esk Creek declined during the three surveys from a 'clean water' category to a 'doubtful water quality, possible mild pollution' category, as indicated by SIGNAL scores. Neurum Creek and Sandy Creek recorded high SIGNAL scores for littoral and riffle habitats, achieving a 'good water quality' rating at the first survey. However, this rating decreased for both sites during the subsequent survey: Neurum Creek decreased to a 'doubtful water quality' category, while the Sandy Creek site was rated as being affected by 'possible mild pollution'.
- The Kilcoy Creek site had generally low macroinvertebrate species richness, with the SIGNAL scores indicating moderate pollution.
- Fifteen fish species were recorded at the site located in the middle reaches of Lake Wivenhoe; this was the highest number of species recorded at any of the survey sites (Table 8.2).
- Fish caught at the top end of Lake Wivenhoe recorded high tissue metal concentrations (mercury, chromium, copper, zinc, nickel, lead), which may indicate that heavy metals are present in the sediments in that area, possibly as a result of deposition of contaminated sediments from the Upper Brisbane River.

Table 8.2: Fish in SEQ Water's storages

The most abundant species in SEQWater's storages are:

- Bony bream (*Nematalosa erebi*)—17% of catch
- Snub-nosed garfish (*Arrhamphus scleroleps*)—16%
- Fork-tailed catfish (*Arius graeffei*)—12%
- Flyspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*)—12%
- Tilapia (*Oreochromis mossambicus*)—8% (most abundant introduced species)

Fish of recreational importance (35% of catch) in SEQWater's storages include:

- Golden perch (*Macquaria ambigua*)
- Silver perch (*Bidyanus bidyanus*)
- Australian bass (*Macquaria novemaculeata*)
- Fork-tailed catfish (*Arius graeffei*)
- Snub-nosed garfish (*Arrhampus sclerolepis*)
- Eel-tailed catfish (*Tandanus tandanus*)
- Spangled perch (*Leiopotherapon unicolor*)
- Mary River cod (*Macullochella peelii mariensis*)

Pressures on the waterways

A summary of pressures and stresses affecting the Wivenhoe and Somerset Dams catchment is contained in Table 8.3.

Table 8.3: Summary of the major pressures and stresses affecting water quality in Wivenhoe and Somerset Dams

- Erosion
- Increasing sediment loads
- Sewage inputs
- Unsewered areas
- Stormwater runoff
- Bacteria and parasitic contaminants
- Algal blooms
- Power boating activities (Somerset only)

Inappropriate management of:

- Industrial development
- Rural residential subdivisions
- Land clearing, including removal of riparian vegetation
- Cattle grazing and access to streams

Land clearing

Most vegetation in the riparian zones and the dam catchments has been either cleared or modified. Only very few remnant pockets of native forest remain around the lakes. The main impacts are land clearing for grazing, agriculture and rural residential subdivisions. Ash input into the water as a result of burning off grazing land around Lake Somerset may increase phosphate levels in the water.

Since 1996: increased

Recreational activities

The non-motorised recreational activities permitted on the lakes are thought to have only a minimal impact on aquatic habitat and water quality (e.g. increased levels of *E. coli* may occur at designated recreation areas). Both non-motorised and motorised recreational

activities are permitted on Lake Somerset. Motorised power boating activities on Lake Somerset may have physical and/or chemical impacts on the aquatic ecosystem (e.g. through inputs of PAHs from motor emissions into the sediments) and these impacts are likely to increase.
Since 1996: increased

Input of catchment sediments

The lakes are effective traps for sediments originating in the catchment as a result of erosion processes and surface runoff. Sediment accumulation from catchment sources affects water quality and aquatic habitats within the lakes, and may degrade benthic areas. The input of sediments is most likely to be an issue in the upper reaches of the lakes, particularly in the deeper parts along the old river channels. Also affecting water quality is direct input of sediments from in-stream erosion and surface runoff resulting from degraded riparian zones and cleared land surrounding the lakes.
Since 1996: increased

Water transfers and extraction

Releases from Somerset Dam are used to supplement Lake Wivenhoe and to operate the hydro-electricity plant in the dam wall. Fluctuations in Lake Wivenhoe are due to regular water releases for the supply of Mt Crosby Weir and seasonal water abstraction via the Tarong pipeline. Further extraction of water takes place at the Esk and Kilcoy offtakes, and at a number of licensed pumps for farm use and rural dwellings. The fluctuation in water levels in Lake Wivenhoe is likely to increase over time due to greater water demand from bulk water customers, resulting in increased releases from the dam.
Since 1996: increased

Groundwater recharge

As water levels drop because of water use or drought, groundwater seepage back into the lakes can carry with it pollutants, such as chemical residues from old cattle dips, nutrients from fertilisers and herbicide or pesticide residues.
Since 1996: insufficient data, likely to increase

Agriculture

Inappropriate land management practices in agricultural areas can lead to the contamination of inflowing streams with pesticides, herbicides and fertilisers, as well as erosion and sediment inputs into streams.
Since 1996: increased

Cattle access and grazing

Cattle have generally unrestricted access to streams flowing into both Lakes Wivenhoe and Somerset and to their shores, resulting in nutrient and sediment inputs into the lakes. There are also a number of dairies and feedlots in the catchments that can potentially contribute nutrient and sediment inputs to streams feeding into the lakes.
Since 1996: increased

South East Queensland Water Corporation

Evidence of land clearing around Lake Wivenhoe

Dumps

There are several dumps/landfill sites throughout the Wivenhoe and Somerset catchments. Subsurface leaching and runoff during prolonged rainfall events can potentially lead to contaminants entering streams that feed into the lakes.
Since 1996: number of dumps stable, but existing dump expanded

Rural residential development

Numerous areas in the catchments of Lakes Wivenhoe and Somerset are being subdivided for rural residential development. The majority of these areas are not sewered, and wastewater is treated using septic systems. These areas are a potential source of elevated nutrients, particularly nitrate, since wastewater from septic systems can seep into the groundwater. Land clearing for residential development has the potential to increase stormwater runoff and soil erosion into streams feeding into the lakes.
Since 1996: increased

South East Queensland Water Corporation

Rural residential development in the Somerset catchment

Extractive industries

There are approximately two locations for sand and gravel extractive industries in streams feeding into Lake Wivenhoe and six in the Lake Somerset catchment, with the potential to increase sediment loads into the lakes.
Since 1996: increased

Sewage treatment plants

There are five significant STPs located within the Lake Wivenhoe catchment and four within the Lake Somerset catchment; some discharge treated effluent into streams, while others use land irrigation to dispose of wastewater.

Since 1996: septics systems increased, STPs stable

Abattoir

A major abattoir is located near Kilcoy. Abattoirs can be point sources of nutrient-rich discharges into waterways.

Since 1996: existing abattoir expanded

SEQ Water's projects for its three storages

- Completed a pollutant load export model for Wivenhoe
- Currently initiating projects assessing quantitative pollutant loads in its storages
- Undertaking sediment investigations in storages, looking at the sources and impacts of sediments on water quality
- Conducted a risk assessment workshop to scope storage water quality and human health issues for its three storages at the end of April 2001
- The SEQWater Water Quality Strategy released in May 2001.
- Assisting with catchment development strategies
- Providing town planning advice to local councils, and finalising guidelines to assist development application assessment
- Produces a newsletter ('*Water Quality Focus*')
- Expanded stream flow event monitoring
- Major research project on human health epidemiology of recreational exposure to cyanobacteria (NRCET), with more than 850 people surveyed to date
- Study into the impacts of cattle access to stream banks and aquatic management
- Development of Guidelines for Water Quality Management Manual
- Investigation into erosion hazard and pollutant exports

Water Quality Monitoring Program

South-East Queensland Water has in place a comprehensive water quality monitoring program for Lake Wivenhoe and Lake Somerset, including a number of sites downstream from the Wivenhoe Dam wall located in the Brisbane River and Lockyer Creek. There are also sites downstream from the Somerset Dam wall located in the Stanley River. The regular water quality sampling schedule consists of sampling on a monthly basis at 11 sites for Wivenhoe and 8 sites for Somerset, with additional sampling taking place fortnightly, including enumeration of algal numbers, testing for nutrient levels, general water quality, and the presence or otherwise of parasites and bacteriological contaminants.

Environmental Protection Agency

Wivenhoe Dam wall

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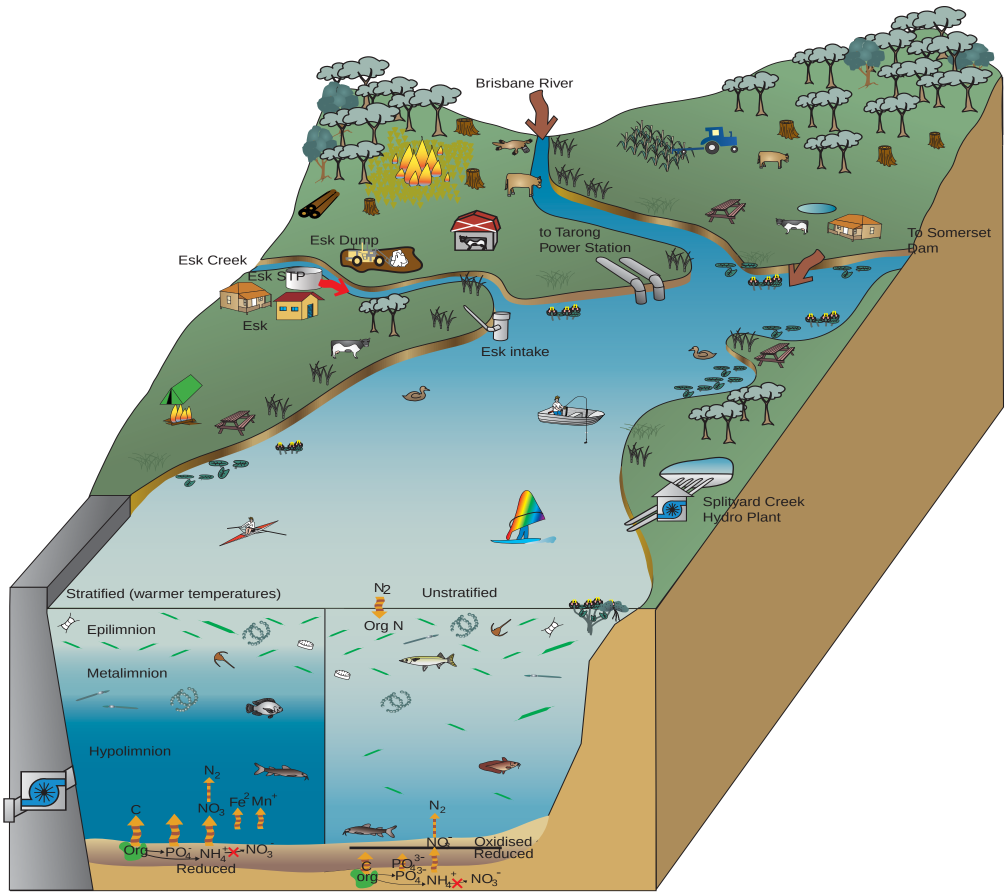
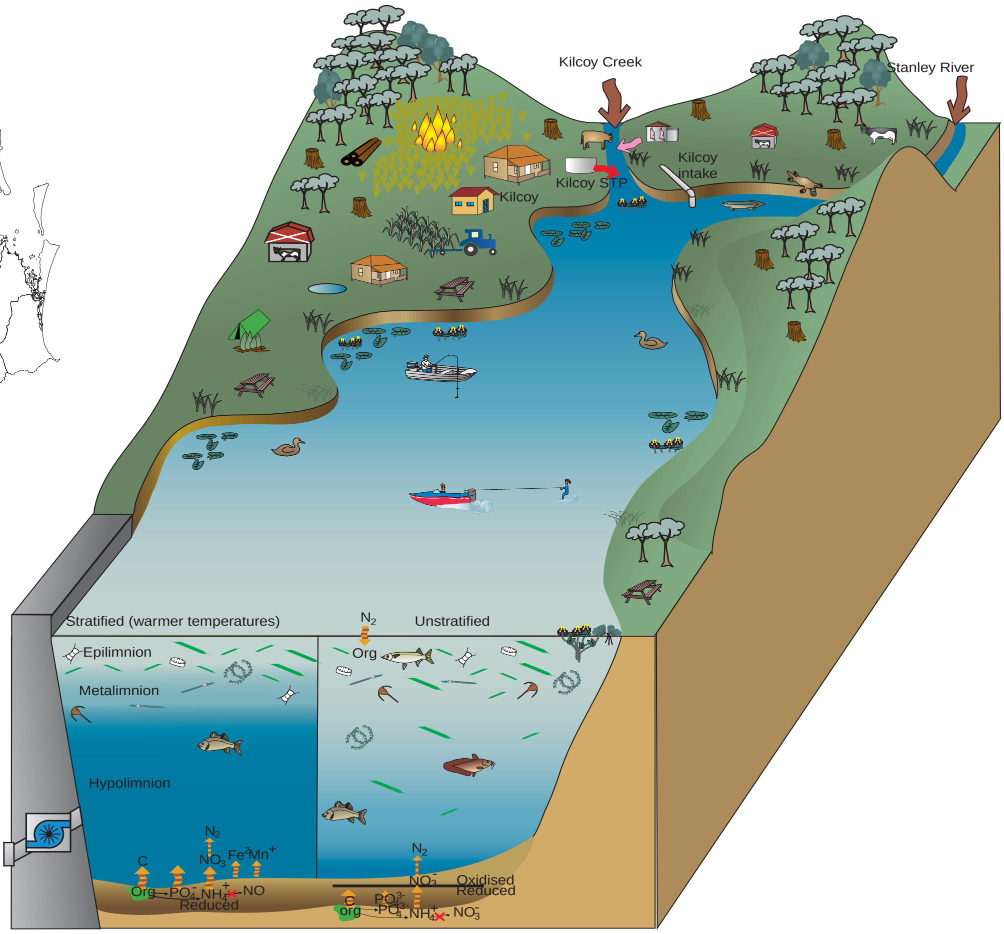
Responses to the pressures on the waterways

Issues	Local initiatives	Responses
Land clearing	• Brisbane Valley-Kilcoy Landcare projects **Wivenhoe** • North East Downs Landcare Group prepared the Brisbane River Upper Emu Creek Strategy. • Toowoomba Council developing a Water Quality Protection Strategy for Cressbrook and Perseverance Dams • Upper Brisbane Catchment Network **Somerset** • Caboolture Region Integrated Catchment Management • Caboolture Shire Council—Catchment Management Officer • Catchment Coordinator appointed	
Input of catchment sediments	**Wivenhoe** • Projects by catchment and Landcare groups • Esk, Crows Nest and Kilcoy Councils have responsibility to develop urban stormwater management plans. **Somerset** • Caboolture Shire Council has begun an Urban Stormwater Quality Management Plan. • Caloundra City Council's draft Urban Stormwater Management Strategy • Regional Framework for Growth Management • Integrated Planning Act • SEQ Natural Resource Management Strategy • CRICM's *Downstream* newsletter • Rivers and the Range Schools Project • Caboolture Council's 'Adopt a Waterway School Education Program Manual' and"'Caring for Shire Creeks' booklet • Caboolture Region Environment Education Centre • Catchment Wise Officer	• An Environmental Management Support System allows predictions to be made in relation to changes to water quality as a result of different land use and development practices, enabling stakeholders to develop future actions to deal with this issue.
Water transfers and extraction		• Many of these issues will be dealt with during the development of the Moreton Region Water Resource Plan, which includes development of environmental flow management strategies. This Water Resource Plan is scheduled for completion in 2005.
Agriculture	• Projects by Brisbane Valley-Kilcoy Landcare **Wivenhoe** • North East Downs Landcare • Crows Nest Creek Catchment • Rosalie North Landcare **Somerset** • Caboolture Region Integrated Catchment Management Group • Caloundra City Council projects • Caboolture Shire Councils 'Adopt a Waterway' • Bushcare's Land for Wildlife Program • Voluntary Code of Practice by Queensland Farmers Federation	• Environmental Planning Project is currently under way to develop a range of tools that can be used by local governments, rural property owners and industry organisations to minimise impacts on the region's catchments and waterways. It is anticipated that stakeholders will develop future management actions based on the outcomes of this project.
Cattle access and grazing		• It is anticipated that the Agriculture and Rural Industries component of the Environmental Planning Task will develop tools which will allow stakeholders to effectively deal with this issue
Rural residential development		• In 2002, an investigation into the magnitude of impacts from on-site sewage treatment facilities will commence. The results of this will enable stakeholders to develop future actions to deal with this issue.
Extractive industries		• A review of the regulatory regime for extractive industry is currently under way. Future management actions to deal with extractive industry issues will be developed based on the outcomes of this review.
Sewage treatment plants		• An agreed process for achieving sustainable nitrogen loads from major point sources i outlined in the SEQRWQMS. This process allows stakeholders the flexibility to determine the most efficient means for achieving sustainable loads



Conceptual model for Wivenhoe Dam



Conceptual model for Somerset Dam

Chapter 9

Lockyer Creek

James Udy, Joanne Clapcott and Mark Kennard

Description of the waterways

The Lockyer catchment covers 2954km^2 and encompasses the local government Shires of Laidley, Gatton, Crows Nest and Cambooya and the southern section of the Esk Shire and Ipswich and Toowoomba City Councils. The catchment has the largest proportion of land used for intensive agriculture of all the catchments in south-east Queensland. The native vegetation consists mostly of dry eucalypt, brigalow and softwood scrub forests (Fig 9.1). Clearing and settlement of this region began in the 1840s, and most of the productive floodplains of Lockyer Creek and its tributaries (Tenthill, Laidley, Ma Ma and Buaraba Creek) were cleared for agriculture before 1940. Currently the ridges in the upper catchment remain forested while the foothills are generally used for cattle grazing. The remaining area is predominantly used for intensive agriculture, the many crops including fodder, cereals, and vegetables (Fig 9.2). The Lockyer catchment also includes many water storage areas including farm dams, numerous weirs (23), and several large dams (e.g. Atkinson Dam).

Figure 9.1: Map of Lockyer Creek catchment

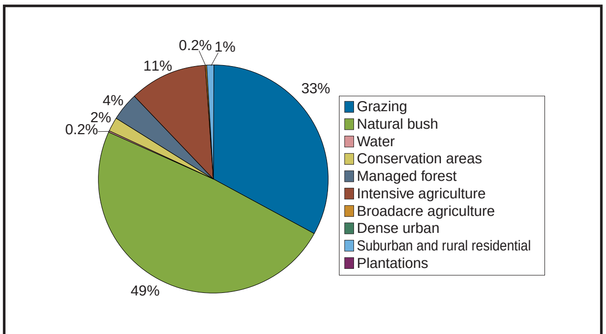


Figure 9.2: Land use in the Lockyer catchment

Historical (1949) photo of Lockyer Creek

Department of Natural Resources and Mines

Current (1997) photo of Lockyer Creek

Department of Natural Resources and Mines

State of the waterways

Water table levels

River systems in this catchment have been highly regulated and are extensively used for irrigation, both directly and indirectly through use of the groundwater. For most of the year the base flow of creeks in the Lockyer catchment is determined by irrigators' needs rather than natural processes of precipitation and water seepage from the water table into the creek. In fact, in many sections of the catchment, the creek is the highest point of the water table and there is a net loss of water from the creek into the groundwater (Fig 9.3).

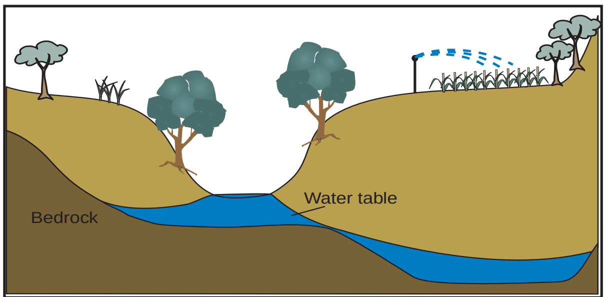


Figure 9.3: Diagram showing how the highest point of the water table is often the creek

Water quality

Nutrients

The Lockyer catchment has relatively low to moderate values for inorganic nitrogen and moderate to high total nitrogen values (Table 9.1).

Table 9.1: Water quality parameter ranges (Sept. 2000—low flow)

Ammonium	0.21–4.5µM
Nitrate	1.4–6.6µM
Total nitrogen	7.1–106.5µM
Phosphate	0.16–5.1µM
Total phosphorus	0.57–8.3µM

The low to moderate concentrations of inorganic nitrogen suggest that the nutrients entering the stream during periods of low flow are taken up and incorporated by aquatic plants and microbial processes within the stream. This is supported by the AQUALM model which estimates that most of the nutrients entering these streams are supplied during rain events and transported downstream. However, nutrient pools are predicted to remain in the sediment during periods of low flow and may support algal or macrophyte growth. The relatively high values for total nitrogen suggest that large amounts of nutrients are incorporated into organic nutrients or attached to suspended sediment particles.

Dissolved oxygen

Large temporal variation in dissolved oxygen (DO) concentrations at Lockyer sites is indicative of poor stream health. DO values vary from a minimum of 10% saturation to a maximum value of 182% saturation. This high variability in DO concentrations over 24 hours indicates high rates of oxygen production during the day and a high biological demand for oxygen at night (Fig 9.4). Totally anaerobic conditions are not in evidence, however, suggesting that the streams are still likely to support macroinvertebrate and fish communities. Low DO concentrations may be a problem in summer when high stream temperatures reduce oxygen solubility and increase oxygen consumption.

Temperature

Temperature variations over 24 hours fluctuate by 2–6°C in the same stream. Streams with diurnal temperature variation at the higher end of this range probably have inadequate shading, and may reach temperatures in summer that could negatively affect some animal species (Fig 9.4).

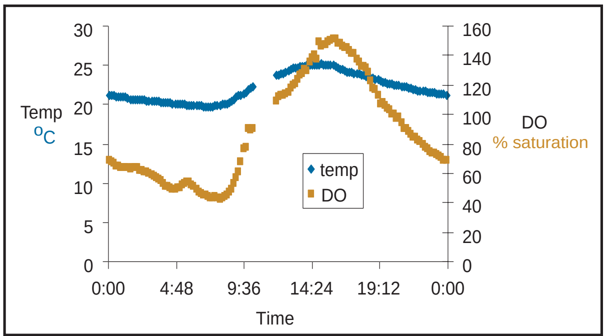


Figure 9.4: Changes in water DO and temperature typical of streams in the Lockyer catchment (Sept. 2000)

Riparian zones

The riparian zone in this catchment is generally narrow and in poor condition, with the riparian zones on the flood-plains having been cleared almost to the edge of the stream banks. The majority of the riparian zones (75%) are in poor or very poor condition, based on width and the number of weed species present. Despite its poor condition, the remaining riparian vegetation still provides valuable shade to creeks in some sections of the catchment, while some creeks in the very upper catchment generally have a riparian zone in good condition.

Salinity

Salinity levels in most streams are not yet high enough to be lethal to aquatic organisms. However, the extensive use of irrigation in this catchment with both groundwater and surface water has significantly altered the water table and resulted in salinity problems, especially in the low-lying sections of the catchment.

In-stream processes

Gross primary production

Values for GPP are relatively low compared to other areas in the south-east Queensland region. This places most sites between the maximum guideline value for upland streams and lowland rivers. Although these rates are still high compared to unimpacted streams, GPP may be restricted in streams of the Lockyer catchment due to light availability. Steep banks and the small amount of riparian vegetation in combination with high water turbidity combine to limit the light in these streams. In addition, rapid changes in water levels as weirs are opened and closed for irrigation and groundwater recharging restrict the establishment of benthic algae and rooted macrophytes. However, excessive algal growth is likely to be a problem at sites with a stable water level and a damaged riparian zone (Table 9.2).

Benthic respiration

Benthic respiration (R_{24}) in the catchment has a mean close to the maximum guideline value for lowland rivers. This suggests that although these streams have been impacted, only moderate oxygen consumption is occurring in the stream bed. The measured rates of oxygen production and consumption in combination with ambient changes in DO suggest that creeks in the Lockyer catchment have moderate to high rates of oxygen demand (Table 9.2).

Denitrification

Denitrification is not very efficient in this catchment as levels fall below rates expected for healthy streams. This is consistent with the other stream indicators that point to poor stream health (Table 9.2).

Table 9.2: Mean values of GPP, R_{24} and denitrification for the catchment compared with maximum recommended guideline values

Parameter	Mean	ANZECC guidelines lowland rivers	ANZECC guidelines upland streams
GPP (mgC/m^2/d)	400	500	150
R_{24} (mgC/m^2/d)	360	400	100
Denitrification (mmolN/m/d)	0.4–3.9		

Macroinvertebrates

AusRivAS and SIGNAL results indicate that most of the sites in the Lockyer catchment are in a moderate condition. Sites in the upper reaches have a few ‘good’ ratings amongst the ‘moderates’, and sites in the lower catchment a few ‘poor’ ratings.

Fish community

At least 17 native fish species are thought to have occurred in the Lockyer catchment prior to European settlement but currently only 11 native species are present. The most dominant native species in terms of abundance are Duboulay’s rainbowfish (*Melanotaenia duboulayi*) and firetailed gudgeons (*Hypseleotris galii*), while eel-tailed catfish (*Tandanus tandanus*) and longfinned eels (*Anguilla reinhardtii*) dominate the biomass. The southern purple-spotted gudgeon (*Mogurnda adspersa*) is also found in the catchment. Two exotic fish species, Gambusia (*Gambusia holbrooki*) and carp (*Cyprinus carpio*) are known to occur, with Gambusia making up 25% of the total catch (Table 9.3). As a result of human impacts, natural populations of six native species, including three migratory species–Australian bass (*Macquaria novemaculeata*), sea mullet (*Mugil cephalus*) and freshwater mullet (*Myxus petardi*)–may no longer be present in the catchment. Anthropogenic impacts contributing to the poor condition of the fish fauna of Lockyer Creek include impacts associated with flow regulation and barriers to fish movement, poor water quality, degraded in-stream habitat and riparian degradation due to agricultural activities.

Table 9.3: Freshwater fish species known or expected to occur in Lockyer Creek. Also shown is the relative abundance (total 1171 fish) and relative biomass (total 16.9kg) of each species collected during sampling at five sites in Lockyer Creek. Species expected to occur in the catchment but not collected are denoted by *. Species stocked in dams in the catchment are denoted by (S).

Native Species	Common name	% abundance	% biomass
Melanotaenia duboulayi	Duboulay’s rainbowfish	37.23	2.72
Hypseleotris galii	Firetailed gudgeon	11.87	0.52
Mogurnda adspersa	Southern purple-spotted gudgeon	6.92	1.74
Craterocephalus marjoriae	Marjorie’s hardyhead	6.75	0.33
Craterocephalus stercusmuscarum fulvus	Flyspecked hardyhead	4.18	0.22
Hypseleotris klunzingeri	Western carp gudgeon	1.71	0.08
Tandanus tandanus	Eel-tailed catfish	1.45	46.63
Ambassis agassizii	Agassiz’s glassfish	1.37	0.12
Leiopotherapon unicolor	Spangled perch	0.77	0.60
Anguilla reinhardtii	Longfinned eel	0.43	38.91
Phylipnodon spp.	Dwarf flathead gudgeon	0.34	0.02
Glossamia aprion	Mouth almighty	*	
Pseodomugil signifer	Southern blue-eye	*	
Retropinna semoni	Australian smelt	*	
Macquaria novemaculeata	Australian bass (S)	*	
Mugil cephalus	Sea mullet	*	
Myxus petardi	Freshwater mullet	*	
Macculochella peelii mariensis	Mary River cod (S)		
Macquaria ambigua	Golden perch (S)		
Bidyanus bidyanus	Silver perch (S)		
Scleropages leichardtii	Saratoga (S)		
Exotic species			
Gambusia holbrooki	Eastern Gambusia	25.70	0.64
Cyprinus carpio	European carp	1.28	7.48

Pressures on the waterways

Clearing and land use

The main pressures on Lockyer Creek and its tributaries relate to the extensive clearing of the catchment and associated agricultural land use. Clearing of forests to provide land for agriculture and the removal and degradation of the riparian vegetation have led to the instability of waterways. Extensive gully erosion and incision of the main channel has occurred, especially in the lower sections of the catchment.

Although most of the lower catchment was cleared before the 1940s, clearing of woody vegetation continues, an average of 5.81km^2 or 0.2% of the catchment having been cleared every year since 1988. This catchment, however, is degraded due to the land use practices (intensive agriculture and irrigation) rather than just the clearing of natural vegetation.
Since 1996: little change

Population pressures

The population of this catchment is currently increasing at a rapid rate, the majority of growth occurring on the outskirts of small towns as urban and rural residential developments. The population of the Lockyer catchment was estimated to be over 33 300 people in 2000, of whom 34% live in the regional centres of Gatton and Laidley, which have STPs. This represents a 20% increase from a population of 27 500 in 1991 and highlights the potential for continued population growth in regional centres and on small rural allotments.
Since 1996: increased, with rural residential and urban subdivisions

Water flow regulation

Current agricultural land uses have caused major changes to the hydrology and ecology of Lockyer Creek. Increases in crop irrigation and water extraction have resulted in the regulation of river flow, and changes to the groundwater dynamics. DNR-approved weirs within the Lockyer catchment have increased from 5 in 1940 to 23 in 1995, the majority having been added since the 1970s. This increase in river regulation has enabled an expansion in the amount of land that can be irrigated, approximately 154km^2 of land, or 5.2% of the catchment, being covered by DNR licenses to irrigate. However, as groundwater (from bores) can be used to irrigate in both the upper and lower Lockyer without a licence, the amount of land that is being actively irrigated is probably closer to 10% of the catchment.
Since 1996: water usage and irrigation increased

Healthy Waterways Library

Agricultural practices and irrigation have major effects on the Lockyer Creek catchment.

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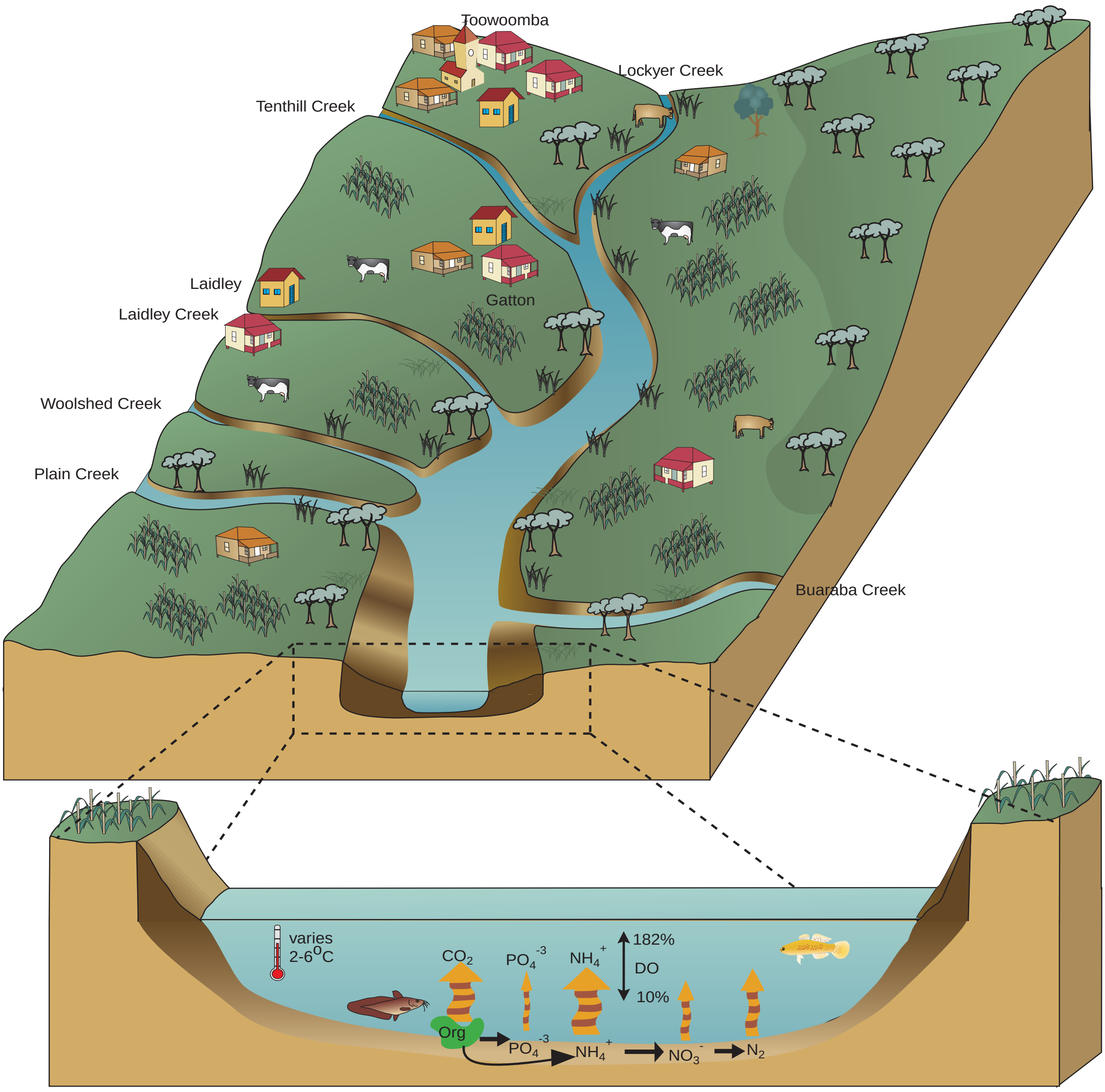
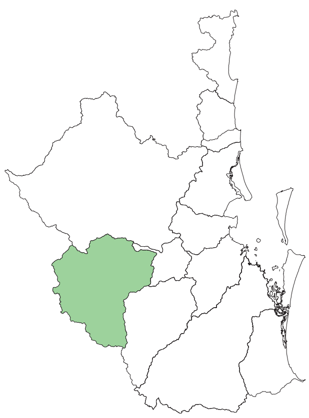
Responses to the pressures on the waterways

Issues	Local initiatives	Responses
Clearing and land use	• Lockyer Catchment Coordinating Committee—45 actions under way • Integrated Natural Resource Management Strategy	• In 2002, stakeholders of the Partnership will begin to identify priority areas for riparian and stormwater management and set targets for on-ground works. This process will focus on implementing on-ground works to deal with this issue. • Environmental Planning Project is currently under way to develop a range of tools that can be used by local governments, rural property owners and industry organisations to minimise impacts on the region's catchments and waterways. It is anticipated that stakeholders will develop future management actions based on the outcomes of this project.
Population pressures	• Flood Scoping Study • Proposal in the Catchment Management Plan for implementation of a floodplain management program • Gatton, Laidley and Esk Councils must develop urban stormwater management plans • Voluntary Code of Practice by Queensland Farmers Federation • QFVG has a Farmcare Code of Practice and is developing Environmental Management Systems to deal with waterway management. • Gatton Shire—strategic sewage plan • Irrigation system being prepared for Helidon STP • Laidley Council reuses local sewage effluent for irrigation of lucerne. • 'Recycled Water for Irrigation in the Lockyer Valley and on the Darling Downs'	• The SEQ Regional Framework for Growth Management is the basis for planning for the projected increases in the regional population. All member organisations are using the framework to guide sustainable growth in the region through a range of implementation mechanisms including planning schemes, corporate plans and a range of service delivery programs. • In 2002, an investigation into the magnitude of impacts from on-site sewage treatment facilities will commence. The results of this will enable stakeholders to develop future actions to deal with this issue.
Water flow regulation		• Many of these issues will be deal with during the development of the Moreton Region Water Resource Plan, which includes development of environmental flow management strategies. This Water Resource Plan is scheduled for completion in 2005.



Conceptual model for the Lockyer Creek catchment



Chapter 10

Bremer River

Eva Abal and Kate Moore

Description of the waterways

The Bremer River catchment (Fig 10.1), covering an area of 2032km^2, extends from the junction of the Brisbane River south-west to the Great Dividing Range and includes four sub-catchments (Western and Franklin Vale Creeks, Bundamba Creek, Purga Creek and Warrill Creek). Ipswich City Council covers half the catchment and Boonah Shire Council covers the southern half of the catchment. The population of Ipswich and the surrounding area was 150 000 in 2000 and is projected to reach 215 000 in 2011.

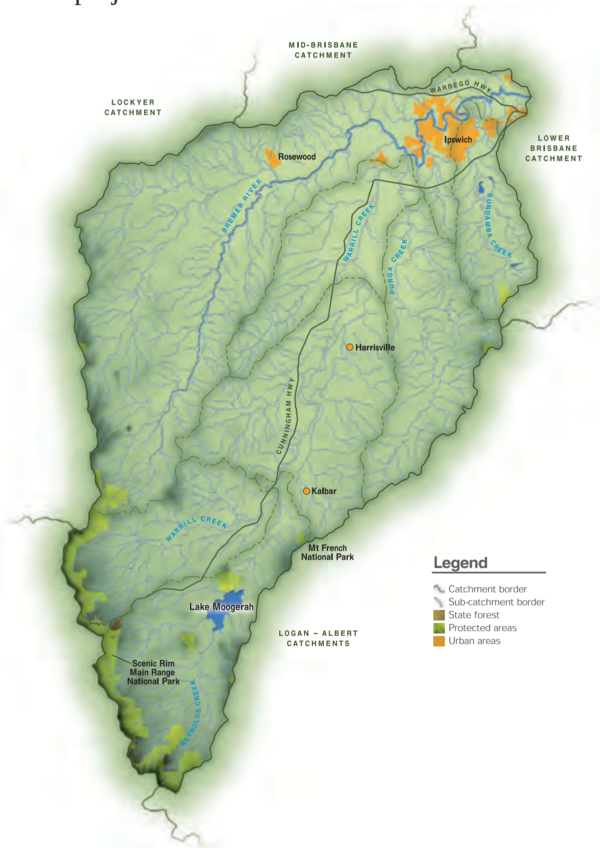


Figure 10.1: Map of the Bremer River catchment

The tidal limit of the Bremer River is approximately 19km from the Brisbane/Bremer junction at the Kingsmill Road Bridge in Ipswich. With a depth range of 2–-5m, tidal flushing dominates as the freshwater inflows are insignificant, resulting in a consistently well mixed river. Approximately 25% of the water in the Bremer estuary flows into the Brisbane River on ebb tide, with significant tidal exchange for 4km up the Bremer.

The present vegetation includes eucalypt open forests, acacia open forests, semi-evergreen vine forest and thickets, croplands and grasslands. The lower catchment is considered mostly urbanised, while the rest of the catchment is rural (Fig 10.2).

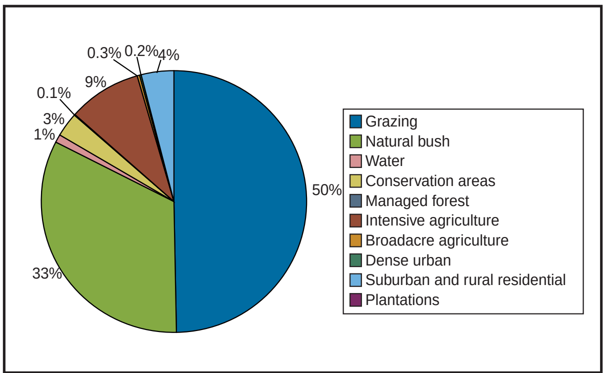


Figure 10.2: Land use in the Bremer River catchment

Historical vegetation included extensive hoop pine forests (*Araucaria cunninghamii*), expansive blue gum forests (*Eucalyptus tereticornis*), dense scrub and brigalow. The riparian areas were dominated by crows ash (*Flindersia australis*), red cedar (*Toona australis*), black bean (*Castanopermum australe*), with tea tree (*Melaleuca irbyana*) in swamp areas. The area was first settled in 1840 and extensive tree clearing was carried out for sheep and cattle grazing. Erosion processes and turbidity were first recorded in the Bremer River in the 1850s. Agriculture was introduced to the area in 1870. Extensive clearing of shoals, rocks, debris and shallows and dredging all affected the tidal influence of the river. In the mid 20th century, dams and weirs were constructed, which modified the flow of the river. (Table 10.1).

Table 10.1: Weirs and dams in the main tributaries of the Bremer River

Storage purpose	Stream	Upstream (km)	Storage capacity	Major
Lake Moogerah	Reynolds Creek	15.3	92 500ML	
Kent's Lagoon Weir	Reynolds Creek	1.2		Diversion weir
Upper Warrill Weir	Reynolds Creek	12.9		Diversion weir
Aratula Weir	Warrill Creek	60.0	54ML	Diversion weir
Warroolaba Creek Weir	Warrill Creek	35.0		
West Warrill Creek Weir	Warrill Creek	28.5		Diversion weir
Churchbank Weir	Warrill Creek	3.2	176ML	
Junction Weir	Warrill/Reynolds Creek			
Berrys Lagoon	Bremer River/Warrill Creek			

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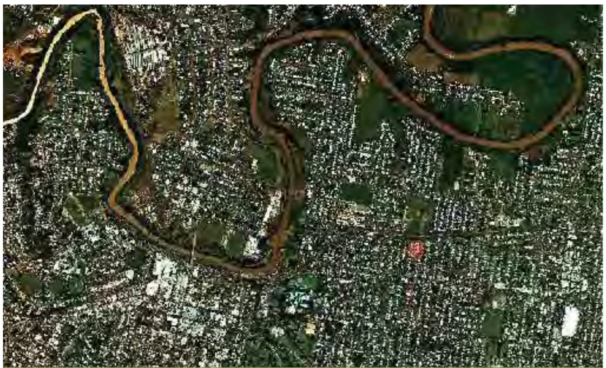
Historical (1944) photo of the Bremer River through Ipswich



Department of Natural Resources and Mines

Current (1997) photo of the Bremer River through Ipswich

State of the waterways

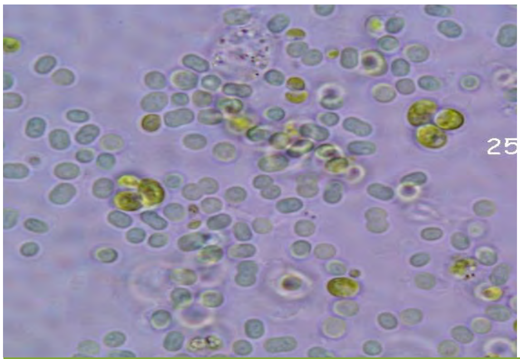
The Bremer River is a degraded system, characterised by high nutrient loads and turbidity, high phytoplankton biomass, light-limited phytoplankton and abundant bacteria especially along the estuarine reaches. The riparian vegetation in lower reaches has been mostly cleared and the river banks are predominantly weed-infested. Stormwater and sewage inputs predominate in the urban areas around Ipswich. In the lower reaches, there is a diversity of nutrient and sediment sources, including run-off from farming activities, sewage discharge and industries. A long residence time of 190 days (the highest in the Moreton Bay region) means there is little flushing of the system to remove nutrients and pollutants.

Healthy Waterways Library

The Bremer River is a highly degraded river system.

Heterotrophic system

The Bremer River is considered a heterotrophic system. It has a high carbon source that is external to the river and not derived from primary production. The source of the carbon, which supports a large population of heterotrophic bacteria, is currently unknown, but may be from licensed discharges, unlicensed discharges, and/or catchment sources. It is not fully understood yet why bacteria dominate rather than phytoplankton in the nutrient-rich environment.



Healthy Waterways Library

Heterotrophic bacteria dominate in the Bremer River.

Water quality parameters

The water quality in the Bremer River is poor. The total phosphorus, nitrogen and *E. coli* levels exceed guidelines set by ANZECC. Nutrient concentrations are highest in the tidal areas, and turbidity results in secchi depths of less than 0.5m. Sediment loads from stormwater and agricultural runoff total 205 554t/yr. There is also evidence of salinity outbreaks in Purga and Warrill Creeks (Table 10.2). Long-term trends, seasonality and cyclicity in monthly water quality data series recorded from nine sampling stations in the Bremer River between 1993 and 1999 by the Queensland EPA indicated apparent long-term decline in dissolved oxygen and rapid increase in turbidity from mid-1996 onwards, and increasing chlorophyll *a* until 1997, when the latter levelled out presumably as turbidity increased significantly (Fig 10.3).

Table 10.2: Summary of water quality parameters (various sources)

Temperature—air	19.7°C
Temperature—water	18.7°C
pH	7.54
Average salinity	1022µS/cm
Purga Creek salinity	3880µS/cm
Suspended solids	66–110mg/L
Secchi depth	30–60cm
Average turbidity	11NTU
Chlorophyll *a*	Highest in Moreton Bay
Dissolved oxygen	30-60% (wet-dry periods)
Primary productivity	<20mg C $m^{-3}h^{-1}$
Nitrogenous compounds	>20µM
Phosphorus	>55µM
Silica	1–100mg/L
Nitrate	Average—4.7µM
Areas exceeding	7.1µM
Phosphate	30µM
BOD	1–2mg/L

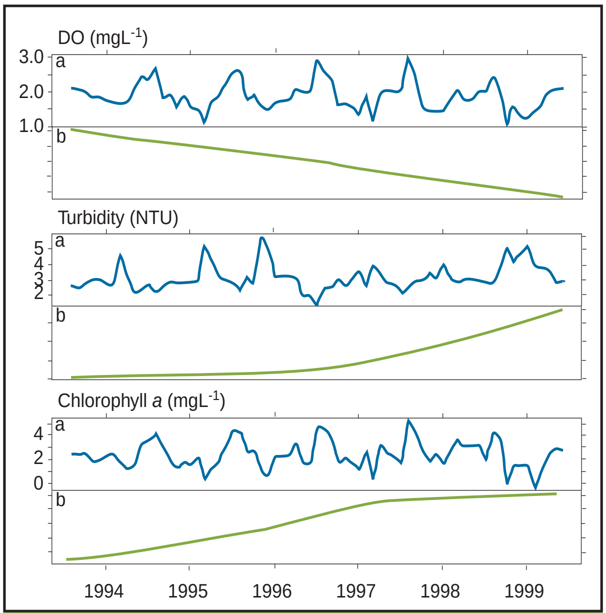


Figure 10.3: Dissolved oxygen, turbidity and chlorophyll *a* levels at 15km upstream in the Bremer River from 1993 to 1999. The top panel in each is the recorded data and the bottom panel is the relative trend recorded (Stratton et al., 2001).

Dissolved oxygen

Dissolved oxygen levels in estuarine sites on the Bremer are 10% lower than in other unimpacted estuarine sites and may be due to low primary productivity and/or high heterotrophic activity. There has been a long-term decline in DO levels during the 1990s. There is a significant sag in DO levels in the lower reaches due to known point source discharges, and a sag in the upper reaches due to the effects from known discharges and the residual flow.

Turbidity

The catchment is also characterised by high concentrations of suspended solids with low light penetration. Rainfall, tidal change, water release from storage facilities and land use practices combine to give high turbidity levels. They are highest in the downstream reaches and in the wet summer season, when catchment sediment input is highest.

Chlorophyll a

Chlorophyll *a* levels are higher in the Bremer River than in all other catchments in the Moreton Bay region, with occasional large blooms. Chlorophyll *a* is inversely related to turbidity levels in that it is lowest in the lower estuary and in the summer wet season due to light limitation.

Salinity

Some areas of the catchment have unacceptable salinity levels for a freshwater system (>1500µS/cm); such an area is Purga Creek, where salinity of 3880µS/cm may affect agricultural activities by reducing crop choice.

Flow regulation

For most of the year the Bremer River is dominated by tidal inflows. It is only in very wet conditions that there is significant freshwater flow. These events have a large impact on the system and flush out the system many times over. Warrill Creek flow is regulated from Reynolds Creek downstream and impacts on the system.

Nutrients and productivity

There are high levels of both inorganic and organic nutrients, with many external sources of nutrients and little net nutrient removal from the system. Levels are highest in winter/spring dry weather due to reduced biological demand and flow rates relative to point source discharges. The Bremer River estuary system is net heterotrophic; that is, respiration exceeds primary production. Dissolved organic carbon is the main fraction of the total pool of organic carbon in the Bremer; only less than 10% of the organic carbon is particulate (Fig 10.4). Studies on the Bremer River have demonstrated that the river has low primary production; primary production is restricted to a shallow euphotic zone of 0.75m. There is insufficient carbon from the sediments, groundwater, EPA-licensed point sources and primary productivity to support this high heterotrophic bacterial production. Other possible sources of carbon such as catchment runoff, stormwater flows and land disposal inputs need further investigation.

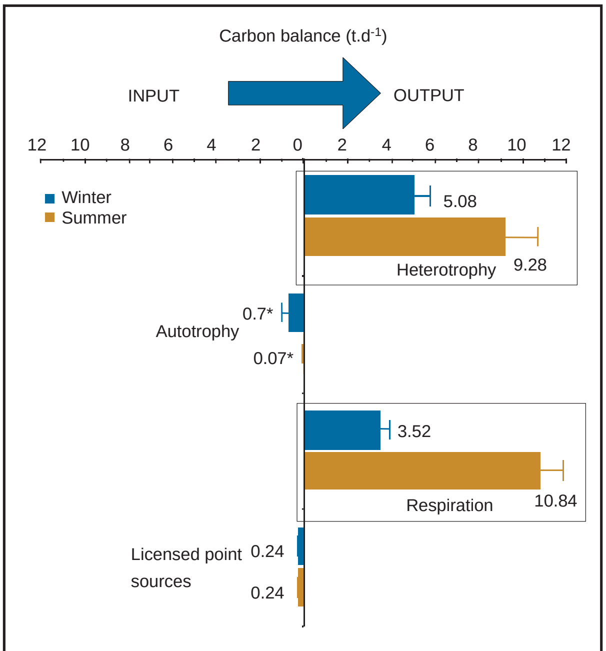


Figure 10.4: Carbon budget for Bremer River in dry and wet seasons. Respiration exceeds primary production, making the system net heterotropic (Stratton et a.l, 2001).

Riparian vegetation

The riparian vegetation is in poor condition,more than 50% of the catchment having a riparian zone of <5m. In many cases it does not even cover banks and stream beds, over 75% of the total stream length in the catchment being cleared to bank edge. The lack of riparian vegetation and cover disrupts energy cycling and movement by altering rates of primary production, reducing riparian inputs and filtering of sediments and nutrients, trapping of large woody debris and snags and loss of habitat. There are increased primary production, raised water temperatures, reduced dissolved oxygen levels and favoring of certain algae due to increased light levels.

Weeds comprise 14–44% of riparian vegetation, thistles, introduced grasses, burrs, Chinese Elm, lantana, willow and milkweeds being common throughout the area. In isolated areas of the catchment the vegetation is in better condition.

Aquatic habitat

The aquatic habitat is in poor to moderate condition, with erosion processes exceeding aggradation processes, and all areas of the river are affected by erosion. Biological life cycle processes, migrations, breeding patterns, availability of food and nutrients to downstream areas are disrupted by altered flows. There is limited shading, material input and retention in the lower catchment. The aquatic biota, too, is considered in poor condition, noxious species (water hyacinth and salvinia) being present in the middle and lower catchment. The headwaters have greater biodiversity, with rare Lamington spiny crayfish and threatened and rare frogs present.

Pressures on the waterways

Land use

The Bremer River catchment supports a wide range of industries that may have a direct or indirect effect on the river system. Known discharges into the Bremer River include abattoirs, STP effluent, stormwater runoff pipes, industries using land-based disposal, sewer overflows, and a gravel washing site.
Since 1996: insufficient data

Point source discharges

There are STPs at Bundamba, Tivoli, Kalbar and Rosewood. Bundamba Creek receives discharge from a power plant discharge and stormwater, and Warrill Creek receives discharge from an STP (Tables 10.2 and 10.3).
Since 1996: STP upgrades

Table 10.4: Load per day for known point sources on the Bremer River

	Average calculated load kg/day						
Source	**BOD_5**	**NH_3**	**NO_x**	**TKN**	**Org N**	**N_{total}**	**P_{total}**
Bundamba STP	30.7	13.6	30	31.7	18.2	61.6	75.7
Tivoli STP	127		139	93		223	105
AMH Abattoir	60					210	

Water extraction

Moogerah Dam in the catchment supplies Warrill and Reynolds Creeks, irrigation water and water for urban and industrial use. The water scheme operator (Sunwater) regulates water flow on Reynolds and Warrill Creeks.
Since 1996: insufficient data

Non-point source discharges

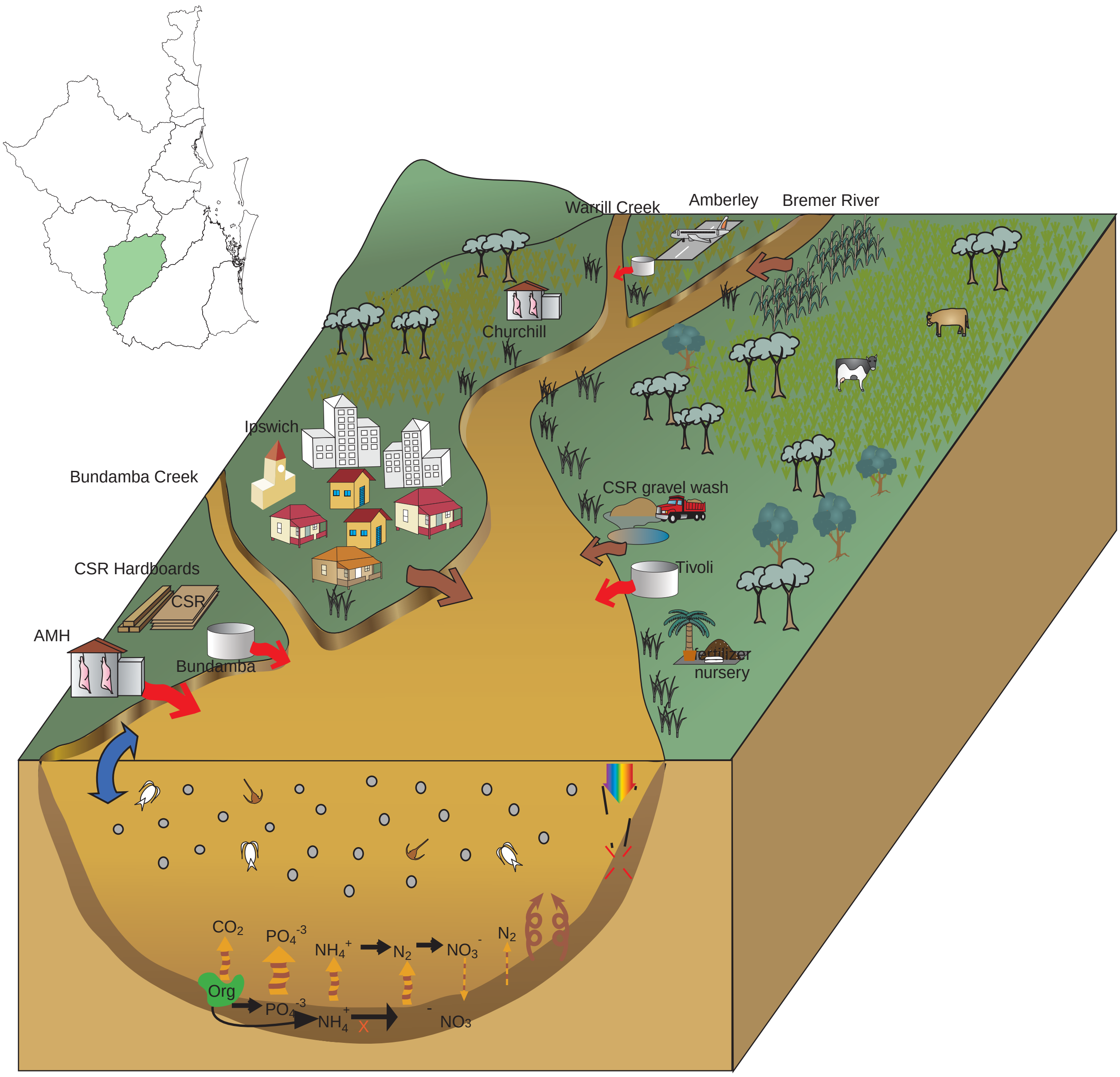
Possible non-point sources include runoff from stormwater, agriculture, groundwater infiltration, and industries, including land waste disposal areas. Land disposal practices within the Bremer catchment may impact on the river during dry weather. Such sources have not been quantified to the same extent as the point sources. One recommendation for the future management of the Bremer is to audit all potential non-point sources of pollution and then design strategies to remediate the inputs. In terms of inorganic nutrients, the removal of discharges from licensed discharges would have a beneficial impact on water quality in the river by increasing dissolved oxygen concentration due to reduced inorganic nutrient concentrations. However, extreme turbidity, very poor flushing and high dissolved organic carbon inputs also contribute to the degradation of the river system. An encouraging factor, though, is that the Bremer River catchment is supported by some of the most proactive local councils and focused catchment groups, attempting to improve conditions over time.
Since 1996: no change


Healthy Waterways Library

Sewage treatment plants are just one of the point source discharges into the Bremer River.

Responses to the pressures on the waterways

Issues	Local initiatives	Responses
Land use	• Boonah and District Landcare Group • Mihi Creek Catchment Care Group • Boonah Shire Improvement Trust projects • Ipswich Envirocare, Fassifern Field Naturalist Group, Ipswich River Improvement Trust, West Moreton Landcare Group, High Country Landcare • Coordination between Bremer Catchment Association and Boonah Shire Council on various projects • Bremer Catchment Association Streambanks Management Project • Weed eradication activities by Boonah and District Landcare Group, Boonah Shire Council and Ipswich City Council • State of Bremer River and Major Tributaries • Removal of large woody weeds by the Boonah Shire River Improvement Trust	• Range of local programs and plans outlining management actions to deal with this issue. • An Environmental Management Support System allows predictions to be made in relation to changes to water quality as a result of different land use and development practices, enabling stakeholders to develop future actions to deal with this issue. • Environmental Planning Project is currently under way to develop a range of tools that can be used by local governments, rural property owners and industry organisations to minimise impacts on the region's catchments and waterways. It is anticipated that stakeholders will develop future management actions based on the outcomes of this project.
Point source discharges	• Upgrade to 5mg/L nitrogen from Bundamba • Planning for diversion of Tivoli flows to Bundamba STP • Augmentation of Bundamba STP • Upgrading of Kalbar STP • Trialling sand filter at Aratula CED scheme • 80% effluent from Kalbar STP reused • Ipswich City Council has an infiltration/inflow strategy in development.	• Many of these issues will be dealt with during the development of the Moreton Region Water Resource Plan, which includes development of environmental flow management strategies. This Water Resource Plan is scheduled for completion in 2005.
Water extraction		• In 2002, stakeholders of the Partnership will begin to identify priority areas for riparian and stormwater management and set targets for on-ground works. This process will focus on implementing on-ground works to deal with this issue.
Non-point source discharges	• Bremer River Catchment Management actions to manage erosion and sedimentation • Boonah and District Landcare—soil erosion • West Moreton Landcare's major gully erosion project • Voluntary Code of Practice by Queensland Farmers Federation • Ipswich City Council monitors runoff and constructs Stormwater Quality Improvement Devices (SQIDs). • Boonah Shire Council has an Environmental Management Plan for road construction.	



Conceptual model for Bremer River

Sources of information

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Chapter 11

Mid Brisbane River

Thorsten Mosisch

Description of the waterways

The Mid Brisbane River section extends from Mt Crosby Weir to the Wivenhoe Dam wall approximately 150km from the river mouth. This stretch of the Brisbane River is used as a natural water supply conduit for raw water releases from Wivenhoe Dam to Mt Crosby Weir. Water is released from Wivenhoe Dam every day through the regulators, and takes approximately two days to flow down the 61.5km of river channel to Mt Crosby. The volume of water released changes on a day-to-day basis depending on demand from bulk water customers. The water treatment facility at Mt Crosby supplies drinking water to more than 1.5 million residents in south-east Queensland. Major townships located in the Mid Brisbane River catchment are Fernvale, Lowood and Coominya. The Mid Brisbane River is an important regional resource for recreation, as it is close to major population centres and easily accessible (Fig 11.1).

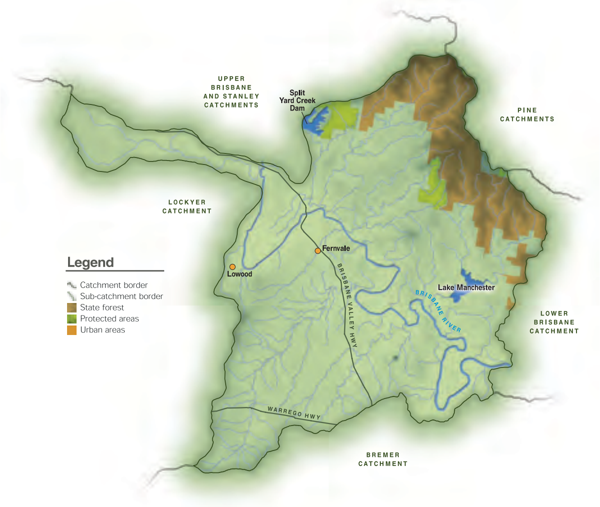


Figure 11.1: Map of the Mid Brisbane River catchment

The Mid Brisbane River sub-catchment is relatively small (547km^2). The larger Lockyer Creek catchment (2971km^2) discharges into the Mid Brisbane River 4km downstream from Wivenhoe Dam wall but flow is controlled by O'Reillys Weir. Brisbane Forest Park (part of the D'Aguilar Range) borders the sub-catchment to the north-east, and the expansive Lockyer Valley agricultural area abuts it to the south-west. Major streams flowing into the Mid Brisbane River are Lockyer Creek, Black Snake Creek, Sandy Creek, Banks Creek and England Creek.

The dominant land uses in the catchment are grazing, managed native forests and intensive agriculture, while 44% of the catchment remains as natural bush (Fig 11.2).

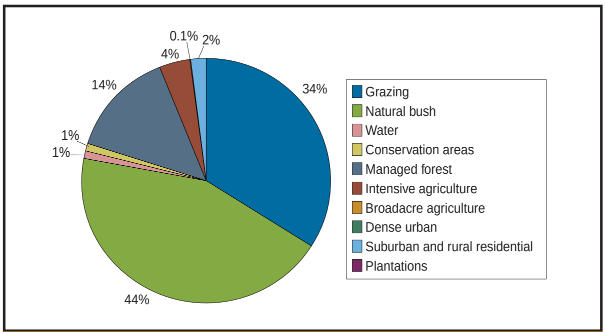
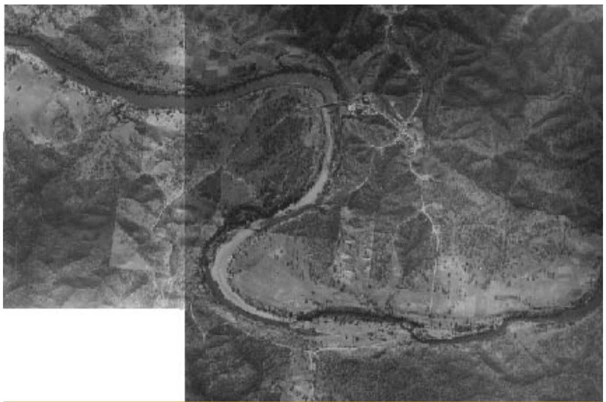


Figure 11.2: Land use in the Mid Brisbane River catchment



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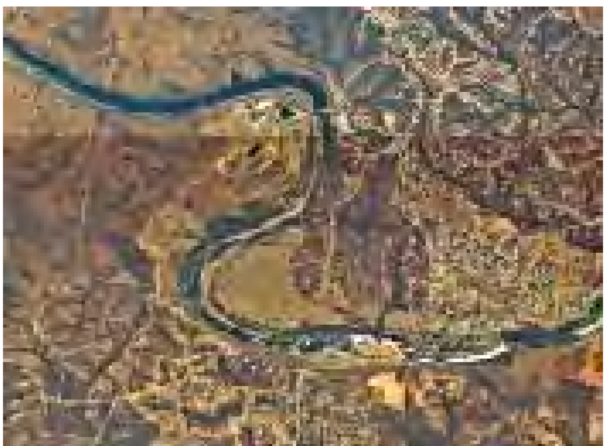
Historical (1944) photo of the Mid Brisbane River at Mt Crosby weir



Department of Natural Resources and Mines

Current (1997) photo of the Mid Brisbane River at Mt Crosby weir

State of the waterways

Catchment vegetation

Most land clearing has taken place in the agricultural areas on the south-western side of the river. Streams flowing into the Brisbane River from this side of the catchment generally transport high sediment and nutrient loads, and may also carry pesticides and herbicides from intensive agricultural activities in that area. Less clearing has taken place on the north-eastern side of the Mid Brisbane River catchment. This area tends to be more intact, with less intensive agriculture. Brisbane Forest Park takes up a significant part of the northern and eastern areas of the catchment, and these sections are relatively undisturbed.

Riparian vegetation

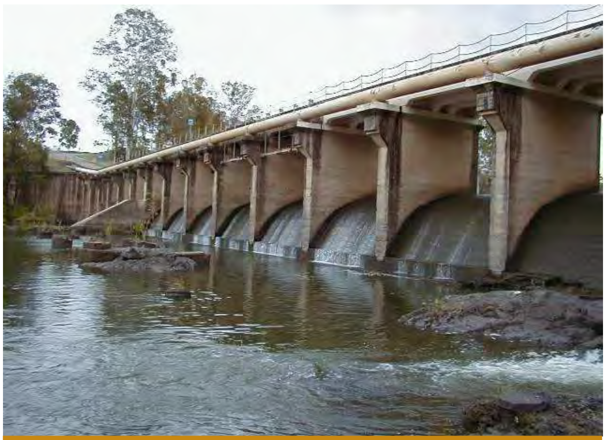
Although extensive land clearing has taken place in the catchment, stretches of the Mid Brisbane River feature some of the more intact regional riparian corridors in the region, with a high degree of biodiversity. Flow regulation in the Mid Brisbane River appears not to have impacted on the riparian vegetation; rather, constantly elevated base flows have resulted in favourable conditions for the growth of emergent macrophytes along river banks. Inappropriate land use practices are the main cause of riparian zone degradation in this area.

Stream habitat

Wivenhoe Dam has changed the flow regime along the 61.5km of river channel between the dam wall and Mt Crosby Weir, leading to elevated base flow in that part of the river. As a result, there is a loss of riffle habitat in the Mid Brisbane River due to ponding and increased flow depths. This has generally resulted in a lowering of channel diversity in this section of the river. The relatively constant flow may have some effect on taxa which favour pools and waters of low velocity, resulting in changes in faunal composition. There are also reports of platypus in the Mid Brisbane River.

Fish community

Overall, there is a lack of data on the condition of the fish community in the Mid Brisbane River. A total of 24 freshwater fish species are known to occur in this section of the river, including seven exotic fish species. Australian bass (*Macquaria novemaculeata*) are not found above Mt Crosby weir, as these fish are unable to negotiate the fish ladder successfully.



Environmental Protection Agency

Although a fish ladder is constructed within the Mt Crosby Weir, it still represents a barrier to the upstream migration of some fish species.

Water quality

Water quality in the Mid Brisbane River is generally good to moderate, especially under conditions of low flow, when releases of good quality raw water from Wivenhoe Dam dominate. During storm events, inflows of poorer quality water from Lockyer Creek and other creeks draining the catchment dominate, resulting in higher sediment loads, nutrient levels and other contaminants.

Groundwater in the Lockyer catchment contains elevated levels of nitrogen. There is also the danger of other compounds in the groundwater of the Lockyer catchment reaching the Mid Brisbane River.

Pressures on the Waterways

Major issues

Major issues that are of importance to the overall state of the water quality and ecological health of the Mid-Brisbane River include:

- erosion (clearing/overgrazing);
- sediment loads, in particular from Lockyer Creek;
- sewage inputs;
- unsewered areas/septics;
- stormwater runoff;
- bacteria and parasitic contaminants;
- algal blooms;
- water abstraction—irrigation, farm supply, stock watering, industrial use;
- flow regulation—Wivenhoe Dam, Mt Crosby weir;
- rural residential subdivisions;
- land clearing, including removal of riparian vegetation;
- cattle grazing (including access to river channel);
- dairies;
- agricultural activities—cropping;
- extractive industries (sand/gravel);
- industrial development;
- timber harvesting;
- exotic flora/fauna;
- recreational activities.

Flow regime

The current flow regime in the Mid Brisbane River as a result of dam releases is characterised by relatively constant base flows at very high levels. Discharge waters from Wivenhoe Dam are generally cooler than water in the river downstream. This thermal depression may affect fish spawning, invertebrates, and in-stream primary production. High flow events have been reduced significantly as a result of flow regulation.
Since 1996: stable, but changes from year to year depending on water demand

Fish movement

Wivenhoe Dam creates a barrier to the movement of fish between the Upper and Mid/Tidal Brisbane River, and the downstream movement of organic material from the upper catchment. The fish ladder at Mt Crosby Weir is of a poor design and functions properly only within a small range of flows.
Since 1996: stable

Recreation

Recreational activities in the river (e.g. canoeing, swimming) and in riparian areas (e.g. camping) are very common, and may lead to degradation of riparian zones. Fishing in the river is popular as well.
Since 1996: increased

Rural residential development

An aggressive expansion of unsewered rural residential development is resulting in increasing numbers of septic systems in the area, which may be a threat to groundwater.
Since 1996: increased

Catchment loads

The biggest current threat to the water quality of the Mid Brisbane River is the input of sediment, nutrient, pesticide, herbicide and other pollutant inputs from Lockyer Creek. Brisbane Forest Park also contributes to sediment inputs into the Mid Brisbane River in the form of overland flows. There is the potential for algal blooms at Mt Crosby Weir due to increased nutrient loads in runoff from inappropriate land uses upstream. The proposed scheme to resue water from Luggage Point for irrigation of the Lockyer Valley could result in an increase in agricultural use and runoff/ groundwater pollution, depending on treatment of the recycled water. This could ultimately enter the Mid Brisbane River and may impact on water quality.
Since 1996: increased

Riparian vegetation

Extensive clearing in this area is not currently an issue, but the expansion of agricultural areas has the potential to increase the degradation of riparian zones in the future.
Since 1996: stable

Extractive industry

There are approximately six operators of extractive industries for sand/gravel in the Mid Brisbane River, both in-stream and offstream. These operations have been continuing for many years and have resulted in significant river channel modification, including the conversion of riffle habitat to pool habitat. In total, approximately 23km of river channel has been affected by extractive operations.
Since 1996: stable within river channel, but off-river extraction sites increased

Healthy Waterways Library

The Mid Brisbane River is in fair condition but flow is determined by releases from the Wivenhoe Dam.

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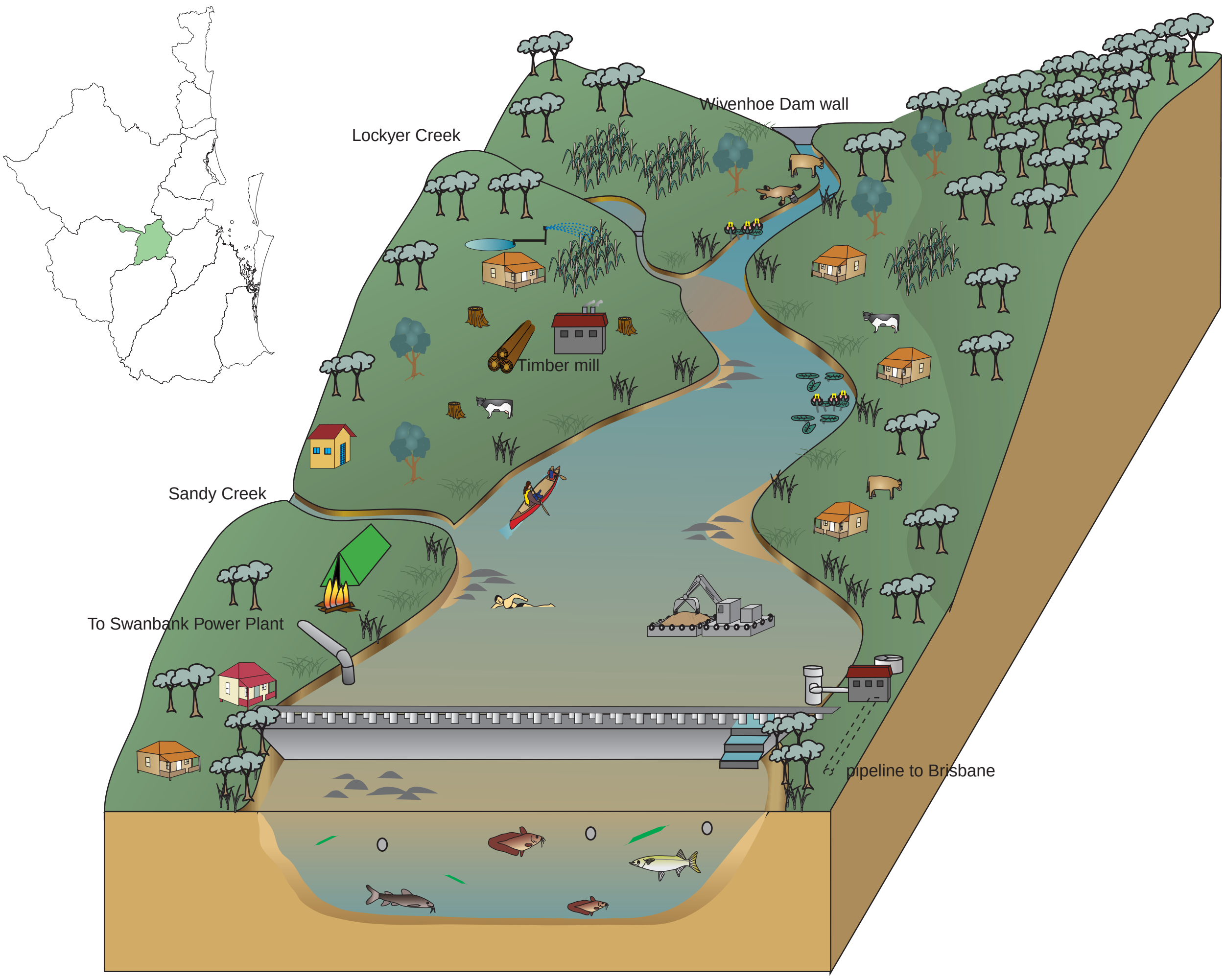
Responses to the pressures on the waterways

Issues	Local initiatives	Responses
Flow regime		• Many of these issues will be dealt with during the development of the Moreton Region Water Resource Plan, which includes development of environmental flow management strategies. This Water Resource Plan is scheduled for completion in 2005.
Recreation		• Sport and Recreation Queensland, in conjunction with a range of stakeholders, has completed the Brisbane River Recreation Management Issues Paper which outlines the key recreation issues affecting catchment and waterways health. • Recreation issues and associated management actions will also be considered by the Upper Brisbane Region Catchment Network during the development of a catchment management strategy for the area.
Rural residential development	• Brisbane Valley-Kilcoy Landcare projects • Catchment Coordinator has been appointed and the Upper Brisbane Catchment Network has formed to link the catchment groups.	• In 2002, an investigation into the magnitude of impacts from on-site sewage treatment facilities will commence. The results of this will enable stakeholders to develop future actions to deal with this issue.
Catchment loads	• Voluntary Code of Practice by Queensland Farmers Federation • Esk, Ipswich and Brisbane Councils must develop urban stormwater management plans.	• An Environmental Management Support System allows predictions to be made in relation to changes to water quality as a result of different land use and development practices, enabling stakeholders to develop future actions to deal with this issue.
Riparian vegetation	• Restoration projects by Brisbane Valley-Kilcoy Landcare	• In 2002, stakeholders of the Partnership will begin to identify priority areas for riparian and stormwater management and set targets for on-ground works. This process will focus on implementing on-ground works to deal with this issue.
Extractive industry		• A review of the regulatory regime for extractive industry is currently under way. Future management actions to deal with extractive industry issues will be developed based on the outcomes of this review.



Conceptual model for the Mid Brisbane River catchment

Chapter 12

Tidal Brisbane River

Ivan Holland, Paul Maxwell and Angela Grice

Description of the waterways

The Tidal Brisbane River catchment covers approximately 980km^2 and stretches from the river mouth in Moreton Bay to the Mt Crosby Weir approximately 90km upstream. The Bremer River intersects the Brisbane River approximately 73km upstream.

Historically, the Brisbane River contained upstream bars and shallows and has a natural tidal limit of only 16km. The current tidal limit now extends 85km upstream due to continual channel dredging. There are a large number of tributaries in the Tidal Brisbane River catchment including Breakfast, Bulimba, Norman and Oxley Creeks (Fig 12.1).

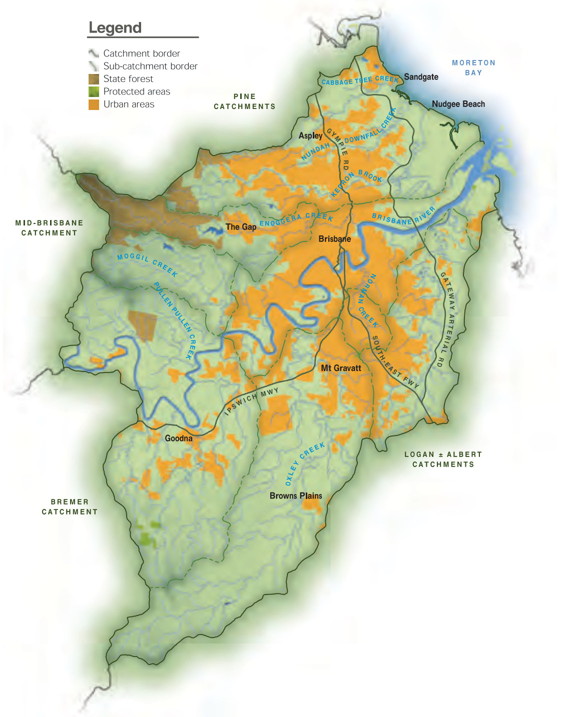


Figure 12.1: Map of the Tidal Brisbane River catchment

The Tidal Brisbane River catchment is a highly modified region with 52% of the catchment occupied by urban areas. Some grazing occurs higher in the catchment (10.7% of catchment area), while 29.7% of the catchment area remains as relatively natural bushland and 4.3% as managed forest (Fig 12.2). The majority of the Tidal Brisbane River catchment is contained within the Brisbane City Council local government area with small portions in Logan City and Ipswich City Council areas, and Redland and Beaudesert Shire Council areas.

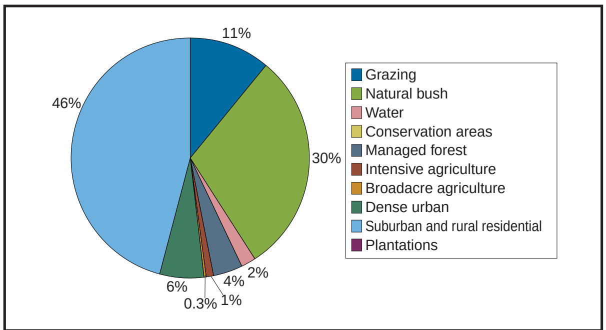


Figure 12.2: Land use in the Tidal Brisbane River catchment

Department of Natural Resources and Mines

Historical (1949) photo of the Tidal Brisbane River

Department of Natural Resources and Mines

Historical (1997) photo of the Tidal Brisbane River

State of the waterways

The ecosystem health of the Brisbane River estuary is generally poor. Flushing times range from 110 days at the mouth through to 189 days at the Bremer River confluence, which is approximately double that of the other major river estuaries. Prolonged flushing times cause nutrient and sediment loads to be concentrated in the middle reaches of the estuary. The concentrations of nutrients and suspended solids are far greater in the Brisbane River than in any other major estuary flowing into Moreton Bay due to large sewage and stormwater inputs. Elevated turbidity limits the growth of phytoplankton and reduces biological processing of inorganic nutrients. The middle reach of the Brisbane River estuary exhibits persistently low levels of dissolved oxygen, which is a threat to aquatic life. The nitrogen sewage plume in the Brisbane River is larger than in the other river estuaries, the highest δ^{15}N values being recorded just downriver of the Bremer River junction.

Environmental Protection Agency

The Tidal Brisbane River has poor water quality, especially around the middle reaches.

Water quality

Nutrients

In comparison with the other major estuaries discharging into Moreton Bay, the Brisbane River has excessive total nitrogen and total phosphorus levels, reaching values of 305µM N and 42µM P, respectively, both of which far exceed ANZECC guidelines. In the last 50 years there has been a 22-fold increase in nitrate and an 11-fold increase in phosphate in the Brisbane River.

The high nutrient loads are derived from a combination of domestic and industrial wastewater, and rural and urban stormwater runoff. Concentrations of ammonium and nitrate peak near the Indooroopilly Bridge, downriver of the Oxley STP.

Ammonium concentrations are comparatively low in other sections of the Brisbane River estuary, generally not exceeding 10µM (but still 7 times greater than QWQ guidelines). Nitrogen oxide concentrations in the poorly flushed middle section estuary are extremely high, being consistently greater than 200µM.

Table 12.1: Water quality in the Tidal Brisbane River. Brisbane River has the worst water quality of all estuaries flowing into Moreton Bay.

Parameter	Median	Range
Dissolved oxygen (%)	80	20–176
Turbidity (NTU)	21	0–1000
Secchi depth (m)	0.4	0.05–3.5
Total nitrogen (µM N)	107	20–305
Ammonia (µM N)	0.7	0.13–19
Nitrogen oxides (µM N)	70	0.4–263
Total phosphorus (µM P)	16	0.7–42
Filterable reactive phosphorus (µM P)	12	0.3–38

Sewage plumes

The plume of sewage nitrogen mapped using δ^{15}N signatures is greatest at the confluence of the Bremer River and extends downriver to below the Redbank STP, 64km from the mouth. The δ^{15}N signature in this section of the Brisbane River is higher than in any of the other major river estuaries that flow into Moreton Bay. The sewage plume remains consistently high heading downriver and peaks again 42km from the mouth, just downriver of the Oxley STP effluent discharge point. The sewage plume from the Brisbane River emanates into the southern section of Bramble Bay (Fig 12.3).

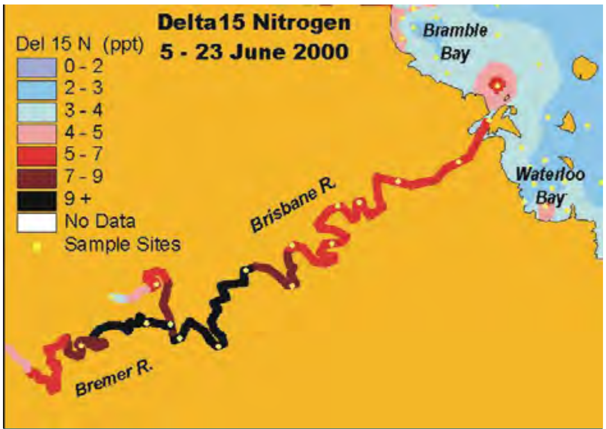


Figure 12.3: Sewage plume map of the Tidal Brisbane River. The sewage plume in the Brisbane River is greater than in any of the other major river estuaries that flow into Moreton Bay.

Nutrient processing

Considerable concentrations of nutrients are constantly being flushed by the Brisbane River into Moreton Bay. Biological processing of nutrients by plants and/or bacteria is substantially limited in the Brisbane River due to elevated concentrations of suspended sediment. The amount of nutrients entering the estuary from multiple discharges is far greater than the amount of biological processing. There is some evidence of ammonium being processed in less turbid areas of the upper and lower sections of the Brisbane River estuary (Fig 12.4).

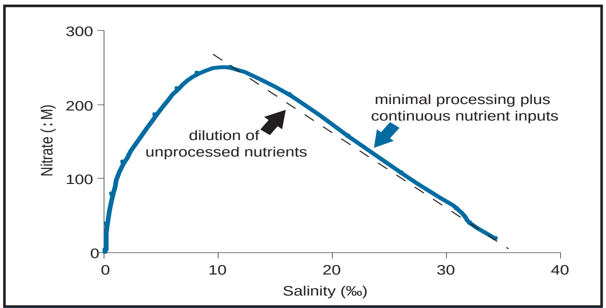


Figure 12.4: The amount of nutrients entering the Brisbane River estuary from multiple discharges is far greater than the amount of biological processing.

Turbidity

The Brisbane River catchment exports 450 000 tonnes of suspended sediment into Moreton Bay every year from sub-catchments such as the Bremer and Lockyer, mostly after large storm events and heavy rainfall. Turbidity in the Brisbane River is ten times greater than in other subtropical east Australian estuaries. Turbidity regularly exceeds 50NTU, which is approximately 5 times greater than ANZECC and QWQ guidelines. Turbidity in the upper section of the river is generally lower than other parts of the river, although after a high flow event in early 2001 turbidity reached 1000NTU.

The middle section of the estuary is the most turbid, with secchi depths rarely complying with ANZECC and QWQ guidelines. Secchi depths are as low as 0.2m between the city at 22km upriver and Moggill at 65km upriver. Oxley Creek experiences intervals of extremely poor water clarity in its northern reaches due to heavy loads of fine colloidal sediment from upstream extractive industry. The mouth of the Brisbane River is well flushed and consequently has lower turbidity than the other parts of the river (Fig 12.5).

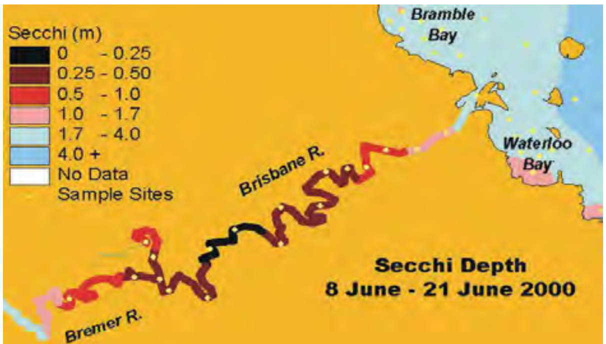


Figure 12.5: Map of secchi depths in the Tidal Brisbane River. The middle section of the estuary is the most turbid, with secchi depths rarely complying with ANZECC and QWQ guidelines.

Although suspended sediment in the Brisbane River has increased 4-fold in last 80 years, long-term trend analysis has shown a progressive improvement in turbidity by 6–11% each year since 1994 (Fig 12.6).

Phytoplankton

Phytoplankton biomass and growth in the Brisbane River are generally low due to high levels of suspended sediment. In the middle reaches, where the turbidity is greatest, phytoplankton productivity is limited due to light availability. Phytoplankton blooms occur outside the middle turbid section of the river due to proportionally greater light availability. The phytoplankton in both the upper reaches and the well-flushed mouth grow in response to nutrient addition, predominantly nitrogen, thus indicating further nitrogen addition in the natural environment may increase phytoplankton biomass (Figs 12.7 and 12.8).

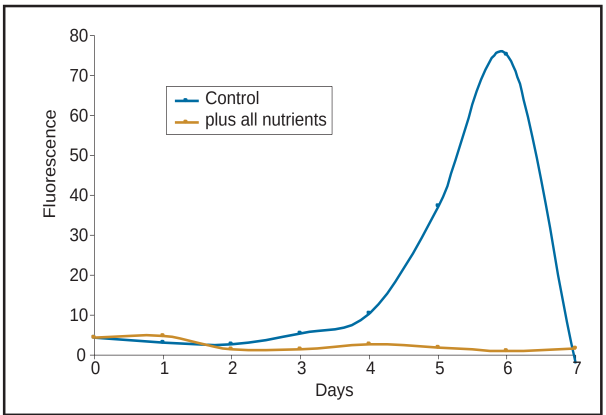


Figure 12.7: Phytoplankton growth in the middle reaches of the Tidal Brisbane River. Phytoplankton growth in the turbid middle reaches is stimulated primarily by increased light availability.

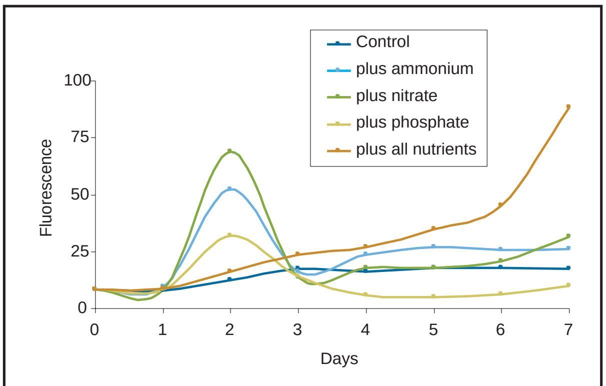


Figure 12.8: Phytoplankton in the less turbid upper Tidal Brisbane River grow in response to elevated nutrient levels, primarily nitrogen.

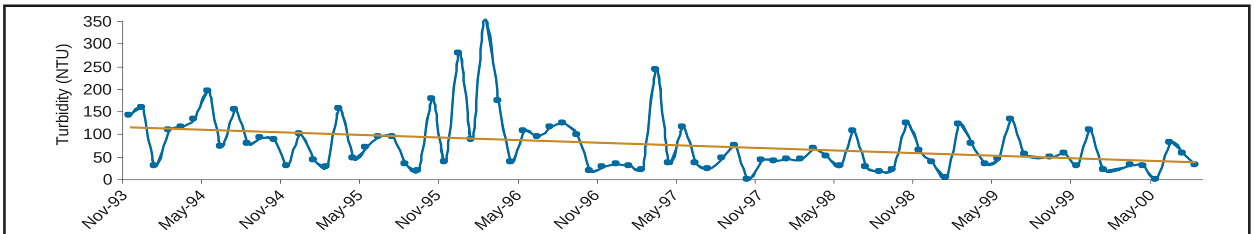


Figure 12.6: Long-term trend of nutrients and turbidity in the Brisbane River. There has been a progressive improvement in turbidity in the Brisbane River by 6–11% each year since 1994.

Faecal contamination

The concentration of faecal material in the Tidal Brisbane River is extremely variable. There is a correlation between high faecal contamination and high runoff from rainfall. Concentrations of faecal coliforms in the Tidal Brisbane River often exceed the ANZECC guidelines for primary contact recreation (e.g. swimming).

Toxicants

Although limited data are available on metal and organic toxicants in the Brisbane River, it is known that some toxicants exist in high concentrations in the sediments of the river at some sites. Concentrations of Dieldrin (a now-banned organochloride previously used as an insecticide) in the Brisbane River exceed ANZECC screening guidelines. Concentrations of DDE, PAHs and PCBs in the Brisbane River sediment have also exceeded the screening levels in some sampling. Although levels of some DDE, PAHs and PCBs exceed the ANZECC screening guidelines in some locations, a screening level risk assessment of the risk to human health from consumption of seafood revealed no risk from metals, PAHs or pesticides at any sites.

Introduced pests

A comprehensive survey of 29 sites near highly used shipping berths in the Port of Brisbane, including the Brisbane River, revealed no introduced marine pests.

Brisbane River tributaries

Very little water quality or ecosystem health data is available for the major tributaries of the Brisbane River although many of the factors affecting water quality in the Brisbane River also impact on the major tributaries (Table 12.2). Breeding populations of 26 native fish species occur in most freshwater creeks in the catchment. These populations are most abundant in areas with intact riparian vegetation.

Table 12.2: Water quality of major Brisbane River tributaries

Watercourse	Water quality	Reason
Bulimba Creek	Poor	High nutrient concentrations from catchment sources and tidal exchange with Brisbane River
Enoggera/ Breakfast Creek	Poor	High nutrient concentrations due to tidal exhange with Brisbane River
Norman Creek	Poor	High nutrient concentrations and high phytoplankton biomass
Oxley Creek	Very poor	High suspended sediment and high nutrient concentrations from Inala STP
Pullen Pullen	Good	Suspended sediment, nutrients and phytoplankton biomass are low
Moggill Creek	Good	Suspended sediment, nutrients and phytoplankton biomass are low

The following creeks are in the direct vicinity of the Tidal Brisbane River but flow directly into Bramble Bay.

Nundah Creek

The lower estuarine section of Nundah Creek is impacted by tidal influx from the nutrient-rich waters of Cabbage Tree Creek and by the Sandgate STP. Nutrient concentrations in Nundah Creek decrease upstream.

Kedron Brook

Water quality in the estuarine section of Kedron Brook is moderately impacted. Tidal exchange with water from Bramble Bay potentially impacts on the lower estuarine reaches of Kedron Brook with high nutrient and organic loads. High phytoplankton biomass has been recorded in the estuarine section of Kedron Brook.

Environmental Protection Agency

Kedron Brook is a highly modified stream in the Tidal Brisbane River catchment.

Nudgee Creek

Water quality in Nudgee Creek is affected by the Nudgee STP, which discharges into the tidal reach of the creek. High concentrations of nutrients, particularly ammonium and total phosphorus, have been recorded in the creek.

Environmental Protection Agency

Nudgee Creek has high levels of nutrients.

Pressures on the waterways

Population

The population of Brisbane has increased from 809 860 people in 1996 to 831 823 people currently, with the population for the Tidal Brisbane River catchment area predicted to grow by 12.1% by 2011.
Since 1996: increased

Boating and fisheries

Commercial fishing in the Brisbane River estuary, Brisbane Airport Floodway, Kedron Brook and Tingalpa Creek was quantified in 1999. A maximum of 10 boats are used in these areas, with a catch of 42.6 tonnes (DPI Fisheries).

The Tidal Brisbane River has a high level of recreational and commercial boating usage. Disturbance and destabilisation of the river bed and banks through wave wash and water pollution from exhausts and oil leaks have been identified as contributors to riparian habitat loss.
Since 1996: increased

Catchment loads

Major point source discharges

Eleven STPs discharge treated effluent into the waterways of the Tidal Brisbane River catchment. Luggage Point STP at the mouth of the Brisbane River is the largest in the region, while the second largest is the STP at Oxley Creek (Table 12.3). Together these plants service one million people. Major STP upgrades occurring in the catchment include those at Luggage Point (2001–2002), Gibson Island (2001-2004), Fairfield (2002) and Oxley (2002).

Key industrial discharges also occur at the Caltex and BP oil refineries and the Incitec fertiliser plant. Nutrients (and any toxicants) in these discharges are exported to Moreton Bay or buried and resuspended with estuarine sediments.
Since 1996: no change in nutrient loads

Table 12.3: Hydraulic load for some of the Brisbane City Council operated STPs. Data are from 2000–2001.

Sewage treatment plant	Hydraulic load (ML/d)
Luggage Point	138
Gibson Island	43
Fairfield	2.7
Oxley Creek	54
Inala	5.5
Wacol	5.3
Karana Downs	0.5

Non-point source discharges

Stormwater from uncontrolled residential building sites has the potential to carry 200 000 tonnes of sediment per year into the Brisbane River.

Dredging has increased the sediment-trapping capacity of the estuary: more than a 2-fold increase since 1962 in the flood water volume is needed to flush the estuary. Upriver retention of water in dams reduces the catchment sediment load entering the estuary but has contributed to the increase in trapping capacity of the estuary by reducing the freshwater flow. Approximately 20% more sediment was deposited in the estuary during a 1 in 20 year flood in May 1996 than would have been deposited before construction of Wivenhoe Dam.
Since 1996: increased

Extractive industries

Extractive industry dredging operations ceased in the tidal reaches of the Brisbane River at the end of December 1998. The dredging exclusion zone now extends from Norris Point (New Farm) to Karana Downs 81km upriver. Navigational dredging and maintenance dredging for flood mitigation purposes are still carried out as required. During 1998, 205 270m^3 of material was removed from the Brisbane River.

A present there are two hardrock and five sand and gravel extractive industries near the Brisbane River and five sand extractive industries along Oxley Creek.
Since 1996: decreased

Flow modification

Water extraction and impoundment in the Upper Brisbane River Catchment area has resulted in greatly reduced freshwater flows into the Tidal Brisbane River estuary. Regulated water flow over the Wivenhoe Dam has significantly affected the flushing time of the Tidal Brisbane River. During flood events, the retention of floodwater restricts the flow of the river and prevents the Tidal Brisbane River from flushing fresh to the mouth. Additionally, sediment loads are retained by the dam during flood events reducing sediment input into the estuary. During dry periods, however, the constant flow from the dam increases sediment input to the river above historical levels.

Channelling of natural waterways in urbanised areas into hard lining and concrete low-flow channels increases the velocity of stormwater runoff entering the river system. This further increases the flow of pollutant and sediment loads into the river system.
Since 1996: insufficient data

Land use

The Tidal Brisbane River catchment area contains the largest concentration of residential, commercial and industrial activities in Queensland. Historically, the expansion of urban and industrialised areas in the region has dramatically affected the water quality of the Tidal Brisbane River. Changes in land use bringing an increase in urban and industrialised areas have increased stormwater runoff and, ultimately, sediment inputs into the river system. In general, increased sediment input is of most concern as other pollutants such as nutrients, metals, pesticides and hydrocarbons attach to sediment particles in stormwater runoff. It is estimated that approximately 77.50km^2 of land will be required each year for housing and other purposes in the Moreton Bay catchment (Table 12.4).

Since 1996: increase in urban and industrial land use

Table 12.4: Export rate of pollutants from various land use areas in the Brisbane City Council local government area

Land use	Export rate kg/ha/yr			
	Litter	TSS	TN	TP
Vegetated	0	27	0.89	0.038
Rural residential	5	107	5.66	0.698
Urban residential	20	471	8.56	1.203
Commercial	90	855	12.62	3.112
Industrial	90	658	12.76	2.049

Riparian vegetation

Extensive clearing of vegetation has occurred in the Tidal Brisbane River catchment area to provide land for housing developments and industrial subdivisions. Clearing between 1981 and 1991 removed 50km^2 with approximately 25km^2 more bushland expected to be removed in the future. Removal and degradation of remaining vegetation through urban and industrial development is projected to increase, ultimately increasing the velocity and volume of stormwater runoff and further reducing water quality. Vegetation mapping recorded an average annual loss of riparian/wetland vegetation of 0.94km^2 per year between 1991 and 1997. The Brisbane City Council area has lost over 6km^2 of mangroves since 1974.

Since 1996: decrease in extent of vegetation, but rate of decrease slowing

Sources of information

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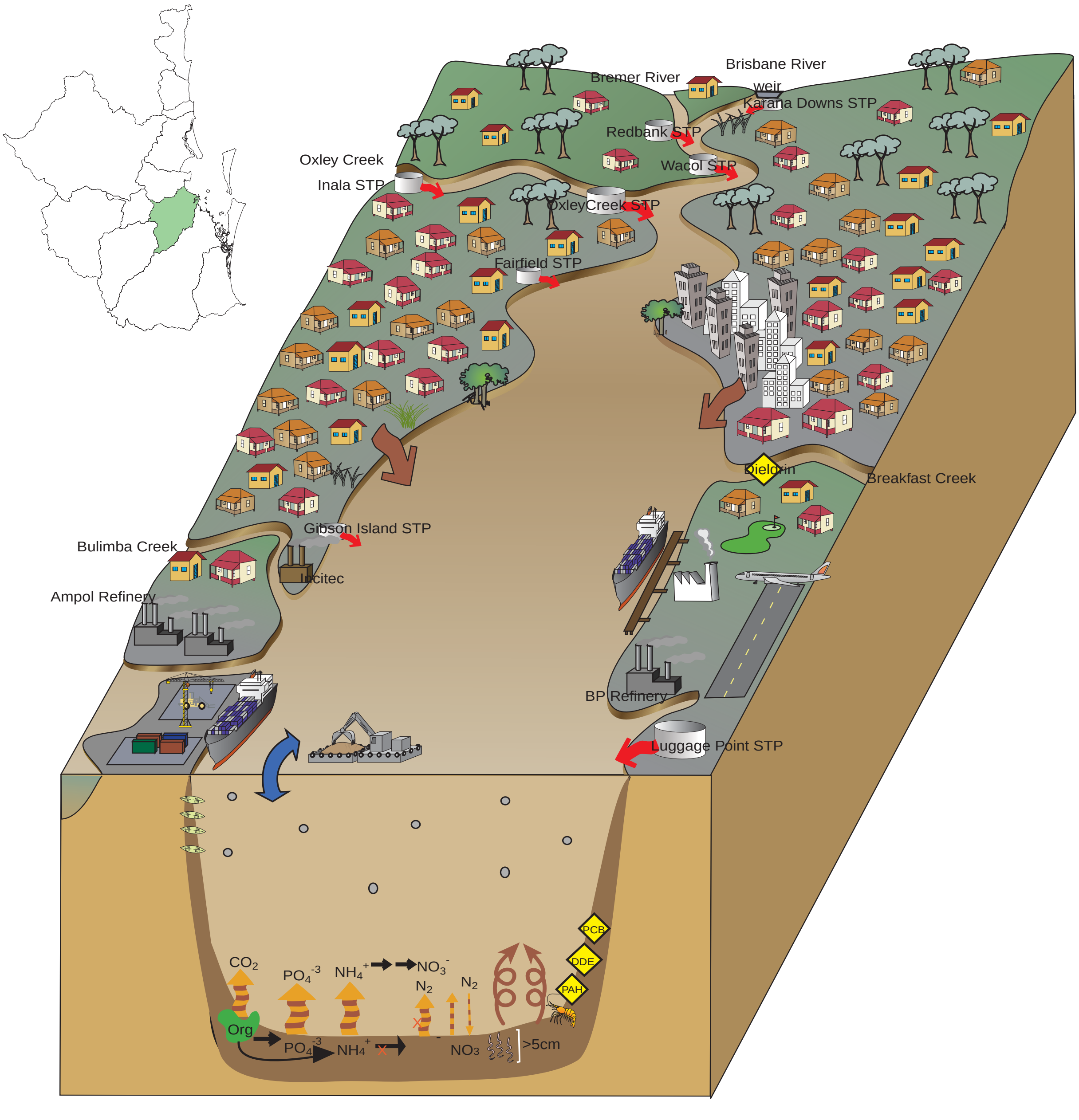
Responses to the pressures on the waterways

Issues	Local initiatives	Management Actions
Population		• The SEQ Regional Framework for Growth Management is the basis for planning for the projected increases in the regional population. All member organisations are using the framework to guide sustainable growth in the region through a range of implementation mechanisms including planning schemes, corporate plans and a range of service delivery programs. • Range of local programs and plans outlining management actions to deal with this issue
Catchment loads —Major point source discharges	• BCC has completed feasibility studies into improved nitrogen removal at Sandgate, Luggage Point, Oxley Creek and Inala STPs. • BP Refinery has improved wastewater discharge. • Caltex Refineries has improved wastewater discharge at Lytton. • Incitec Fertiliser plant has reduced total nitrogen load by 90%. • BCC is constructing a reverse osmosis plant to supply 12ML/d of reuse water to BP's Bulwer Island facility. • Some reuse of effluent at Fairfield, Inala and Gibson Island STPs • Oxley and Sandgate STPs were remediated in accordance with environmental management plans. • All new biosolids will be removed from Luggage Point in accordance with Environmental Management Program and Brisbane Water Biosolids Management Strategy. • BCC has established a Sewage Overflow Abatement Program. • Goodna upgrade planning • Broad investigation for Goodna and Carole Park WWC • Springfield reuse demonstration with DNR	• An agreed schedule of discharge targets and associated plant upgrades has been developed for STPs in the Tidal Brisbane River. These improvements aim to achieve the sustainable nitrogen loads targets outlined in the SEQRWQMS.
—Non-point source discharges	• Brisbane City Urban Stormwater Management Strategy • City Plan 2000, supported by Codes and Planning Scheme Policies for Acid Sulfate Soils, Stormwater Management and Waterways • BCC Water Quality Management Guidelines, including acid sulfate soils, erosion and sediment control • Guidelines on Identifying and Applying Water Quality Objectives in Brisbane City • Erosion and Sediment Control Standard • BCC Sediment Basin Design Guidelines • Enforcement program to ensure industry and Council compliance with *Environmental Protection (Water) Policy 1997* • BCC Guidelines for Pollutant Export Modelling and associated stormwater monitoring program • Maintenance of approximately 100 stormwater quality improvement devices (SQIDs) (30 by BCC) • Healthy Waterways Brisbane River Debris Clean Up sponsored by EPA, BCC, DoT, ICC and PoBC • Development of Water Sensitive Urban Design pilot projects in Brisbane City	• Range of local programs and plans outlining management actions to deal with this issue • In 2002, stakeholders of the Partnership will begin to identify priority areas for riparian and stormwater management and set targets for on-ground works. This process will focus on implementing on-ground works to address this issue.
Extractive industries		• A review of the regulatory regime for extractive industry is currently under way. Future management actions to deal with extractive industry issues will be developed based on the outcomes of this review.
Flow modification		• Many of these issues will be deal with during the development of the Moreton Region Water Resource Plan, which includes development of environmental flow management strategies. This Water Resource Plan is scheduled for completion in 2005.

Responses to pressures on the waterways cont’d

Issues	Local initiatives	Responses
Land use	• Catchment Management Plans have been prepared for Oxley, Bulimba, Wolston, Pullen Pullen, Cubberla, Toowong, Norman, Moggill, Breakfast/Enoggera, Cabbage Tree, Breakfast/Enoggera, Kedron Brook, Wynnum, Lota, and Tingalpa Creeks. • BCC has a program to prepare 2-4 Waterway Management Plans each year. • BCC facilitates a City-wide Catchment Group and supports approximately 14 community-based catchment groups. • City Plan 2000, supported by Codes for Waterways; Wetlands; Stormwater Management; and Biodiversity	• Environmental Planning Project is currently under way to develop a range of tools that can be used by local governments, rural property owners and industry organisations to minimise impacts on the region’s catchments and waterways. It is anticipated that stakeholders will develop future management actions based on the outcomes of this project.
Riparian management	• Waterway Management Plans and Reports inform of location and selection of creek restoration and natural channel design projects. • BCC Natural Channel Design Guidelines • Waterways Code in City Plan states that corridors are preferably kept clear of development.	



Conceptual model for the Tidal Brisbane River

Chapter 13
Logan/Albert Rivers and Redland Waterways

Liz O'Brien, Paul Maxwell, Ivan Holland, Angela Grice and Dieter Tracey

Description of the waterways

The catchment of the Logan and Albert Rivers is characterised by meandering courses. The Logan River is 185km long and flows across an extensive flood-plain delta for much of its length. The headwaters are located in Mt Barney National Park and are in relatively pristine condition. The upper reaches of the river are largely cleared for grazing, dairying and some irrigated agriculture. The remainder of the Logan River flows through a combination of urban and rural residential areas and is comprised of bar-built estuaries dominated by tidal exchange. The headwaters of the Albert River and Canungra Creek rise in Lamington National Park and flow through grazing, farming and rural residential areas, eventually entering the Logan River 11.2km upstream from the mouth. Teviot Brook is approximately 103km long; it has headwaters at Wilsons Peak and after passing through national parkland, it enters agricultural farmlands. It then passes through the township of Boonah and enters grazing land before joining the Logan River at Cedar Pocket. The Logan River enters Moreton Bay at a point just south of Lagoon Island (Fig 13.1). Land use in the Logan and Albert Rivers catchment is dominated by grazing and natural bush (Fig 13.2).

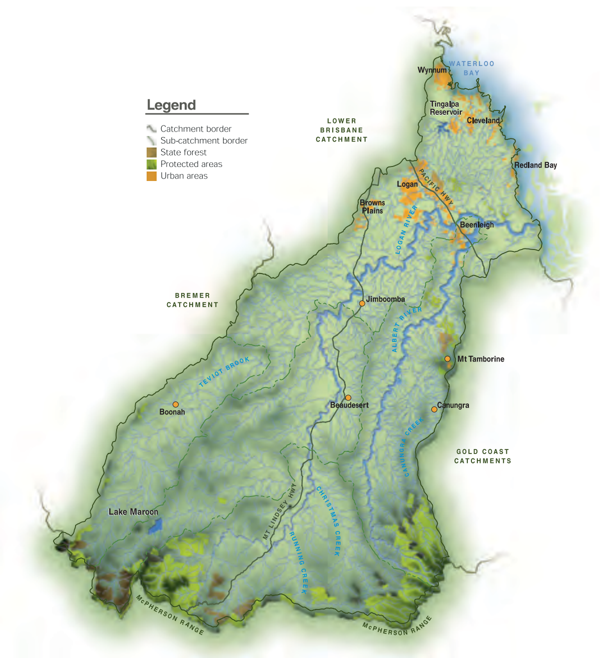


Figure 13.1: Map of the Logan and Albert Rivers and Redland catchment

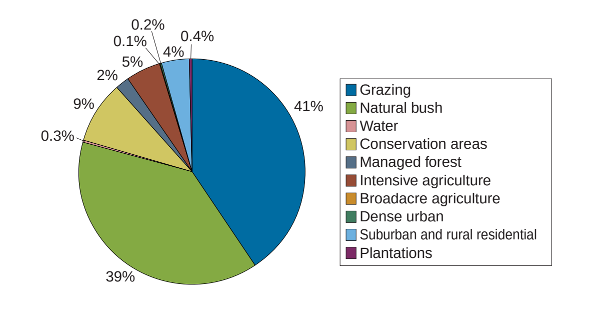


Figure 13.2: Land use in the Logan and Albert Rivers and Redland catchment

The combined Logan, Albert and Teviot catchments cover 3740km^2. The Logan River catchment is the largest and covers 2986km^2, while the Albert River sub-catchment covers 754km^2. The Beaudesert Shire Council is the main local authority governing the catchment (Table 13.1).

The Redland catchment covers 236km^2 and is located on the coastal area east of the Brisbane River catchment and north of the Logan-Albert Catchment. It consists of a number of smaller creeks that flow directly into Moreton Bay. The sub-catchments of the Redlands include Tingalpa and Coolnwynpin Creeks, Tarradarrapin Creek, Hilliards Creek, Cleveland, Eprapah Creek, and Moogurrapum and Weinam Creeks. The area also includes Waterloo Bay, Raby Bay and Toondah Harbour. Many of the small tidal creeks of the Redland catchment are within a Habitat Zone of Moreton Bay Marine Park and form part of the Moreton Bay Ramsar site. Land uses in the catchment include poultry farming, plant nurseries, flower farms, market gardens, urban areas and bushland.

Table 13.1: The Logan and Albert Rivers and Redland catchment is governed by several local government authorities.

Council	Logan area (km^2)	Albert area (km^2)	Redlands area(km^2)
Beaudesert Shire	1896	665	-
Boonah Shire	801	-	-
Logan City	173	-	16.4
Gold Coast City	65	89	-
Brisbane City	25	-	44.6
Redland Shire	24	-	175

Department of Natural Resources and Mines

Historical (1944) photo of the Logan and Albert Rivers confluence

Department of Natural Resources and Mines

Current (1997) photo of the Logan and Albert Rivers confluence

State of the waterways

Freshwater

For much of its length the Logan River traverses an extensive alluvial floodplain and has a deeply incised channel that is susceptible to erosion.

Healthy Waterways Library

Blue Rock Creek in the Upper Logan River catchment

Water quality

Nutrients

Nutrient concentrations in the freshwater reaches of the Logan and Albert Rivers catchments are frequently high and for the most part exceed QWQ guidelines. Land uses in the area that may affect nutrient concentrations include cattle grazing, poultry farming, a rendering plant, soil conditioning, a tannery, a gelatine factory and a landfill. Many of these activities are located within the Bromelton industrial area just west of Beaudesert on the Logan River. Ammonium concentrations are high upstream and downstream of the Beaudesert STP.

The freshwater reaches of the Albert River are characterised by high total phosphorus levels exceeding QWQ guidelines. Total nitrogen and ammonia levels generally comply with QWQ guidelines. Total phosphorus concentrations in the Albert River exceeded QWQ guidelines in 1999. Nutrient concentrations in Canungra Creek are consistently more elevated downstream from the Canungra STP than upstream, and exceed QWQ guidelines for ammonia and total phosphorus.

Tarradarrapin Creek has high ammonia concentrations compared with guideline levels, and these have increased significantly since 1996. Freshwater reaches of Eprapah Creek are also high in ammonia, one site being investigated in a targeted study.

Suspended sediment

Except in the very upper reaches of the Logan River, concentrations of suspended solids consistently exceed QWQ guidelines. Lower freshwater sections of the Albert River and Canungra Creek comply with QWQ guidelines for suspended solids.

Dissolved oxygen

Some freshwater sections in the Logan and Albert River catchments are generally well oxygenated and comply with QWQ guidelines. Most tributaries in Logan City, however, do not meet ANZECC guidelines on a regular basis. The middle of Tarradarrapin Creek has low dissolved oxygen levels, but levels in the upper reaches comply with guidelines.

Faecal indicator bacteria

Faecal coliform concentrations have exceeded ANZECC guideline levels for primary contact recreation on several occasions. These coliforms are of animal origin and appropriate measures to deal with the problem are being investigated.

Riparian vegetation

Below the near-pristine headwaters, riparian zones in the freshwater Logan and Albert River catchments have largely been cleared or degraded as a result of agricultural and other land uses. In combination with the naturally steep, narrow channel, this makes these streams particularly susceptible to erosion during periods of high flow.

Coastal and estuarine waters

The tidal Logan and Albert Rivers are highly impacted and in poor condition. The detection of a large sewage plume affecting Southern Moreton Bay, further seagrass loss from the area and limited denitrification occurring in the river are of particular concern.

Water quality

Nutrients

Due to the variety of pressures on the Logan River the concentrations of nutrients are high and for the most part exceed ANZECC and QWQ guidelines for aquatic ecosystem protection. Levels of total nitrogen and phosphorus far exceed guideline levels (Table 13.2).

Table 13.2: Summary of water quality conditions in the Logan River estuary, May 2000-May 2001. Water quality in this waterway is consistently poor.

Parameter	Median	Range
Dissolved oxygen (%)	84	60 - 104
Turbidity (NTU)	21	1 - 200
Secchi depth (m)	0.6	0.1 - 2.4
Total nitrogen (µM N)	55	10 - 234
Ammonia (µM N)	1.6	0.1 - 92
Nitrogen oxides (µM N)	21	0.1 - 182
Total phosphorus (µM P)	8	1 - 51
Filterable reactive phosphorus (µM P)	5	0.3 - 48

The dominant nutrients in the system are nitrogen oxides, which are most concentrated in the middle section of the estuary near the Loganholme STP discharge 17.4km upstream. Nutrient concentrations are also elevated near the Albert River confluence at approximately 11.2 km. A number of known point source discharges in the lower Logan and Albert Rivers could influence nutrients at this location. These include the Beenleigh STP in the lower Albert River, the smaller Mt Cotton and Aquatic Gardens STPs in the Logan River and various aquaculture farms (Fig 13.3).

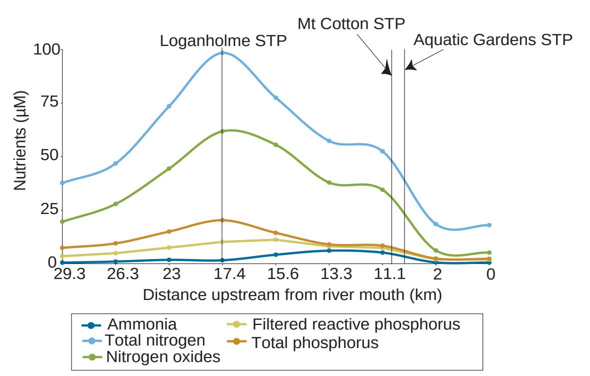


Figure 13.3: Graph of nitrogen and phosphorus concentrations in the Logan River estuary. Nutrient concentrations in the Logan River are highest near the STP discharges.

Sewage plumes

The plume of sewage nitrogen in the Logan River is greatest near the Loganholme STP and extends downriver. The $\delta^{15}N$ sewage nitrogen signature also peaks near the mouth of the Logan River in response to the Mt Cotton and Aquatic Gardens STPs and effluent from aquaculture. The $\delta^{15}N$ sewage nitrogen signature in this section of the river could also be affected by the nutrients being discharged by the Beenleigh STP into the Albert River. In June 2000, the sewage plume extending from the Logan River into southern Moreton Bay was the largest of any in the river estuaries flowing into Moreton Bay (Fig 13.4).

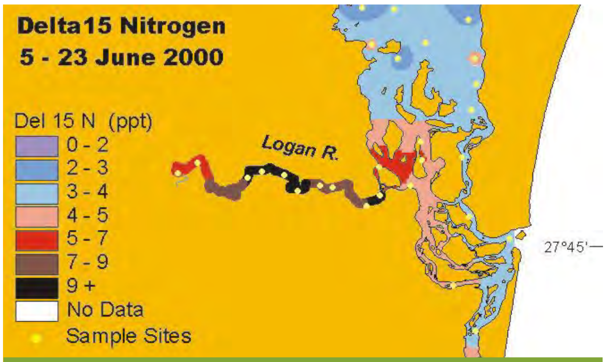


Figure 13.4: A plume of treated effluent extends into Moreton Bay from the mouth of the Logan River.

Biological processing of nutrients

In the less turbid zones phytoplankton uptake is greater and organic nitrogen forms a larger proportion of the total nitrogen in the water column. The quantity of nutrient inputs into the estuary exceeds the in-stream processing of nutrients by plants and/or bacteria. This results in the flushing of nutrients from Logan River into Moreton Bay (Fig 13.5).

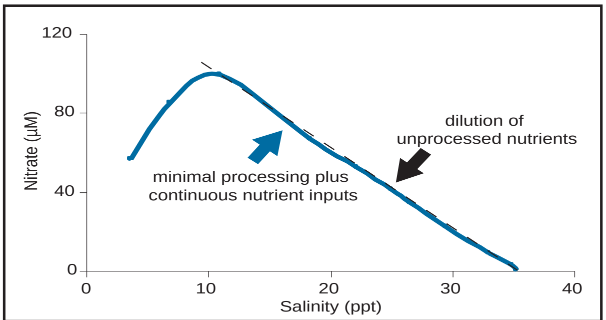


Figure 13.5: A mixing plot of nitrogen oxide concentrations versus salinity in Logan River. Nutrient inputs into the Logan River estuary are greater than the in-stream processing, which results in inorganic nutrients being passed unprocessed into southern Moreton Bay.

Turbidity

In addition to high nutrient concentrations, the Logan and Albert Rivers experience very high turbidity. The Logan River has consistently elevated turbidity in the upper section of the estuary exceeding ANZECC and QWQ guidelines. This indicates that the major source of suspended sediment in the Logan River estuary is derived from land use practices in the upper catchment.

Secchi depth in the Logan River does not comply with guidelines in the middle and upper sections of the estuary. In the upper estuary the secchi depth rarely exceeds 0.3m.

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The zone of high turbidity in the estuary regularly extends towards the mouth and during periods of high flow discharges sediment into southern Moreton Bay. Logan River is the main source of sediment in southern Moreton Bay and this sediment is the probable cause of seagrass loss in this area.

Phytoplankton

The highest concentrations of phytoplankton occur in the uppermost estuarine reaches of the Logan River, where nutrient concentrations are high and dispersion rates low. Concentrations of chlorophyll *a* in this section of the river regularly exceed ANZECC and QWQ guidelines. Phytoplankton in the Logan River have a high capacity to assimilate nutrients in the water column, resulting in phytoplankton blooms (Fig 13.6).

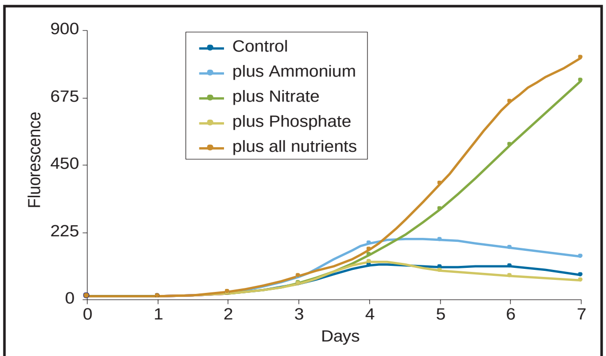


Figure 13.6: Graph of phytoplankton growth in response to nutrient enrichment. Phytoplankton in the upper estuarine reaches respond primarily to elevated nitrogen levels.

Faecal indicator bacteria

Faecal coliform concentrations have exceeded ANZECC guideline levels for primary contact recreation on five of nine occasions. Typical river catchment runoff due to moderately high rainfall in the preceding 72 hours could account for some of the high concentrations recorded. However, moderate to high measurements were also recorded on days with little to no rainfall, indicating that there is significant background contamination in the river.

Preliminary investigations using faecal sterols (molecules from the intestines of humans and other animals) showed that the contamination was from a mixture of human and animal sources. Further sampling is required to confirm these results, but combined with regular non-compliance with ANZECC guidelines, they indicate that the river is unsuitable for primary contact recreation (e.g. swimming). Note, however, that primary contact recreation in the estuary is rare, and the river has consistently complied with guidelines for more popular secondary contact activities such as boating and fishing.

Sediment toxicants

Sediments from the Logan and Albert Rivers contain detectable concentrations of the pesticide Dieldrin. This pesticide was historically used to protect fruit, pastures, sugar cane and bananas, although usage ceased in 1994. Agricultural and domestic insecticides such as DDE, chlorpyrifos, and trans-chlordane have been detected in the sediment of the Albert River.

Riparian vegetation

Navigational dredging at the mouth of the Logan River is thought to have extended the natural range of the local mangrove populations upstream. Mangrove forests are largely intact along the river banks and there are extensive forests at the river mouth. The area of mangroves in Logan Shire has increased by 0.047km^2 from 0.134km^2 in 1974 to 0.181km^2 in 1998. However, the majority of the riparian vegetation of the Logan River is in very poor condition based on percentage cover, width and disturbance.

Biodiversity

Limited information is currently available on the biodiversity in the waterways of the Logan and Albert Rivers catchment.

Tingalpa Creek

Water quality in Tingalpa Creek is generally poor, concentrations of dissolved oxygen decreasing progressively through the mid-estuarine section. There are elevated nitrogen and phosphorus levels in the creek, especially surrounding the Capalaba STP discharge. Nutrient concentrations decrease downstream from the discharge location. There have been significant improvments in most nutrient levels in the estuarine reaches.

Tarradarrapin Creek

The water quality of Tarradarrapin Creek is poor. Dissolved oxygen levels are low and high levels of nitrogen and phosphorus are evident. In addition, there is prolific growth of iron bacteria in the creek, which is generally considered to be an indication of organically polluted water.

Coolnwynpin Creek

Coolnwynpin Creek is characterised by high nutrient concentrations especially at the junction with Tingalpa Creek, near the Capalaba STP discharge.

Pressures on the waterways

Population growth

The current population of Logan City is just under 170 000 and that of Beaudesert Shire is 54 000; it is predicted that the catchment's population will continue to increase by approximately 3% per year (Table 13.3).

Table 13.3: Populations in Logan City and Beaudesert Shire are projected to increase substantially by 2011.

Council	2000	2011	increase
Logan City	169 073	186 325	17 252
Beaudesert Shire	54 246	73 390	19 145

Urbanised areas produce a concentration of wastes including wastewater and garbage. An increasing population will result in an extra load on the local waste processing facilities.
Since 1996: increased

Fisheries

Both recreational and commercial fishing occur in the Logan River. Currently 12 950 vessels are registered for Gold Coast City and Logan City (2.5% of residents, compared with 1.6% of residents in Brisbane) and boat numbers are expected to double by 2006. Activities include cast netting for prawns, which may affect the reproductive capacity of the population. At a commercial scale, 20–30 tonnes of greasyback, school and banana prawns are harvested from the Logan and Albert River estuaries annually.

The Logan and Albert Rivers catchment has the highest intensity of prawn farms (125ha, 7 farms) within a single catchment in Australia. The existing prawn farmers are keen to expand operations and new investors are seeking to establish farms in the area.
Since 1996: increased

Catchment loads

Major point source discharges

The wastes from this urbanised catchment are processed by a number of STPs that discharge treated effluent to the waterways, including four that discharge directly to the Logan River. Discharges are potentially high in nutrients, organic matter, pathogens and other pollutants (Table 13.4).

Table 13.4: Location of STPs in the Logan and Albert Rivers catchment

STP	Waterway	km from mouth
Aquatic Gardens	Logan River	8
Mt Cotton	Logan River	11
Loganholme	Logan River	17
Beaudesert	Logan River	105
Boonah	Teviot Brook	52
Kooralbyn	Cannon Creek	15
Beenleigh	Albert River	4
Canungra	Canungra Creek	23

Currently, 40ML of wastewater is produced per day (235 litres/person/day) in Logan City, while Beaudesert Shire produces 3ML per day. With the predicted growth in population, these volumes are expected to increase. The Slacks Creek STP has been closed and sewage diverted to the Loganholme STP since June 2000.
Since 1996: no change

Non-point source discharges

In addition to the wastewater processed by STPs, there are also 5700 septic systems in Logan City and 7200 in Beaudesert Shire.

Marine prawn aquaculture requires the addition of food and maintenance of phytoplankton blooms. The water discharged is generally high in nitrogen, suspended solids and chlorophyll *a*. During periods of high rainfall surface water and stormwater runoff to waterways can include nutrients from fertilisers and animal waste products, as well as pesticides and herbicides from agriculture and residential applications. Petroleum hydrocarbons from roads are also a significant source of pollution.
Since 1996: no change

Flow modification

Lake Maroon, situated on a creek in the Upper Logan catchment, is the biggest contributor to flow modification in the system. Water is extracted from the Logan River for irrigation at 59–60km upriver and can significantly reduce flow in the river. The Beaudesert Shire also extracts water from the Logan River for use as drinking water. Levee banks are present on the upper Teviot Brook and also in the lower catchment around the canelands which stop the usual floodplain processes.
Since 1996: insufficient data

Land use

Landfills have the potential to impact on waterways through subsurface leaching or runoff of nutrients and other chemicals during high rainfall events. There are several landfills in close proximity to waterways in the catchment.

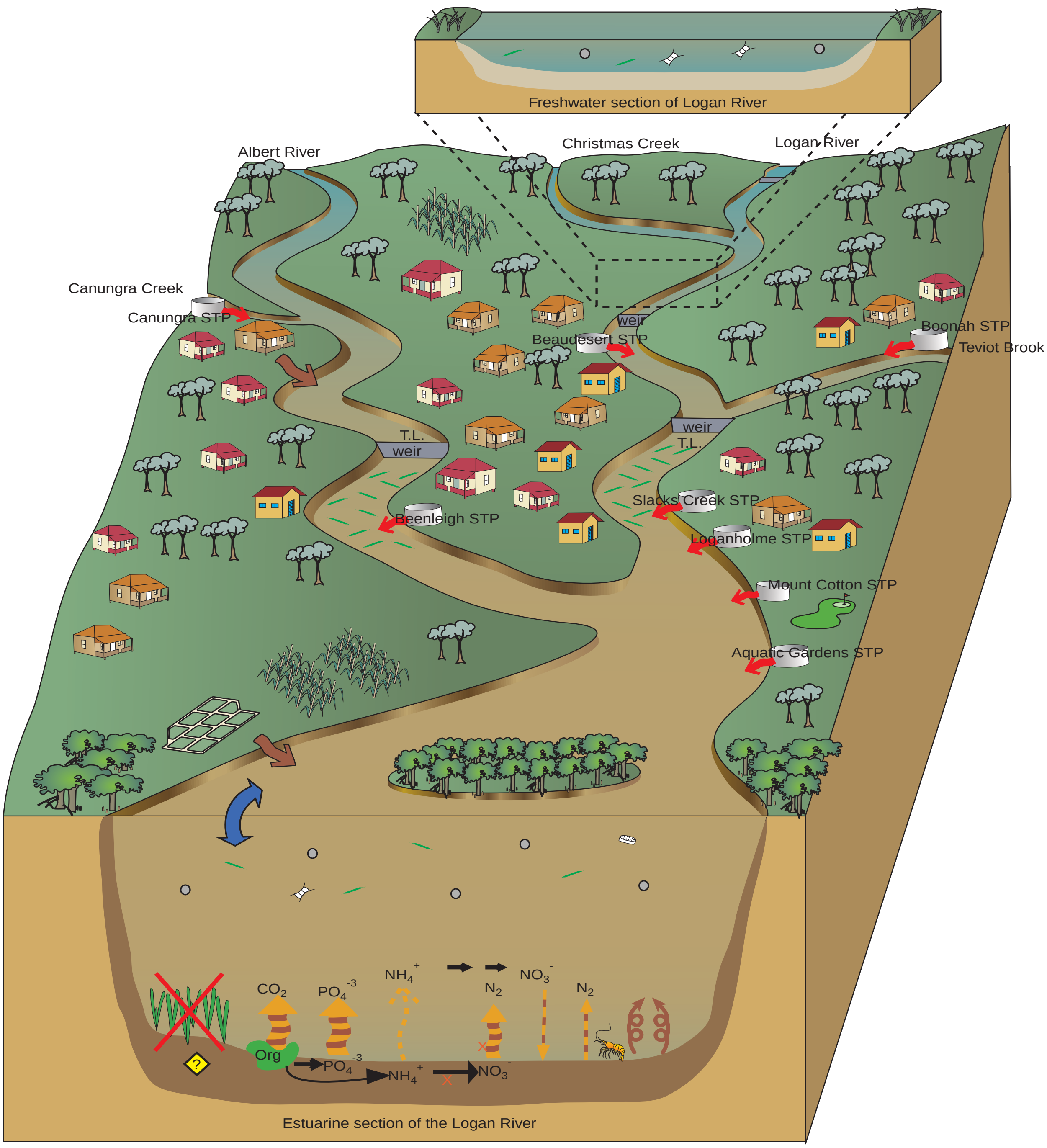
There is a concentration of industrial activity in the upper reaches of the Logan River. The Bromelton industrial area includes environmentally relevant activities such as rendering operations, soil conditioner manufacturing (e.g. worm farming), tannery activities or works for curing skins, and meat processing activities.

Boat building and repair facilities, and a marina with refuelling amenities are located in the estuarine section of the Logan River. Accidental spills of fuel, oil, grey water and anti-fouling chemicals are potential sources of pollutants to the waterway. Disturbance of the land can also expose acid sulfate soils in some areas of the Logan and Albert Rivers catchment.

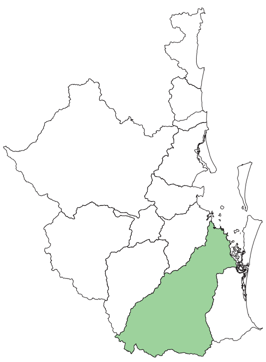
Extractive industries near the Logan River include four sand, one sand and gravel and one hard rock. Three hard rock extractive industries operate near the Albert River. Sand and gravel is also extracted from Woollaman Creek, a tributary of Teviot Brook.
Since 1996: increased urban and industrial land use

Responses to the pressures on the waterways

Issues	Local initiatives	Responses
Population growth		• The SEQ Regional Framework for Growth Management is the basis for planning for the projected increases in the regional population. All member organisations are using the framework to guide sustainable growth in the region through a range of implementation mechanisms including planning schemes, corporate plans and a range of service delivery programs. • Range of local programs and plans outlining management actions to deal with this issue
Catchment loads —Major point source discharges	• Logan, Coomera, South Moreton Bay Regional Wastewater Study • Gold Coast City Council's 'Northern Wastewater Strategy and Reclaimed Water Scheme' • Logan City Council is upgrading Loganholme STP. • Boonah Shire Council is investigating upgrades at Boonah (currently 60% wastewater reused) and Kalbar (currently 90% reused) STPs. • Beaudesert Shire Council is investigating increased reuse at its STP (currently 30% reused). • Logan City Council is involved in the Lockyer Reuse Study. • Canungra STP reuses 50% of its wastewater. • Gold Coast City Council is investigating reuse as part of the Northern Wastewater Strategy. • No sludge is stored on site at Loganholme or Beenleigh STP. • Redland Shire Council achieved 5mg/L total nitrogen at Thorneside and Capalaba STPs. • Investigations into upgrade of Victoria Point and Cleveland STPs • Reuse of wastewater at Capalaba and Victoria Point STPs	• An agreed process for achieving sustainable nitrogen loads from major point sources in outlined in the SEQRWQMS. This process allows stakeholders the flexibility to determine the most efficient means for achieving sustainable loads
—Non-point source discharges	• Redland Shire Council is developing urban stormwater quality management plans. • Boonah Shire Council is developing environmental mangement plans for roads. • Logan City Council is reviewing its development manual, using BCC guidelines. • All councils participate in the Urban Stormwater Information Group. • Voluntary Code of Practice by Queensland Farmers Federation • Logan City Council has adopted the Logan City Council Urban Stormwater Quality Management Plan.	• In 2002, an investigation into the magnitude of impacts from on-site sewage treatment facilities will commence. The results of this will enable stakeholders to develop future actions to deal with this issue. • Environmental Planning Project is currently under way to develop a range of tools that can be used by local governments, rural property owners and industry organisations to minimise impacts on the region's catchments and waterways. It is anticipated that stakeholders will develop future management actions based on the outcomes of this project. • In 2002, stakeholders of the Partnership will begin to identify priority areas for riparian and stormwater management and set targets for on-ground works. This process will focus on implementing on-ground works to address this issue.
Flow modification		• Many of these issues will be addressed during the development of the Logan-Albert Water Resource Plan, which includes development of environmental flow management strategies. This Water Resource Plan is scheduled for completion in 2005.
Land use	• Catchment Coordinator appointed • Draft Catchment Management policy initiated by local government authorities • Boonah and Beaudesert Landcare • Bushcare groups • Logan-Albert Rivers Catchment Association • Logan-Nerang Water Qualtiy Management Committee • Logan City Council has adopted a Waterways Protection Policy and Manual. • Projects by Bushcare, Boonah Landcare, Beaudesert • Council initiatives • Logan City Council's Waterways Strategy • Serpentine Native Dog Conservation Plan • Redland Shire Council's Environmental Inventory Database, Conservation Reserve Inventory and Pest Management Plan • Gold Coast Nature Conservation Strategy	• An Environmental Management Support System allows predictions to be made in relation to changes to water quality as a result of different land use and development practices, enabling stakeholders to develop future actions to deal with this issue.



Conceptual model for the Logan and Albert Rivers catchment



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Chapter 14

Gold Coast Waterways

Liz O’Brien and Dieter Tracey

Description of the waterways

The Gold Coast catchment covers 5490km^2 and encompasses waterways south of the Logan River, the islands in Southern Moreton Bay and coastal areas south to the New South Wales border. The area is bordered by mountain ranges to the west, a relatively narrow coastal plain and a long stretch of ocean beaches. The northern estuaries flow into the Gold Coast Broadwater, which is protected in the east by South Stradbroke Island (Fig 14.1). The majority of the Gold Coast catchment is contained within the Gold Coast City Council local government area, but a small portion of the western catchment is contained in the Beaudesert Shire Council area.

Figure 14.1: Map of the Gold Coast waterways catchment

The three major rivers in the Gold Coast catchment, the Pimpama, Coomera and Nerang Rivers, all flow to the Broadwater. The Logan and Albert Rivers are considered separately in Chapter 13. There are also large creek catchments: Coombabah Creek, which flows to the Northern Broadwater; Mudgeeraba which flows into the Nerang River, and Tallebudgera and Currumbin Creeks, which flow directly into the Pacific Ocean. There are also numerous other waterways in the catchment that together cover 7% of the land area (Table 14.1).

Table 14.1: Some of the larger waterways in the catchment

Stream name	Length (km)	Stream name	Length (km)
Bonogin Creek	12.1	Clagiraba Creek	7
Coombabah Creek	17.1	Coomera River	46.1
Currumbin Creek	23.7	Guanaba Creek	6.7
Hotham Creek	15.3	Howard Creek	4.8
Little Nerang Creek	28.0	Little Tallebudgera	11.2
Mudgeeraba Creek	26.3	Nerang River	57.8
Pimpama River	29.3	Running Creek	4.8
Saltwater Creek	17.3	Tallebudgera Creek	29.4
Wongawallen Creek	8.2		

The Gold Coast waterways contain large areas of high conservation value within the Moreton Bay Marine Park and Moreton Bay Ramsar site. The region’s low-lying islands of Woogoompah, Kangaroo, and parts of Coomera make up part of the Southern Moreton Bay Islands National Park. McCoys Creek, in the region’s central west is a Protection Zone of the Marine Park, where all forms of collecting are prohibited.

Grazing and natural bush occupy a large percentage of the catchment, the rest of the catchment being taken up by various other land uses (Fig 14.2).

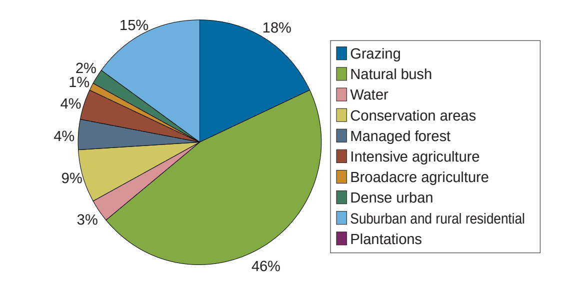


Figure 14.2: Land use in the Gold Coast waterways catchment

Historical (1961) photo of the Gold Coast including Chevron Island and Paradise Waters

Current (1998) photo of the Gold Coast including Chevron Island, Paradise Waters and Broadbeach Waters

State of the waterways

Freshwater

Apart from the Pimpama River, which has a small coastal catchment, the headwaters of the major Gold Coast waterways rise in relatively pristine areas in the McPherson Ranges near the Queensland-NSW border. The upper and middle reaches of these waterways flow through agricultural and rural residential areas. The middle reaches of the Coomera River flow through the forested Land Warfare Centre near Canungra. The Hinze Dam impounds the Nerang River approximately 36km from the river mouth.

The Hinze Dam on the Nerang River

Water quality

The freshwater reaches of the Gold Coast waterways are characterised by generally good water quality, with low to moderate nutrient levels and low turbidity. However, elevated nutrient levels are evident at some sites and nutrient concentrations appear to be increasing in some areas.

Dissolved oxygen

Dissolved oxygen levels are generally high. Some depression of DO in the lower freshwater reaches of the Pimpama River may be associated with acid sulfate soil runoff.

Nutrients

Though lower than in many south-east Queensland rivers and creeks, nutrient levels in some freshwater reaches of the Gold Coast waterways exceed guideline values. In the Pimpama River elevated levels of total nitrogen and ammonia are of concern. Ammonia and total phosphorus concentrations are elevated above QWQ guideline values in the Coomera River catchment, and oxidised nitrogen levels are elevated at the freshwater site on Currumbin Creek. Monitoring data have revealed increases in nutrient concentrations in some sections of the Coomera and Nerang Rivers and in Tallebudgera and Currumbin Creeks from an increase in development in the area.

Water clarity

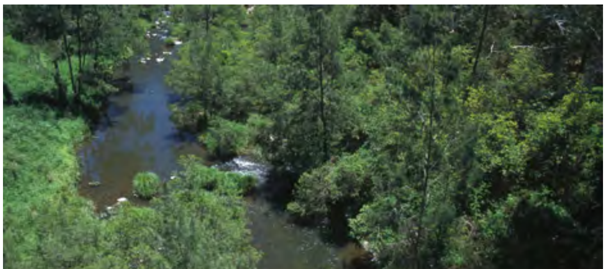
Water clarity in the Gold Coast waterways, as measured by suspended solids and turbidity, usually complies with QWQ guidelines.

Acid sulfate soils

Acidic water in the Pimpama estuary and waterways of the Merrimac-Carrara floodplain results from the disturbance of acid sulfate soils in the catchment. Significantly low pH values were recorded in the middle reaches of the Pimpama River and Hotham Creek in 1996 due to a possible acid sulfate event. Values have steadily improved since then.

Riparian vegetation

The forested upper catchments of the Gold Coast waterways have intact riparian zones that contribute to the generally good water quality in their middle reaches. Significant clearing and degradation of riparian areas are associated with agricultural and other land uses in the mid to upper catchments.



The upper reaches of the Nerang River have good riparian vegetation.

Coastal and estuarine waters

Water quality

In spite of the pressures on the waterways in the Gold Coast catchment, water quality is relatively good.

Nutrients

Concentrations of nutrients in the estuarine Gold Coast catchment are generally within guideline concentrations. However, there are isolated examples of poor water quality in some waterways. Northern areas such as Behm Creek and Jacobs Well generally have high concentrations of nutrients (e.g. TN = 11–38µM). It is proposed that this is mostly a result of nutrient runoff from the mainland. The estuarine section of Pimpama River is high in nitrogen, especially ammonia (7–14µM), and, to a lesser extent, total phosphorus (160–2880µM). Loders Creek has high concentrations of total nitrogen (28–60µM) and total phosphorus (1.6–5µM).

Effluent from the Merrimac and Elanora STPs joins with the Coombabah STP effluent and is diverted to an ocean outfall located at the Southport Seaway entrance to the Broadwater. Due to high tidal flushing and short residence times (2–3 days) in the Broadwater, concentrations of nutrients are low (e.g. TN = 2.8–20µM). However, the extent of the sewage plume from the Seaway is unknown.

The diversion of wastewater from previous discharge sites has resulted in improved water quality in the vicinity of these sites. Concentrations of phosphorus have decreased in the Nerang River, and nitrogen and chlorophyll *a* concentrations have decreased in Tallebudgera Creek (Fig 14.3). The Coomera River, the Broadwater and Tallebudgera and Currumbin Creeks generally have relatively good water quality.

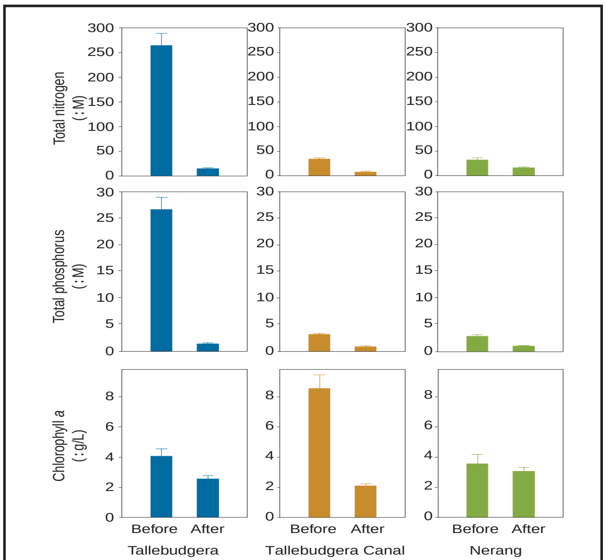


Figure 14.3: Measurements of total nitrogen, total phosphorus and chlorophyll *a* concentrations at the Elanora and Merrimac discharge sites before and after diversion of effluent to the Gold Coast Seaway

Contaminants

Stormwater runoff from an urbanised and rural catchment is likely to contain pesticides as well as nutrients and sediments. Analysis of sediment from the Pimpama and Coomera Rivers reveal traces of Dieldrin that are above the ANZECC screening guideline but below the recommended maximum. Other pesticides have also been detected in these and other waterways but are below screening guidelines.

Marine organisms are also capable of accumulating toxicants such as pesticides, bacteria and metals in their tissue. Some canals can experience poor flushing and analyses indicate that the biota (oysters) are accumulating pesticides, bacteria and metals.

Human health—primary contact

Due to the high concentration of water-based recreation in the Gold Coast region, sites are monitored to detect faecal contamination. Concentrations of faecal coliform units are generally within the levels recommended by NHMRC, but occasionally exceed the recommended concentrations during periods of high rainfall. It is proposed that animals, not humans, are the potential source of contamination in these instances.

Phytoplankton

Since the removal of effluent discharge to Tallebudgera Creek, chlorophyll *a* concentrations have decreased and no algal blooms have been detected. The high level of flushing in the Nerang River estuary appears to prevent the accumulation of algal biomass. However, there are indications of irregular algal blooms in the estuarine section of the Pimpama River (Fig 14.4) and an occasional bloom in the freshwater reaches of the Coomera River.

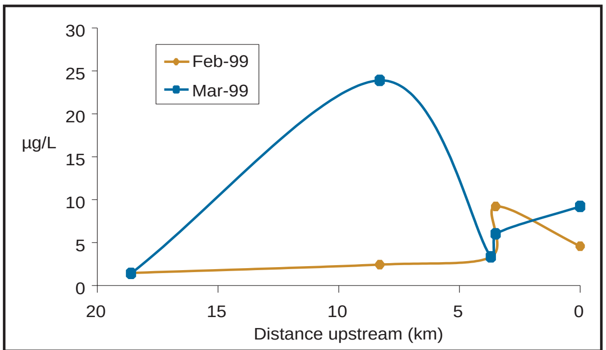


Figure 14.4: Variation in concentrations of chlorophyll *a* in Pimpama River indicates an algal bloom in March in the mid-estuarine section of the river.

Turbidity

The high turbidity occasionally experienced in the Northern Broadwater and Behm Creek is most likely to be a result of resuspension due to strong tidal currents. Concentrations of suspended solids in the Pimpama River are high in estuarine areas and have increased. Sediment deposition has been reported in Coombabah Lake and Loders Creek.

Seagrass

Extensive seagrass meadows occur in the Gold Coast area north of the Broadwater. These beds comprise mainly two species, *Zostera capricorni* and *Halophila ovalis*. Seagrass has recently disappeared from a long-term monitoring site in the northern Broadwater, but this loss is most likely to be due to the dynamic sand movement that occurs in this well-flushed region (Fig 14.5).

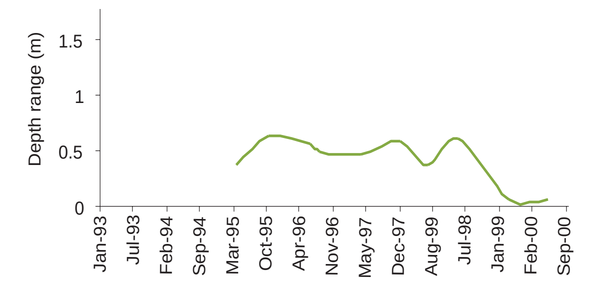


Figure 14.5: Seagrass depth range for the northern Broadwater in the Gold Coast waterways (EHMP)

Riparian vegetation

A considerable area of mangrove forest occurs in the northern regions of the Gold Coast and remnant communities inhabit the tidal sections of the waterways. Extensive areas of saltmarsh and mangroves have been lost through urban development and construction of artificial wetlands.

Table 14.2: Declared Fish Habitat Areas in the Gold Coast waterways and the areas they cover

Fish Habitat Area	Covers:
Jumpinpin-Broadwater	Jumpinpin and Broadwater from the southern extremity of Crab Island to the south-western end of North Stradbroke Island
Pimpama	McCoys Creek and parts of the Pimpama River
Coomera	Coomera River from Paradise Point to north of Coomera Island
Coombabah	Coombabah Lake and part of Coombabah Creek upstream of Saltwater Creek
Tallebudgera	Tallebudgera Creek from 800m upstream of the Pacific Highway crossing to the Old Railway Line Crossing
Currumbin	Currumbin Creek adjacent to the Palm Beach Currumbin High School

Biodiversity

There are a number of declared Fish Habitat Areas in the Gold Coast (Table 14.2). These areas are designed to protect fish habitats and minimise disturbances to the environment. Coombabah Creek is also a designated RAMSAR and JAMBA site. The waters off the Gold Coast are also reported to support at least 1600 marine species. This is indicative of the good water quality in this region.

Pressures on the waterways

Population growth

Population growth in coastal areas of the catchment is amongst the highest in the State: over 400 000 people live in the catchment. The growth rate in the Gold Coast region is currently predicted to be 2.2% per annum for the period 2006–2011. However, this forecast is a decrease from previous years. In addition to the high growth rate, a majority of the coastal sections of the Gold Coast are intensively populated.

Watercourses in the Gold Coast area have been altered to satisfy demands of residents for waterside living. Dense canal estates are common along the coastal strip of the Gold Coast and account for 78% of canal estates in Queensland. Intensive housing on waterways provides a direct route for urban runoff that can include a variety of nutrients and chemicals, including pesticides (especially termiticides) and herbicides. Animal faeces have been identified as a potential source of faecal contamination in these waterways. Dredging may also occur to maintain channel depths within the canals for recreational vessels.

Since 1996: increased

Tourism

The Gold Coast is a very popular tourist destination, an estimated 12% of the population being visitors. The beaches, in particular, are a major tourist attraction. As a result, there is a 20% increase on the national average landfill waste produced per resident and an added load on wastewater processing plants. There is also, however, a strong pressure to maintain high water quality in the waterways and along the coast for aesthetic reasons.

Since 1996: increased

Sewage treatment plants

Intensive urbanisation produces a concentration of wastes and a resultant increase in processing infrastructure. Gold Coast Water processes wastewater at four STPs located in the region. Ninety percent of the processed wastewater is from domestic use and 10% is sourced from industry. Nutrients and pathogens are the major threats to the health of waterways from these facilities.

Three of the four STPs, Elanora, Merrimac and Coombabah, release their effluent to the Gold Coast Seaway (Table 14.3). Release is timed to coincide with the outgoing tide to promote maximum dilution of effluent. By 2003, all STPs in the Gold Coast will be treating wastewater to a tertiary level. Some effluent from STPs is beneficially reused to irrigate golf courses, playing fields, public gardens and nature strips. Biosolids from the plants are also reused in composting. Alum sludge, a by-product of drinking water purification, is processed with wastewater at Merrimac STP to increase the phosphorus removal capacity of the plant. In addition to the STPs, there are 13 000 septic systems in the Gold Coast City Council area.
Since 1996: two plants decommissioned, one upgraded

Table 14.3: Three STPs in the Gold Coast annually process high volumes of wastewater, which is then routed to the Gold Coast Seaway in the Broadwater.

STP	Effluent (ML/yr)
Coombabah	23 572
Elanora	9 505
Merrimac	9 814

Water storage

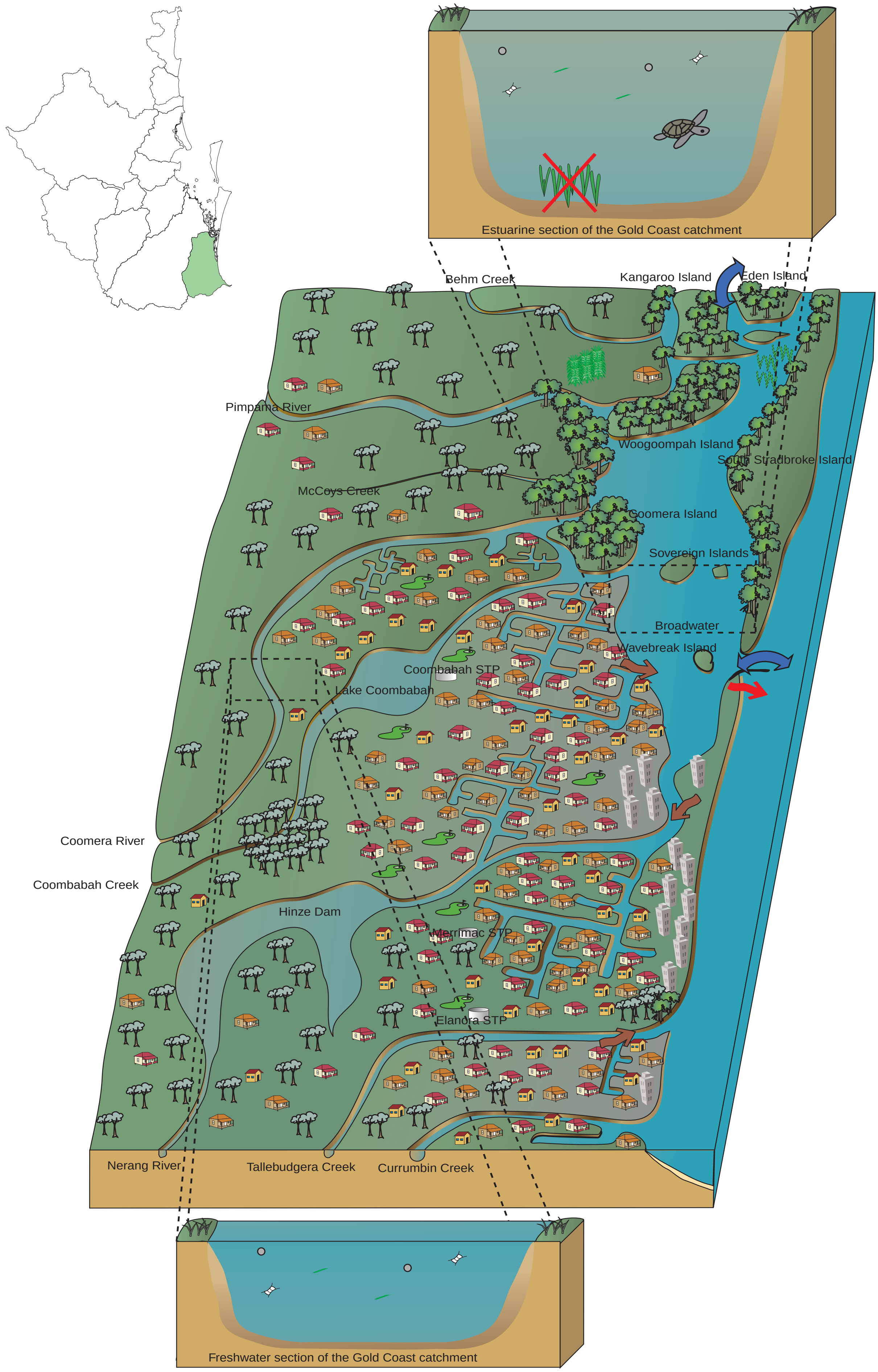
The Nerang River has been modified to accommodate the Hinze Dam, which is the major water supply for the Gold Coast. The required environmental flow for the Nerang River is not known and water is currently released at a rate designed to satisfy the needs of irrigators.
Since 1996: no change in capacity but insufficient data regarding extraction volume

Land use

In the catchment, overland runoff during high rainfall is likely to include sediment, nutrients, herbicides and pesticides that can potentially enter waterways. Disturbance of acid sulfate soils has the potential to reduce the pH of waterways during high rainfall.
Since 1996: increased development

Responses to the pressures on the waterways

Issues	Local initiatives	Responses
Population growth		• The SEQ Regional Framework for Growth Management is the basis for planning for the projected increases in the regional population. All member organisations are using the framework to guide sustainable growth in the region through a range of implementation mechanisms including planning schemes, corporate plans and a range of service delivery programs.
Tourism		• Range of local programs and plans outlining management actions to deal with this issue.
Sewage treatment plants	• Logan, Coomera and Southern Moreton Bay Regional Wastewater Management Study • Northern Wastewater Strategy and Reclaimed Water Scheme • No biosolids on-site at Merrimac, Elanora and Coombabah STPs	• An agreed process for achieving sustainable nitrogen loads from major point sources is outlined in the SEQRWQMS. This process allows stakeholders the flexibility to determine the most efficient means for achieving sustainable loads.
Water storage		• Many of these issues will be dealt with during the development of the Moreton Region Water Resource Plan, which includes development of environmental flow management strategies. This Water Resource Plan is scheduled for completion in 2005.
Land use	• Catchment Coordinator appointed • Investigating development of a Catchment Management Strategy • Planning for catchment management plans in Coombabah, Saltwater, Tallebudgera, Mudgeeraba, Worongary and Flatrock Creeks • Waterwatch in the city area • Landcare/Catchment groups in Coombabah-Saltwater, Pimpama-Hotham, Loders Creek, Biggera Creek, Mudgeeraba Creek, Tallebudgera Creek, Numinbah and Springbrook • Landcare groups at Numinbah • Nature Conservation Strategy and Aquatic and Riparian Ecological Assessment • Gold Coast Council is developing a stormwater total management plan, has prepared a best practice guide for stormwater from building sites, is developing approval conditions under the Integrated Planning Act, is installing SQIDs, and participates in the Urban Stormwater Information Group. • Voluntary Code of Practice by Queensland Farmers Federation	• An Environmental Management Support System allows predictions to be made in relation to changes to water quality as a result of different land use and development practices, enabling stakeholders to develop future actions to deal with this issue. • An Environmental Planning Project is currently under way to develop a range of tools that can be used by local governments, rural property owners and industry organisations to minimise impacts on the region's catchments and waterways. It is anticipated that stakeholders will develop future management actions based on the outcomes of this project. • In 2002, stakeholders of the Partnership will begin to identify priority areas for riparian and stormwater management and set targets for on-ground works. This process will focus on implementing on-ground works to deal with this issue.



Conceptual model for the Gold Coast waterways

Sources of information

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Environmental Protection Agency

The lower parts of the Nerang River are dominated by urban development.

Chapter 15

Moreton Bay

Angela Grice, Paul Maxwell and Ivan Holland

Description of the waterways

Moreton Bay is a semi-enclosed embayment 80km in length, ranging in width from 35km in the north to 5km in the south. Many of the major rivers and creeks in south-east Queensland flow into the Bay; these include the Caboolture, Pine, Brisbane, Bremer and Logan Rivers. The combined catchment area of rivers and creeks discharging into Moreton Bay is approximately 22 000km^2, while the area of the Bay itself is (1523km^2). This represents roughly a 14:1 ratio of catchment to bay area (Fig 15.1). Moreton Bay was declared a Marine Park in 1993 and has been listed as a wetland of international significance under the Ramsar Convention.

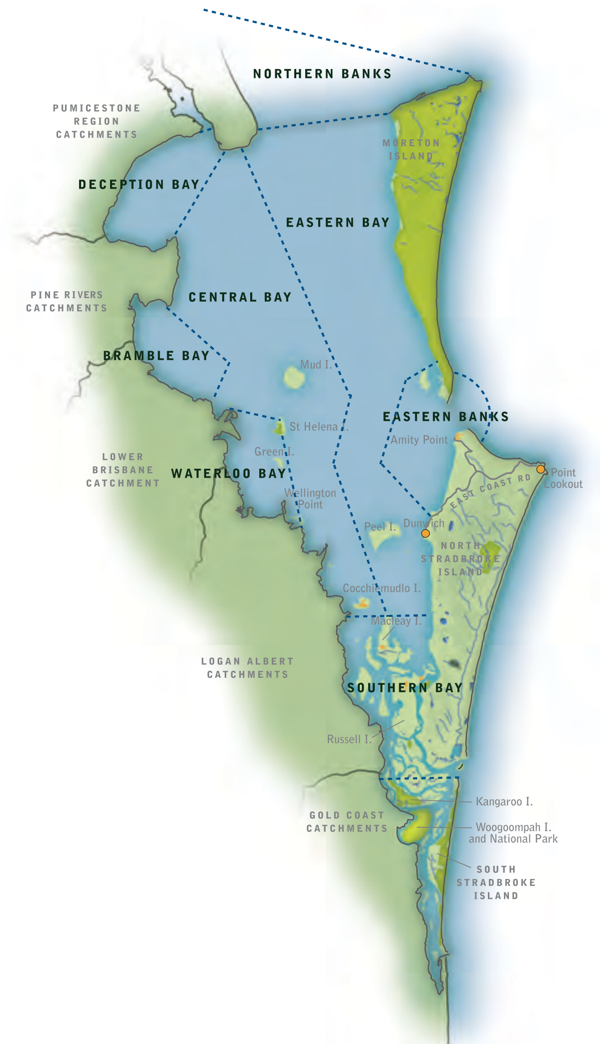
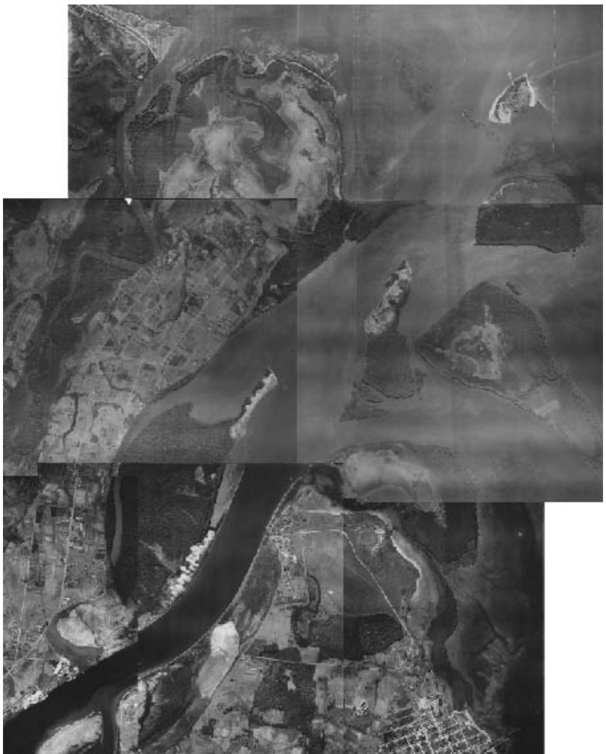


Figure 15.1: Map of Moreton Bay with different zones

TheBay is enclosed on three sides but is well flushed by strong tides and winds in its eastern and central portions. Tides circulate water clockwise and the majority of sediments are deposited on the northern side of river mouths.



Department of Natural Resources and Mines

Historical (1946) photo of the Brisbane River mouth

Department of Natural Resources and Mines

Current (1997) photo of the Brisbane River mouth

Moreton Bay includes three major islands, Moreton, North Stradbroke and South Stradbroke, which form its eastern barrier. The western side of Moreton Bay is divided into Deception Bay, Bramble Bay and Waterloo Bay. The remainder of the Bay is divided into five regions: Northern Banks, Central Bay, Eastern Bay, Eastern Banks, and Southern Bay.

Flora and fauna

Moreton Bay is home to a very diverse range of flora and fauna, largely due to the biogeographical overlap of tropical and subtropical taxa. Ecosystems occurring within this region include rocky and coral reefs, seagrass meadows, saltmarshes, mangroves and ocean beaches.

Macroalgae

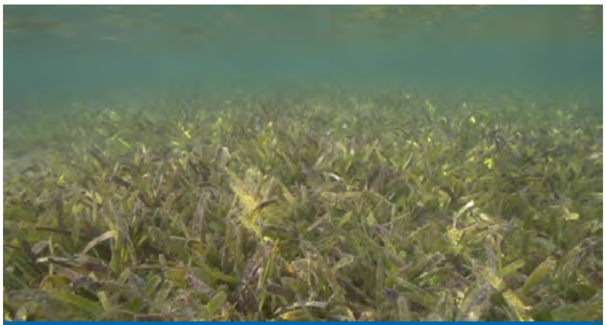
Numerous species of macroalgae are found on rocky reefs and within seagrass meadows in Moreton Bay. Approximately 285 species of Chlorophyta, Phaeophyta and Rhodophyta have been identified within the Bay, with total area coverage of more than $106 km^2$. The macroalgae of Moreton Bay comprise three biogeographic groups. Tropical and subtropical groups predominate (64%), some having their southernmost distribution limits in the Bay. Temperate species make up 15.2% of the species identified, and cosmopolitan species make up the remaining 20.8%. Some of Moreton Bay's macroalgal species are found in many different habitats, whereas others are restricted in their range by ecological needs. Macroalgal communities in Moreton Bay are just as severely impacted by prolonged pollution as other communities, showing decreases in species diversity, reduced community complexity and a shift in community dominance from larger macroalgae to blooms of fewer opportunistic and stress-tolerant species like *Ulva* sp., *Cladophora* sp. and *Caulerpa taxifolia*.

Cribb, A.B. *Seaweed of Queensland*

Macroalga *Caulerpa* found in Moreton Bay

Seagrass

Seagrass meadows are found in shallow, subtidal and intertidal areas of Moreton Bay and cover almost $250 km^2$ (1.1%) of the Bay's area. Despite this relatively small coverage, seagrasses form one of the critical habitats for biodiversity in the region. They provide a major food source for dugongs and turtles, and nursery grounds for commercially important species including prawns. Additionally, seagrasses assimilate and recycle nutrients within the ecosystem, trap sediments and stabilise the seabed. Seven seagrass species are found in the bay: *Zostera capricorni*, *Halophila ovalis*, *Halophila spinulosa*, *Halophila decipens*, *Halodule uninervis*, *Syringodium isoetifolium* and *Cymodocea serrulata*. The sensitivity of seagrasses to changes in water quality has led to the use of these plants as biological indicators of long-term trends in water quality. However, the effects of water quality on the biota linked to seagrass meadows in Moreton Bay is largely unknown.



Chris Roelfema, Marine Botany, UQ

Seagrass beds in Moreton Bay

Fringing vegetation

Extensive mangrove forests line intertidal and estuarine waterways and cover approximately $140 km^2$ (0.6%) of Moreton Bay's area. Eight species of mangroves are found in Moreton Bay: *Acrostichum speciosum*, *Aegiceras corniculatum*, *Avicennia marina*, *Bruguiera gymnorrhiza*, *Ceriops australis*, *Excocecaria agallocha*, *Lumnitzera racemosa* and *Rhizophora stylosa*. They provide important habitat for the juveniles of many fish, crab and prawn species and are important as roost sites and feeding grounds for local and migrating birds. Mangroves cover large areas on the islands and on the mainland coasts of Moreton Bay. Mangroves play an essential role in stabilising coastal foreshore areas and in binding up fine silt sediment. Erosion is reduced, along with turbidity, and deeper estuarine channels are maintained.

Coastal wetland areas including saltmarshes, samphire, grassland, swamp oak, sedgeland, paperbark and heath communities cover approximately $190 km^2$ in Moreton Bay and are found fringing its islands and coastal areas.

Healthy Waterways Library

Mangroves cover large intertidal areas in Moreton Bay.

Coral

Coral communities are broadly distributed throughout Moreton Bay. They occur on the mainland coast at Wellington Point and Cleveland, on the islands of Waterloo Bay; Peel, Goat, Coochiemudlo, and Macleay Islands; and at Myora off North Stradbroke Island. Corals require a hard substrate on which to attach and most are found in Moreton Bay at depths of less than 3m. Approximately 40 species of corals have been identified from reefs and are often patchy and interspersed amongst seagrass and sandy substrates. The coral assemblages found in western Moreton Bay are comprised mainly of stress-tolerant species (e.g. *Favia speciosa*), whereas in the more pristine waters of eastern Moreton Bay species diversity and coral cover are considerably greater.

Various corals found in Moreton Bay

Other fauna

Approximately 600 dugongs inhabit Moreton Bay. Dugongs are listed as vulnerable to extinction by the World Conservation Union due to the large-scale hunting that occurred around the end of the 19th century. Dugongs graze on the shallow seagrass beds in Moreton Bay, highlighting the importance of seagrass conservation.

Dugongs graze on the shallow seagrass beds in Moreton Bay.

Moreton Bay is also an important feeding ground for approximately 10 000 marine turtles. Six species have been identified: loggerhead turtle, green turtle, hawksbill turtle, leatherback turtle, olive ridley turtle and flatback turtle. Only the green, loggerhead and hawksbill turtles have resident populations in the Bay.

More than 273 species of birds from 65 families have been recorded in Moreton Bay; these include 33 species of migratory and 11 species of resident shorebird. The Moreton Bay-Great Sandy Straits Region is the second most important migratory shorebird refuge in terms of population numbers in Queensland. For roosting and feeding sites it is particularly important for seven species of migratory shorebirds: Pacific golden plover (*Pluvalis fulva*), grey-tailed tattler (*Heterosceles brevipes*), lesser sand plover (*Charadrius mongolus*), eastern curlew (*Numenius madagascariensis*), bar-tailed godwit (*Limosa lapponica*), curlew sandpiper (*Calidris ferruginea*) and the pied oystercatcher (*Haematopus longirostris*). The protection of roosting and feeding sites in Moreton Bay under the Ramsar Convention is vitally important for the protection of shorebird populations.

Moreton Bay is home to many shorebirds.

Distribution of invertebrate and fish communities

Approximately 3225 species of invertebrates and 713 fish species have been recorded in Moreton Bay; of these, 27 are apparently endemic to the area. In general, high species numbers occur around the mouth of the Brisbane River and along the western shores of the Bay, gradually receding to the north and east. This is reflective of the estuarine influence from the many rivers and creeks that flow into Moreton Bay, which presumably provide an overlay of nutrient-rich sediments and a variety of particle sizes supporting a variety of feeding types. A second centre of high diversity is around the northern end of North Stradbroke Island and includes Peel, Bird and Goat Islands and Myora. The assemblages there comprise predominantly marine-based species forming an estuarine/marine dichotomy in terms of species distribution in Moreton Bay. The sandy sediments of the northern and eastern openings of the Bay are extremely species-poor.

The Bay serves as a refuge for several species of both temperate and tropical animals, and in some cases is the boundary of their ranges. This is particularly evident for fish species, where 141 species are at the southern limit of their range and 24 at their northern limit.

State of the waterways
Northern Banks of Moreton Bay

The Northern Banks is a relatively pristine region encompassing the northern region of sand banks in Moreton Bay, between Bribie and Moreton Islands.

Water quality

Water quality in the Northern Banks is excellent due to the absence of any major point source or diffuse loads and constant flushing with oceanic water through North Passage. All water quality parameters meet the criteria for ANZECC guidelines. Concentrations of both nitrogen and phosphorus are very low. There is a high degree of light penetration through the water column due to low levels of suspended particles. This is indicated by high secchi disc readings that range from 4m to greater than 10m depth, and very low turbidity levels (<1NTU).

Phytoplankton

A diverse community of phytoplankton occurs in the water column and on the shallow sand banks of northern Moreton Bay. This community exhibits low productivity levels due to the low nutrient concentrations and strong water movement in the area. Chlorophyll *a* levels in the water column are consistently less than 1mg/L (Fig 15.2).

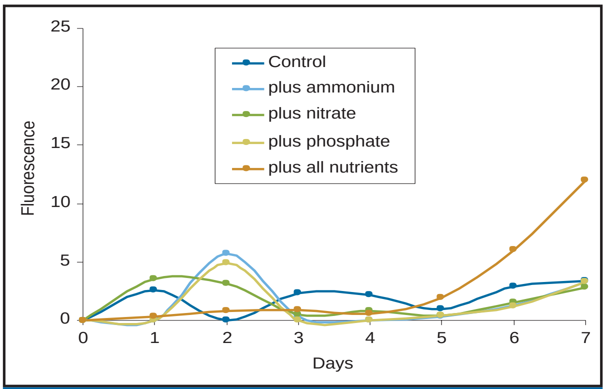
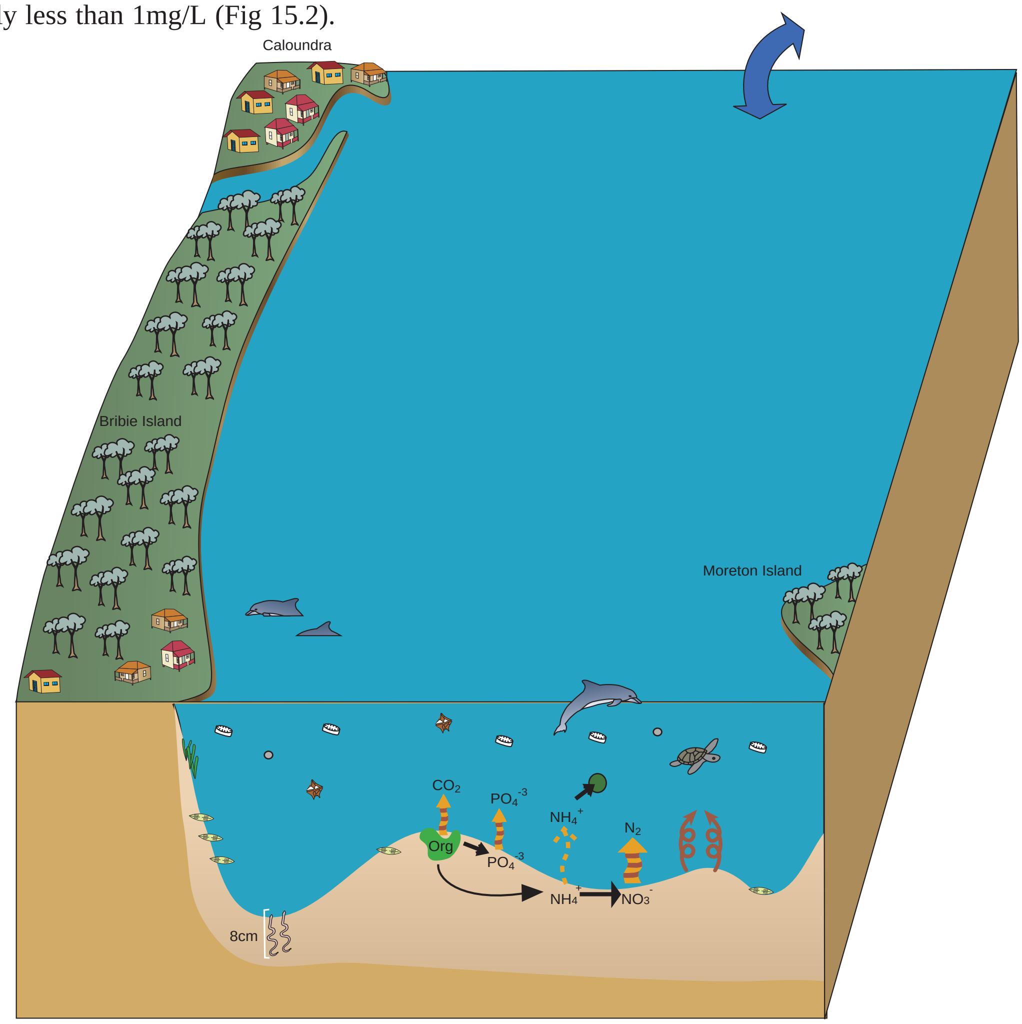


Figure 15.2: Phytoplankton growth response to nutrient enrichment is relatively low in northern Moreton Bay as phytoplankton are adapted to low nutrient environments.

Sediments

The sandy bottom sediments of the Northern Banks are constantly resuspended and shifted by strong currents, resulting in an aerobic environment in the sediments. Sediment nutrient processes are intact in this region, as indicated by efficient denitrification and little to no nutrient flux from the sediments. Sparse seagrass meadows occur on some of the sand banks in this region. Due to the mobile nature of the sandy sediments, the species diversity of benthic invertebrate fauna in this zone is typically poor.



Conceptual model for Northern Banks

Eastern Bay

Eastern Bay is a relatively pristine region with excellent water quality and ecosystem health. It is home to a diverse array of ecosystems including coral communities, extensive seagrass beds and mangrove forests. This region extends through the eastern section of Moreton Bay, encompassing the western side of Moreton Island and the top half of North Stradbroke Island. The northern and southern limits of Eastern Bay are Comboyuro Point on Moreton Island and Macleay Island in the southern Bay.

The area around Peel Island has been declared a Fish Habitat Area, covering the land below the high tide mark and the water covering the land and foreshores of Peel Island, Bird Island and Goat Island and the tidal land to the depth contour of 2m below low water.

Water quality

Water column nutrient concentrations are relatively low in Eastern Bay and overall water quality is excellent, all water quality parameters meeting ANZECC guidelines. Nitrogen and phosphorus levels are low year round and there is excellent light penetration through the water column. Flushing through North Passage, South Passage and Jumpinpin ensures that minor contributions from stormwater runoff and sewage discharges do not reside and impact on the system.

Phytoplankton

Phytoplankton communities in this region are diverse and are adapted to low-nutrient environments. Phytoplankton biomass and productivity are low due to the low nutrient concentrations in the water column and relatively strong currents. Populations of benthic microalgae are high in biomass, particularly in the shallower regions (<5m depth).

Sediments

Sediment nutrient processes are intact. Nitrogen input predominantly arises from nitrogen fixation associated with seagrasses, and there is little release of nitrogen or phosphorus to the water column. The water and sediments around Myora and Peel, Bird and Goat Islands contain the highest species diversity in Moreton Bay. This is due in part to the presence of well-developed coral reefs and a mix of hard and muddy-sand substrates.

Coral

The most extensive coral community in Moreton Bay occurs at Peel Island, extending along the northern and western sides of the island. The coral communities at Peel Island are dominated by *Favia* species (brain corals) adapted to relatively turbid environments. This is in contrast with the coral communities adjacent to Moreton and Stradbroke Islands (e.g. at Tangalooma and Myora), which are comprised largely of *Acropora* species and require excellent water quality.

Eastern Banks

The Eastern Banks region of eastern Moreton Bay encompasses more than 100km^2, and includes the Moreton, Boolong, Chain, Maroom and Amity Banks. This relatively pristine area of Moreton Bay has extensive seagrass meadows covering large portions of the sandy banks, and receives considerable flushing with oceanic water via the Rous Channel.

Chris Roelfsema, Marine Botany, UQ

Dugong feeding trail through a seagrass meadow in Eastern Moreton Bay

Water quality

Water quality at the Eastern Banks is also excellent. Nutrient and turbidity levels in the water column are the lowest in Moreton Bay. This is due to the absence of any major sediment and nutrient inputs from point and diffuse sources, and daily flushing with oceanic water through the Rous Channel.

Seagrass

The depth of seagrass beds in this region is evidence of the excellent light penetration through the water column. For example, the seagrass species *Zostera capricorni* occupies a 3m depth range at Crab Island, which is more than twice the depth range of seagrasses in the western embayments (Fig 15.3). All seven Moreton Bay seagrass species can be found in the Eastern Banks region.

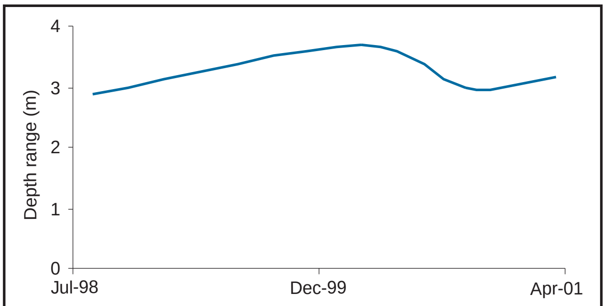


Figure 15.3: The seagrass *Zostera capricorni* can occupy a 3m depth range in Eastern Banks. Excellent water quality enables sufficient light to penetrate through the water column at the these depths for seagrass growth.

Phytoplankton

Phytoplankton abundance at Eastern Banks is extremely low due to low nutrient availability, and unlike phytoplankton from the river estuaries, this community demonstrates little ability to respond to nutrient-enriched conditions.

Biodiversity of fauna

The Eastern Banks is a part of a distinct centre of high invertebrate diversity, especially in the region north of Myora. Recruitment to this area is apparently sustained by the influx of clean coastal waters through the Rous and Rainbow Channels. Many of the species found here are considered the southern outliers of a more tropical Great Barrier Reef assemblage. The South Passage around Amity is a centre for high fish species diversity predominantly comprised of marine-based species.

Lyngbya blooms

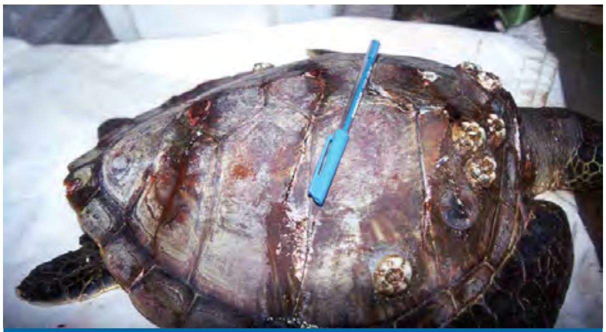
In 2000, the first major outbreak of the cyanobacteria *Lyngbya majuscula* was recorded on Amity and Moreton Banks. Dense quantities of *Lyngbya* established on these seagrass beds, smothering underlying seagrasses. A similar outbreak occurred in 2001. These outbreaks are of grave concern, particularly as the seagrass beds affected are the primary grazing meadows for the dugongs and turtles that inhabit Moreton Bay. The impact of these outbreaks on the seagrass ecosystem and associated animals is currently under investigation.

Healthy Waterways Library

Lyngbya majuscula blooms have occurred on Amity and Moreton Banks over the past few years

Conservation zone and Fish Habitat

The Eastern Banks are used as a primary grazing area by dugongs and turtles and has been designated as a Conservation Zone of the Marine Park as a result. The Eastern Banks comprises two turtle and dugong ‘go slow areas’ which were declared in 1997 to reduce the incidence of boat strike on the marine park’s turtle and dugong populations. The Rous Channel provides an important access for boats as well as resident dugongs and turtles that travel between the East Australia Current and Moreton Bay. Fibropapilloma, a type of tumour found on turtles, has been recorded in 20% of green turtles examined on the Moreton Banks. The cause of the tumours is unknown.



Environmental Protection Agency

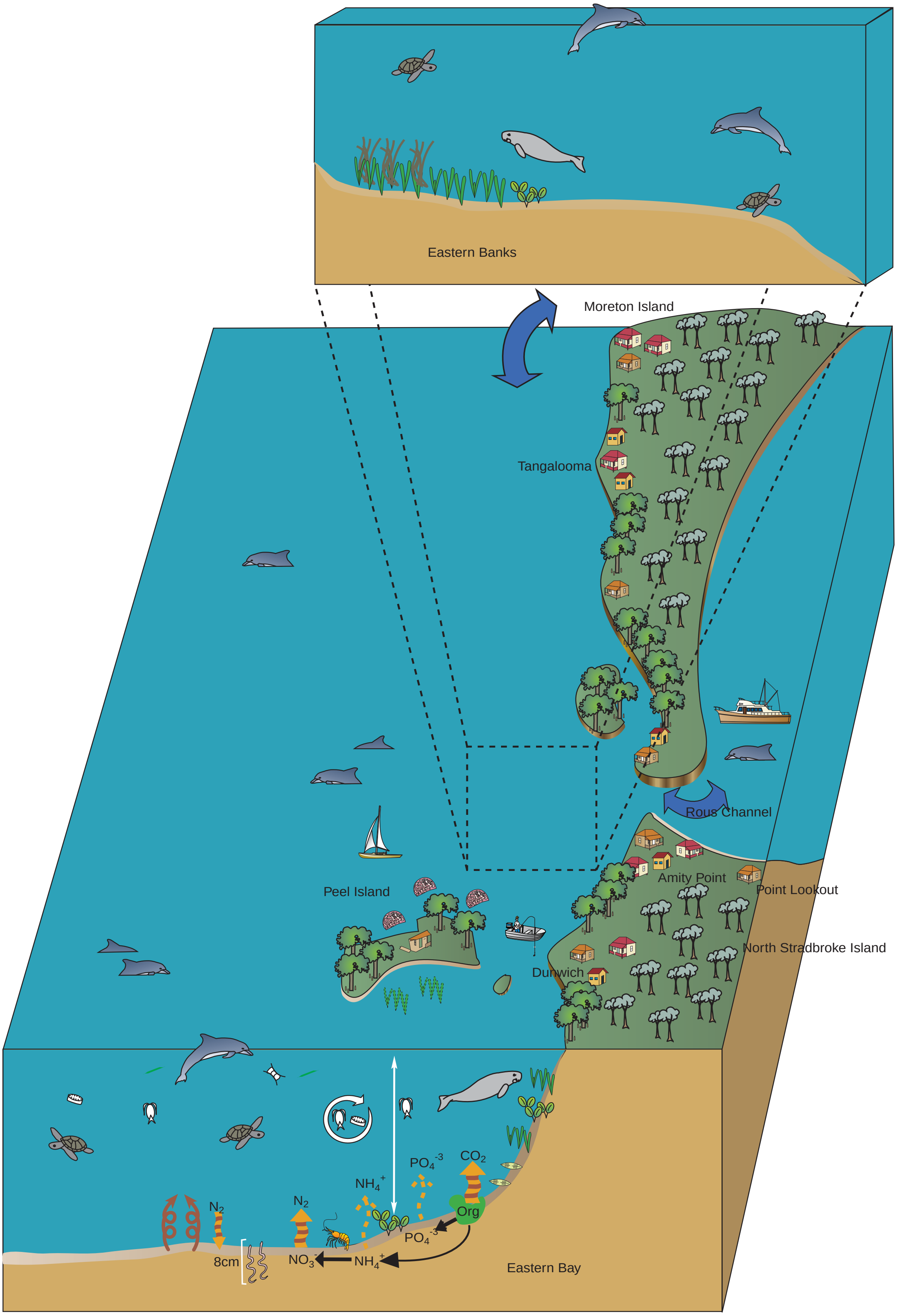
Turtles in Moreton Bay have recently been found with Fibropapilloma but the cause is not known.

Eastern Banks is contained in two declared Fish Habitat Areas, Myora-Amity Banks and Moreton Banks, due to its importance as a prawn and fish nursery area. The Myora-Amity Banks Fish Habitat Area covers the tidal lands and the waters covering the lands of the Chain, Maroom, Amity, Warragamba and Pelican sand banks down to the 2m depth contour below low water and covers part of the North Stradbroke Island foreshores between south of Amity to north of Dunwich.

The Moreton Banks Fish Habitat Area covers the Coonungai and Boolong Banks and extends north to Tangalooma, covering to the 2m depth contour below low water. Species of value to fisheries in both areas include bream, black kingfish, flathead, garfish, school mackerel, snapper, spotted mackerel, sea mullet, tailor, whiting, banana prawns, eastern king prawns, bay prawns, mud crabs, sand crabs and oysters.

Mangroves

The south-western part of Moreton Island has large stands of fringing mangroves, particularly on Crab Island, which maintains a large bird population. Large natural increases in mangrove density have been recorded on the south-west side of Moreton Island.



Conceptual model for Eastern Moreton Bay and Eastern Banks

Northern Deception Bay

Water quality

Water quality in this region is generally good due to a combination of flushing from North Passage and Pumicestone Passage and relatively low inputs of nutrients and sediments from the Caboolture River. Residence times in Northern Deception Bay are predicted to be between 55 and 58 days.

Nutrients

During dry periods, ammonium and nitrate concentrations in Northern Deception Bay are commonly below detectable levels (200nM N). In wet periods these nutrient levels increase but tend to remain relatively low compared to other coastal areas. Levels of inorganic phosphorus are also relatively low (dry periods <500µM P; wet periods <1000µM P). Elevated levels of total nitrogen occur periodically in Deception Bay, however, which can be attributed in part to abundant phytoplankton present in the water column. No detectable sewage plume extends from the Caboolture River, as inorganic nitrogen discharged from this source is processed biologically within the Caboolture River estuary.

Phytoplankton

Phytoplankton levels are highest at the mouth of the Caboolture River and decrease with distance from the coast (chlorophyll *a* range: 1–3mg/L). The highest phytoplankton levels occur following major wet periods in summer, resulting in chlorophyll *a* concentrations of up to 8mg/L.

Water clarity

Turbidity in Northern Deception Bay is relatively low throughout the year (range: 0–20NTU). Turbidity is highest near the mouth of the Caboolture River and decreases with distance from the coast. Rainfall events deliver sediment from the surrounding catchment but resuspension of existing fine sediment also contributes to elevated levels. Light penetration through the water column is sufficient for the requirements of seagrasses in this area for most of the year (secchi depth >1.7m).

Sediments

Sediment nutrient processes in Northern Deception Bay are largely intact. Denitrification by anaerobic bacteria occurs in the sediments and relatively low rates of ammonium exude from the sediment into the water column. Toxicant levels in the sediments meet ANZECC guidelines. The sediments of Northern Deception Bay have typically poor assemblages of invertebrate infauna and mobile epibenthic species. The distribution of fish species shows a shift toward more estuarine-based species and the region is not as species-rich as estuarine areas further south in Moreton Bay.

Seagrass

Northern Deception Bay currently supports extensive seagrass meadows, comprising mixed beds of *Zostera capricorni*, *Halophila ovalis*, *Halophila spinulosa* and *Syringodium isoetifolium*. Seagrass meadows in this area are generally healthy, although the occurrence of *Lyngbya* blooms has led to localised seagrass loss adjacent to Godwin Beach since 1996.

Lyngbya blooms

One of the greatest current threats to the ecosystem health of Moreton Bay is the proliferation of the toxic cyanobacterium *Lyngbya majuscula*. Outbreaks of *Lyngbya* in Northern Deception Bay have occurred with increasing frequency and magnitude throughout the late 1990s. In 1999, 100 fishers and 1300 swimmers in Australia reported human health problems including breathing difficulty and skin and eye irritations from contact with *Lyngbya*. The extent of the impact of *Lyngbya majuscula* on ecosystem health has not yet been fully ascertained. What is known is that *Lyngbya* affects crab and fish catches, smothers seagrass, deters fish, and releases nitrogen and other nutrients as it decomposes. *Lyngbya* also washes up onto beaches and mangroves, smothering pneumatophores and leading to mangrove dieback.

The causes of the *Lyngbya* outbreaks in Moreton Bay are currently under investigation. It has been suggested that the stimulation of *Lyngbya* outbreaks is related to high levels of water column iron and the presence of humic substances that make the iron bioavailable to *Lyngbya*, resulting from terrigenous runoff (Fig 15.4).

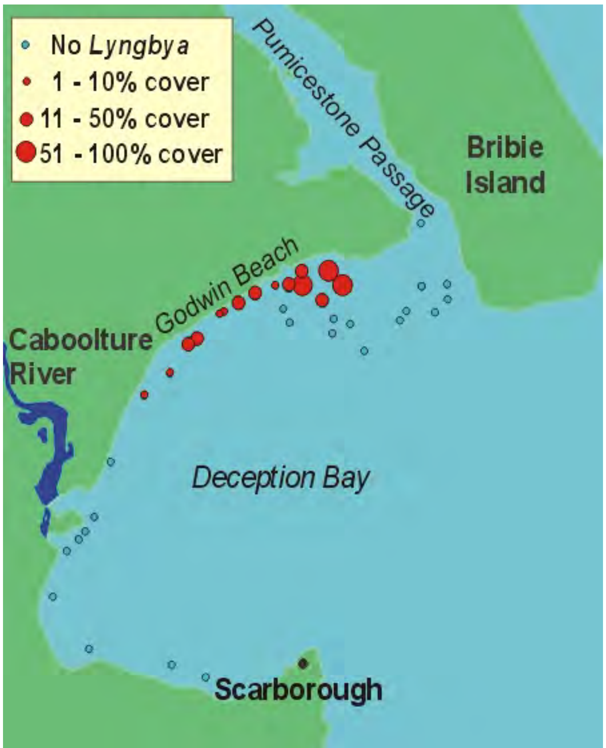


Figure 15.4: Percentage cover of *Lyngbya majuscula* in Deception Bay, February 2001

Macroalgae

Extensive beds of the green alga *Caulerpa taxifolia* inhabit this region. This macroalga was first reported in Moreton Bay over 50 years ago but there is current concern that its distribution is increasing and the species is out-competing existing seagrasses in some areas. Invasion by *C. taxifola* has been shown to lead to impoverishment of algal and seagrass communities and causes substantial changes in the fauna associated with the original vegetation.

Mangroves

Mangrove forests in Northern Deception Bay are largely intact, but are coming under increasing threat from urban developments.

Jellyfish

Large numbers of the jellyfish *Catostylus mosaicus* occur periodically in Deception Bay. This is possibly related to large populations of zooplankton occurring in this region, which would provide a sizeable source of food for the jellyfish.

Southern Deception Bay

Southern Deception Bay is considered separately from Northern Deception Bay because it is more heavily influenced by nutrient and sediment loads from the Caboolture River and surrounding catchment.

Water quality

Water quality in Southern Deception Bay is slightly more degraded than in Northern Deception Bay, possessing greater overall nutrient, turbidity and phytoplankton levels, particularly during the warmer months. This can be attributed to a greater influence of sediment and nutrient loads from the Caboolture River, the influence of the Brisbane River, and reduced flushing times via the North Passage. Residence times in Southern Deception Bay range from 58 to 62 days.

Nutrients

During the dry season, nitrate and ammonium levels in Southern Deception Bay are commonly below detection limits, similar to Northern Deception Bay. However, in the warmer months levels of nutrients and sediments are slightly elevated. As with the Northern section, no sewage plume has been detected in Southern Deception Bay.

Phytoplankton

Phytoplankton levels in Southern Deception Bay are generally quite low during dry periods. However, in summer phytoplankton levels are considerably higher (Fig 15.5). Phytoplankton biomass and diversity are intermediate between Bramble Bay and Eastern Moreton Bay. There is an unusually high proportion of dinoflagellates in Southern Deception Bay.

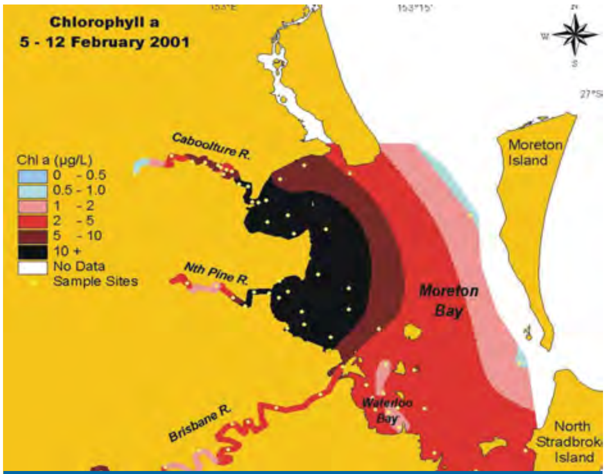


Figure 15.5: Phytoplankton biomass in Moreton Bay following a rain event, February 2001. Water quality in Southern Deception Bay may be affected by the Brisbane River plume during wet periods.

Sediments

The sediments of Southern Deception Bay are somewhat impacted. Moderate levels of denitrification occur in the sediment, and some nutrients are released from the sediment into the water column. As in Northern Deception Bay, the sediments of Southern Deception Bay have typically poor assemblages of invertebrate infauna and mobile epibenthic species.

Fish Habitat Area

Two sections of Southern Deception Bay have been declared Fish Habitat Areas: Deception Bay and Kippa Ring. The Deception Bay Fish Habitat Area covers the tidal land and the waters covering the land of the Caboolture River, Burpengary Creek and into Deception Bay to the southern alignment of Emerald Avenue until the 2m depth contour. The Kippa Ring Fish Habitat Area covers the land below high water mark until the 2m depth contour below low water and extending east from Coman Street to Nathan Road.

These areas are a hauling ground for net fishermen and an important juvenile finfish and crustacean area, with a local recreational crab fishery. Species of value in both habitat areas include; Australian bass, bream, blue salmon, estuary cod, flathead, garfish, jewfish, luderick, mangrove jack, sea mullet, tailor, whiting, mud crabs, sand crabs, and banana, school, greasyback and bay prawns.

Zooplankton

There is a large and diverse population of zooplankton in Southern Deception Bay. This population may support large numbers of the blue jellyfish *Catostylus mosaicus*, which also occur in Northern Deception Bay.

Mangroves

Shoreline mangrove woodlands with sandy-mud foreshores adjacent to tidal flats are dominated by *Avicennia*. Mangrove forests in this area are largely intact, and provide important habitats for invertebrates and fish. There has been some natural increase in mangrove cover in the area.

Seagrass

Extensive seagrass meadows disappeared from Southern Deception Bay following a major flood event in May 1996. An estimated 15km^2 of seagrass were lost in this region, and no subsequent recovery has occurred (Fig 15.6). The water column in the area is currently too turbid to provide the light conditions necessary for seagrass growth. Wind and tidal movement cause the resuspension of fine sediments on the sea floor. Trawling in the area may also contribute to sediment resuspension.

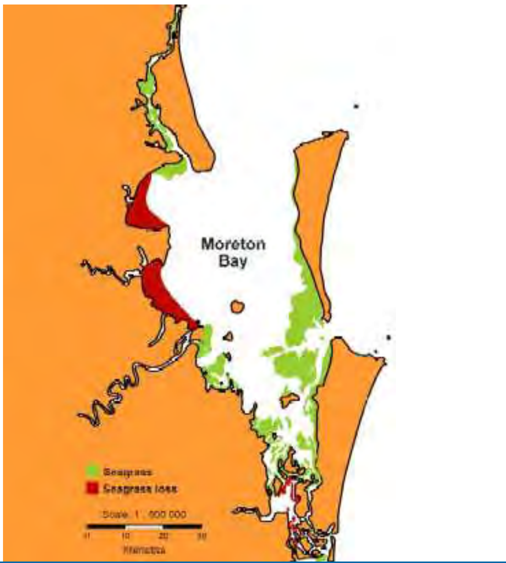
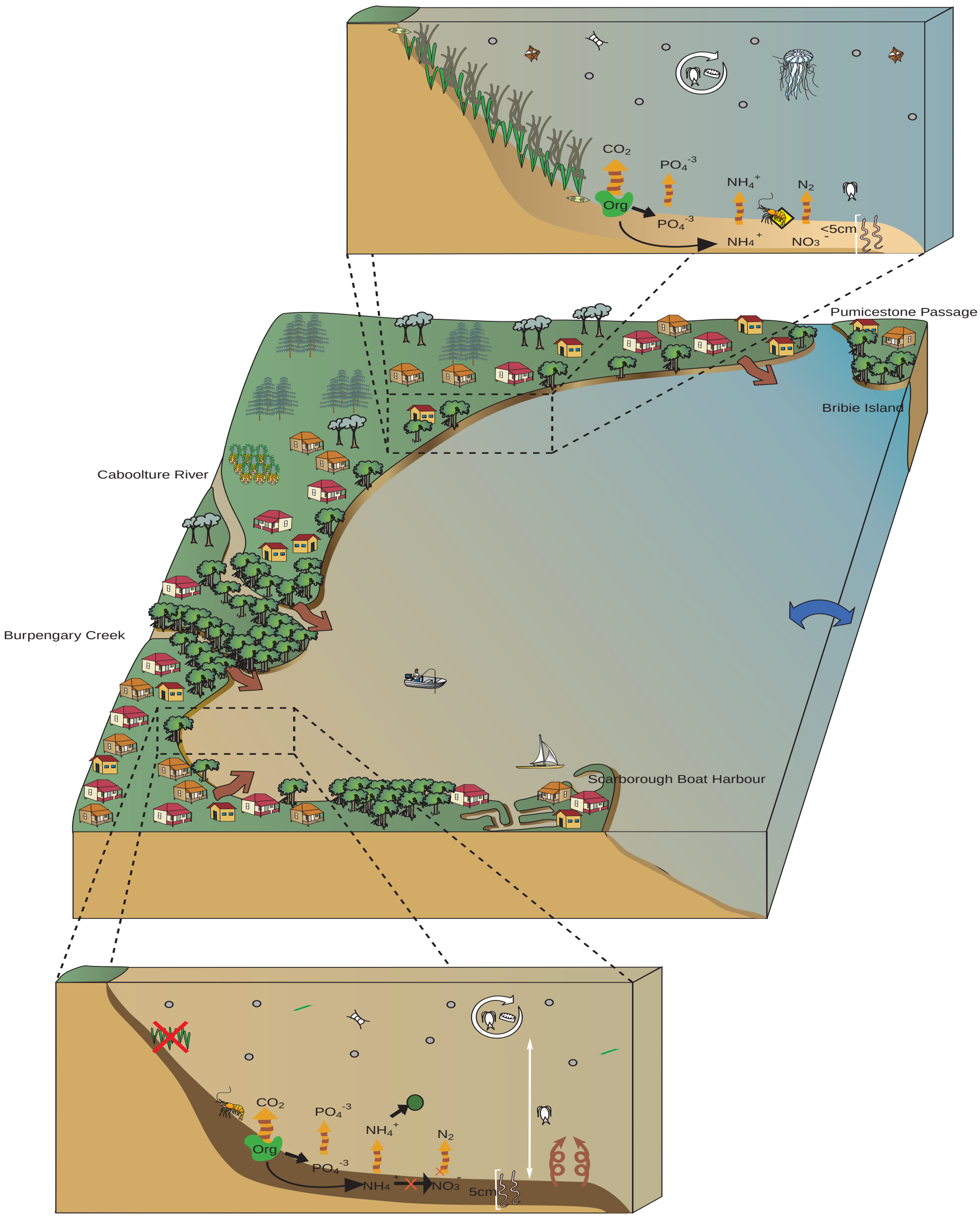


Figure 15.6: Approximately 15 km^2 of seagrass have been lost from Southern Deception Bay since 1996.



Conceptual model for Northern and Southern Deception Bay

Bramble Bay

Bramble Bay is the most degraded embayment of Moreton Bay. This is primarily a result of the high levels of nutrients and sediments that are transported into Bramble Bay from the Brisbane and Pine Rivers. Approximately 63% of the total sediment load and 51% of the nitrogen load into Moreton Bay is predicted to enter via the Brisbane River alone. Significant proportions of nutrients are also transported into Bramble Bay from Hays Inlet and Cabbage Tree Creek. Also contributing to Bramble Bay's poor condition is poor flushing, the area possessing the longest residence time of Moreton Bay (59 to 62 days). Bramble Bay is within a General Use Zone of Moreton Bay Marine Park and contains areas within the Moreton Bay Ramsar site.

Water quality

Nutrients

Nutrient concentrations in Bramble Bay, including inorganic and total nitrogen and phosphorus, are the highest in Moreton Bay. As in the other embayments within Moreton Bay, levels of inorganic nitrogen remain low during dry periods (Fig 15.7). However, during wet periods both ammonium and nitrate levels increase considerably (Fig 15.8). For example, in February 2001 ammonium and nitrate concentrations were recorded at 10µM and 40µM N, respectively. These levels are extremely high for coastal embayments, and have considerable ecological implications. The high nutrient concentrations in Bramble Bay are largely attributable to inputs from the Brisbane and Pine Rivers, though isolated nutrient plumes containing ammonium and nitrate also extend from Cabbage Tree Creek.

Figure 15.7: The water quality in Bramble Bay varies considerably throughout the year, with good water quality recorded during the drier winter months.

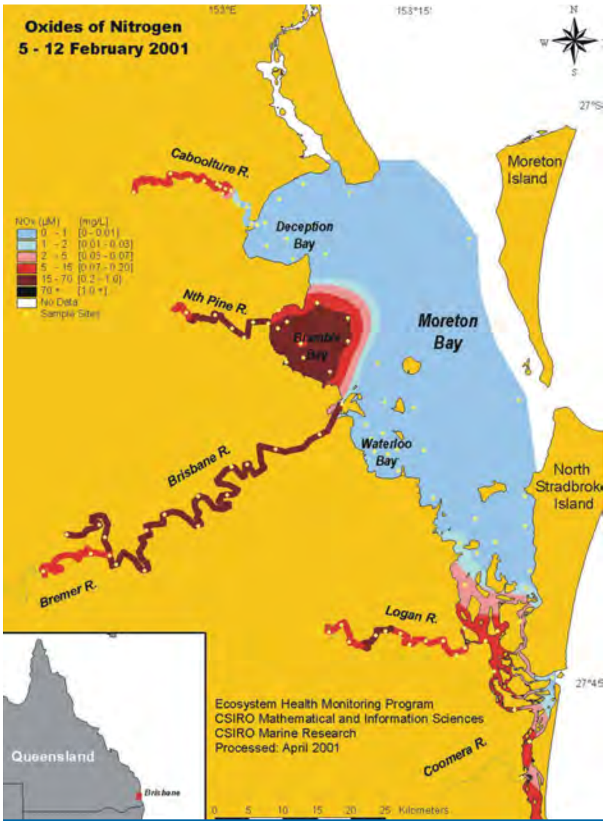


Figure 15.8: Water quality deteriorates considerably during the wetter summer months.

Phytoplankton

Phytoplankton abundance in Bramble Bay is consistently higher than in any other functional zone within Moreton Bay. Chlorophyll *a* levels commonly range between 1mg/L and 5mg/L throughout the entire year. Algal blooms are more prevalent during summer months and blooms approaching 80mg/L have been recorded. The diversity of the phytoplankton community is relatively low. The low species diversity, consistently high phytoplankton biomass, and bloom-crash cycles of phytoplankton blooms indicate that the ecosystem of Bramble Bay is not stable (Fig 15.9).

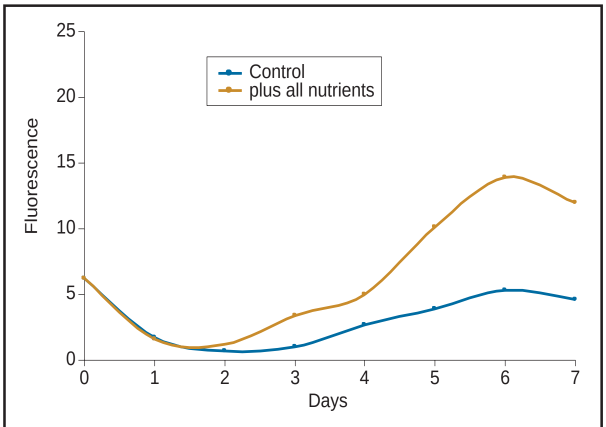


Figure 15.9: Phytoplankton response for Bramble Bay

Sewage plumes

The most prominent sewage plumes of Moreton Bay occur in Bramble Bay. The extent of these plumes varies with season. In summer, two distinct sewage plumes emanate from the Brisbane and Pine Rivers, extending up to 20km away from the point sources (Fig 15.10). In winter, the sewage plume is considerably reduced, probably due to reduced flows from the river estuaries into the Bay (Fig 15.11).

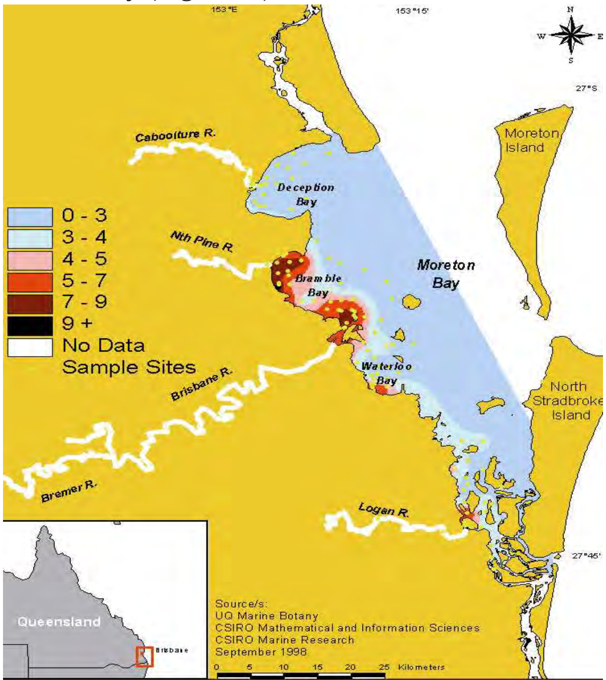


Figure 15.10: The extent of the sewage plumes from the river estuaries varies throughout the year, with larger sewage plumes extending into Moreton Bay in summer months.

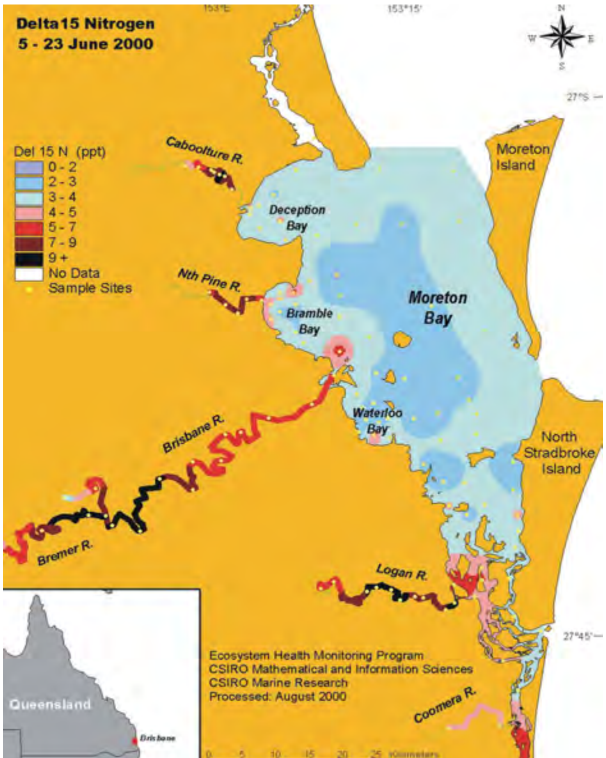


Figure 15.11: Less sewage enters Moreton Bay in winter months.

Macroalgal proliferation

Elevated nutrient levels in Bramble Bay have caused the periodic proliferation of sea lettuce (*Ulva lactuca*), an opportunistic macroalga. Extensive beds of sea lettuce cover the intertidal reaches of Hays Inlet and the Redcliffe Peninsula in winter months.

Cribb, A.B. *Seaweed of Queensland*

Ulva lactuca blooms are common occurrences in the Bramble Bay area.

Water clarity

Bramble Bay also contains the highest levels of suspended particles, based on high turbidity and low secchi disc values. This is caused by the deposition of new sediments from the catchment in combination with continual resuspension of existing muddy sediments. Studies on sediment patterns in Bramble Bay have shown that wind and tidal current provide sufficient energy to resuspend fine muddy sediments from the shallow sea floor on a daily basis.

Seagrass loss

Historically, dugongs and turtles grazed on seagrass beds within Bramble Bay, but high turbidity and nutrients eliminated these beds at least 30 years ago. Current water quality conditions of Bramble Bay are unsuitable for the re-establishment of seagrass meadows.

Sediments

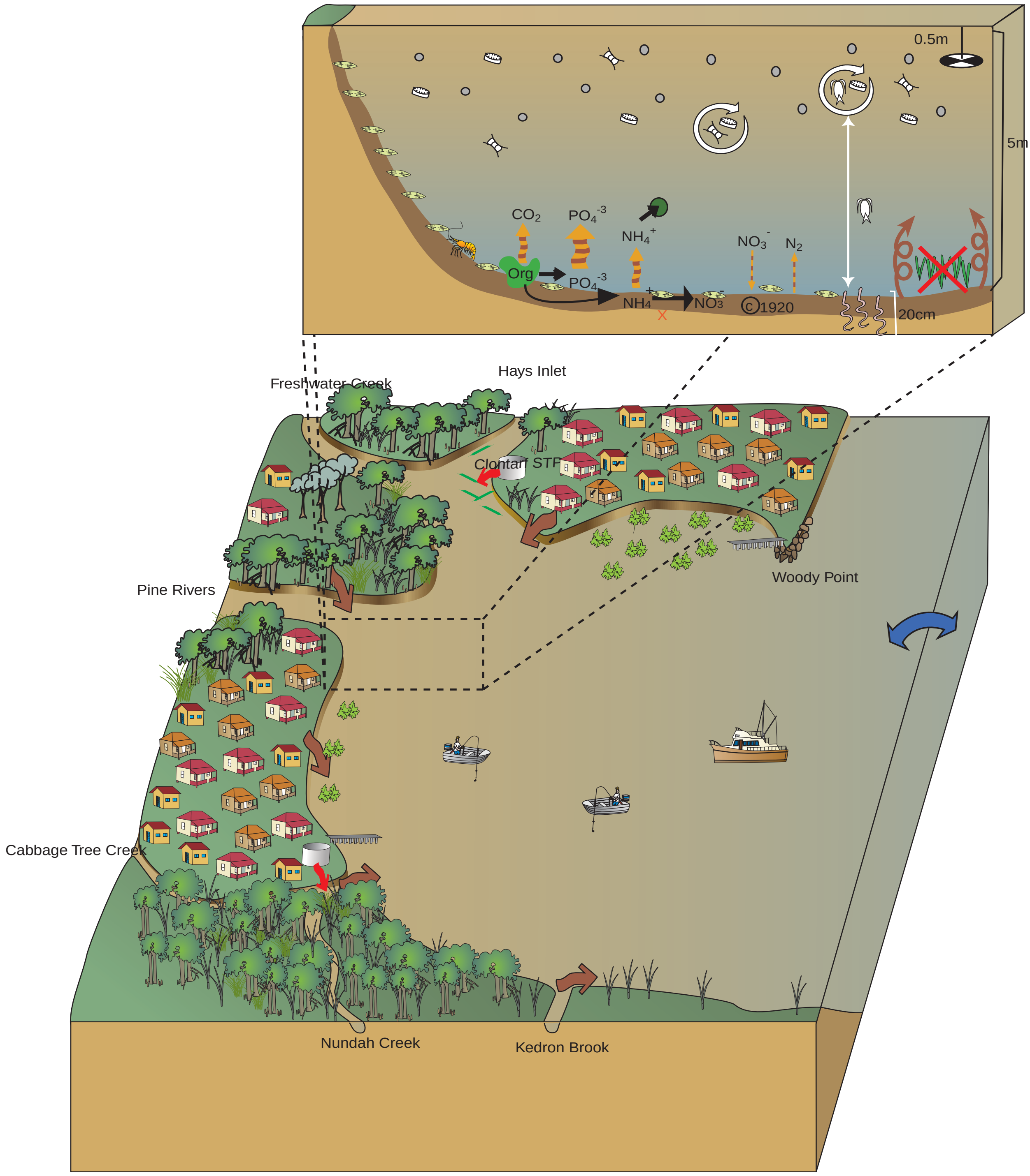
The natural microbial processes of denitrification that convert inorganic nitrogen into nitrogen gas are not effective in the sediments of Bramble Bay. As a result, nutrients such as ammonium are being leached into the water column. Despite the degraded nature of Bramble Bay's water quality and seagrass beds, the sediments house a relatively high diversity of invertebrate infauna and mobile epibenthic species. This is presumably a result of nutrient-enriched sediments emanating from the Brisbane River estuary, in which a variety of sediment sizes enables a diverse array of feeding types. Regular nutrient enrichment combined with annual or unpredictable flood events would add an element of instability to the fauna and could further stimulate recruitment and encourage high diversity.

Mangroves

Mangrove forests occur in the Boondall Wetlands, Tinchi Tamba Reserve at the mouth of Pine River, and Hays Inlet. The area contains large sections of shoal estuarine flats and stands of the mangrove *Excoeceria* which are uncommon elsewhere in Moreton Bay.

Fish Habitat Area

Hays Inlet is a declared Fish Habitat Area because of its recreational fishery value. Important fishery species found in the habitat area include Australian bass, bream, blue salmon, estuary cod, flathead, garfish, jewfish, luderick, mangrove jack, sea mullet, tailor, whiting, mud crabs, sand crabs, banana prawns and eastern king prawns. The habitat area extends from 10m inshore of the Hornibrook Highway into Hays Inlet. It also covers the Pine River north from its midstream line to approximately 3km downriver.



Conceptual model for Bramble Bay

Waterloo Bay

Waterloo Bay is the only embayment on the western side of Moreton Bay that supports corals, macroalgae and extensive, healthy seagrass beds. It is listed within a Habitat Zone of Moreton Bay Marine Park and contains areas within the Moreton Bay Ramsar site. Waterloo Bay is influenced to some extent by the Brisbane River plume and numerous creeks that flow directly into this area (Wynnum, Lota, Tingalpa, Coolnwynpin and Tarradarrapin Creeks). Currently there is concern that Waterloo Bay is at risk of deterioration, particularly as the Brisbane River plume, the Wynnum STP and the nutrient-enriched Tingalpa Creek all exert pressures on the state of the Bay's ecosystem.


Environmental Protection Agency

Corals, mostly *Faviid* species, are found in Waterloo Bay.

Water quality

Overall, Waterloo Bay has relatively low nutrient and suspended sediment levels compared to the other embayments. This is largely due to the pattern of water circulation in the area during summer months. In summer, water on the western side of Moreton Bay moves in a net clockwise direction so nutrients from Brisbane River are transported northwards. In winter, the circulation pattern is reversed and modelling predicts a net anti-clockwise circulation in these western embayments, delivering discharges from the Brisbane River to Waterloo Bay. However, the reduced flow from the Brisbane River during winter results in a relatively low level of impact during this time. The residence time of water in Waterloo Bay has been estimated at 55 to 62 days.

Water quality monitoring consistently reveals higher nutrient and suspended sediment levels in northern Waterloo Bay than in southern Waterloo Bay. This can be attributed to the influence of the Brisbane River on the northern part of the Bay. Ammonia levels have decreased at over 20% per year since 1996, with a decrease in chlorophyll *a*. Metal and pesticide concentrations comply with guidelines, except at one site near Wellington Point where nickel is elevated.

Sewage plumes

Sewage nutrients (high $\delta^{15}N$) from the Brisbane River and Tingalpa Creek extend into Waterloo Bay, although the extent of the Brisbane River sewage plume varies considerably according to season. A large sewage plume across the entire Waterloo Bay area was detected in March 1998, but there was no sewage plume in June 2000. In contrast, a small sewage plume emanates from Tingalpa Creek during both summer and winter. The extent of the STP plume in Waterloo Bay has decreased slightly since 1997–98, presumably due to upgrades to the STPs in Tingalpa Creek.

Sediments

Denitrification occurs in the sediments of Waterloo Bay. Currently, there is concern however that increased nutrient loading into the region or a decrease in oxygen in the sediment could lead to nutrient flux from the sediment into the water column.

Flora and fauna

Waterloo Bay still supports healthy seagrass beds, predominantly *Zostera capricorni*. The depth ranges of seagrass at Fisherman Islands, Wynnum and Birkdale have not changed since 1993, showing that these seagrasses are currently stable (Fig 15.12). A variety of macroalgal species also inhabit Waterloo Bay. Dugongs and turtles graze on the seagrass beds in Waterloo Bay and are occasionally seen near Manly Harbour. Mangrove communities line much of the shoreline of Waterloo Bay, including Tingalpa Creek. The sediments of Waterloo Bay support less diversity than do the more nutrient impacted northern embayments such as Bramble Bay and the mouth of the Brisbane River.

Corals

Waterloo Bay supports a robust assemblage of coral. The island chain extending from Wellington Point and including King, Green, St Helena and Mud Islands houses patches of coral separated by sandy substrate and seagrass beds. Colony growth forms are mostly massive, with more stress-tolerant species such as *Favia* presiding. The corals in the area are presumed to be under stress from flood events and disharges from the Brisbane River and the creeks flowing into Waterloo Bay, but the stability of coral assemblages in the area is largely unknown.

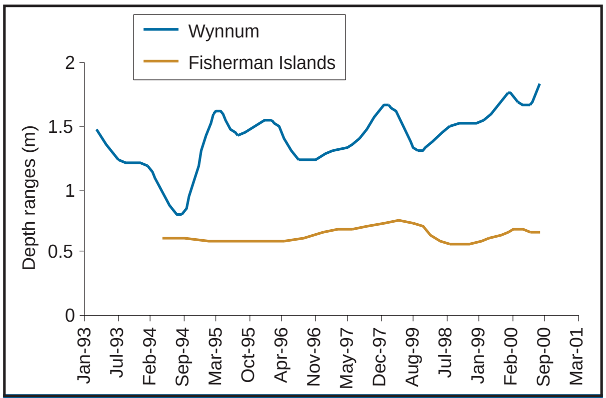
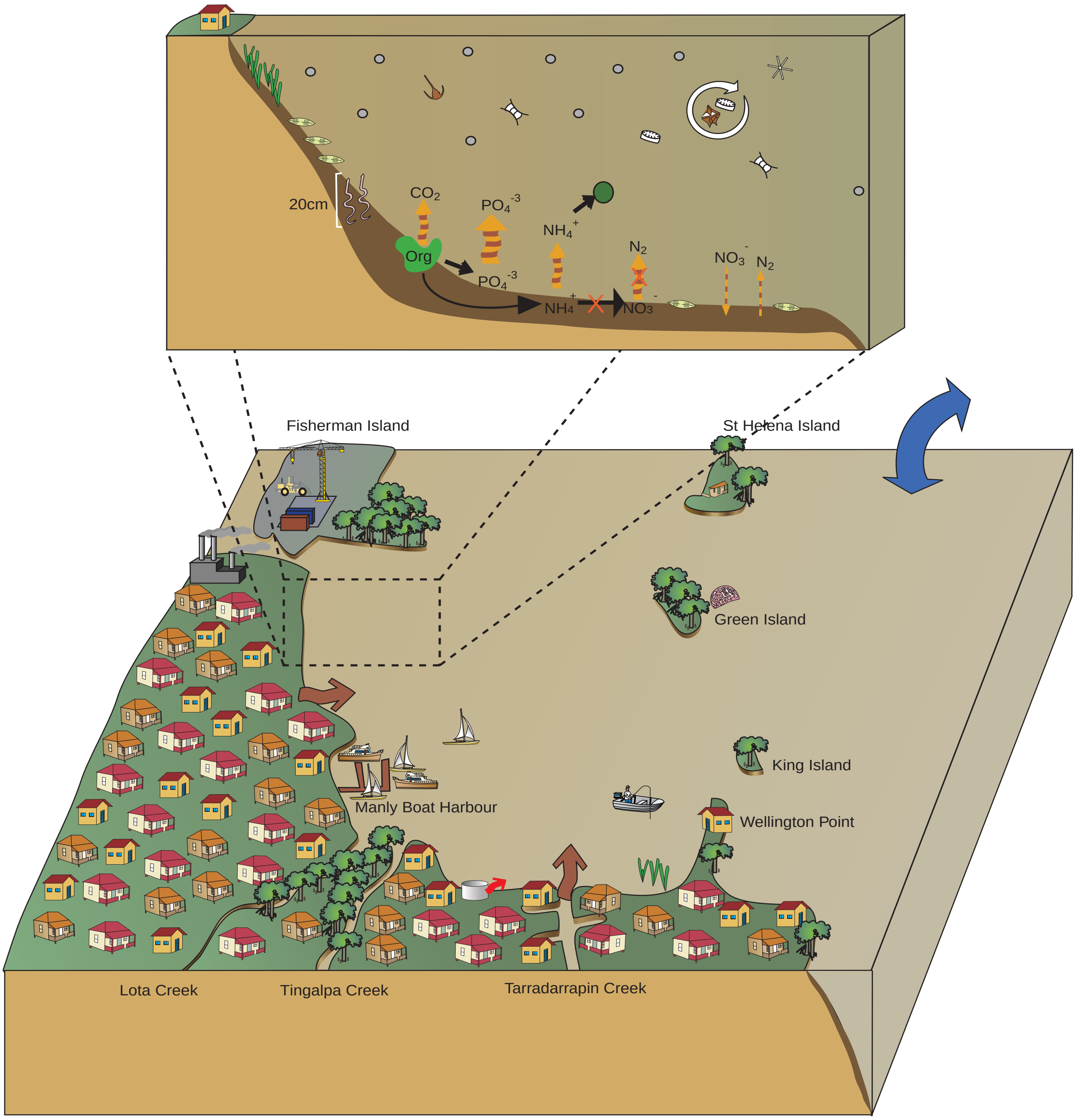


Figure 15.12: Waterloo Bay is the only embayment in western Moreton Bay that still possesses extensive meadows of healthy seagrass. The depth range that the seagrasses occupy in Waterloo Bay has not changed since monitoring began in 1993.



Conceptual model for Waterloo Bay

Central Bay

Central Bay encompasses the central portion of the Bay and stretches from the southern tip of Bribie Island in the north to Victoria Point and Potts Point on Macleay Island in the south. As a result of the circulation patterns in this section of the Bay, water quality and ecosystem health are generally good, with residence time of about 50–55 days.

Water quality

Nutrients

Water column nutrient concentrations are generally low, especially in the western portion, with no sewage plume existing anywhere in Central Bay.

Phytoplankton

Phytoplankton communities in this region are diverse and are adapted to low-nutrient environments. Phytoplankton biomass and productivity are low due to low nutrient concentrations in the water column and relatively strong currents. Chlorophyll *a* concentrations reach 5µg/L in summer, which exceeds QWQ Guidelines for enclosed coastal waters. Chlorophyll *a* concentrations are highest in the western part of the Bay and decrease heading east.

Water clarity

As a result of low suspended solids in the water column and generally good water quality, the seagrass depth range and distribution in Central Bay is some of the best in the Moreton Bay region. The seagrass beds at Peel Island are the deepest beds in Moreton Bay at 3m, indicating excellent light penetration into the water column. The beds at Victoria Point have the largest depth range, from 0.4m to 2.2m deep. Seagrass beds have been monitored at two sites in the Central Bay since 1993 and in recent years depth range has increased, indicating good water quality (Fig 15.13).

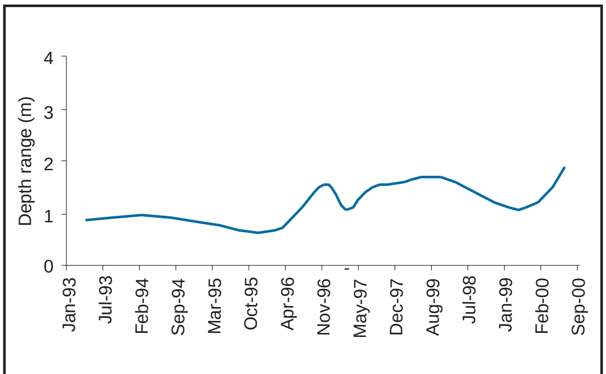


Figure 15.13: Depth ranges of *Zostera capricorni* for Victoria Point. Seagrass beds here are some of the deepest in Moreton Bay, indicating excellent water quality and light penetration.

Sediments

Sediment processes in the Central Bay are essentially intact, with efficient denitrification occurring.

Eprapah Creek

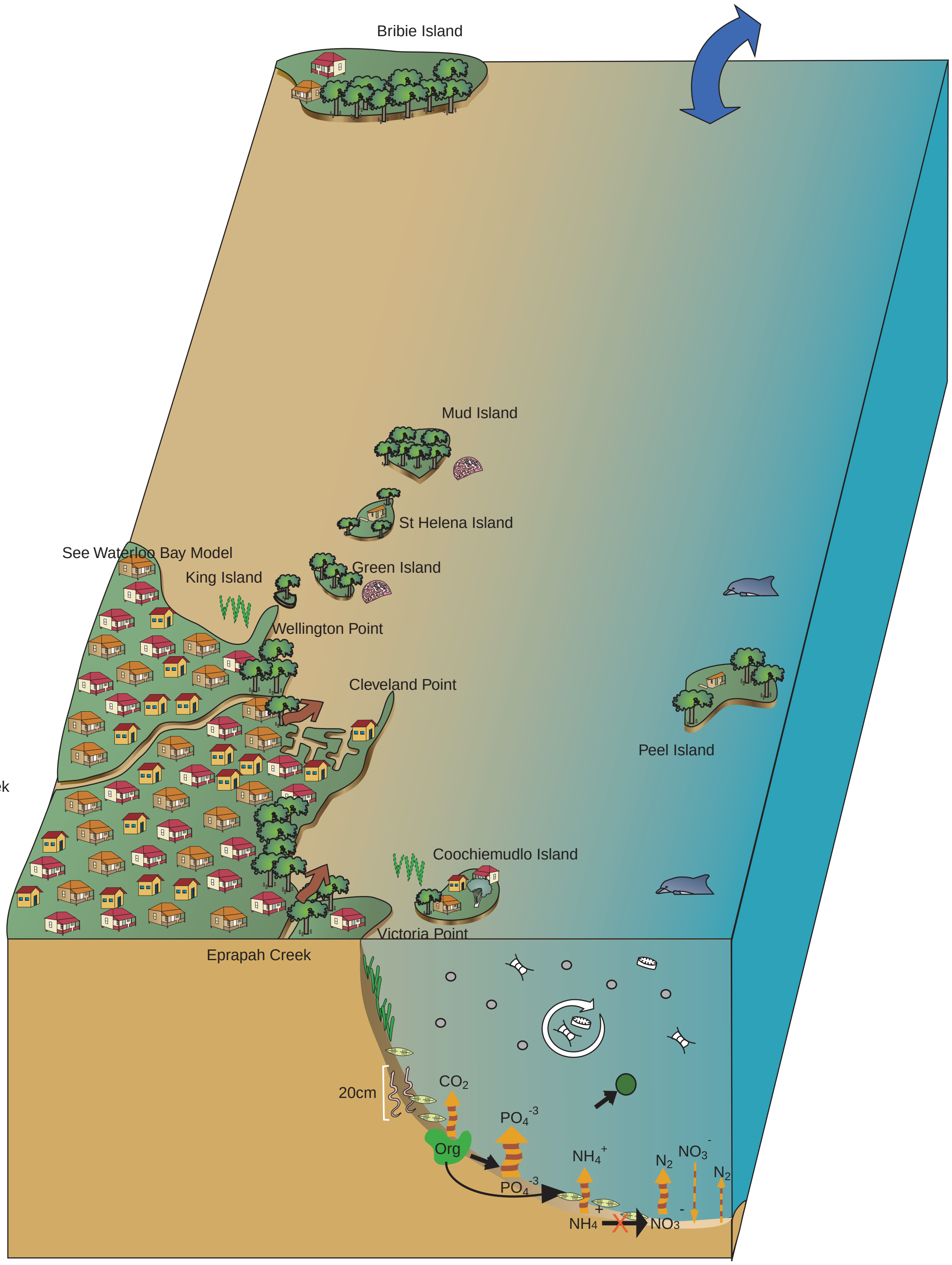
The water quality of Eprapah Creek is generally poor. It is characterised by low levels of oxygen, high concentrations of chlorophyll *a* and elevated levels of nutrients including nitrogen and phosphorus in the water column. The elevated level of nutrients in the creek is due to the impact of wastewater discharge from the Victoria Point STP. Concentrations of both ammonium and nitrate are highest near the discharge.

Hilliards Creek

Hilliards Creek is a heavily impacted waterway with very poor water quality. It seems likely that a very large percentage of the dry season flow is maintained by the input of treated discharge from the Cleveland STP. As a result, the creek has very high concentrations of nitrogen and phosphorus and low concentrations of dissolved oxygen along its entire length.

Environmental Protection Agency

Sailing is a popular activity in the Central Bay.



Conceptual model for Central Moreton Bay

Southern Bay

Southern Bay comprises a region with extensive mangroves and seagrass beds. This region streches from the Logan River mouth to the Pelican Banks, extending from the mainland to the bordering islands and encompassing a broad diversity of ecosystems. Southern Bay is within the Moreton Bay Ramsar site and comprises areas zoned Habitat and Conservation under the Marine Park Zoning Plan. The low-lying islands of Cobby Cobby and Willies are part of the Southern Moreton Bay Islands National Park. The Swan Bay Protection Zone is located at the southern tip of North Stradbroke Island and has high habitat and cultural values. The Willies Island Protection Zone is the southern limit of distribution for the rare black mangrove, *Lumnitzera racemosa*. All forms of collecting are prohibited within the Willies Island and Swan Bay Protection Zones.

Water quality

The major waterway affecting the water quality of the Southern Bay is the Logan River. The river contributes significant nutrient and sediment loads into the Southern Bay as a result of inputs from stormwater, urbanisation, agriculture and aquaculture. Water circulation is affected by the complexity of channels through the islands and sand bars and ultimately the ocean inlet at Jumpinpin. Residence times within the region vary from 0 to 48 days.

Nutrients

Water column nutrient concentrations are generally low. A sewage plume extending from the Logan River extends more than 15km from north of Pannikin Island south to Kangaroo Island.

Water clarity

Turbidity levels in the Southern Bay are relatively high. The seagrass depth range and distribution in the Southern Bay has been highly variable for at least the past five years, indicating an overall decline in the water quality of the area. Seagrass beds have been monitored at four sites in the Southern Bay since 1993 and in recent years seagrass depth range has decreased, particularly since 1996. At this stage, there is no sign of recovery, with the exception of Long Island seagrasses, which have been recently re-established (February–March 2001) (Fig 15.14).

Phytoplankton

Phytoplankton productivity in the western region of the Southern Bay is light-limited, whereas in the eastern region productivity is nutrient-limited.

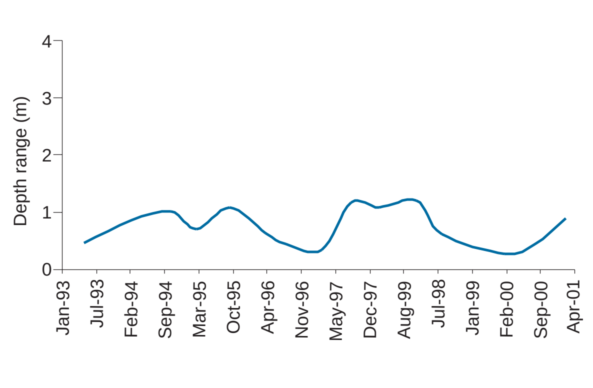


Figure 15.14: The distribution of seagrass has declined in the Southern Bay since 1996. Seagrass has been lost from Long Island due to degraded water quality.

Sediments

Sediment processes in the Southern Bay are essentially intact, with efficient denitrification occurring in this region. However, no denitrification occurs at the mouth of the Logan River. Invertebrate infauna and mobile epibenthic species are poorly represented in the Southern Bay. Species diversity in these animals and fish species is considerably lower here than in areas further north. The Southern Bay, however, is still an important region for fishery habitats.

Macroalgae

Extensive beds of the green macroalga *Caulerpa taxifolia* have established on Pelican Banks east of Coochiemudlo Island and Canaipa Passage east of Russell Island. There is concern that this species may be able to out-compete and hence displace seagrasses in some areas (Fig 15.15).

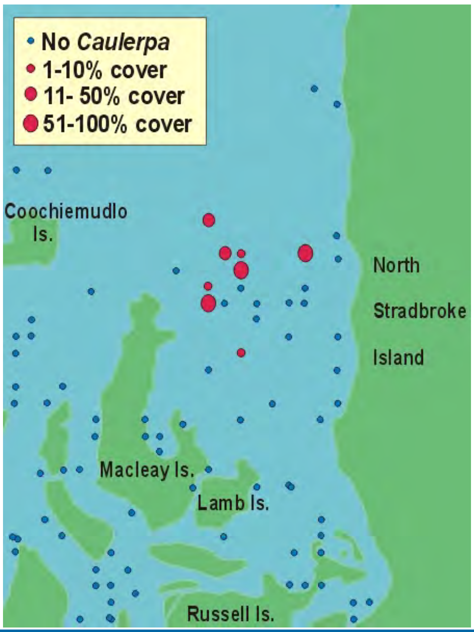


Figure 15.15: Dense meadows of *Caulerpa taxifola*, which occur on Pelican Banks and in Canaipa Passage, may be out-competing naturally occurring seagrass.

Mangroves

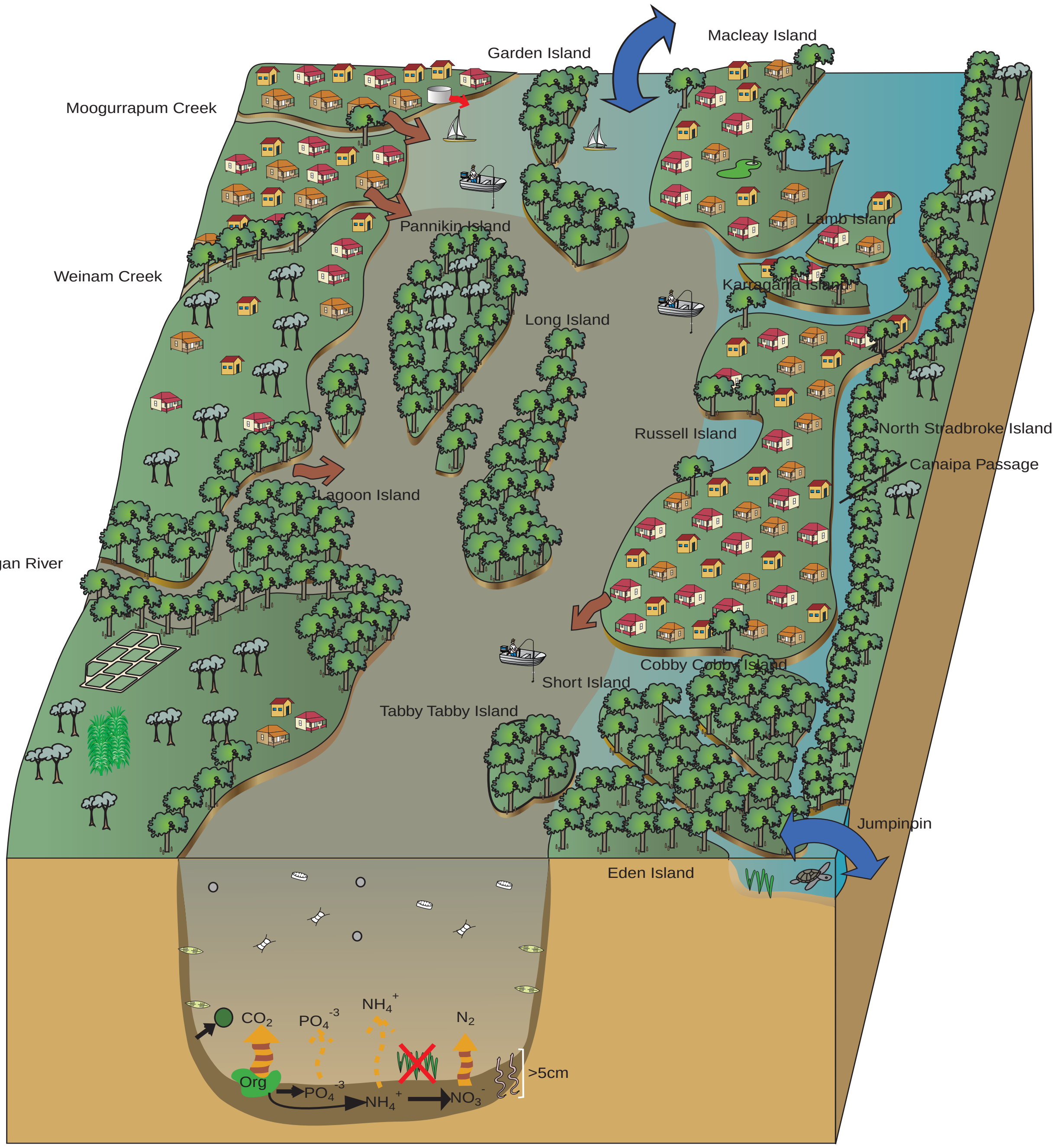
The coastal areas and islands within the Southern Bay are covered in extensive mangroves. Areas of mangrove forests have been lost due to hail damage in 1997 as well as coastal development. There has been a concurrent increase in the extent of mangrove distribution due to incursion of mangroves into areas of saltmarsh at the upper tidal limits because of changes in tidal ranges caused by construction of the Seaway. Lower low tides have resulted in decreased seagrass meadows in the area.

Moogurrapum and Weinam Creeks

The water quality of Moogurrapum and Weinam Creeks is quite poor. The concentration of dissolved oxygen is low and nitrogen and phosphorus levels are high.

Fish Habitat Area

The Jumpinpin-Broadwater region of the Southern Bay has been declared a Fish Habitat Area. Its seagrass meadows and shallow estuarine areas support local valuable recreational and commercial crab fisheries and house a unique system of islands and complex estuarine deposits. It is also an important bream spawning area. Species of value to fishery management in the area include bream, estuary cod, flathead, jewfish, mangrove jack, school mackerel, sea mullet, snapper, tailor, whiting, eastern king prawns, bay prawns, oysters, mud and sand crabs. Stands of the mangroves *Avicennia* and *Rhizophora* dominate the estuary and associated islands, forming an important region for fish nurseries.



Conceptual model for the Southern Bay

Pressures on the waterways

Moreton Bay is subject to a wide range of pressures that impact on its water quality and ecosystem health. Many of these are related to the associated impacts of a large and expanding population in south-east Queensland.

Sewage inputs, stormwater runoff, land clearing and loss of riparian vegetation all affect the water quality and ecosystem health of the region. Considerable pressure arises from recreational activities, which also impact on the Bay's ecology. Moreton Bay is the recipient of impacts from throughout a catchment 15 times greater in size than the Bay itself.

Major point source discharges

Eleven major STPs discharge concentrated volumes of nutrient-enriched wastewater directly into Moreton Bay. This is in addition to the 16 other STPs that discharge into the river estuaries leading into the Bay (Table 15.1). Approximately 70–75% of the total point source load to Moreton Bay is via the Brisbane River estuary. Luggage Point and Oxley Creek STP are the two largest point source discharges in the region. The Luggage Point plant alone provides approximately half of the total point source nutrient load into the Brisbane River and a third of the total point source nutrient load into Moreton Bay. STPs account for approximately 92% of the total point source nitrogen load into Moreton Bay, while industrial and small point sources make up the remaining 8%.

Table 15.1: Major point source loads discharged directly into Moreton Bay

STP	Average dry weather flow (ML/year)	% of total
Victoria Point	770	0.8
Cleveland	1 500	1.5
Thorneside	1 750	1.8
Redcliffe	5 950	6.0
Luggage Point	58 400	59.0
Sandgate	6 390	6.5
Bracken Ridge	730	0.7
Wynnum	2 930	3.0
Nudgee Beach	40	0.04
Oxley Creek	20 440	21.0
Total	**98 900**	

Moreton Bay is a natural sink for materials from the waterways of south-east Queensland, therefore, pollutant influxes to the Bay are a major environmental hazard. It has been estimated that pollutants in the Bay take 30–300 days to be reduced by 90%. In dry weather treated effluent supplies the majority of pollutants that enter the Bay, while in wet weather pollutants tend to originate in runoff from rural and urban areas. After a flood event, it takes approximately four months for the Bay to return to pre-flood conditions.

Mangroves (2.3km^2) surrounding the discharges of the Luggage Point, Wynnum North and Redcliffe STPs are showing signs of stress and dying. Excessive nutrient loads are causing excessive macroalgal growth which smothers roots and blocks natural drainage processes, causing the mangroves to 'drown'. Rehabilitation works by BCC have been undertaken to restore tidal flushing rates.

Since 1996: no change

Land use changes and population growth

The Moreton Bay catchment includes the major urban areas of Brisbane, Ipswich and Logan as well as extensive areas of coastal development. The current population for south-east Queensland is just over two million. This has been the fastest growing region in Australia over the past decade. Urban development has occurred primarily on the coast to the north and south of Brisbane, providing a dense population throughout most of the coastal regions along Moreton Bay. The urban areas immediately surrounding Moreton Bay are projected to increase to 6% of the total Moreton Bay catchment area over the next 10 years at the expense of rural lands close to urban centres.

A shift in land use towards increased urban and industrial areas has increased the volume and velocity of stormwater runoff and ultimately increased sediment and nutrient inputs into Moreton Bay. In general, increased sediment input is of most concern as other pollutants such as nutrients, metals, pesticides and hydrocarbons attach to sediment particles in stormwater runoff.

The Brisbane River catchment is the most significant contributor of sediments and nutrients from non-point sources entering the Bay. Due to river flow patterns and tidal currents, pollutants from land use activities in all the river catchments are transported during rainfall and flood events and deposited on the western shores of the Bay (Table 15.2).

Since 1996: increased

Table 15.2: Predicted catchment loads into Moreton Bay per year for low flow and high flow events

	Low flow	High flow
Nitrogen	2 487 tonnes	3 345 tonnes
Phosphorus	490 tonnes	569 tonnes

Removal and degradation of vegetation

Rates of historical vegetation clearing along the shores of Moreton Bay are largely unknown. However, encroaching urban development threatens the remaining areas of saltmarsh-claypan and mangroves. Land reclamation for marina and canal developments and the construction of sea walls have diminished the range of bayside habitat and limit the movement of many aquatic species. In particular, mangrove degradation decreases the available nursery habitat for many fish and intertidal species.

In 1998 the Moreton Bay catchment area had approximately 370km^2 of coastal wetland vegetation, which included mangroves and paperbark communities, only 18.1% being in national parks and reserves. The 7.22km^2 of coastal melaleuca woodland (inland to the 5m contour) recorded in Brisbane in 1997 is likely to be less than 10% of the area existing before European settlement, estimated at 1300km^2.

There has been an overall net loss of 3.13km^2 of mangroves between 1974 and 1998; Brisbane and the Gold Coast, however, were the only local government areas to record a net loss in mangrove areas, with the remaining local government areas recording a net gain of 3.75km^2 (Table 15.3).

Since 1996: net loss of vegetation

Table 15.3: Areas of mangrove lost in local government areas between 1974 and 1998. Only Brisbane and Gold Coast City Council areas recorded a loss in mangrove areas.

Local gov't area	Area 1974 (km^2)	Area 1998 (km^2)	Change in area (km^2)
Brisbane	28.35	22.30	–6.05
Caboolture	16.78	17.96	1.18
Caloundra	10.89	12.16	1.26
Gold Coast	50.98	50.14	–0.83
Logan	0.13	0.18	0.04
Pine Rivers	6.31	6.92	0.60
Redcliffe	3.71	3.75	0.03
Redland	33.59	34.21	0.62
Total	**150.78**	**147.65**	**–3.13**

Sand extraction

Five commercial operators currently hold permits from the EPA to extract sand from sand banks and shipping channels in Moreton Bay; they operate at twelve sites in seven areas. They are permitted to extract up to 540 000m^3 of material each year, with actual extraction volumes estimated at 50–75% of this number. The volume of commercial sand extraction in the Bay has increased from 81 900m^3 in 1995, to 163 370m^3 in 1997, to 226 900m^3 in 1999. Future commercial demand is estimated to be 600 000–800 000m^3/yr, with a market ceiling of 1 000 000–1 200 000m^3/yr. In March 2001, all sand extraction was prohibited in Moreton Bay Marine Park Conservation Zones, which include the Rous Channel, Pumicestone Passage and the Southern Bay.

Since 1996: increased

Ballast water

Approximately 1000 overseas vessels and 1000 Australian vessels enter the Port of Brisbane each year. The majority of these ships are container ships and tankers carrying oil and other petroleum products. Ballast water discharge from container ships has been implicated in the introduction of more than 170 foreign species to Australian coastal waters. Some of these now cause significant ecological and economic impacts. On average, 38% of the Dead Weight Tonnage or approximately 14 754 tonnes of water is discharged per ship per year.

The majority of discharge occurs alongside the berth and is almost always closely coordinated with the cargo loading program. Some bulk carriers at the Fairway Buoy off Caloundra and off Mud Island at the main pre-berth anchorage are permitted to undertake preliminary deballasting of 5–20% of the fair weather ballast. However, these amounts are limited by the need to maintain manoeuvrability and because vessel masters and local marine pilots are reluctant to allow significant deballasting prior to berthing. Port berths for the Port of Brisbane are generally concentrated around the mouth of the Brisbane River, which provides a potential habitat for introduced marine species.

Since 1996: no data

Fisheries

Moreton Bay comprises 3% of the total Queensland coastline but represents approximately 30% of the State's recreational fishing effort and 13% of the State's total commercial catch, with up to 50% in some major species. Various commercial fishing methods including trawling, netting, line fishing, crabbing, aquarium fish collection and bait collecting have been used in Moreton Bay for many years.

The commercial fishery in 1997 produced between 2000 and 3000 tonnes of seafood annually, mainly prawns, finfish and crabs, and some reef fish. In 1997 approximately 1150 people were employed in the Moreton Bay region; of these, about 800 worked within the Bay itself. Between 1996 and 2000, total catch for all of the fisheries in Moreton Bay has remained fairly consistent, averaging approximately 3000 tonnes per year. The average catch per day per boat has declined by 30% while there has been an increased trend in the total number of days spent fishing in the past four years. Net and otter trawling remain the most common fishing methods used in the Bay. Approximately 350 licensed commercial fishing boats, with an estimated value of more than $50 million in equipment, operate in Moreton Bay.

Recreational fishing is an especially popular activity in Moreton Bay. Approximately 300 000 recreational fishermen harvest 250 tonnes of crab and 1250 tonnes of finfish per year. This number has remained fairly constant over the past four years but is projected to increase with increases in population and tourism in south-east Queensland. The recreational catch of six species, snapper, whiting, bream, mudcrab, flathead, and tailor regularly exceeds the commercial catch, but total catch and days of effort per fisher are largely unknown for recreational fishing.

Since 1996: no change in total catch

Recreational and commercial boating

Moreton Bay is a very important area for recreational boating. There are 62 733 recreational boats registered in the Moreton Bay catchment area. This represents a 72% increase since 1980, with the majority registered in Brisbane and the Gold Coast (Fig 15.16). There has been a 7% annual increase in total number of motor boat registrations in south-east Queensland since 1996.

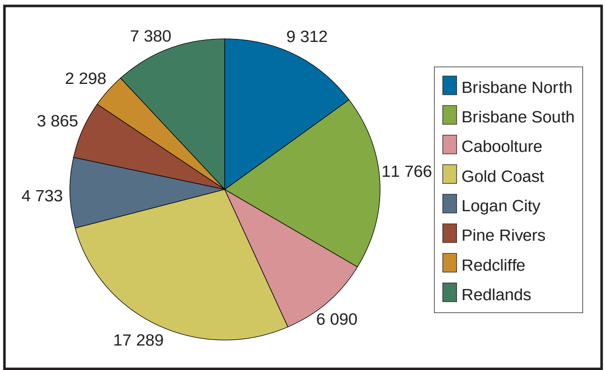


Figure 15.16: Recreational boating registrations for the Moreton Bay catchment area

Boat strikes are implicated in the deaths of significant numbers of turtles. Approximately 20–50% of all recorded boat-related deaths of turtles in Queensland occur in Moreton Bay. Injuries caused by boat strike have been reported to slow growth, limit egg production and in some cases prevent breeding.

Healthy Waterways Library

Recreational boating is a popular pastime in Moreton Bay.

The Marine Park (Moreton Bay) Zoning Plan 1997 was gazetted in December 1997. The Marine Park is divided into five zones, with activities being allowed 'as of right', prohibited, or restricted to permit holders in each zone. Some activities are subject to special management within designated areas for example, as boating in critical turtle and dugong habitats. Speed restrictions were implemented in areas known as habitat for turtles and dugongs were implemented to decrease boat-related injury and death.

Disturbance and destabilisation of riverbed and banks through wave wash and water pollution from exhausts and oil leaks have been identified as key contributors to riparian habitat loss. The estimated release of fuel and oil from vessels with 2-stroke engines in Moreton Bay is approximately 4 320 000L/yr. The oil component of this is about four times the largest oil spill reported in the Bay in the period 1991–99.
Since 1996: increases in boat registrations

Toxic cyanobacterium, *Lyngbya majuscula*

The toxic cyanobacterium *Lyngbya majuscula* is a filamentous species forming strands of 10–30cm long filaments, which grow loosely attached to seagrass, macroalgae and rock outcrops. *Lyngbya* possesses a suite of toxins and is found in subtropical and tropical estuarine and coastal waters worldwide. *Lyngbya* is reported to cause severe contact dermatitis, eye irritation and respiratory problems.

There have been anecdotal reports of *Lyngbya* blooms in Northern Deception Bay since 1992; however, in the summers of 1996–97, 1997–98 and 2000–01, large blooms of *Lyngbya* were identified in Northern Deception Bay. The blooms were found at a depth of <3m in areas with sandy sediment and were attached to seagrass, especially *Zostera capricorni* and *Syringodium isoetifolium*, and to benthic green algae.

Seagrass loss in Northern Deception Bay has been correlated to the areas of *Lyngbya* blooms. Initial research during the *Lyngbya* blooms in Deception Bay also reported decreased oxygen in the water column. High rates of nitrogen fixation, particularly associated with peak bloom biomass, is likely to have resulted in significant localised input of bioavailable nitrogen following the release of organic and inorganic nitrogen during the decay process. Declines in crab and fish harvests in years of *Lyngbya* blooms have not yet been assessed.
Since 1996: increased

Proposed Port of Brisbane expansion

The Port of Brisbane Corporation has proposed a future expansion to take place on Fisherman Island. Under the current proposal, reclamation of approximately 2.3km^2 has been planned for container and general cargo wharves and terminals. The fill required for the reclamation is estimated at approximately 17.5 million m^3, 6.5 million m^3 coming from dredging of new berth areas and 11 million m^3 from existing navigational dredging of the Brisbane River over the next 20–25 years.

Impact to the environment is expected to be the direct loss of the subtidal seabed as well as the loss of 0.9km^2 of seagrass beds. Temporary man-made migratory bird roosting sites and feeding habitats are also predicted to be lost, but construction of a 0.12km^2 permanent roosting site on Fisherman Islands has begun.
Since 1996: increased

Aquaculture

There are numerous aquaculture facilities (prawn and oyster farms) that impact on Moreton Bay. Discharge impacts are localised and, as yet, farms are not numerous enough to cause serious water quality problems.
Since 1996: no data

Responses to the pressures on the waterways

Issues	Local initiatives	Responses
Major point source discharges	• Redland Shire Council is developing plans for sewage management. • Redland Shire Council is in the process of supplying reticulated sewage to parts of Dunwich and planning upgrades of all plants to tertiary level. • No solids stored at STPs in Redland—disposed of at worm farm facility • No solids stored at Wynnum STP • Brisbane Water Biosolids Management Strategy will deal with remediation of old stockpiles and sustainable use of new biosolids. • Logan Coomera and Southern Moreton Bay Regional Wastewater Management Study	• An agreed schedule of discharge targets and associated plant upgrades has been developed for STPs and major industrial discharges to Moreton Bay. These improvements aim to achieve the sustainable nitrogen load targets outlined in the SEQRWQMS.
Land use changes and population growth	• Redland Shire Council has prepared a draft catchment management strategy. • Brisbane City Council has developed catchment management plans for Lota and Wynnum Creeks and plans to develop others. • Bushcare, Landcare and fauna preservation groups • Waterwatch and Coastcare • Eprapah Creek Catchment Landcare Association • Bayside Environmental Network • Australian Marine Conservation Society • Minjerriba Planning and Management Study • Quandamooka Aboriginal and Sea Management Agency and the Quandamooka Land Council • Urban Stormwater Quality Management Strategy by Brisbane City Council, with Redland Shire Council to follow • Stormwater quality improvement devices installed at Manly by Brisbane City Council • Redland Shire Council has obtained an NHT grant for an artificial wetland at Wellington Point. • Minjerriba Planning and Management Study and Redland Shire Counci'ls catchment planning process will guide stormwater management plans. • Urban Stormwater Information Groups • Redland Shire Council conducted acid sulfate soil mapping and developed a plan to manage acid sulfate soils. • Voluntary Code of Practice by QFF • Regulation by Redland Council and EPA through Integrated Planning Act and Environmental Protection Act • Port of Brisbane Environmental Management System incorporates stormwater management. • Installation of SQIDs at Fisherman Islands and construction of best practice marine waste facilities at Whyte Island	• The SEQ Regional Framework for Growth Management is the basis for planning for the projected increases in the regional population. All member organisations are using the framework to guide sustainable growth in the region through a range of implementation mechanisms including planning schemes, corporate plans and a range of service delivery programs. • Range of local programs and plans outlining management actions to address this issue.
Removal and degradation of vegetation	• Restoration projects by local groups such as fauna preservation groups, Bushcare, Landcare, Waterwatch, Coastcare, Eprapah Creek Catchment Landcare Association, Bayside Environmental Network and Australian Marine Conservation Society • Council initiatives • Redland Shire Council's Environmental Inventory Database and Conservation Reserve Inventory, priority vegetation management sites along Coolnwynpin Creek and the Pest Management Plan • Initiation of mangrove transplantation initiatives on reclaimed foreshore areas by the Port of Brisbane	• In the SEQRWQMS, the DPI and EPA, in conjunction with stakeholders, have agreed to determine the viability of a plan for the restoration and rehabilitation of marine plants by 2002. • In 2002, stakeholders of the Partnership will begin to identify priority areas for riparian and stormwater management and set targets for on-ground works. This process will focus on implementing on-ground works to deal with this issue

Responses cont'd

Issues	Local initiatives	Responses
Sand extraction		• A study into the impacts of sand extraction in Moreton Bay is currently under way. Future management actions to deal with the sand extraction issues may be developed based on the outcomes of this study. • A review of the regulatory regime for extractive industry is currently under way. Future management actions to deal with extractive industry issues will be developed based on the outcomes of this review.
Ballast water		• Implementation of the National Ballast Water Management Strategy for International Vessels has commenced within the Port of Brisbane. The National Ballast Water Management Strategy for Coastal Vessels is scheduled to be implemented in July 2002. Implementation of these strategies reduces the risk of introduction of exotic marine species.
Fisheries	• Fish stocks are assessed in individual QFMA Fishery Management planning processes. • Queensland Boating and Fisheries Patrol has appointed an Aboriginal Liaison Officer. • Establishment of indigenous community shellfish areas. • Spanner crab subject to QFMA management planning process and undergoing research by DPI	
Recreational and commercial boating	• A research program is currently under way in Moreton Bay and the Gold Coast to better understand the impacts of ship-sourced pollution (sewage, heavy metals and hydrocarbons).	• Additional vessel sewage requirements that will apply to all coastal waters will be introduced through amendments to the *Transport Operations (Marine Pollution) Act 1995*
Lyngbya		• A draft *Lyngbya* Management Strategy has been developed. The draft strategy outlines a range of management and mitigation actions to deal with *Lyngbya* blooms. • Implementation of a comprehensive research program to identify the causes of *Lyngbya* blooms is continuing. Future management actions will be developed based on the outcomes of the research program.
Proposed Port of Brisbane expansion	• Port of Brisbane undertakes annual sediment contaminant surveys.	

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Environmental Protection Agency

The waters around North Stradbroke Island boast high water quality.

Chapter 16
Towards Indicators of Sustainability for the Catchments and Waterways of South-east Queensland

Andrew Mason and Badin Gibbes

A key challenge identified during preparation of this report was the need to place the ecosystem health information presented in this document into its broader social and economic context. In response to this challenge the Moreton Bay Waterways and Catchments Partnership proposes to augment the *State of the Waterways* measures of ecosystem health with a broader, more holistic set of measures of success in achieving the Healthy Waterways Vision. This requires a move from a narrowly focused set of environmental indicators to a broader 'triple bottom line' approach that embraces the economic, social and environmental dimensions of waterways and catchment management. To achieve this it is proposed to develop a process for selection of a set of broader sustainability indicators.

Introduction to sustainability indicators

Since the publication of the United Nations World Commission on Environment and Development report *Our Common Future* in 1987, governments around the world have adopted 'sustainable development' as a key policy objective. Sustainable development means different things to different people, but the most frequently quoted definition is from *Our Common Future*:

> 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.'

Increasingly, governments and communities around the world are recognising that efforts to achieve sustainable development must be underpinned by access to accurate information concerning the social, environmental and economic 'triple bottom line' of sustainability. Worldwide, the development of indicators of sustainability, through a collaborative process involving community, industry and government, is now established as a best practice approach to obtaining this information.

In Australia, the Commonwealth Government through Environment Australia and the ANZECC State of the Environment Taskforce has embraced this move towards development of indicators of sustainability and developed a draft set of 22 'headline sustainability indicators'. The Queensland Government has also drawn on world best practice in developing the *Charter of Social and Fiscal Responsibility*. This framework requires the Government to report annually on the efficiency and effectiveness of its activities in meeting key social, environmental and economic policy objectives. Various local government- and community-based initiatives have also commenced.

A framework for the indicators

The Healthy Waterways Vision provides the highest order goal for the Moreton Bay Waterways and Catchments Partnership:

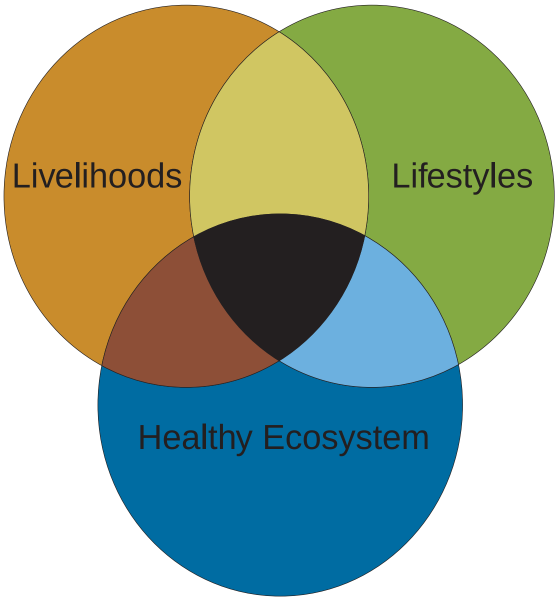
> *South-east Queensland's catchments and its waterways will, by 2020, be a healthy ecosystem supporting the livelihoods and lifestyles of people in south-east Queensland, and will be managed through collaboration between community, government and industry.*

Healthy ecosystems are part of the Healthy Waterways Vision.

This Vision recognises the diversity of interests and actions involved in managing Moreton Bay, its land catchments and waterways and makes reference to three dimensions of waterways and catchment management:

- healthy ecosystem;
- lifestyles; and
- livelihoods.

These three dimensions of waterways and catchment management can be viewed as three interconnected sets of outcomes:



Viewed in this way it is evident that livelihoods (economics) overlaps with lifestyles (society). Both of these dimensions in turn overlap with the ecosystem (environment). Individual outcomes may sit discretely within one dimension or they may cut across all three dimensions. For example, fishing in Moreton Bay is a cross-cutting issue in that it is a lifestyle issue for many people, is a source of a livelihood for others and ultimately depends upon the capacity of the ecosystem to sustain fish stocks.

Environmental Protection Agency

Fishing is a very important activity in the south-east Queensland region and covers the three dimensions of waterways and catchment management.

The selection and monitoring of a set of sustainability indicators that spans the three dimensions of the Vision presents a number of opportunities for the Moreton Bay Waterways and Catchments Partnership.

- First, the indicators will translate the Healthy Waterways Vision into a set of measures of 'on the ground' social, economic and environmental outcomes and so enable measurement of progress towards the Healthy Waterways Vision.

- Second, selection of indicators will assist the Moreton Bay Waterways and Catchments Partnership in focusing its efforts on specific actions aimed at achieving measurable outcomes.

- Third, cost effectiveness can be enhanced through integrated thinking and action. By identifying linkages between issues, sustainability indicators flag where action can drive progress towards multiple dimensions of the Vision and so enhance the cost effectiveness of Moreton Bay Waterways and Catchments Partnership programs; and

- Finally, the involvement of stakeholders in the process of selecting the indicators has the potential to build stakeholder (government, industry and community) awareness and capacity to work with sustainability issues and galvanise support for measures to deal with key challenges.

It is proposed that the indicators will consist of both 'headline' and 'core' indicators. Headline indicators are intended to focus public attention on key sustainability issues and to give a broad overview of whether we are achieving the Healthy Waterways Vision. These indicators will focus on highly meaningful and easily understood measures which provide an attractive snapshot of progress in meeting key challenges. The headline indicators will be selected according to the capacity for the content to be readily understood by a wide range of stakeholders and for their potential to appeal to the broader public and thereby raise awareness of waterways and catchment management issues.

The bulk of the proposed indicators will be 'core' indicators. These measures will be at the core of future reports on progress towards achieving the Healthy Waterways Vision. These indicators will lend themselves to setting clearly defined 'target ranges' that represent satisfactory or sustainable values. By weighing these indicators together it will be possible to produce an overall 'combined index of progress' towards achievement of the Healthy Waterways Vision.

The following section provides examples of headline indicators as a guide to the potential scope of the sustainability indicators to be selected. These indicators cover a wide range of issues but the list is not intended to be comprehensive. Rather their purpose is to show examples of possible indicators and give an indication of the range of waterways and catchment management issues they may cover.

Potential headline indicators

Potential indicator:

Percentage of waterways that are suitable for primary contact recreation

This measure provides valuable information on environmental constraints to recreational use of our waterways, which in turn provides an indirect measure of the lifestyle values. While data are not available for all waterways in the region, current monitoring results indicate that approximately 95% of beach sites in the south-east Queensland region consistently comply with guidelines for primary contact activities such as swimming.

Marine Botany, UQ

Swimming is considered a valued activity in South-east Queensland.

Potential indicator:

The number of waterways with an ecosystem health report card rating of 'C' or better

The community is already familiar with the Ecosystem Health Monitoring Program Report Card rating system which provides a high order composite indicator of ecosystem health. In 2000, report card ratings were given for 20 different bay and estuarine water bodies (8 areas of Moreton Bay and 12 river estuaries) in south-east Queensland. Of these ratings, 11 (55%) were a 'C' or better.

In 2001, report card ratings were given for 32 different bay, estuarine and freshwater bodies (8 areas of Moreton Bay, 12 river estuaries and 12 freshwater catchments) in south-east Queensland. Of these ratings, 19 (59.3%) were a 'C' or better. They included five (15.6%) areas of Moreton Bay, seven (21.8%) river estuaries and seven (21.9%) freshwater catchments.

Potential indicator:

The proportion of the population that is actively participating in catchment management, Landcare or Bushcare groups

This indicator would provide a valuable measure of community participation in and awareness of waterways and catchment management issues. Although not currently collated, data could be sourced from attendance lists and meeting minutes of local catchment and Landcare groups (at present more than 300 local catchment, landcare and bushcare groups operate in south-east Queensland). This information could be augmented by information from core indicators on community awareness or traditional owner involvement in waterways management.

Healthy Waterways Library

Many people are involved in catchment and landcare groups to clean up the waterways.

Potential indicator:

The number of 'on the ground' environmental management initiatives in south-east Queensland managed with the involvement of Aboriginal traditional owners

This information would provide an indication of traditional owner involvement in waterways management within south-east Queensland. At present information is not available on the number of initiatives which have Aboriginal traditional owner involvement.

Potential ndicator:

Dugong stranding and mortality rates, and the size of dugong herds in Moreton Bay

Dugong herd sizes in Moreton Bay appear to be declining. There is a strong correlation between this decline and loss of ecological integrity (seagrass loss and *Lyngbya* blooms). As a charismatic marine mammal, the dugong has the potential to focus public attention on the ecological integrity of the Bay and the pressures exerted upon it. Dugong mortality rates in Moreton Bay appear to be increasing, with 19 dugong deaths recorded within the Bay area in 2000. This is an increase over previous years as shown in Figure 16.1.

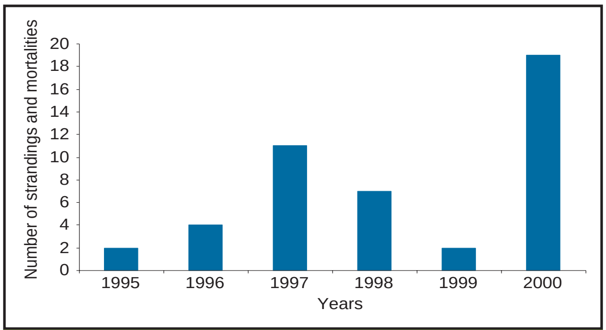


Figure 16.1: Observed dugong strandings and deaths (Moreton Bay)

Information on dugong herd size has been collected for the Moreton Bay region since the late 1980s. Over this time a range of measurement techniques have been used. As a result, a direct comparison of herd size numbers over time is unable to be made. While no firm comparison can be made, it appears as though herd size has decreased from approximately 600 in the late 1980s and early 1990s, to around 344 in 2000 (with an apparent peak in herd size of 896 in 1995). A consistent monitoring technique has now been adopted and will allow more reliable comparisons to be made between future dugong herd size measurements.

Environmental Protection Agency

Moreton Bay is an important habitat for dugongs.

Potential indicator:

The number of people directly employed in commercial fishing in Moreton Bay

This provides an indicator of the capacity of the Moreton Bay ecosystem to provide livelihoods for many people. Approximately 1150 people are directly employed in commercial fishing in the Moreton Bay region, including 800 on the Bay itself. A similar indicator might consider employment in dependent recreation and leisure industries.

Potential indicator:

The annual economic value of the waterways of south-east Queensland

The annual economic value of the waterways of south-east Queensland provides a broad mechanism for measuring both the environmental and economic sustainability of the region's waterways. The annual economic value of some activities that are directly affected by water quality has been estimated at $255 million dollars. The value of commercial and recreational fishing in the Moreton Bay catchment area for the 1998–2020 period has been estimated at $2,867 million. In addition to commercial fishing operations, the Moreton Bay region currently supports about 300 000 recreational anglers. The annual expenditure by recreational anglers on fishing and boating in the Moreton Bay region is estimated to be approximately $200 million.

Department of Environment and Heritage

Recreational fishing is a multi-million-dollar industry in the south-east Queensland region

Figure 16.2 provides a general indication of the total commercial fishing catch in Moreton Bay and the associated economic value derived from that catch. From this figure it can be seen that catches and returns in 1997 declined significantly from those over the 1994–96 period. This information could be augmented by information from core indicators on the dollar value of Moreton Bay's catch of each commercially important species.

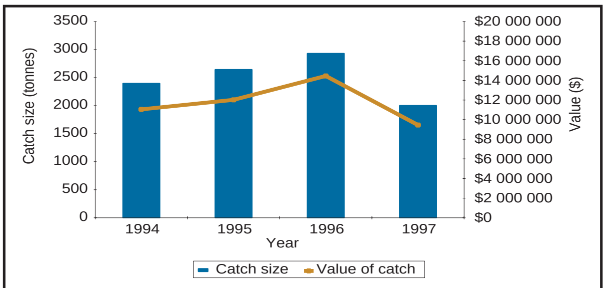


Figure 16.2: Commercial fishing in Moreton Bay

Potential indicator:

Percentage of population served by sewage treatment plants with different levels of treatment

Treatment of wastewater to primary, secondary or tertiary levels exerts different (progressively lessening) pressures on the receiving water environment. This indicator could be augmented by information from core indicators on per capita wastewater discharges. Considered together, these indicators would provide a measure of the outcomes achieved through investment in wastewater treatment plant upgrades.

At present approximately 2.4 million people live in the catchments of south-east Queensland. There are approximately 69 major wastewater treatment systems in the region, with varying levels of treatment. These major treatment systems serve approximately 89% of the residential population, with the remaining 11% of the population residing in unsewered areas where levels of wastewater treatment vary substantially. Table 16.1 provides a summary of the proportion of the population served by different types of sewage treatment plants (STPs).

Table 16.1: Proportion of population served by different types of STPs

Treatment type/ standard	Number of systems	Percentage of population treated
Common effluent drainage	2	0.05%
Secondary treatment	43	64.02%
Advanced secondary	13	22.88%
Tertiary	3	2.47%
On-site sewage system	unknown	estimated 10.58%

A process for selecting the indicators

It is proposed that the indicators will deal with achievement of the Healthy Waterways Vision on a regional scale. It is not envisaged that the indicators developed will deal with subregional or local issues. It is, however, intended that the indicators may provide a useful reference for local governments and catchment groups working to develop subregional sustainability indicators.

It is envisaged that the proposed indicators will be subject to ongoing review, changing over time to reflect changing circumstances and changing stakeholder perception of the Healthy Waterways Vision. Such a continuous process of indicator review will provide opportunities for stakeholder capacity development and provide for expansion of the indicator set to include emerging stakeholder priorities for action.

Indicator selection will serve to translate the Healthy Waterways Vision into a set of desired outcomes. In the working environment of the Moreton Bay Waterways and Catchment Partnership it is essential that this work is undertaken with the active involvement of all stakeholders.

Future work will involve development of criteria for selection of headline and core indicators. Data collection, interpretation and reporting processes will be established. The scope of indicator selection will need to be defined. Here it will be necessary to identify readily available information sources and consider the resourcing implications of indicator monitoring and data interpretation work. Development of an indicator information system and reporting tools will also be undertaken to ensure that information is accessible in a suitable, timely manner for monitoring and evaluation.

Finally, it is likely that the indicators will be piloted and evaluated in a number of local authority areas before they are rolled out across the region.

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Appendix

Water Quality Guidelines

The following tables are the Queensland Ecosystem Protection Guidelines for river, estuarine and marine systems for the east coast of Queensland.

Table 1: Organic N, Ammonia, Oxidised N, Total N, Filterable Reactive P and Total P guideline levels for Queensland

	Organic N	**Ammonia**	**Oxidised N**	**Total N**	**Filt React P**	**Total P**
	µg N/L	**µM**	**µM**	**µM**	**µM**	**µM**
Upper catchment	270	0.923	2.13	22.72	0.64	1.28
Lower catchment	400	1.065	2.84	35.5	0.64	1.6
Upper estuarine	400	2.84	2.13	33.37	0.8	2.24
Mid estuarine	210	1.42	1.065	21.3	0.48	1.12
Enclosed coastal	180	1.065	0.355	14.2	0.48	1.12
Marine	100	1.065	0.213	8.52	0.32	0.8

Table 2: Chlorophyll *a*, Turbidity, Suspended Solids, Dissolved Oxygen, pH and Conductivity guideline levels for Queensland

	Chl *a*	**Turbidity**	**Suspended Solids**	**Secchi depth**	**DO**	**pH**	**Conductivity**
	µg/L	NTU	mg/L	m	%saturation		
Upper catchment	2.0	10	5	n/a	90–105	6.5–8.0	
Lower catchment	5.0	10	5	n/a	90–105	6.5–8.0	570
Upper estuarine	10.0	20	30	0.4	75–100	7.0–8.0	
Mid estuarine	5.0	10	20	0.8	80–100	7.0–8.5	
Enclosed coastal	2.5	7	15	1.0	85–100	7.5–8.4	
Marine	1.0	2	10?	?	90–100	8.0–8.4	

Notes: DO values in freshwater streams apply to flowing waters; DO values in non-flowing waters vary widely. None of the trigger values should be applied during flood events.

Glossary

acid sulfate soil runoff — when exposed to air, waterlogged soil, common in coastal lowlands of south-east Queensland, is converted into acid and releases metals such as iron.

algae — a very broad group of simple organisms including phytoplankton and macroalgae that live in fresh or salt water and are capable of photosynthesis

ammonium — a form of nitrogen easily absorbed by aquatic plants

AMTD — Adopted Middle Thread Distance, distance upstream from the mouth of the river

anaerobic — occurring with little or no oxygen

anthropogenic — resulting from human activities

ANZECC guidelines — Australian and New Zealand Environment and Conservation Council—The Australian Water Quality Guidelines for Fresh and Marine Waters

AQUALM — programs used to model catchment runoff water quality and to estimate runoff and pollutant exports and routing

assimilation — the uptake of inorganic compounds and their incorporation into complex organic compounds

base flow — the regular, steady or fair-weather flow of water into a stream

benthic — the bottom of sea, lake, river etc.

benthic microalgae (BMA) — microscopic plants that live in the sediment (mud or sand) which is an important food source for animals such as prawns

benthic respiration (R_{24}) — the consumption of O_2 by the streambed

bioassay — a quantitative biological analysis using a living organism or tissue

biomass — the amount of living material

carnivores — animals that feed on other animals

catchment — an area of land bounded by natural features such as hills, from which rain falls and flows to a common point, usually ending in a river or creek and eventually the sea.

chlorophyll *a* — pigment that captures light for photosynthesis, found in plants and bacteria

confluence — meeting or flowing together of two or more streams

cyanobacteria — (often called blue-green algae) primitive life form that grows in both fresh water and seawater and that may contain toxins

δ^{15}N — the heavier, rarer isotope of nitrogen that is readily found in sewage effluent. Organisms absorbing sewage nitrogen will have an elevated *^{15}N signal.

DDE — a metabolite of the synthetic insecticide DDT

denitrification	the conversion, carried out by anaerobic bacteria, of the biologically available, oxidised form of nitrogen (NO_3^-) to nitrogen gas (N_2) which is biologically unavailable
detritus	fragments of dead and decomposing plants and animals
diatoms	a group of unicellular, pelagic and benthic microalgae which are characterised by the presence of an intricate silica skeleton
diarrhetic shellfish poisoning (DSP)	gastrointestinal disease caused by the consumption of shellfish contaminated with dinoflagellate toxins. Symptoms include diarrhoea, nausea and vomiting, which occur about 30 minutes after ingestion and can continue up to three days.
diffuse discharges	non-point source discharges such as catchment and stormwater runoff
dinoflagellates	a group of unicellular algae characterised by two flagella
Diuron	herbicide designed to control weeds by inhibiting photosynthesis. Slightly toxic to mammals and birds, more toxic to fish and aquatic invertebrates. Highly persistent in soils, remaining for several years after application.
DO	dissolved oxygen—oxygen from the atmosphere or from a by-product of metabolic processes dissolved in the water column and available for animal and plant uptake
dredging	the process of excavating solid matter from an underwater area
E. coli	the bacterium *Escherichia coli,* the predominant organism of human and animal intestines
erosion	a combination of processes in which materials are loosened, dissolved or worn away and transported from one place to another
hillslope erosion	erosion of sediment from hillslopes by surface wash
channel erosion	erosion of the bank or bed within a stream channel
gully erosion	the erosion of soil by running water that forms clearly defined narrow channels which carry water during or after precipitation
escarpment	cliff or steep slope that is produced by erosion or faulting
estuary	the tidal section of a river which is influenced by inputs of freshwater and tidal movements
eutrophication	the over-enrichment of water by inorganic plant nutrient (nitrate, phosphate); biomass of phytoplankton and zooplankton increases and species diversity decreases, algal blooms become frequent.
faecal coliforms	naturally occurring bacteria in the intestines of mammals and birds; their presence is used as an indicator of contamination by sewage waste.
Fisheries Habitat Areas	natural or artificial habitats that support, directly or indirectly, the production or capture of species important to recreational, commercial and indigenous fishing in Queensland—75 areas across the state managed by the Queensland Fisheries Service
floodplain	the area of land on either side of a creek or river which can be naturally covered with water when the waterway gets too full
flow regulation	the control of the natural flow of a stream by weirs, dams, irrigation etc.

flushing	exchange of water, generally referring to a pulse of rain water flowing through a river or creek or to tidal exchange
gross primary production (GPP)	the total assimilation of carbon in a plant community per unit time
groundwater	water that has soaked into the soil and moves through the ground in close interaction with surface water
hypoxic	having low levels of oxygen
impervious	not permitting the passage of water
impound	to regulate the natural flow of water in a river or stream for irrigation, flood control or similar purpose
inorganic nutrients	nutrients not containing carbon
iron bacteria	bacteria capable of transforming soluble iron compounds into insoluble ferric oxide
irrigation	application of water to the land
JAMBA	Japan-Australia Migratory Bird Agreement, an agreement designed to conserve migratory birds
limiting nutrient	nutrient in short supply relative to the availability of other nutrients; this nutrient will limit the growth of the organism.
co-limitation	more than one nutrient is in short supply, and will limit growth
Lyngbya majuscula	a toxic cyanobacteria which blooms annually in Moreton Bay
macroalgae	multicellular plants that grow in water and are visible to the human eye
macroinvertebrates	animals with no backbone that are visible to the human eye
macrophagic	an organism which feeds on relatively large masses of food
macrophyte	a large aquatic plant such as water lily
managed forest	an area of native vegetation preserved for later use, recreation or forestry purposes
microalgae	unicellular algae only visible under a microscope
microbes	any microorganism, especially a bacteria
NHMRC guidelines	National Health and Medical Research Council—The Australian Guidelines for Recreational Use of Water
nitrate	NO_3^-, the most abundant oxidised form of nitrogen
nitrification	the conversion, carried out by aerobic bacteria, of the reduced form of nitrogen, ammonium, to the oxidised form, nitrite then nitrate
nitrite	NO_2^-, an oxidised form of nitrogen
nitrogen	a nutrient which is essential to all biota, including plants, animals and bacteria, forming proteins and enzymes
nitrogen fixation	the conversion of nitrogen gas (N_2), which is biologically unavailable to most organisms, to ammonia, a process carried out by a select group of bacteria and cyanobacteria

non-point source	a source of nutrients or sediment not restricted to one discharge location
nursery	habitat, usually seagrass and mangroves, that is utilised by larvae and juvenile animals (prawns, crabs and fish)
nutrients	essential elements required by biota
organic nutrients	essential elements derived from a living organism, containing carbon
PAHs	polycyclic aromatic hydrocarbons, often toxic and produced by power boats
pervious	permitting the passage of water
PCBs	polychlorinated biphenyls, a group of toxic, chlorinated aromatic hydrocarbons used in a variety of commercial applications, including paints, inks, adhesives, electrical condensers, batteries, and lubricants; known to cause skin diseases and suspected of causing birth defects and cancer.
pH	a measure of the acidity of a solution; neutral solutions have pH 7, acidic solutions <7 and alkaline solutions >7.
phosphate	PO_4^{-3}, the dominant form of phosphorus
phosphorus	a nutrient which is essential to all biota, including plants, animals and bacteria, found in energy molecules and membranes of cells
phytoplankton	microscopic algae that float in the water
plantations	forests of trees grown for timber, usually exotic pine species *Pinus elliotti* and *Pinus caribaea*
point source	a single point discharge of nutrients or sediments rather than runoff from the land
productivity	the rate at which biomass is produced
QWQ guidelines	Queensland Water Quality guidelines
Ramsar	convention dedicated to the identification and conservation of wetlands of international importance
residence time	the amount of time taken for water to be removed from an area
riffle	a shallow area in a stream with underwater obstructions over which water rushes quickly
riparian vegetation	vegetation/plants along a waterway or on land which adjoins and influences a waterway
salinity	salt content of water
salinity gradient	a change in salinity from a high salt concentration to a low salt concentration
saltmarsh-claypan	herbs or small shrubs which grow behind mangroves at the upper limit of the tidal range
samphire flats	shrubland consisting mostly of *Sarcocornia* spp., *Suaeda australis*, and *Suaeda arbusculoides* species of plants
sand and gravel extraction	the dredging of waterways to obtain sand and gravel for use in the construction industry
sea lettuce (*Ulva lactuca*)	a green macroalgae with ‘sheets’ of green cells radiating from one point to look like a lettuce

seagrass	marine flowering plant that grows submersed in seawater
seagrass depth range	the distance between the upper tidal limit of seagrass distribution and the lower, light-limited distribution
secchi depth	a black and white plate-sized disc is lowered into the water column; the depth in the water at which it can no longer be seen is the secchi depth.
sediment	generally derived from the land and can be found suspended in the water column or on the waterway bottom
sewage	the wastewater that is left over from toilets, showers, the kitchen sink, laundries and industrial discharge is called sewage once it enters into a sewerage system
sewage effluent	the liquid resulting from the treatment of sewage
sewage treatment plant (STP)	the place where sewage is treated, and many of the solids and nutrients removed before the left-over liquid is discharged into the waterways
SIGNAL score	Stream Invertebrate Grade Number—Average Level, an index of water pollution based on tolerance or intolerance of biota to pollution
stormwater	water, often containing pollutants, that runs off roofs, roads and other urban surfaces and drains directly into waterways
SQID	Stormwater Quality Improvement Device—devices, including trash racks and wetlands, that trap some of the pollutants in stormwater, particularly sediments and rubbish, before it reaches waterways
tidal flushing	Exchange of water from the ocean during the tidal cycle
total nitrogen	includes both organic and inorganic forms of nitrogen
total phosphorus	includes both organic and inorganic forms of phosphorus
toxicant	any poisonous agent
tributary	a stream that flows into a larger stream or lake
turbidity	the amount of sediment in the water
urea	soluble waste product, major nitrogenous constituent of urine
wallum	heathland that grows in sandy, low-nutrient, acidic soils on the lowlands and offshore islands of south-east Queensland
water clarity	a measure of the quantity of suspended solids in a liquid
water quality	physical, chemical and biological characteristics of the water column, including nutrients, sediment and chlorophyll *a*
water table	upper surface of the zone of saturation, below which all available pores and spaces are filled with water
water treatment plant	plant where water extracted from waterways or dams is treated for drinking
wetland	an area of vegetation, either temporarily or permanently flooded with freshwater or saltwater, including mangrove, marsh and melaleuca wetlands
zooplankton	animals which live in the water column

Symbol glossary

General activities

- Sugar cane
- Pine plantation
- Cattle
- Abattoir
- Quarry
- Logging
- Dump
- Housing
- Urban development
- Airport
- Sewage treatment plant
- Acid sulfate runoff

- Agriculture
- Pineapples
- Dairy
- Farm dam
- Burning off
- Vehicle associated with construction/ development
- Industry
- Port activities
- Lighthouse
- Monitoring station
- Water offtake pipe
- Sewage outflow

- Hydro-electric plant
- Ship
- Fish ladder
- Stormwater drain
- Irrigation
- Water offtake tower
- Dredge
- Aquaculture farm
- Destratification unit
- Sediment input
- Tannin input

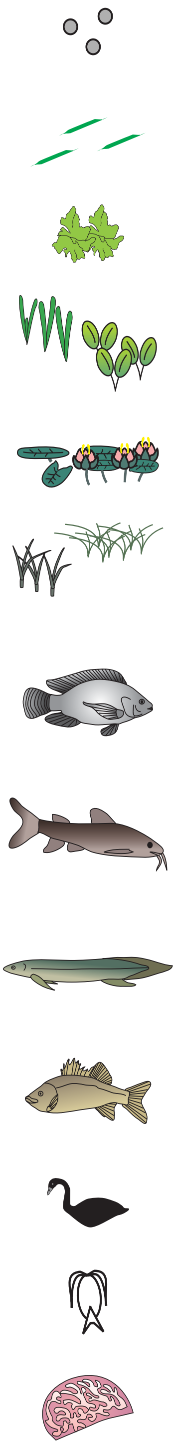
Recreational activities

- Golf course
- Recreational fishing
- Jet skiing
- Canoeing
- Picnic area

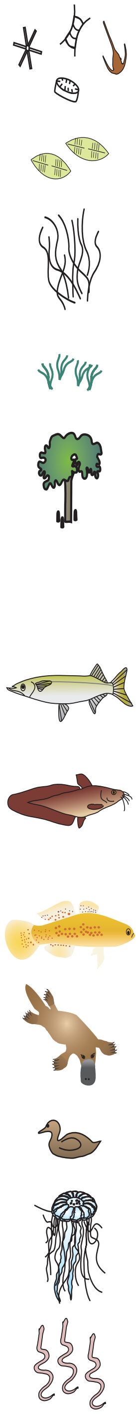
- Camping area
- Shore-based fishing
- Windsurfing
- Rowing

- Houseboat
- Marina and yacht
- Beach activities
- Swimming

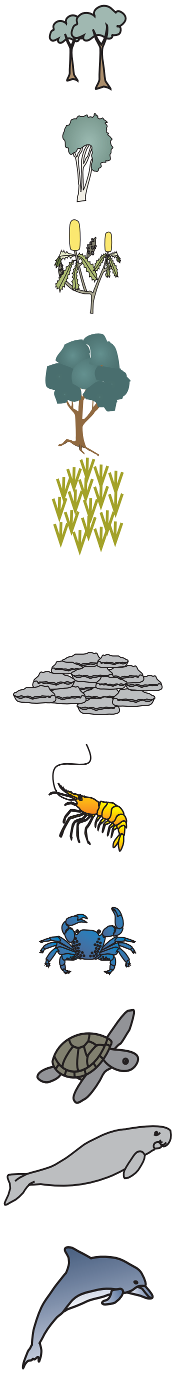
Biota



- Bacteria
- Algal bloom
- Sea lettuce *Ulva lactuca*
- Seagrass
- Freshwater plants
- Reeds
- Tilapia *Oreochromis mossambicus*
- Forktailed catfish *Arius graeffi*
- Lungfish *Neoceratodus forsteri*
- Australian bass *Macquaria novemaculeata*
- Swan
- Zooplankton
- Coral

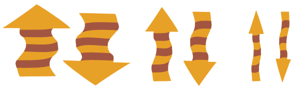


- Phytoplankton
- Benthic microalgae
- *Lyngbya majuscula*
- Filamentous algae
- Mangrove
- Snubnosed garfish *Arrhampus scleropis*
- Eeltailed catfish *Tandanus tandanus*
- Purple spotted gudgeon *Mogurnda adspersa*
- Platypus
- Duck
- Jellyfish
- Worms



- Eucalypt
- Melaleuca
- Banksia
- Tree
- Grassland
- Oysters
- Prawn
- Crab
- Turtle
- Dugong
- Dolphin

Processes


Sediment nutrient fluxes


Blocked process

Denitrification

Surficial denitrification

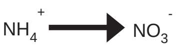
Nitrogen fixation


Low or undetectable sediment nutrient flux

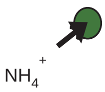
Organic matter

Ammonification

Phophorus remineralization

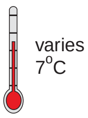


Nitrification



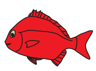
Phytoplankton uptake

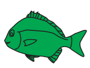

Sediment resuspension



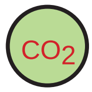
Temperature variation


Seagrass loss

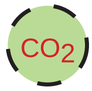

Significant wasetwater-nitrogen signal in body tissues


Low/No wastewater-nitrogen signal in body tissues

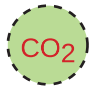
Limitation



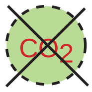
High



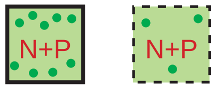
Intermittent



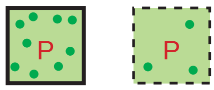
Low



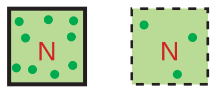
No



High and low response to nitrogen and phosphorus



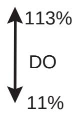
High and low response to phosphorus



High and low response to nitrogen

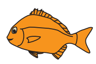

Wind driven resuspension of sediment


Secchi depth



Dissolved oxygen saturation range


Reduced seagrass area


Moderate wastewater-nitrogen signal in body tissues

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